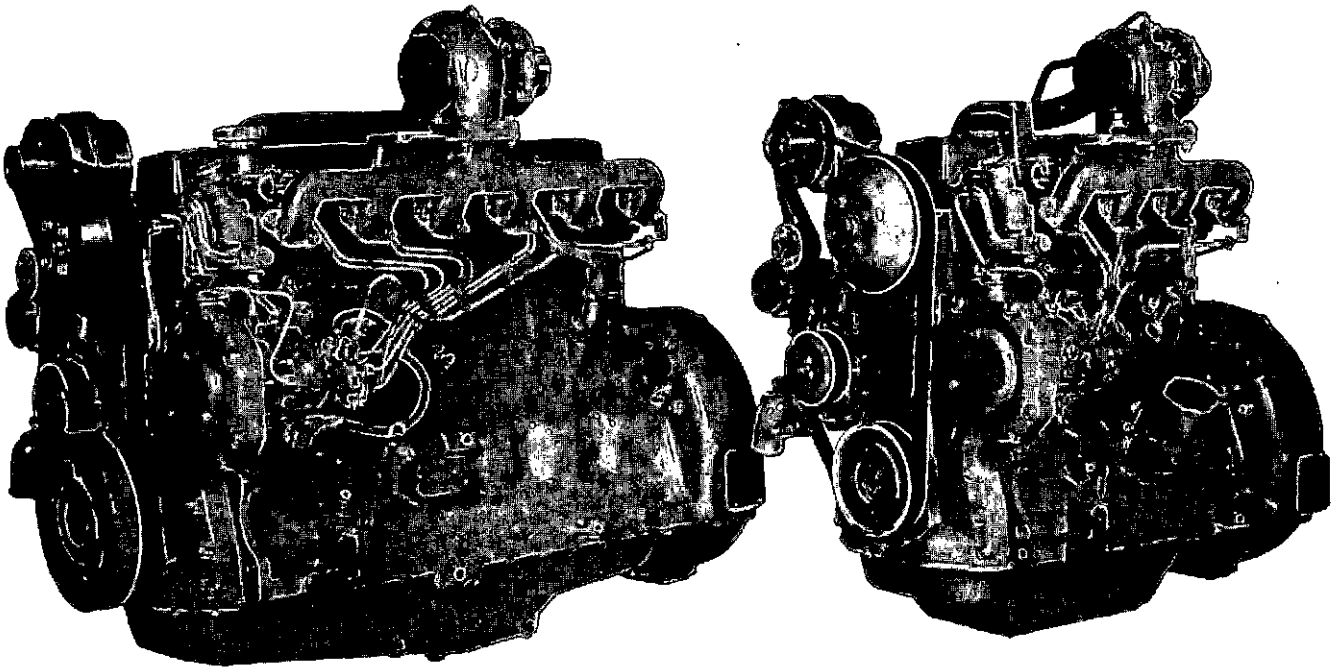
JOHN DEERE
POWERTECH 4.5 L AND 6.8 L ENGINES

ENGINE TRAINING GUIDE



JOHN DEERE

DEERE POWER

FOCUS ON THE CUSTOMER

PURPOSE

This Engine Training Guide (ETG) covers the ***POWERTECH*** 4.5 L and 6.8 L Diesel Engines. It is intended for use as an Instructors Guide to teach this new engine model. It is not a textbook; so the specifications contained in this ETG are for training reference only; they are not maintained current with running production changes.

Instructors are expected to already have a good working knowledge of John Deere Series 300 and 400 Diesel Engines.

It is suggested that this ETG be used with the Component Technical Manual (CTM104), John Deere Applications Manual, Operation and Maintenance Manuals, Parts Catalogs and Service Bulletins. These publications contain more technical, repair, preventive maintenance, engine application data and descriptions of systems and components on each engine.

SPECIAL ACKNOWLEDGEMENTS: The authors wish to thank the following contributors for their help in giving valuable graphics, technical assistance and, reference literature: Lucas Aftermarket Operations; Stanadyne Automotive - Diesel Systems Division; Nippondenso America Inc. and the Donaldson Company. We also wish to thank a host of people at the John Deere Product Engineering Center (350 Group); John Deere Dubuque Engine Division; John Deere Engine Works, Waterloo and John Deere Usine de Saran, France, Service Departments who gave extra advise and assistance on this project.

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TABLE OF CONTENTS

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.

COURSE OBJECTIVES

Upon completion of this course, and with the aid of the necessary component technical manual(s) and special tools, you will be able to:

1. Identify and briefly describe the purpose of all major components of the ***POWERTECH*** 4.5 L and 6.8 L engine models.

2. Follow the material in this Guide to the levels of:
   - Being able to adapt it to develop a training program of your own and teach from it.
   - Using the John Deere technical publications.
   - Doing a complete rebuild of a ***POWERTECH*** 4.5 L and 6.8 L Engines following factory recommended procedures and specifications in the CTM104.
   - Performing periodic maintenance and tune-up procedures on an ***POWERTECH*** 4.5 L and 6.8 L Engines.

3. Discuss and explain the function and operation of each subsystem component and how to properly care for them.

4. Use this ETG as a Student Training handout if applicable.

PREREQUISITES FOR PARTICIPANTS

General FOS Systems
- Engines
- Preventive Maintenance - Engine Portion (FOS-16104BO)
- Familiarity with content of CTM104

MATERIALS REQUIRED

Certain materials are required to teach this course which cannot be provided with this Engine Training Guide and slide set.

1. For at least every two students; One each, Component Technical Manual, Operation and Maintenance Manual and paper Parts Catalog for every engine model.
2. One microfiche reader and appropriate MPC fiche may be used for the class, in lieu of paper parts catalogues.
3. One 35 mm slide projector, carousel, extra bulb and projection screen.
4. Depending on class size, one or more ***POWERTECH*** 4.5 L and 6.8 L Engine and Series 300 engine models complete with all similar options to demonstrate ***POWERTECH*** 4.5 L and 6.8 L engines vs. Series 300 engine models and/or component parts.
5. Appropriate engine rollover stand (with OTC#JT07268) for ***POWERTECH*** 4.5 L and 6.8 L Engines.
6. Special tools as specified in the CTM104.
7. A complete set of mechanic's hand tools.
8. Measuring tools; Inside and outside micrometers, torque wrenches, etc., as specified in CTM104.
9. Complete overhaul gasket sets, liner packings, and oil seals (as applicable).
10. Clean SAE 30W engine oil and non-petroleum based liquid soap for parts lubricating during reassembly.

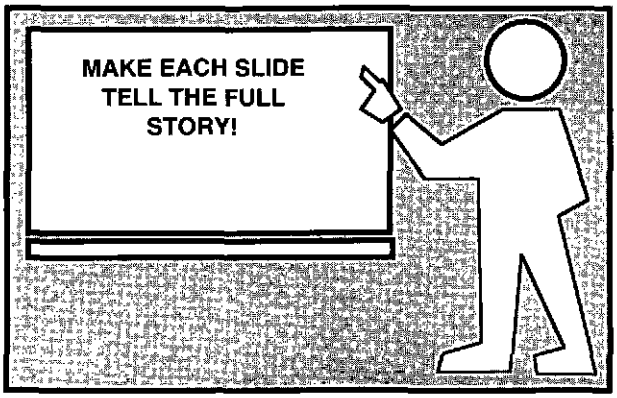
Note to Instructor:

An available selection of loose components may be helpful as "show and tell" training aids to enhance your class.

POWERTECH 4.5 L/6.8 L ENGINE ESSENTIAL TOOLS

Tool No.	Description
JD248A	Control Valve Bushing Tool
JD249	Balancer Shaft Bushing Driver
JD252	Idler Gear Bushing Driver
JD254A	Timing Tool
JD258	Injection Nozzle Carbon Dam Seal Tool
JD286	Con Rod, Piston Pin Large Bushing
JD303	Injection Pump Drive Removal Tool
JDE38A	Injection Nozzle Puller
JDE39	Injection Nozzle Bore Reamer Tool
JDE74	Water Pump Bearing Driver
JDE81-1	Engine Rotation Tool
JDE81-4	Timing Pin (with JDE811 and JDE133)
JDE83	Engine Turning Tool
JDE84	Piston Ring Compressor 106 mm (4.19 in) Bore
JDE85	Piston Ring Expander
JDE88	Con Rod Piston Pin Small Bushing
JDE138	Valve Spring Compressor "C"Clamp Type
JDF13	Injection Nozzle Cleaning Kit
JDF22	Crowsfoot Wrench
JDG22	Slide Hammer Seal Puller
JDG451	Cylinder Liner/Piston Height Gauge (or KJD 10123)
JDG536	Driver (use with JD248A)
JDG670A	Injection Pump Drive Gear Puller (DB4 Pumps)
JDG675	Valve Seat Insert Installing Adapter
JDG676	Valve Seat Pilot Driver
JDG678	Valve Stem Seal Installer
JDG680	Tap
JDG698	Rear Crankshaft Oil Seal/Wear Sleeve Removal Tool
JDG716	Injection Nozzle Tip Puller
JDG739B	Camshaft Bushing Service Set
JDG791A	Idler Gear Installer Pilot
JDG949	Nozzle Wrench
JDG953	Connecting Rod Bushing Remover and Installer
JDG954	Crankshaft Gear/Front Oil Seal Installer
JDG956	Water Pump Bearing Installer
JDG957	Piston Ring Groove Wear Gauge
JDG963	Balancer Shaft Bushing Driver
JDG965	Dipstick Tube Installer
JT30040B	Crankshaft Rear Seal/Sleeve Installing Tool - With Metric Hardware
JTO1674	Compression Tester (D14546BA)
JTO5975	Belt Tensioner Gage (Poly Vee Belt)
JTO7268	Engine Repair Stand Mounting Adaptor
D01062AA	Cylinder Liner Puller (or D01073AA or KCD 10001)
D01109AA	Diesel Fuel Injection Nozzle Tester
D01110AA	Adapter Set (use with D01109AA)
D01168AA	Spring Compression Tester
D051045ST	Cooling System Pressure Pump
D05223ST	6000 lb. Engine Stand (or D01003AA)
D05226ST	Special Adapter
D17004BR	Flexible Cylinder Hone
D17015BR	O-Ring Groove Cleaning Brush
D17526CI	Dial Indicator
D17527CI	Dial Indicator

DIRECTIONS TO THE INSTRUCTOR

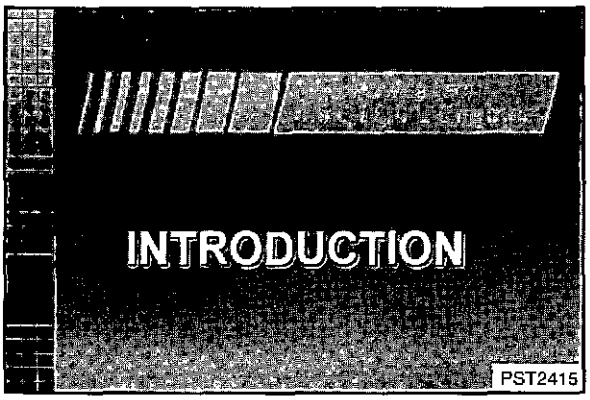


The following items should be considered for discussion with each slide in the program where applicable:

1. Part name
2. Function and operating principles
3. Service checks
4. Service intervals
5. Machinability
6. Oversize/undersize parts availability
7. Remanufactured assemblies available
8. Hidden bolts/capscrews/dowels
9. Special bolts/capscrews
10. Critical bolt/capscrew lengths
11. Special procedures
12. Special torques
13. Interchangeability
14. Application data (minimum line sizes, installation angles, etc.)
15. Troubleshooting
16. Gaskets, seals, etc., that must be ordered separate from assembly kit
17. Difference between production and service parts
18. Difference between standard Deere production (OEM vs. Ag., Ind., and Marine equipment) engines

INTRODUCTION

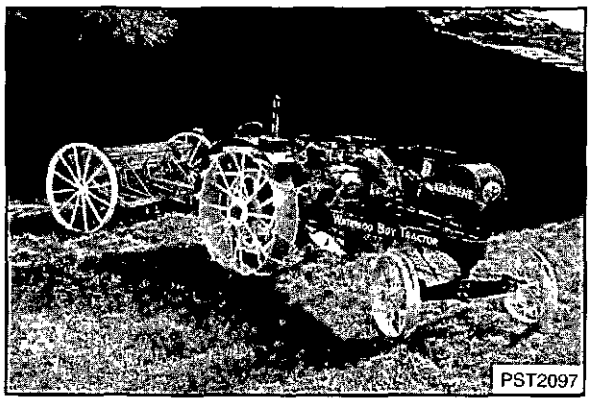
- Industrial equipment
- Agricultural equipment
- OEM engines
  - Marine engines
  - Generators
  - Compressors
  - Etc.



INTRO No. 1

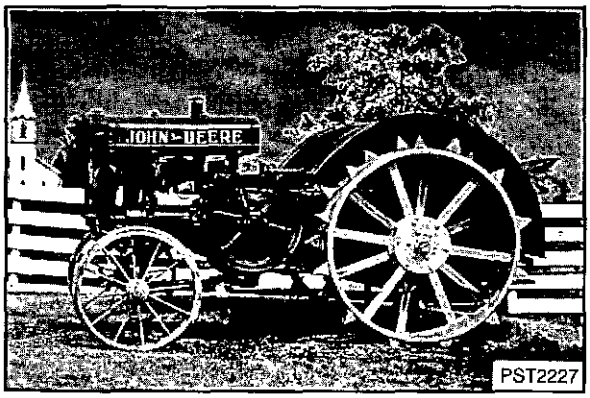
HISTORY AND DEVELOPMENT OF THE JOHN DEERE ENGINE

- In 1918, the John Deere Company purchased the WATERLOO BOY TRACTOR COMPANY, in Waterloo, Iowa, and entered into the agricultural tractor market. This Company produced two models of the Waterloo Boy Tractors as well as a small line of gasoline and kerosene engines.



INTRO No. 2

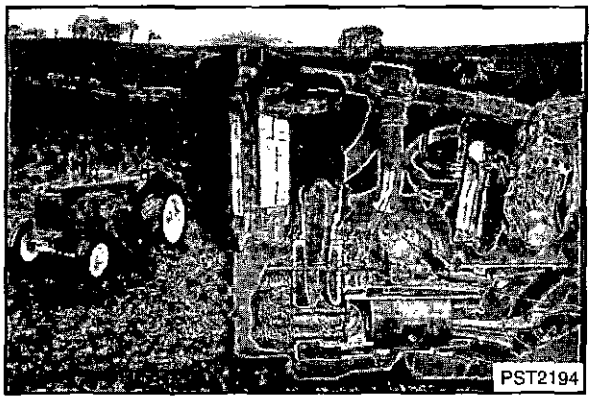
- In 1924, John Deere introduced its first wholly John Deere designed and built engine. This was a 27 hp, 501 cu. in. (8.2 L) displacement, 2-cylinder, gasoline engine, running at 800 rpm. The engine had a 171.45 mm (6 3/4 in.) bore and 177.8 mm (7.0 in.) stroke. It was introduced in the model "D" Tractor.



INTRO No. 3

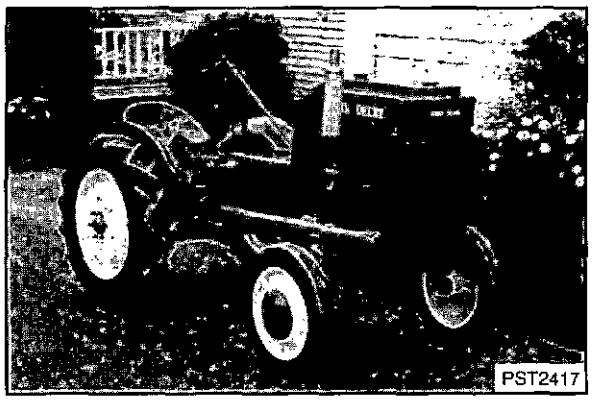
HISTORY AND DEVELOPMENT OF THE JOHN DEERE ENGINE (Cont'd)

- In 1949, John Deere produced its first Diesel engine. It was a 2-cylinder, 416 cu. in. (6.8 L) displacement power plant. This engine had a 146 mm (5-3/4 in.) bore and a 203 mm (8.0 in.) stroke developing 43 hp, at 1000 rpm. It was introduced in the Model "R" Tractor



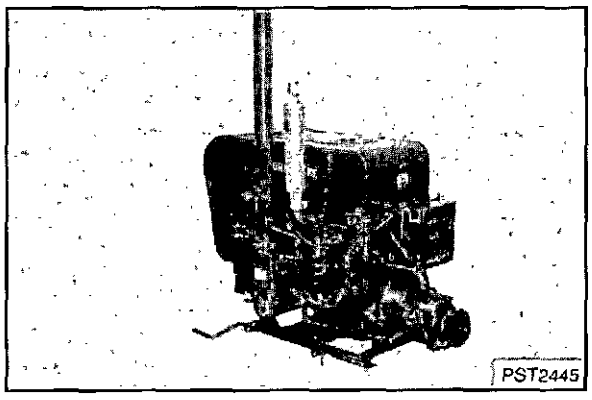
INTRO No. 4

- In 1937 a smaller 2-cylinder upright, flathead gasoline engine was introduced in the Model L tractors. This was a Hercules designed engine manufactured by John Deere at their Moline Tractor Works, Moline, Illinois. It had 66 cu. in. displacement, 3.25" bore, 4.0" stroke and developed 9.27 belt hp@1550 rpm
- In 1946 this factory was moved to an all new factory in Dubuque, IA. The upright 2-cylinder design with overhead valves continued in the Model "M", 40, 320, 420, 330, 430, 440I and 440ICD tractors until 1960



INTRO No. 5

- In 1953 the Dubuque factory introduced a 4-cylinder, 92 cu. in. power unit. While most of the tractor engines produced in both factories had been adapted as power units, this was the first developed specifically as a power unit. It had a 3.125" bore, a 3.0" stroke and was rated at 29 hp intermittent operation or 23 hp continuous operation at 2250 rpm. It was available in gasoline, LP or natural gas models
- In 1956 the 145 cu. in. 4-cylinder and the 217 cu. in. 6-cylinder, gasoline and LP power units were introduced. They were followed by the 155 cu. in., 4-cylinder and 232 cu. in., 6-cylinder, diesel power units. These units used indirect injection, with pre-combustion chambers. They were the forerunners of the "300 Series" engines



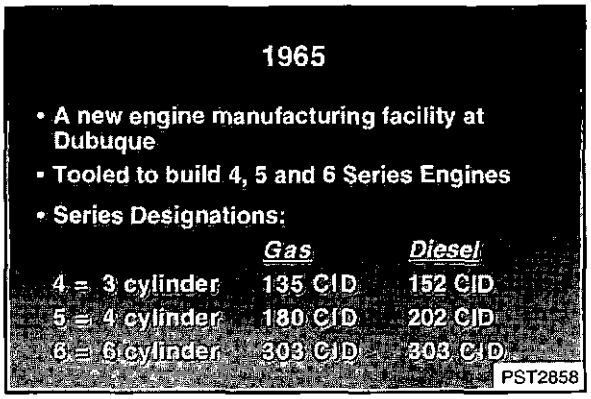
INTRO No. 6

HISTORY AND DEVELOPMENT OF THE JOHN DEERE ENGINE (Cont'd)

- In 1960 the "Wet Sleeve-and-Deck", design were introduced on all engines produced by the John Deere Dubuque Works. Additional sizes were adopted to broaden the Power Unit selection and to power the new John Deere Model 1010 and 2010 tractors

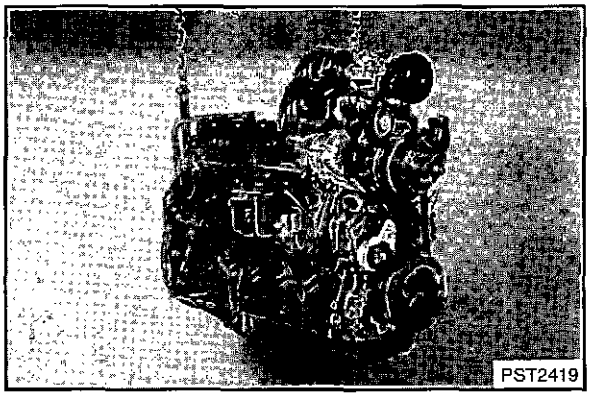
INTRO No. 7

- In 1965 a new facility dedicated to engine manufacturing was added to the John Deere Dubuque Works. The 3, 4, and 6-cylinder, 4, 5 and 6 Series in-line, diesel, LP and gasoline fueled engines were introduced
- In 1966 an almost identical facility was opened in Saran, France. Diesel engines of the same design are produced at both factories



INTRO No. 8

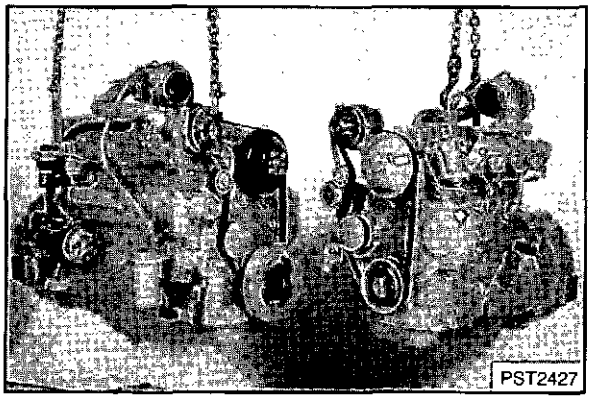
- In the mid 1970's engine oil coolers and spray cooling was introduced. These engines were identified as 300 Series
- In the mid 1980's several major and significant changes were introduced in the 300 Series
- Structural and non-structural engine blocks and auxiliary drives made the engines extremely versatile. John Deere decided to rename these new metric designated engines "Series 300"



INTRO No. 9

HISTORY AND DEVELOPMENT OF THE JOHN DEERE ENGINE (Cont'd)

- In 1995 the new ***POWERTECH*** 4.5 L and 6.8 L engines are introduced. These engines will replace the current lineup of Series 300 engines and will continue to be manufactured at both Dubuque and Saran
- Within each model designation are several power levels. Internal parts differ by power level
- These engines use 99% metric hardware



INTRO No. 10

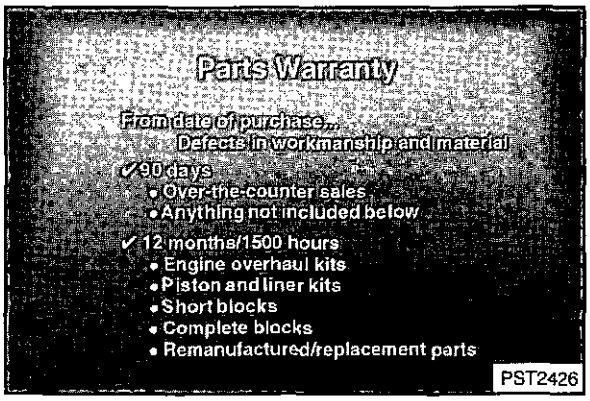
JOHN DEERE ENGINE WARRANTY COVERAGE

- 12 months/unlimited hours or 24 months/2000 hours--- 100% parts and labor coverage
- 1500 hrs use in John Deere Agricultural applications outside No. America, Australia, New Zealand and Rep. of South Africa
- Warranty relates to correction of defects:
  - Is nor a guarantee that engine is or part is free of defect
  - Defects in material and /or workmanship can exist even though care is taken in manufacture, assembly and test
- Warranty agreement establishes:
  - Obligation of John Deere (manufacturer), the engine distributor and dealer to the purchaser
  - Limitation of Warranty
  - Responsibility of the end user as related to care and operation of the engine
- Cost of gaining access to engine when warranty repairs is required (not to be confused with "R & R")
- Travel allowances on OEM engines are for each completed repair incident including total round trip is;
  - Four hours maximum at registered retail rate for one serviceman
  - 320 kilometer (200 miles) maximum at U$S 0.44 per kilometer/U$S 0.70 per mile or equivalent
- Work must be performed by:
  - Authorized John Deere Engine Distributor, Service Dealer or John Deere Agricultural and Industrial Dealers
  - Marine Service Dealers provide warranty service on Marine engines only

INTRO No. 11

PARTS WARRANTY

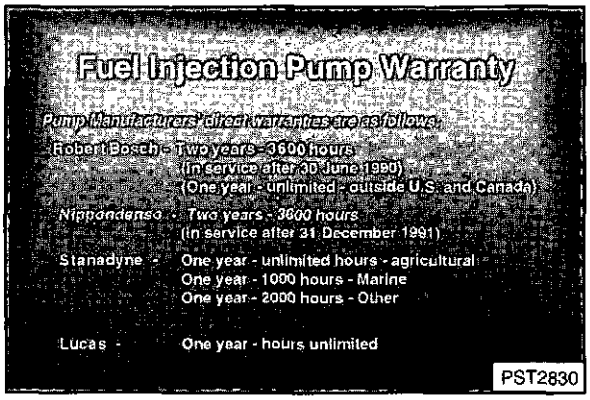
- From date of purchase... defects in workmanship and material
- 90 days
  - *Over-the-counter sales*
  - Anything not included below
- 12 months/1500 hours
  - Engine overhaul kits
  - Piston and liner kits
  - Short blocks
  - Complete blocks
  - Remanufactured/replacement parts



INTRO No. 12

FUEL INJECTION PUMP WARRANTY

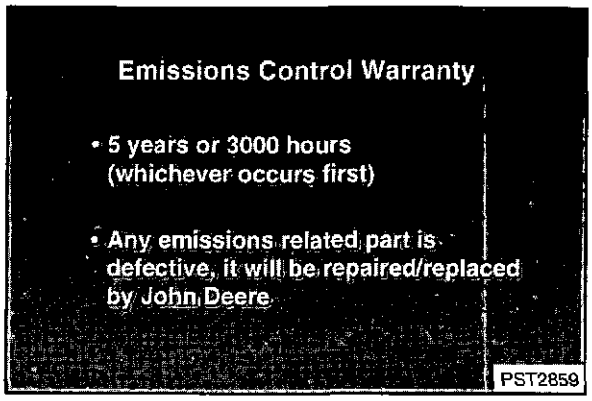
- Injection pump warranty is covered by the pump manufacturer
- Warranty service is performed by pump manufacturer's Authorized Diesel Service Dealer (DSD) accompanied by a completed Diesel Fuel Injection Equipment Warranty Request and Repair Tag, Form DF-2148
- To the retail purchaser of a John Deere engine, the injection pump warranty is always at least equal in length to the standard original engine warranty. Some pump manufacturers, however, warrant for shorter periods.
- John Deere assumes responsibility for injection pump warranty from the end of the manufacturer's warranty to the end of the standard original engine warranty
- If, however, the pump manufacturer's representative does not accept the failure as a warrantable failure, then R&R labor and travel are not reimbursed by John Deere and should not be claimed. Repair of non-warrantable failures are to be invoiced to the customer



INTRO No. 13

U.S. EMISSIONS CONTROL WARRANTY STATEMENT

- Emissions control related parts/components warranted by John Deere
  - 5 years
  - 3000 hours, whichever occurs first
- Engine covered by this warranty designed, built and equipped so as to conform at time of sale:
  - With all U.S. emission standards
  - At time of manufacture
  - Is free of defects in materials and workmanship



INTRO No. 14

- Your emissions control system includes:
  - Fuel Metering System
    - Fuel Injection System
  - Air Induction System
    - Intake Manifold
    - Turbocharger System
    - Charge Air Cooling System
  - Miscellaneous items used in above systems

INTRO No. 15

EPA & CARB OFF-ROAD EMISSIONS STANDARDS

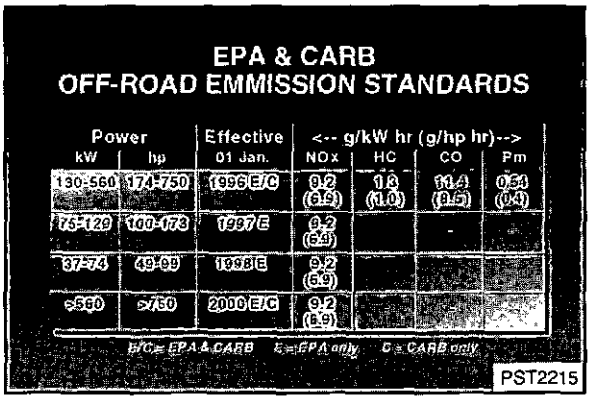
EPA = Environmental Protection Agency
CARB = California Air Resources Board

- Effective date is *engine build date* at the engine manufacturer

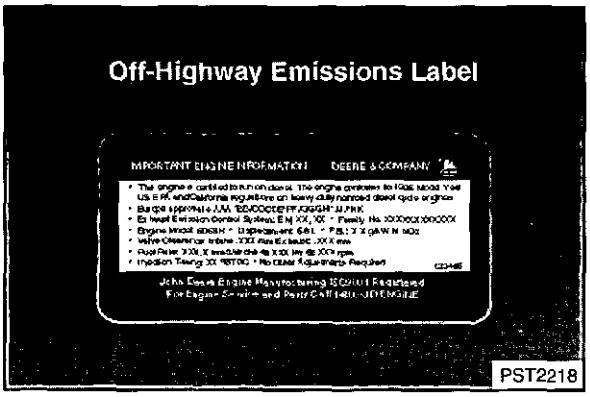
Note: In addition to the emission standards, all EPA *non-road engines must comply with the* US on-highway Federal Smoke Cycle. This cycle establishes smoke opacity standards (20/15/50) reported in terms of percent opacity during an acceleration mode, a lug mode and the peak opacity on either mode

- The scope of the regulations include self propelled *non-road applications and portable* applications
- In general, a portable application is used in one place for less than 12 months
- Portable generator sets are included in the regulations
- Stationary applications used in one place for more than 12 months are not regulated by EPA but could be subject to local regulations such as Air Quality Districts in the State of California
- It is anticipated HC, CO and Pm emission standards for engines between 37 and 129 kW (49 and 173 hp) will be added to coincide with European emissions when they become finalized
- Emissions label (shown at right) is located on vertical, right side of cylinder head, on the air intake manifold

The Emissions Warranty Statement can be found in the ***POWERTECH*** *Engine Operation and Maintenance Manual.*



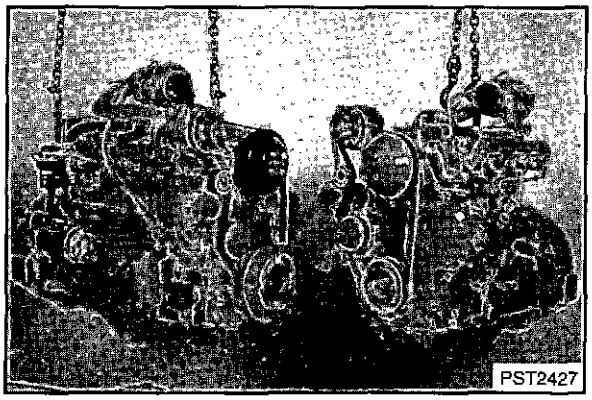
INTRO No. 16



INTRO No. 17

POWERTECH 4.5 L AND 6.8 L ENGINE

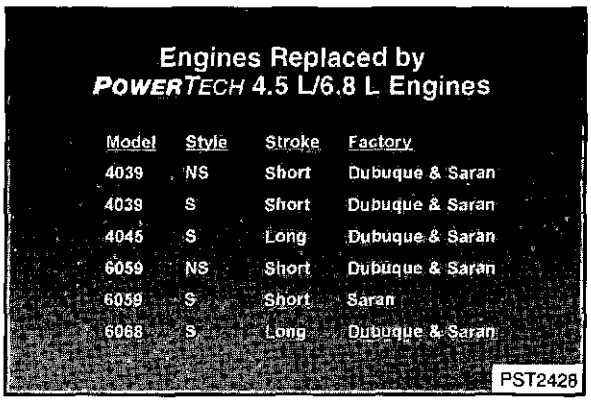
- Uses same machining tools
- Common centerline of block bores
- Parts commonality
- Accessory commonality



INTRO No. 18

ENGINE MODELS REPLACED BY *POWERTECH* 4.5 L AND 6.8 L ENGINE

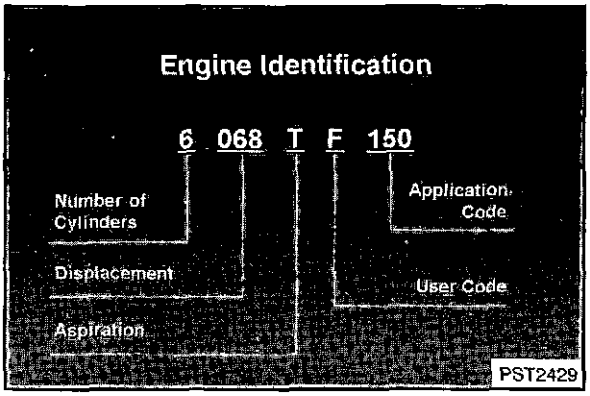
- Replacement will occur gradually as twelve (12) ***POWERTECH*** engines are phased in
- Series 300 build Saran or Dubuque
  - Short-stroke engines--110 mm (4.33 inches) stroke
  - Long-stroke engines--127 mm (5.00 inches) stroke
- Style S (structural block) and NS (non-structural block)



INTRO No. 19

ENGINE MODEL NUMBER

- Number of cylinders
- Displacement is specified in liters
- Aspiration code
  - D = Naturally aspirated
  - T = Turbocharged
  - A = Turbocharged and liquid aftercooled
  - H = Turbocharged and air-to-air aftercooled
- User factory
- Application code



INTRO No. 20

POWERTECH 4.5 AND 6.8 L ENGINES NOMENCLATURE

Example 6068TF150
- Series = *POWERTECH* 6.8 L
- Model = 6068

Number of Cylinders = 6

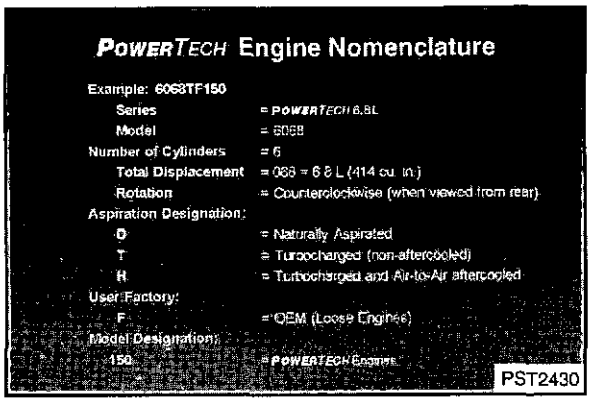
Total Displacement = 068 = 6.8 Liters (414 cubic inches)

Rotation = Counterclockwise (when viewed from rear)

Aspiration Designation:
- D = Naturally aspirated
- T = Turbocharged (non-after-cooled)
- H = Turbocharged and Air-To-Air Aftercooled

User factory:
- F = OEM (Loose Engines)

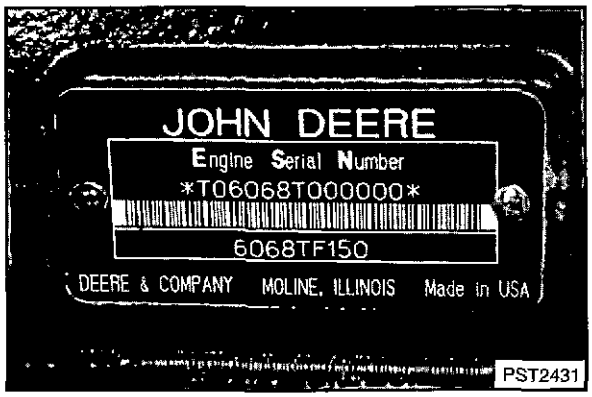
OEM Code:
- 150 = *POWERTECH* Engines



INTRO No. 21

13-DIGIT JOHN DEERE ENGINE SERIAL NUMBER

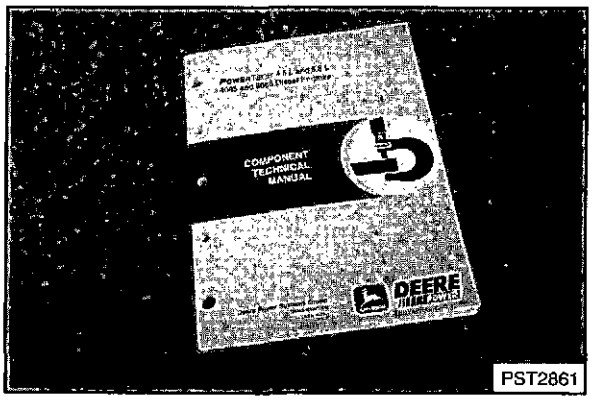
- T0 = Producing factory code
- 6 = Number of cylinders
- 068 = Total displacement
- T = Turbocharged
- 000000 = Build sequence (6-digit)
- Engine factory codes
  - RG = *Waterloo*
  - CD = Saran
  - TO= Dubuque



INTRO No. 22

COMPONENT TECHNICAL MANUAL (CTM)

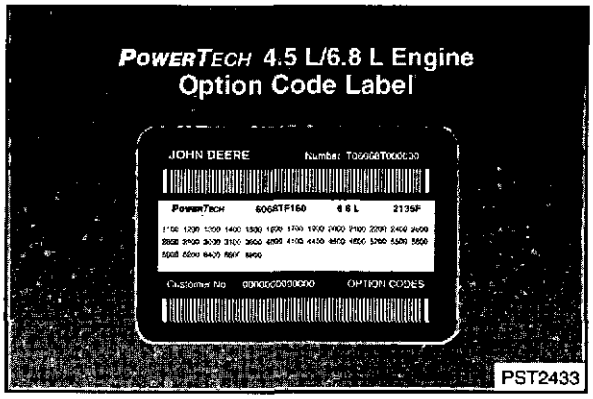
- CTM is broken down into groups
- Tools and specifications
  - At start of each section
  - At each individual operation
- Groups explain
  - Disassembly
  - Inspection/operation
  - Reassembly



INTRO No. 23

OPTION CODE LOCATION AND LISTING (OEM ONLY)

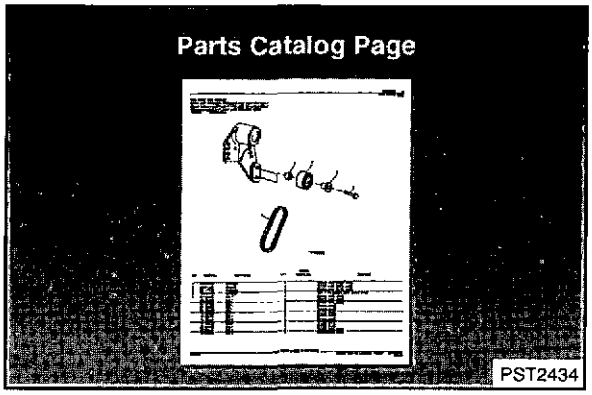
- Located on the front right side rocker arm cover
- Will not survive "hot tank" (record codes in safe place)
- Codes necessary for correct parts acquisition
- Code grouping numbers represent similar (but not identical) parts for different engine models



INTRO No. 24

PARTS FICHE OR CATALOG PAGE

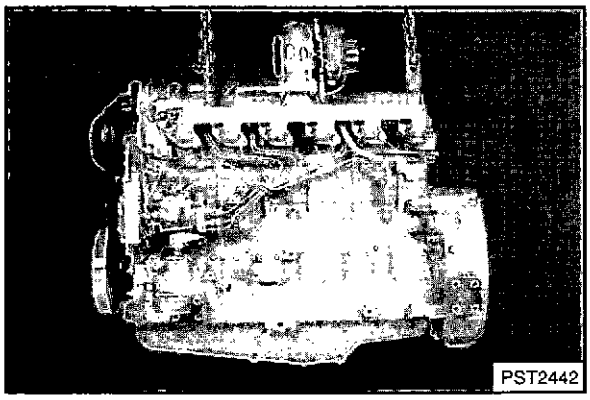
- Use of
  - Index
  - Part number locator (page 1 of microfiche or rear of parts book)
  - Option code numbers
- Part catalog page layout
  - Describe art work and layout on typical page
  - Explain in detail how to use the information in each column on the page
- Point out need for having option code available



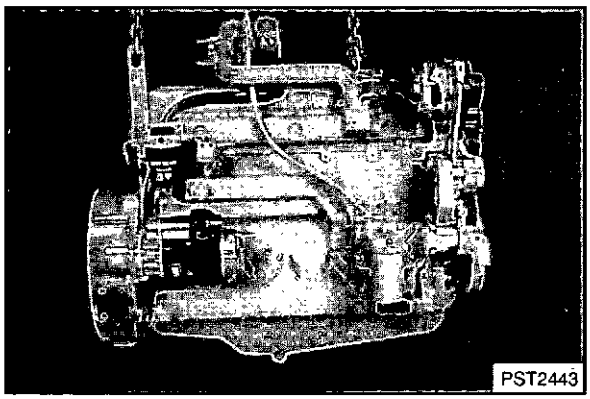
INTRO No. 25

APPLICATION RATINGS

- INDUSTRIAL CONTINUOUS
  - This rating conforms to ISO 3046 continuous power
  - Used when selecting engines for applications of continuous, full-load operation.
- INDUSTRIAL INTERMITTENT
  - Any application greater than (industrial) continuous limit is considered (industrial) intermittent
  - Used when selecting engines for applications which will operate under varying load and speed demands
  - At less than 60% average load factors
  - At less than 1000 hour annual usage
- PRIME POWER GEN-SET RATING
  - Prime power rating only applies to gen-set applications, and is not permitted on Industrial Intermittent or Industrial Continuous applications.
  - The nominal power an engine is capable of delivering is the basis of the calculated generator set rating range for prime power:
    - With a variable load
    - For unlimited hours of operation per year with normal maintenance intervals observed.
  - Prime power gen-set rating incorporates a 10% overload capability for up to 2 hours at a time.
  - Operating time between 100% and 110% of the prime power rating is not to exceed 8% of the total operating run time.
  - This rating conforms to ISO 8528-1 "prime power (PRP)". The permissible average power for the prime or PRP rating is not to exceed 70% of rated prime power when calculated per ISO 8528-1
- STANDBY GEN-SET RATING
  - The standby power rating only applies to gen-set applications and is not permitted on Industrial Intermittent or, Industrial Continuous applications.
  - The standby gen-set rating is the nominal engine power available at varying load factors for up to 500 hours per year with normal maintenance intervals observed.
  - No overload capability is available for this rating.
  - This rating conforms to ISO 8528-1 "limited time running power (LTP)".
  - The calculated generator set rating for standby applications is based on minimum engine power (nominal - 5%) to provide 100% meet-or- exceed performance for assembled standby generator sets.



INTRO No. 26



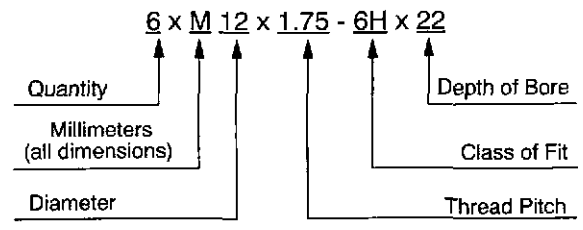
INTRO No. 27

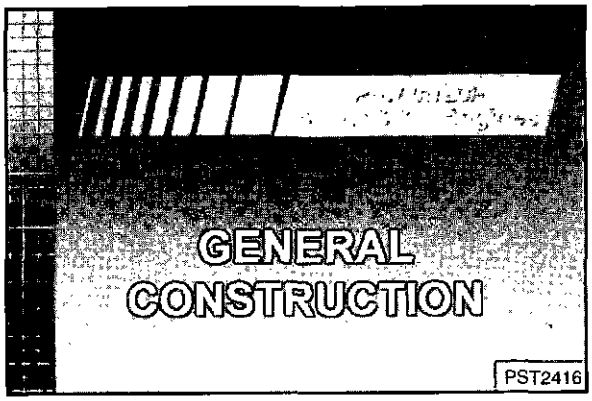
APPLICATION RATINGS (Cont'd)

- CONTINUOUS GEN-SET
  - The calculated generator set rating range for continuous gen-set applications is based on nominal engine power.
  - The nominal power an engine is capable of delivering with a continuous load for an unlimited number of hours per year with normal maintenance intervals observed.
    - This rating conforms to ISO 8528-1 "continuous power (COP)".
    - The permissible average power may be 70% of rated continuous power or higher when calculated per ISO 8528-1
    - The continuous gen-set power rating is common with the Industrial Continuous limit at 1500 and 1800 rpm.
    - Individual Continuous gen-set performance data is not provided.
    - Continuous gen-set performance is included in the generator applications chart.
    - Refer to Industrial curves when Continuous Limit performance details are needed.

GENERAL CONSTRUCTION

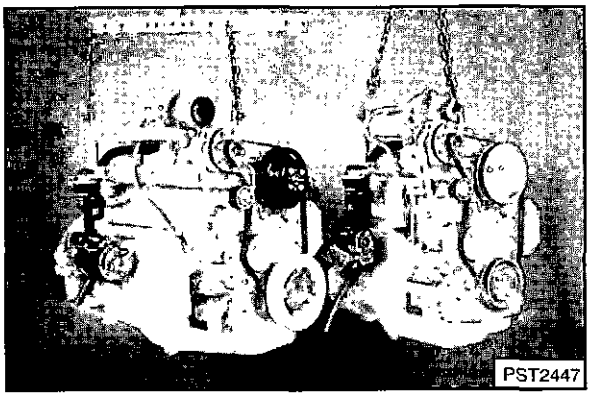
- The ***POWERTECH*** 4.5 L and 6.8 L diesel engines are available in naturally aspirated and turbocharged versions
- ***POWERTECH*** engines have the following features:
  - Emissions Certifiable
  - Increased Reliability
  - Increased Application Flexibility
  - Improved Quality
  - Extended Power Range
  - Reduced Noise (1 to 2 dB(a)
- ***POWERTECH*** 4.5 L and 6.8 L engines have greater displacement than most of the engines they replace
- Major changes in the ***POWERTECH*** engines will increase durability, improve efficiency, allow power growth and result in engines that are more competitive in the market
- Improved durability;
  - All engine blocks are of the non-structural design
  - Improved distribution of coolant flow through the block
  - Roller grooved crankshaft journal fillets
  - Timing gears and cover designed for heavier loads
  - Auxiliary drive rated for 37 kW (50 hp), intermittent at 2500 rpm
  - Camshaft and followers of chilled iron
  - Tee Pee connecting rods on high output engines for reduced weight and stronger pistons
  - Re-entrant bowl pistons for cleaner burning
  - In-block full flow oil cooler protected from external damage
- Improved serviceability:
  - Vertical (open end up) engine oil filter to prevent spillage
  - Cartridge-type water pump mounted in front cover
  - In-block oil cooler
  - Self adjusting poly-vee fan belt
  - Either side dipstick, oil fill and filter option
- Metric fasteners except cylinder head and main bearing capscrews
  - Threaded metric bores are listed as shown in this example:





G.C. No. 1

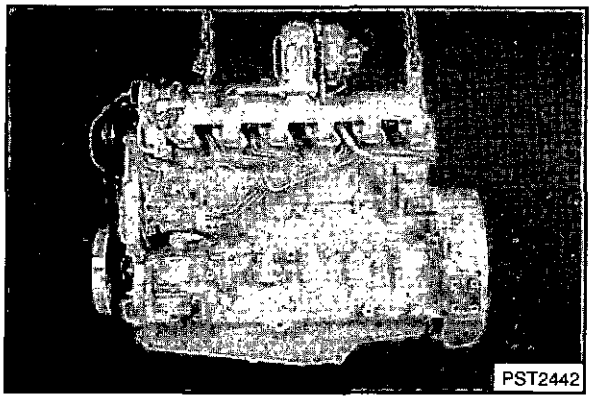
G.C. No. 2



G.C. No. 3

COMPONENT LOCATION - LEFT SIDE OF ENGINE

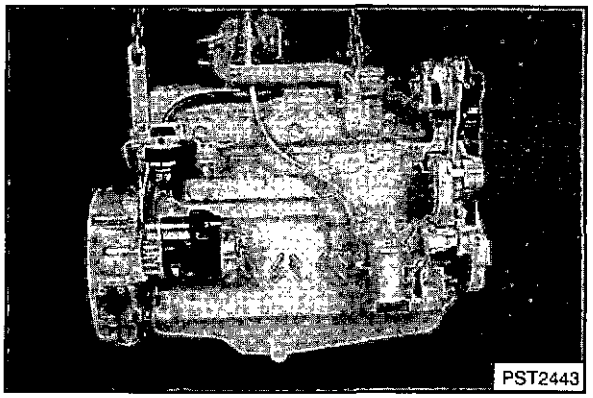
- Efficiency of the cross-flow head design is maintained with integral right-side intake manifold and separate left-hand exhaust manifold design
- Fuel injection pump, lines and nozzles
- Mounting bosses on block
- Thermostat cover and water outlet
- Dipstick (can be located on either side)
- Turbocharger



G.C. No. 4

COMPONENT LOCATION - RIGHT SIDE OF ENGINE

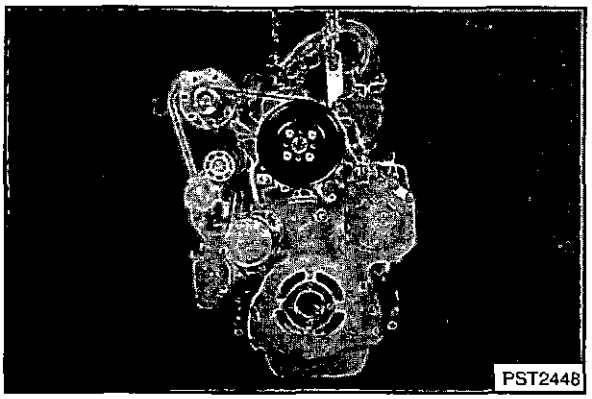
- Oil cooler and oil filter manifold
- Oil filter (can be mounted in three different locations on right side of engine
- Starter (can be mounted right or left)
- Fuel filter (can be mounted right or left)
- Lube line to turbocharger
- Oil fill port (can be located on either side or on top)
- Fuel transfer pump (rotary injection pumps only)
- Gear auxiliary drive
- Alternator
- Integral intake manifold



G.C. No. 5

COMPONENT LOCATION - FRONT OF ENGINE

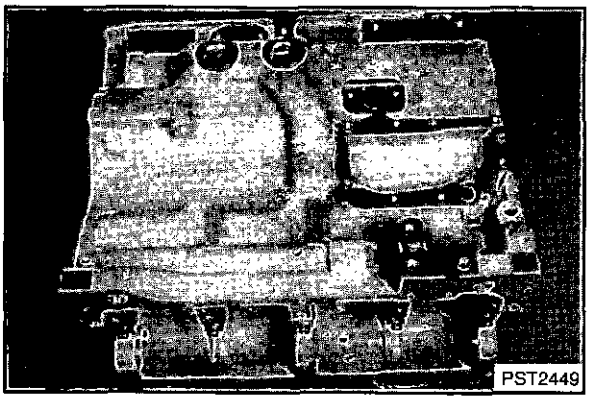
- Front pulley and damper or drive hub
- Belt tightener assembly
- Water pump by-pass line
- Water pump, drive sheave and inlet housing
- Pick-up port for electronic tachometer
- Fan drive
- Injection pump drive access cover
- Alternator mounting bracket
- Aluminum rocker arm cover
- Heavy duty aluminum front cover



G.C. No. 6

CYLINDER BLOCK - RIGHT SIDE VIEW

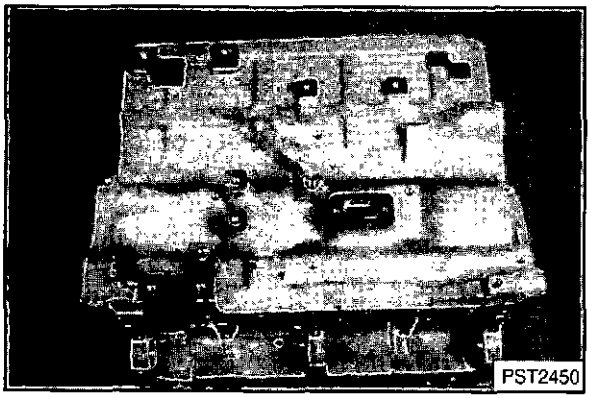
- Cavity for oil cooler
- Clean-out ports for integral water manifold
- Side mounting pads at front (6 x M12 x 1.75 - 6H x 22)
- Oil fill and dipstick ports
- Fuel pump mount pad



G.C. No. 7

CYLINDER BLOCK - LEFT SIDE VIEW

- Turbocharger drain port
- Mounting pads
- Oil fill and dipstick ports
- Raised surfaces on block for noise reduction
- Positioning of engine mounting pads requires a new engine repair stand mounting adaptor JTO7268
- A label is affixed to the adaptor which explains mounting hole location on each engine model
- Required 12 mm and 14 mm hardware is provided with the JTO7268 adaptor



G.C. No. 8

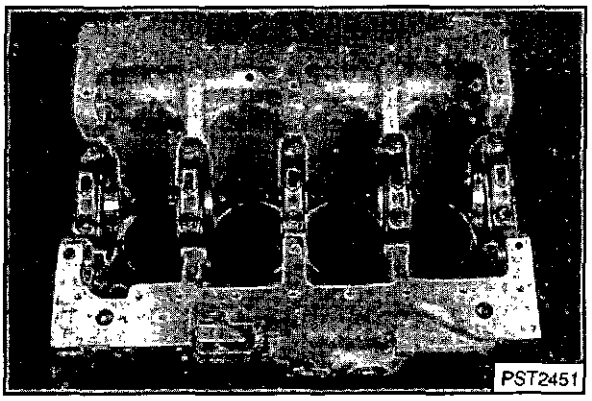
CYLINDER BLOCK - BOTTOM VIEW

- Main bearing supports
- Heavy webbing at main bearing support areas
- Main bearing caps
  - Arrows on caps are pointing toward camshaft
  - Number on cap and pan rail
  - Install cap with bearing notch facing bearing notch in block

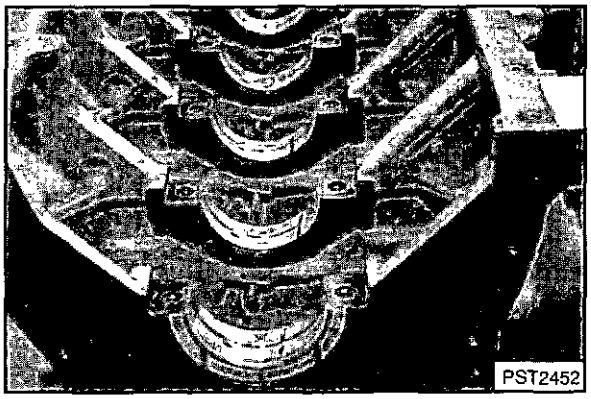
Service Note:

- Replacement main bearing caps are available in a kit.
- The kit gives instructions for set-up and precise line boring of the replacement cap
- This operation must be done by a specialized machine shop.

- Spray cooling orifices are threaded into block



G.C. No. 9



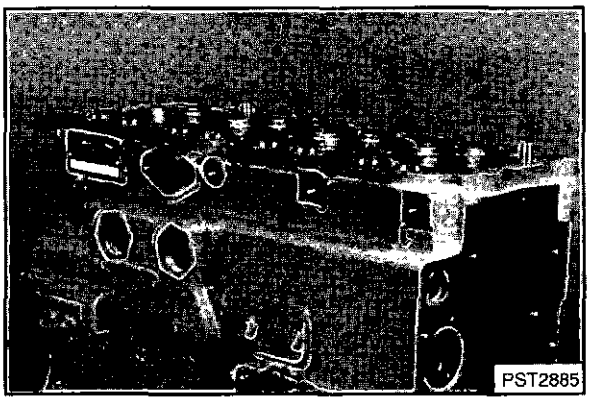
G.C. No. 10

CYLINDER BLOCK - TOP VIEW

- Liner flange counterbore
  - Supports top of liner
  - Bottom of liner flange contact area is machined with a slight tilt upward at I.D. so flange is supported beneath head gasket fire ring to prevent liner flange cracking
- Head gasket surface of cylinder block must not be machined as it will upset controlled machining that establishes piston and liner stand-out
- Dowels on top of block now positions cylinder head as well as the head gasket

Note: On the Series 300, the dowel positioned only the head gasket

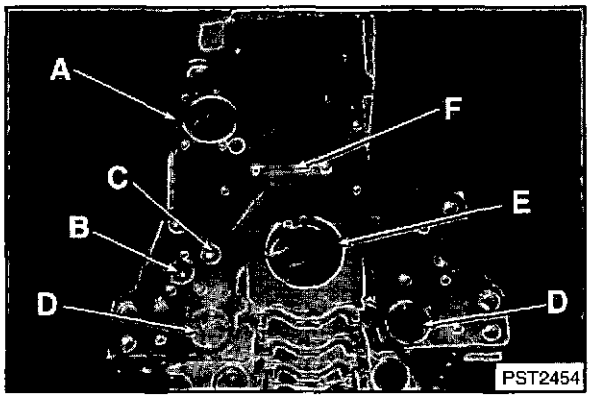
- Water passages are relocated to accommodate revised coolant flow



G.C. No. 11

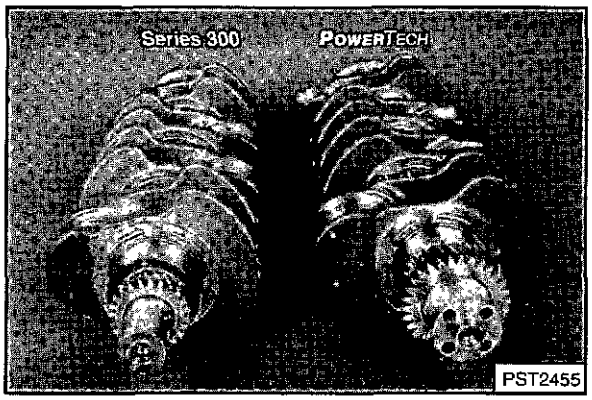
CYLINDER BLOCK - FRONT VIEW

- Camshaft front bore for replaceable bushing (A)
- Bore for lubricating oil by-pass valve (B)
- Bore for pressure regulating valve seat (C)
- Bores for balancer shafts (D) (four-cylinder engines only)
- Crankshaft bearing bores (E)
- Upper idler timing gear lube passage (F)



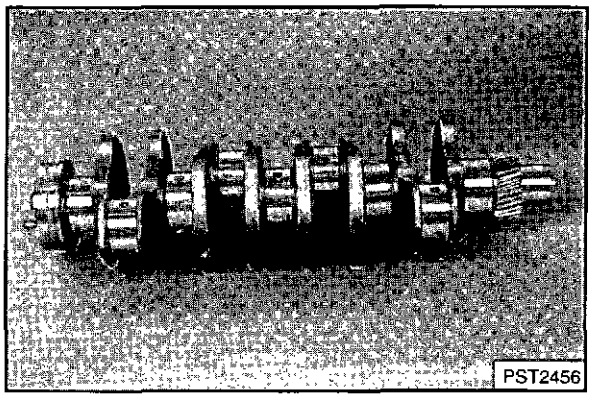
G.C. No. 12

CRANKSHAFT DESIGN



G.C. No. 13

- Crankshafts are designed with a large diameter gear end to provide four threaded attaching holes for securing front pulley and damper or drive spacer
- These items are no longer press fitted and keyed to the crankshaft as on the Series 300
- The front gear is press fit and keyed to the shaft
- Gear on end of crankshaft is larger in diameter to fit larger crankshaft end resulting in diameter changes of related gears
- Front-of-crank (nose) drive capability:
  - All ***POWERTECH*** 4.5 L
    - Intermittent: 305 N•m (225 lb-ft)
    - Continuous: 258 N•m (190 lb-ft)
  - All ***POWERTECH*** 6.8 L
    - Intermittent: 400 N•m (295 lb-ft)
    - Continuous: 339 N•m (250 lb-ft)
- Crankshafts are of two different materials:
  - Nodular iron for all 4.5 L engines.
  - Forged steel for all 6.8 L engines.
  - The longer six-cylinder crankshaft has greater torsional wrap-up and is made from steel which has more torsional stiffness as compared to nodular iron.
  - The strength of both crankshaft material types is equivalent.

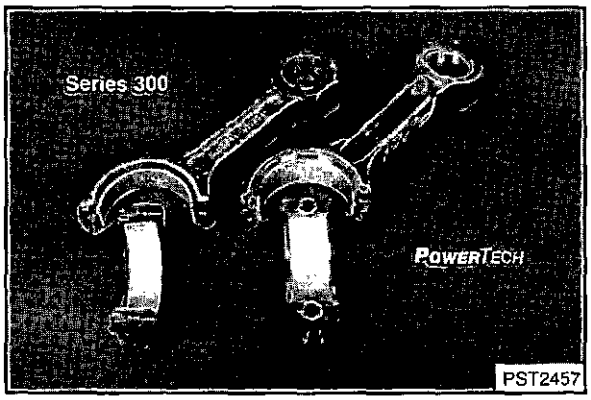


G.C. No. 14

- Crankshafts of either material are induction hardened at all journals
- Connecting rod and main journal fillet are undercut and rolled under extreme pressure
  - Pressure from the rolling process causes the metal in the fillet area to become highly compressed about the undercut.
  - This significantly increases strength where the journal joins the crankshaft cheek
- Crankshaft grinding
  - Only 0.25 mm (0.010 in.) undersize bearings are available
  - **When grinding the journals, do not grind within the undercut fillet area**
- See the section of CTM104 entitled "CRANKSHAFT GRINDING GUIDELINES" for complete details on the proper procedures needed to assist a machine shop operation
- Always check the crankshaft journals for tapered wear and out-of-round during engine rebuild

CONNECTING ROD BEARINGS

- The connecting rod bearings are 5.5 mm (0.215 in) wider than those used in the Series 300
- The bearings are steel backed with aluminum alloy lining
  - Bearings have a tin flashing on the bearing surface, the same material is used in the main bearings.
  - Bearing tangs are located so they cannot be installed in a Series 300 by mistake.
- Tin flash plate is used to provide a surface that can absorb minor abrasion during break-in period and protects the surface during shelf storage of the part



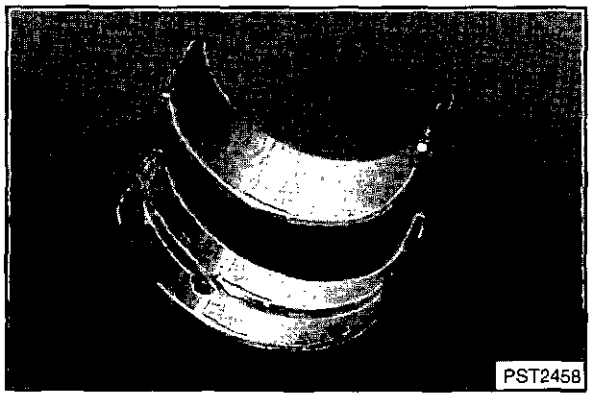
G.C. No. 15

Service Note:

- If a crankshaft requires grinding, be sure to advise the machine shop that only 0.25mm (0.010 in) undersize bearings are available for the undercut and rolled fillet crankshafts.
- Also provide the machine shop with the "Crankshaft Grinding Guidelines" and specifications in CTM104.
- Used bearings with flash coat worn away may still be well within size specification.
- Always check size before discarding bearings

MAIN BEARINGS

- All crankshaft bearings have an oil hole in the block half of the bearing and no oil hole or oil groove in the main cap half
- The bearing tang groove has been relocated in the bearing cap and the bearing tang moved to prevent installation of the bottom bearing half (without oil hole) into the block
- The main bearings are 1 mm (0.039 in.) wider than those used in the Series 300 engines
- Bearing cap half tangs are located so the bearings cannot be installed in Series 300 by mistake
- Bearing material is steel backed aluminum alloy with tin flash plate
- Only 0.25 mm (0.010 in.) undersize are available for service



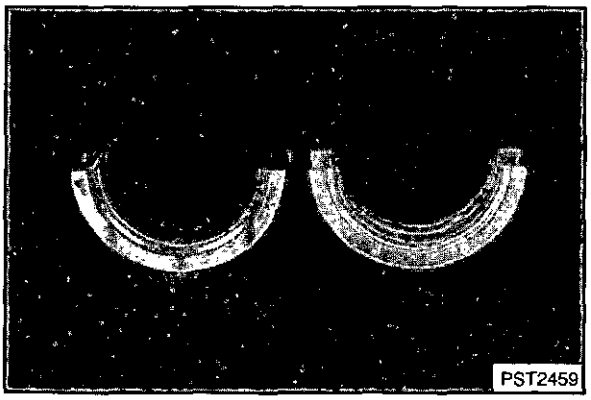
G.C. No. 16

MAIN THRUST BEARING

- A new two-piece high capacity thrust bearing is used in the ***POWERTECH*** 4.5 L and 6.8 L engines
  - Thrust bearing thrust surfaces have unique contours that result in an oil pumping action into the high load areas.
  - The new two-piece bearing has thrust load capacity of 113.5 to 454 kg (250 to 1000 lbs) which is equal to the Series 300 five-piece thrust bearing.

Service Note:

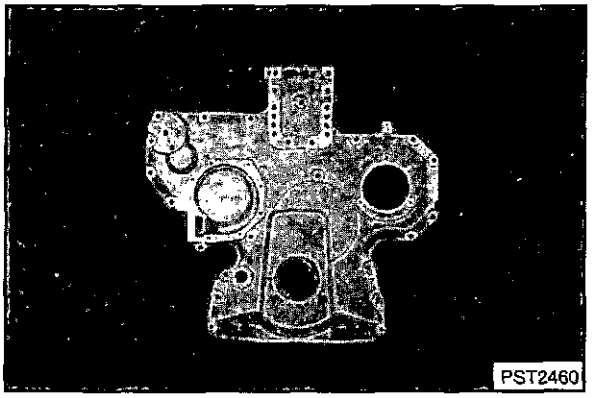
- When rebuilding an engine pre-lubrication of bearing surfaces is very important to be sure scuffing during start-up does not occur.
- While engine oil is excellent, it does run off the surfaces if an engine sets for awhile before it is run.
- Multi-purpose or Moly grease is very good at clinging to the surfaces for long periods of time and may be used as a pre-lube.



G.C. No. 17

FRONT CRANKSHAFT SEAL CONSTRUCTION AND INSTALLATION

- The front crankshaft seal is a lip-type seal that runs on a wear sleeve
- A wear sleeve is provided with service seal
- Assembly instructions and installation tool is provided with the seal kit
- A new sleeve should be installed with a new oil seal
- The front seal is press fit into the front gear cover
  - Seal lip points toward gear train
  - Lubricate seal lips with engine oil when installing
  - If O.D. of seal is not pre-coated, apply sealant to the surface that contacts the front cover



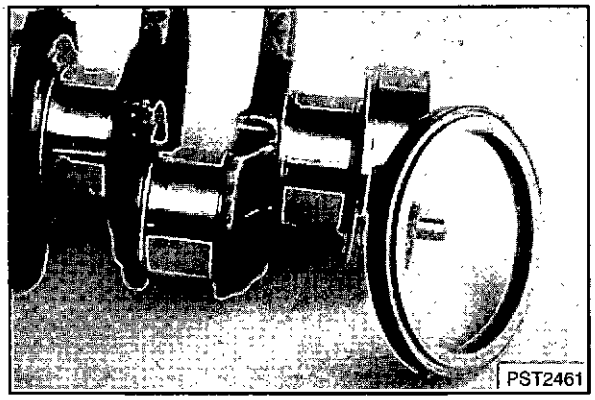
G.C. No. 18

REAR CRANKSHAFT SEAL

- Sealing of the flywheel end of the crankshaft is provided by a cartridge-type double-lip seal and wear sleeve
- This seal is press fit onto the crankshaft and into the flywheel housing at the same time using special installer tool set JT30040
- Current production seals have a wear sleeve that is flanged on both sides to prevent separation of the sleeve from the seal during handling
- The seal is to be installed with no lubrication as lubricant can cause early seal failure
  - The seal is designed to break-in without lubrication.
  - High friction creates heat for initial seating or mating of the members.
  - A very thin coating of sealant is recommended on the outside diameter of the crankshaft flange prior to mounting the rear seal/sleeve assembly.
- Rear seals are supplied with gasket sets
- Rear seals are not supplied with short blocks

Service Note:

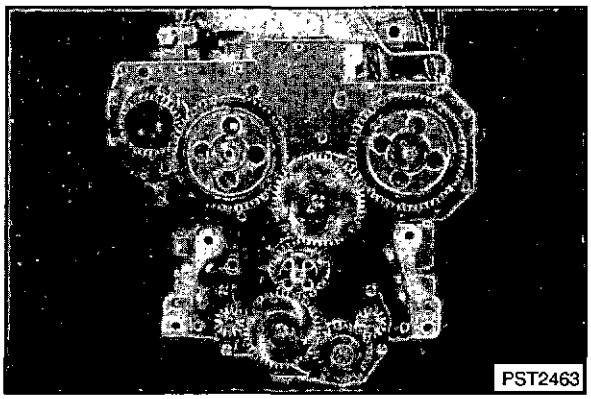
- The seal can be removed using a screw equipped impact puller.
- If care is taken to prevent damage to other surfaces, a rolling head bar can also be used.



G.C. No. 19

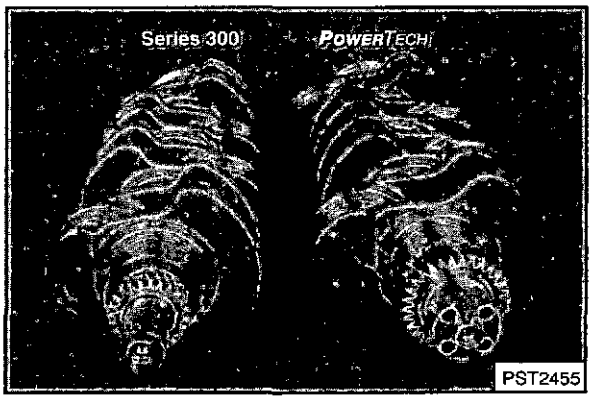
GEAR TRAIN

- The gear train is located at the front of the engine
  - A stamped steel plate bolted to the engine block supports timing gears, oil pump, injection pump and auxiliary drive.
  - The ***POWERTECH*** engine front plate is 14% thicker than the front plate of the Series 300 engines.



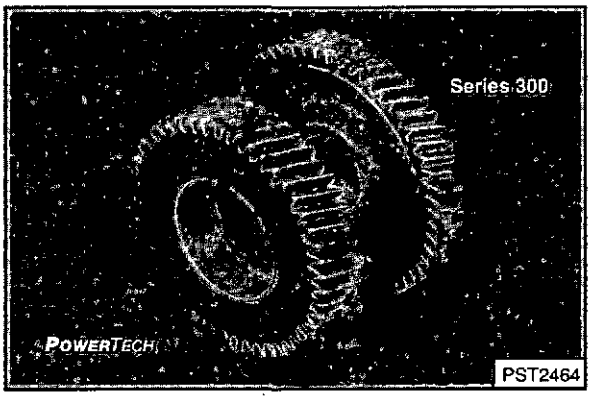
G.C. No. 20

- The gears are made of heat treated steel and are helically cut
- Crankshaft and upper idler gear in the ***POWERTECH*** engine are very thick compared to similar gears on the Series 300 engine



G.C. No. 21

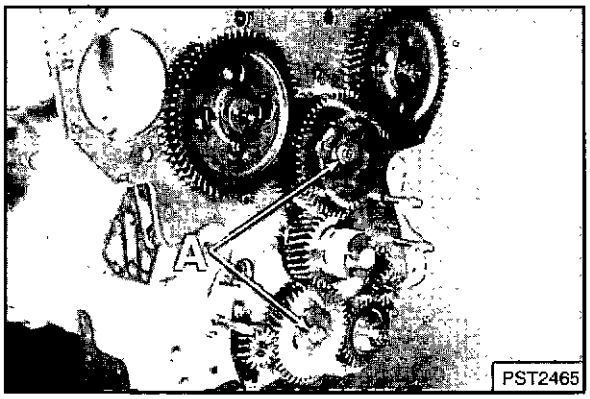
- Since the crankshaft drive gear is larger in diameter than the drive gear on the Series 300 engine, the diameter of related driven gears has also changed
- Speed sensor location in the front cover allows sensing directly from the injection pump drive gear teeth
- ***POWERTECH*** upper idler gear shown in the foreground, Series 300 upper idler gear shown in the rear



G.C. No. 22

IDLER GEARS

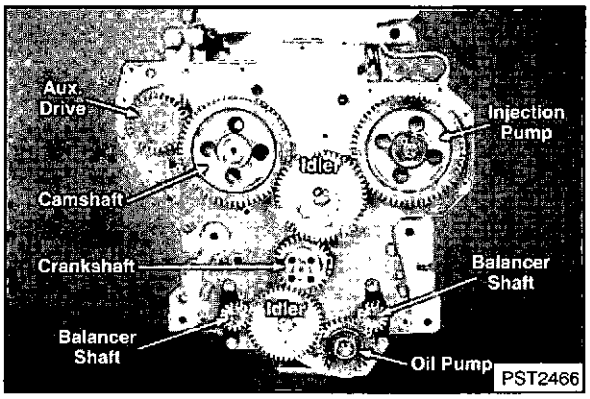
- The idler gear hubs (A) are bolted to the front plate
- Roll-pins are used to locate the hubs and prevent thrust washer rotation
- The upper idler bushing is pressure lubricated and the lower idler bushing is splash lubricated. The lower idler bushing is grooved and the upper is not



G.C. No. 23

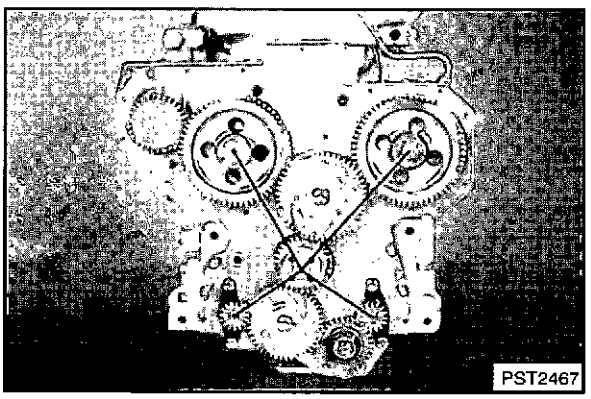
TIMING THE GEAR TRAIN

- Time with engine at T.D.C. no. 1 cylinder on compression stroke
  - Idler gears need not be in place
  - Use engine rotating tool (JDE83 or JDG820) to bring engine to T.D.C.
  - Tool used depends on flywheel installed
  - Insert timing pin in the special index hole in the flywheel



G.C. No. 24

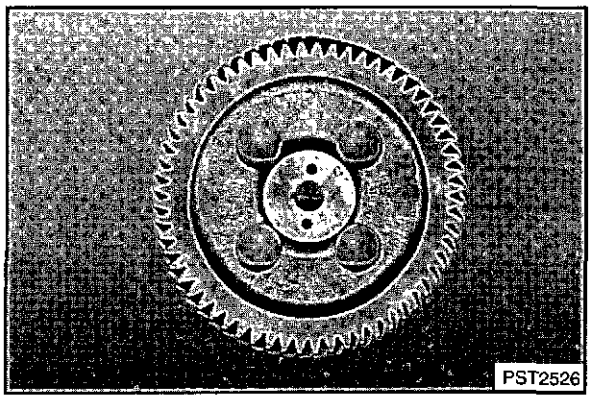
- Align the timing marks of all gears to the crankshaft centerline using special timing tool (JD254A)



G.C. No. 25

TIMING THE GEAR TRAIN (Cont'd)

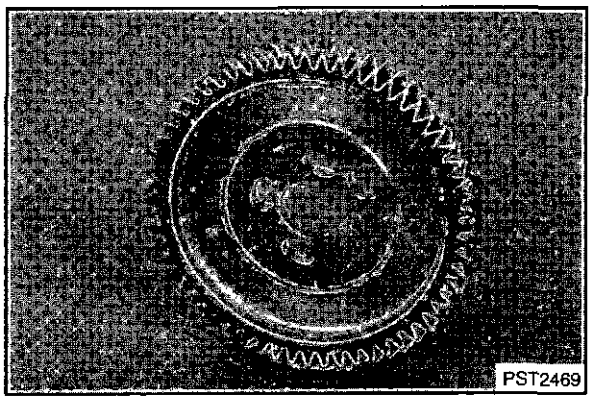
- Injection pump drive gear for the rotary distributor type pumps is marked 4 for all four-cylinder engines and **S6** and **L6** for six-cylinder engines
- **S6** is for Stanadyne pumps
- **L6** is for Lucas pumps
- Align the appropriate mark with crankshaft centerline using JD254A Timing Tool



G.C. No. 26

- In-line injection pump drive gear has elongated holes so it can be aligned to the pin timed hub of the injection pump
- Install idler gears when all marks are properly aligned and re-check with timing tool to be certain marks remain properly positioned

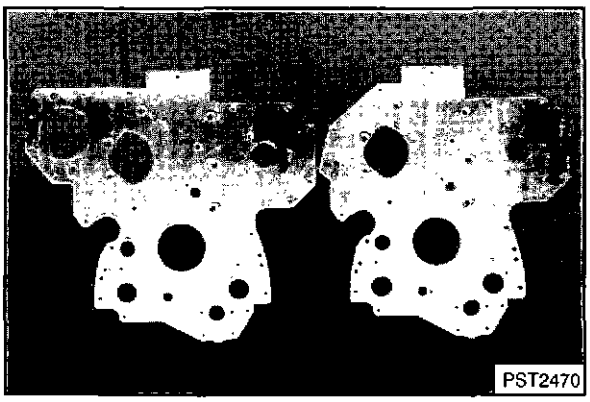
Service Note: On in-line pump drive gear it is necessary to make a reference mark on gear before removing pump. This will allow proper gear position for assembly if pump is to be installed after front cover



G.C. No. 27

ENGINE BLOCK FRONT PLATE

- Two designs of engine block front plates are used on the engine
- Standard equipment front plate is designed to accept an auxiliary drive
- Optional equipment front plate does not accept auxiliary drive

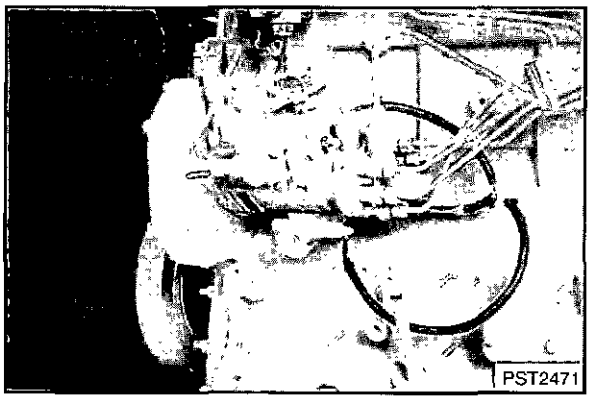


G.C. No. 28

Service Note:

- Front plates for rotary distributor injection pump equipped engines have a dynamic timing mark stamped into the front plate.
- If plate is ever replaced a timing mark must be scribed into the new front plate.
- See CTM104 for the procedure.

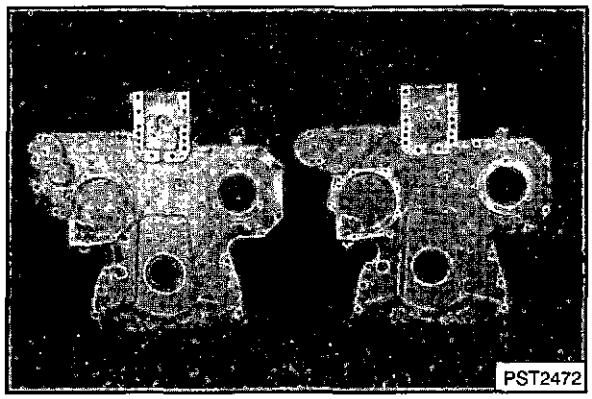
Note: Timing marks on photo have been exaggerated for easier viewing



G.C. No. 29

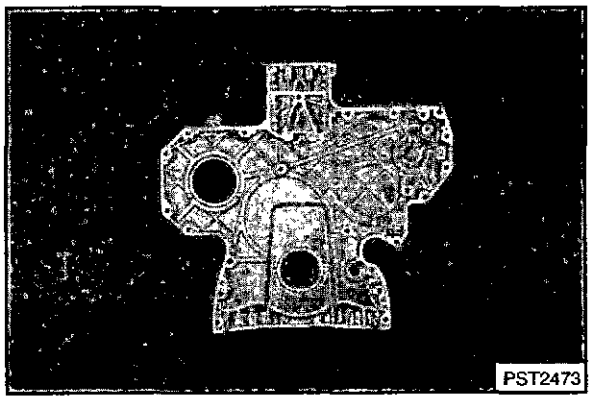
GEAR TRAIN COVER

- Two engine gear train front covers are available to fit the front plates
- The mounting for the poly-vee belt tightener is integral with the auxiliary drive front cover
- The mounting for the poly-vee belt tightener on the no auxiliary drive cover is a separate bracket that bolts to the cover
- 15 possible position adjustments for belt pulley hub



G.C. No. 30

- Inside of covers are ribbed purposely to increase strength and reduce noise



G.C. No. 31

CAMSHAFT AND FOLLOWERS

- Camshafts for the ***POWERTECH*** 4.5 L and 6.8 L engines are of chilled iron which provides a very smooth and extremely hard wear surface
- Camshaft lobes are tapered to provide positive rotation of the barrel faced cam followers
- A slot at the rear journal of the camshaft meters oil up to the rocker arms
- A round lobe near the rear of the camshaft drives the fuel pump through a special push rod
- Front bearing journal of camshaft is supported by a replaceable bushing in the cylinder block
- Bushing provides a durable support surface when camshaft gear is loaded by auxiliary driven equipment
- Remaining journals do not require bushings

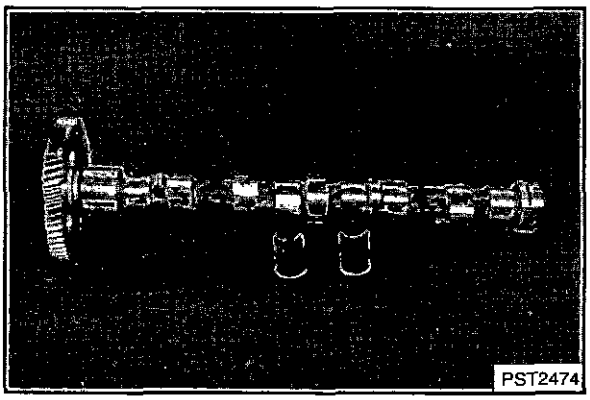
Service Note:

- When assembling an engine always coat the cam lobes, journals and followers with a Moly Grease to prevent scuffing at start-up
- Be sure to install the fuel pump push rod and cam followers before installing the cylinder head.
- They cannot be installed after the head is in place

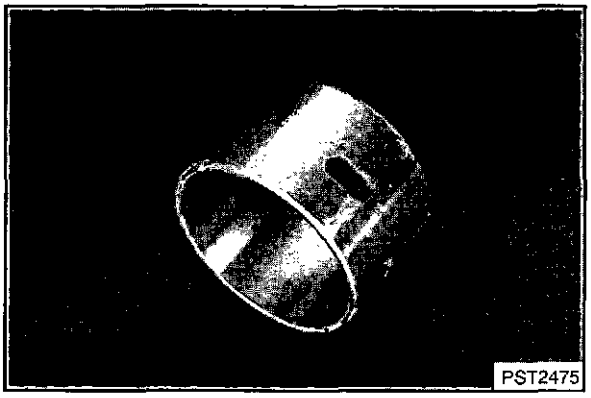
- Cam followers are of high carbon chilled iron material to complement the camshaft wear-life
- Cam followers are spherical shaped at camshaft contact surface to mate with the tapered cam lobes which results in rotation of the followers during operation. This insures even wear and long service life
- Cam follower transmits movement from the camshaft to the rocker arms through solid steel pushrods which have hardened ends. Holes in the sides of the followers pass lubrication to the block bores and allow oil drain-back

Service Note:

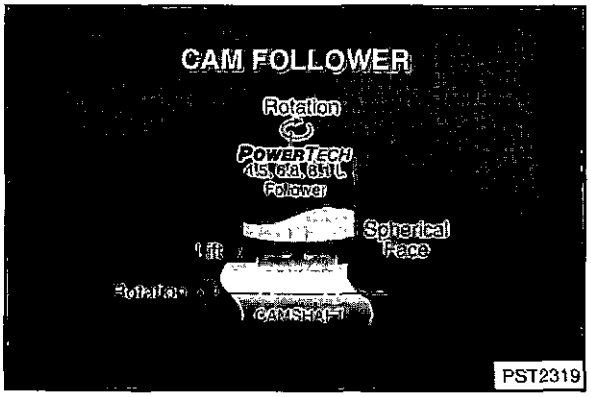
- Followers can be installed from top of block after camshaft has been installed
- Followers seat-in to the cam lobe and should never be inter-mixed during rebuild
- Camshaft should not be reground
- If a new camshaft is installed, always replace the followers
- Grease the followers with Moly Grease to prevent start-up scuffing



G.C. No. 32



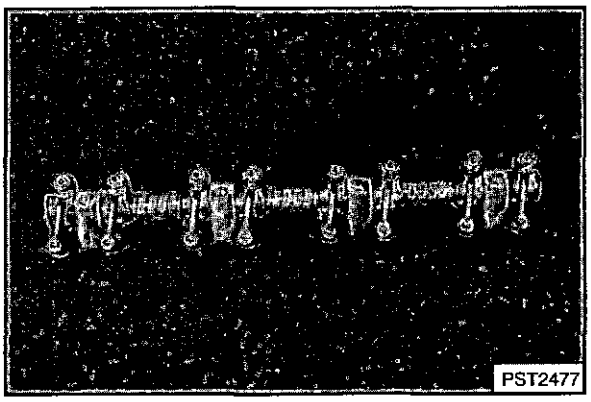
G.C. No. 33



G.C. No. 34

ROCKER ARM SHAFT ASSEMBLY

- Rocker arms pivot on a single shaft and are separated by springs and support brackets
- Each arm is lubricated by a drilled outlet in the rocker arm shaft
- Rocker arm wear pad geometry is designed to reduce wear pad and valve stem tip wear
- Rocker arms are not interchangeable with earlier engines
- Lubrication is directed from the hollow rocker shaft through a diagonally drilled hole in the rocker arm to lubricate the upper end of the push-rod
- Valve clearance adjustment is accomplished by:
  - Loosening a jam-nut on the adjuster screw
  - Making the adjustment
  - Then tightening the jam-nut while holding the adjuster screw
  - Adjust valve clearance at 2000 hour intervals
  - Valve adjustment is made when engine is cold



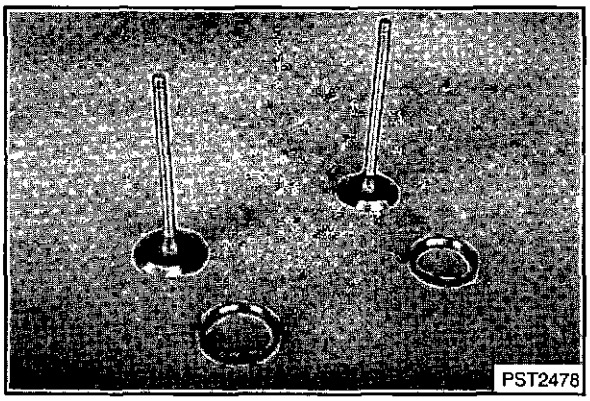
G.C. No. 35

VALVES

- ***POWERTECH*** diesel engines use common valve components that provide maximum durability and performance under all operating conditions
  - One style intake valve and one style exhaust valve is used in all ***POWERTECH*** 4.5 L and 6.8 L diesel engines.
  - A large diameter valve head and optimized port shapes allow maximum air flow with minimal restriction for improved engine breathing.
  - These are the same valves as used in the Series 300 engines.
  - Intake valves are made of SIL-1 material and have a 29.25 degree sealing surface angle. Seat angle is 30 degrees.
  - Exhaust valve is made of 23-8N material with same surface and seat angle as intake valve.
    - Valve stems are chrome plated to prevent scuffing and prolong valve life.
    - When required, valves with oversized stems are available for service.
    - Valve stems have hardened ends and do not require wear caps.
    - Intake and exhaust valve seat inserts are used in the cylinder head.

Service Note:

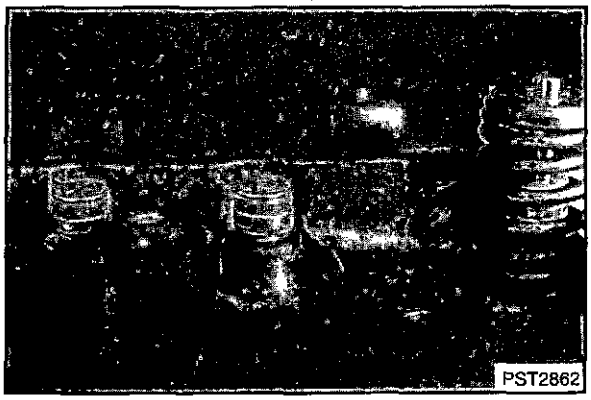
- Tool reliefs in the cylinder head beneath the valve seats have been removed to improve air flow
- See CTM104 (Group 05) for valve seat removal instructions



G.C. No. 36

VALVE SEALS

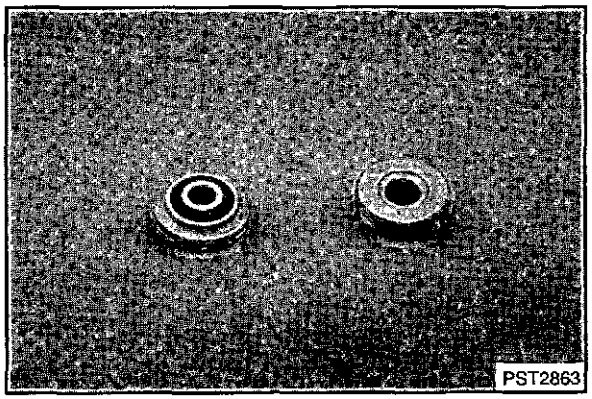
- Valve seals are used on each valve stem
- The seals meter oil down the stem to give adequate valve stem to valve guide lubrication
- Valve seals are mounted on the valve guide tower of the cylinder head



G.C. No. 37

VALVE ROTATORS

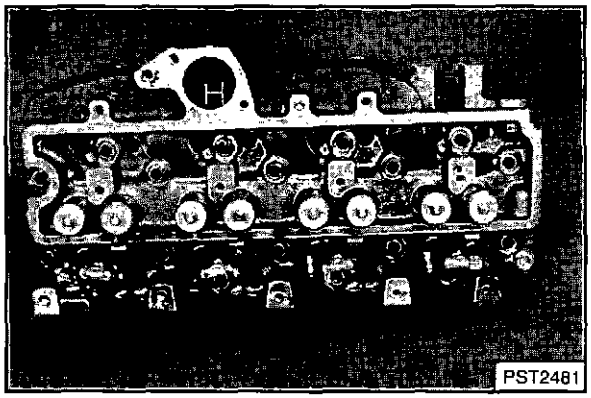
- All valves are equipped with valve rotators
  - By alternate action of the compression and release the rotators turn the valve approximately three degrees per actuation.
  - This action scours carbon and other deposits from the valve stem, valve face and seat area
- Rotators improve the gas seal to provide cooler valves and less erosion of the valve head and valve seat area
- Rotators may appear different, depending on supplier, but the function is the same



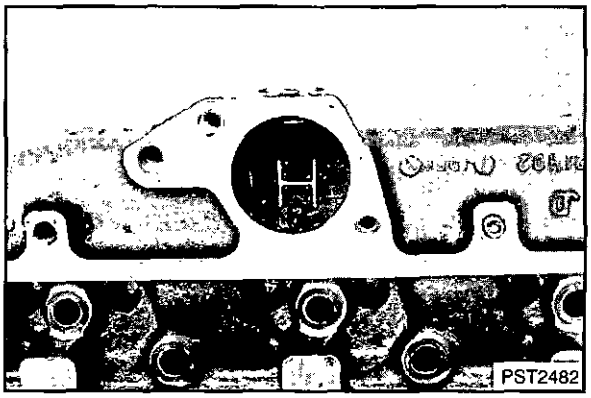
G.C. No. 38

CYLINDER HEADS

- A total of four different cylinder heads are available for use on the ***POWERTECH*** 4.5 L and 6.8 L engines
  - A four-cylinder high-swirl head and a four cylinder medium-swirl head.
  - A six-cylinder high-swirl head and a six-cylinder medium-swirl head.
- Swirl is controlled by the size and shape of the cylinder head intake ports
- Engine testing is used to determine the swirl level required to meet emissions regulations and optimize performance
- As a general rule the high-swirl cylinder head is used where low speed performance is desired
- The medium-swirl head is used where high speed performance is needed
- Cylinder heads are identified by a letter embossed inside the intake manifold that can be observed through the air intake opening in the manifold
  - "H" indicates high swirl
  - "M" indicates medium swirl
- Valve guides are integral to the head and are threaded to provide a path for lubrication between the guide and valve stem
- Internal design of the head reduces heat rejection to the cooling system
- Since the cylinder head and piston combinations provide a more efficient combustion chamber and fuel is more completely burned, much of the heat that was previously a waste product is now usable power
- Large diameter contoured valve seats offer less restriction to air flow into the cylinder
- The threads of the cylinder head bolts are English but metric socket can be used
- Numbers appear on the bolt heads which identify them as special bolts
- Head bolts are tightened using the torque-turn method. See CTM104 (Group 05) for details



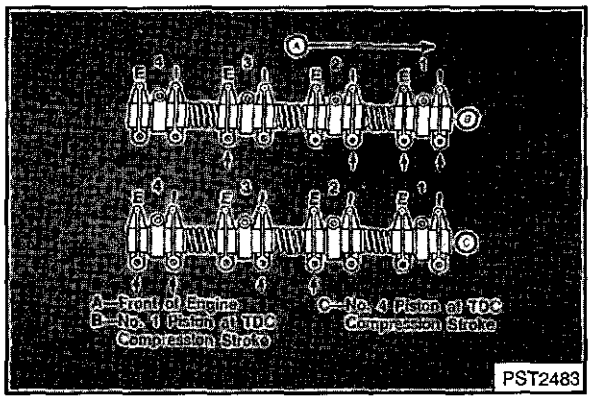
G.C. No. 39



G.C. No. 40

VALVE ADJUSTMENT

- Valve placement order in the head is the same as the Series 300 engines:
  - (1) Intake
  - (2) Exhaust
  - (3) Intake
  - (4) Exhaust etc.,
  - ending with exhaust.
- Valve adjustment should be made every 2000 hours. Consult CTM104 for adjustment specifications and procedures



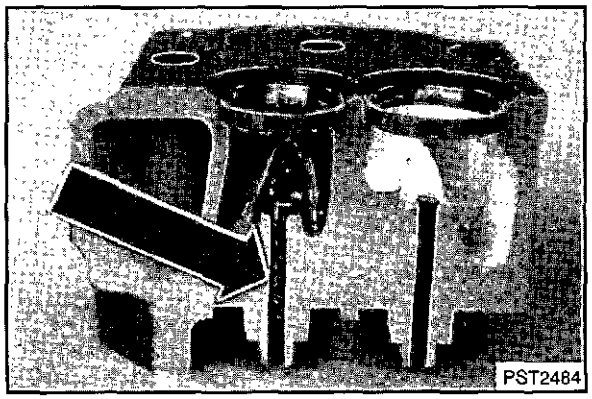
G.C. No. 41

VALVE GUIDE DESIGN FEATURES AND SERVICE PROCEDURES

- Valve guides are integral to the head
- No valve guide inserts are used
- *All valve guides are threaded*
- "Threaded" refers to a very shallow spiral cut in the valve guide to hold a meter supply of oil to keep the valve stems lubricated
- "Knurling", by comparison, refers to a groove that is rolled into the inside diameter of the guide to upset the metal and cause the bore to become smaller
  - The bore is then reamed to bring it back to the desired size.
  - *This process also creates a spiral passage* to meter oil to the stem and guide for lubrication.

Service Note:

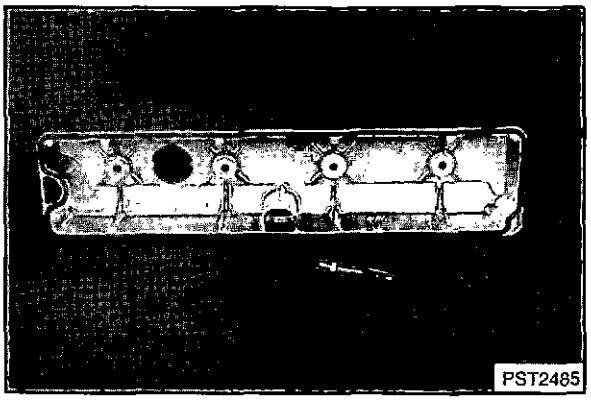
- Replacement valve guides are not available for service.
- Bores may be returned to standard size by knurling and honing.
- Valves with oversized stems are available for service if knurling will not restore to standard size.
- If guide is reamed to an oversize, knurling and honing should also be applied to restore the lubrication groove.



G.C. No. 42

ROCKER ARM COVER

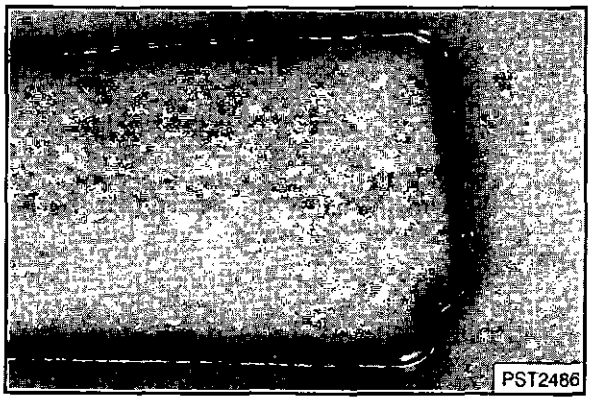
- A new aluminum rocker arm cover is used
- The cover is semi-isolation mounted to reduce noise
- Cover is mounted to the rocker arm attaching bolts which have a threaded tower that extends through the cover
- O-rings are placed under special large flanged nuts that secure the cover to the engine



G.C. No. 43

ROCKER ARM COVER SEALING RING

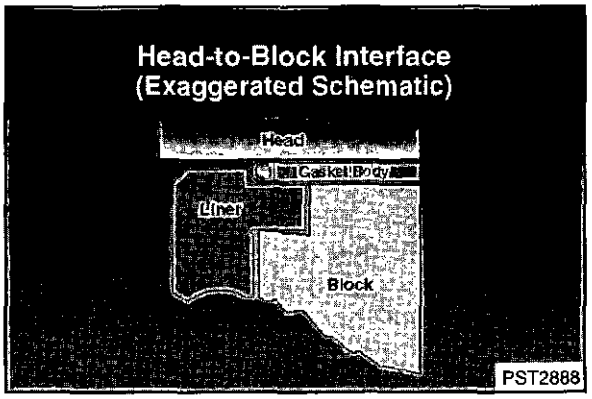
- A replaceable, triangular cross-sectioned, double-lipped sealing ring installs in a groove in the cover to prevent leakage around the cover



G.C. No. 44

HEAD-TO-BLOCK INTERFACE

- Cylinder block is the "wet sleeve" design wherein the cylinders are in direct contact with the coolant
- The cylinder head clamps down on the head gasket to form a compressed and stabilized fit of the liner flange in the block counterbore
- Coolant and compression is sealed by the gasket fire-ring and body
- Liner flange contact area in the counterbore is machined with a 1/2 degree upward slope toward the inside diameter
- This slight tilt assures that the flange is supported in the area beneath the head gasket fire ring to prevent liner flange cracking when the fire ring compresses against the flange
- The root of the outside diameter of the liner flange support counterbore is an undercut radius
  - This radius eliminates the possibility of a non-undercut radius that would support only the O.D. of the flange.
  - This would result in a cracked liner flange
- Liner flange stand out above the fire deck is 0.035 - 0.10 mm (0.001 to 0.004 in.) This is necessary to provide adequate compressive support of the liner and sealing of the head gasket to liner joint



G.C. No. 45

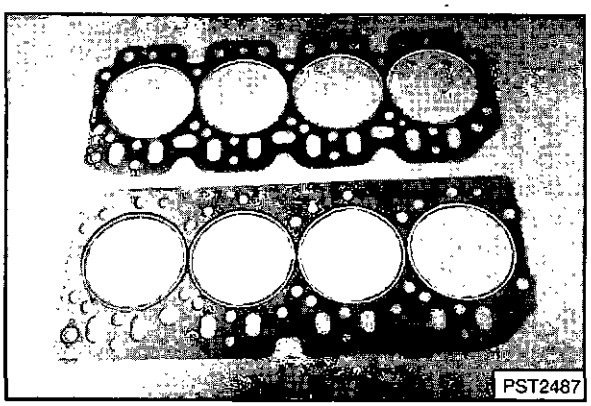
HEAD GASKET

- New compressed graphite cylinder head gaskets are used on the ***POWERTECH*** engines
- The graphite material is applied to both sides of a metal core

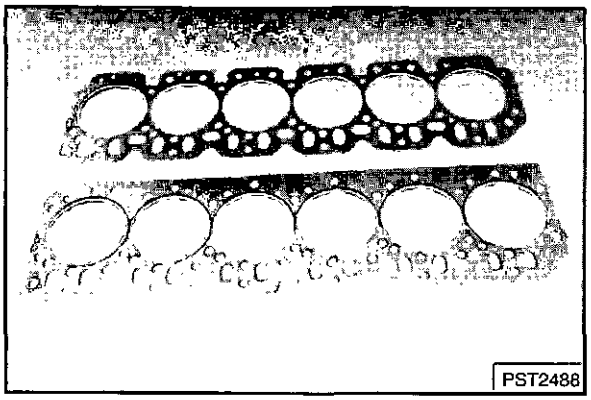
Service Note:

- A gasket of similar material has been used on the Series 300 engines for approximately one year.
- Do not install a Series 300 head gasket on the ***POWERTECH*** engine as it will block flow of critical coolant passages and cause the engine to overheat.
- A ***POWERTECH*** head gasket should not be installed on a Series 300 engine as it will block coolant passages on that engine.
- While the bolt circle is the same on both gaskets, the gaskets must not be interchanged on the engines.

- Top gasket in both photos at right are Series 300. Bottom gasket is for ***POWERTECH*** engines



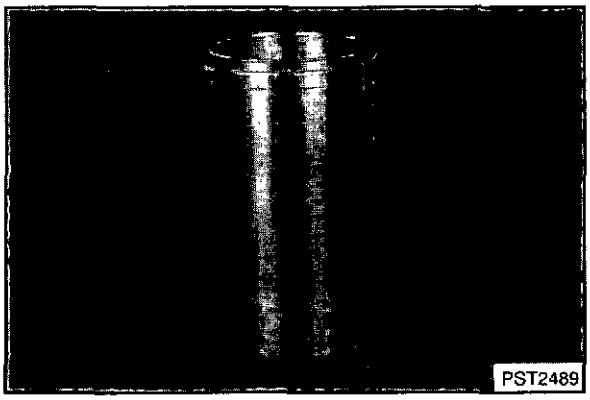
G.C. No. 46



G.C. No. 47

CYLINDER LINERS

- Cylinder liners are made of cast iron
- On high output engines the liners are hardened to provide excellent wear life in conditions of heavier loading
- Cylinder liner dimensions are constantly computer checked during the machining process to assure they are produced to exacting specifications
  - Replacement piston/liner sets are available for engine rebuild.
  - Service liners are machined to the same dimensions as production liners.
- Liners are internally honed with a 45 degree cross-hatched pattern
  - A second pass honing process called "plateau honing", eliminates the peaks in the cross-hatch.
  - The process produces a surface that retains lubrication and provides early seating of the piston rings without scuffing during the break-in period.
- Liners are machined with a smooth taper at the bottom end to provide easy installation into the lower block bore sealing rings



G.C. No. 48

CYLINDER LINER SEALS

- O-ring seals at the bottom of the liner separate the engine coolant from the crankcase lubricating oil
- The seals also restrict movement of the liner to reduce vibration caused by piston thrust
- Material used in the seals are:

  Top seal = Black "Neoprene" rectangular section packing

  Middle seal = Orange or white "Silicone" O-ring

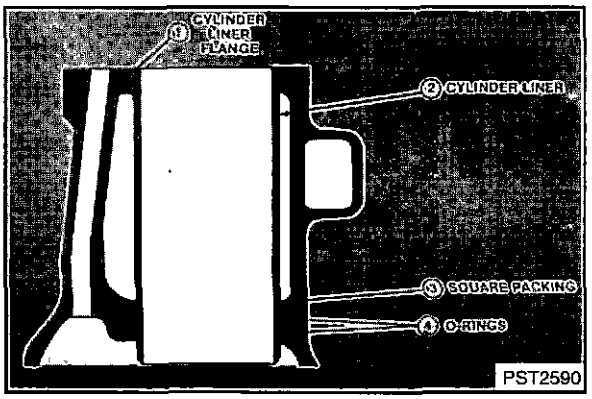
  Bottom seal = Black "Viton" O-ring

  - Material is selected for the specific function it is required to perform.
  - Neoprene is an excellent sealing material for coolant.
  - Silicone is able to withstand very hot conditions as is required in the mid seal application where it is not directly cooled by oil or coolant.
  - Viton is able to withstand hot oil and the affects of additives that are found in cylinder oils, without material degradation.

Service Note:

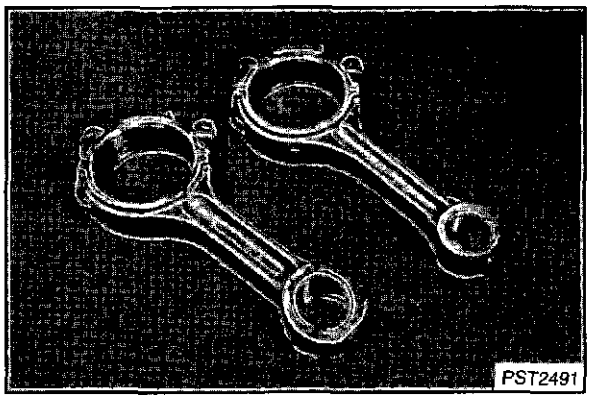
- Seals are to be lubricated only with a non-petroleum based soap during installation as oil may cause swelling of the material, making installation difficult.
- Carefully observe the top seal during installation to be sure it is not twisted.

- Soap for lubricating the seals is available under service part number AR54749
- If everything is cleaned and lubricated properly, using a clean piece of wood to protect your hand, it will be possible to push the liner into the block bore by hand using only hand pressure
  - This procedure eliminates the possibility of shearing a seal as can occur when driving the liner into the bore with a wood block.
  - Liners that have been in service for long periods will tend to stick in the block.
  - Use of the KCD10001 or D01062AA Cylinder Liner puller may be necessary.



G.C. No. 49

CONNECTING ROD DESIGN AND SERVICE PROCEDURES

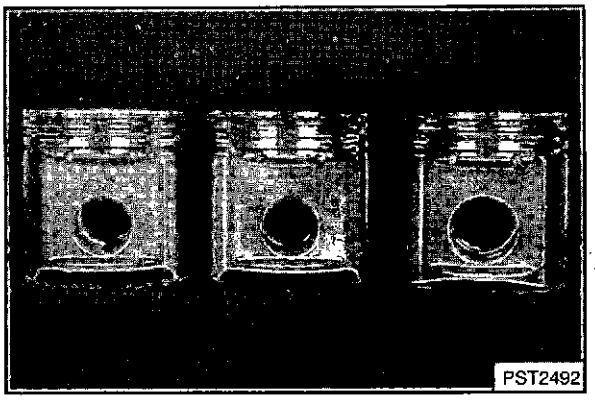


G.C. No. 50

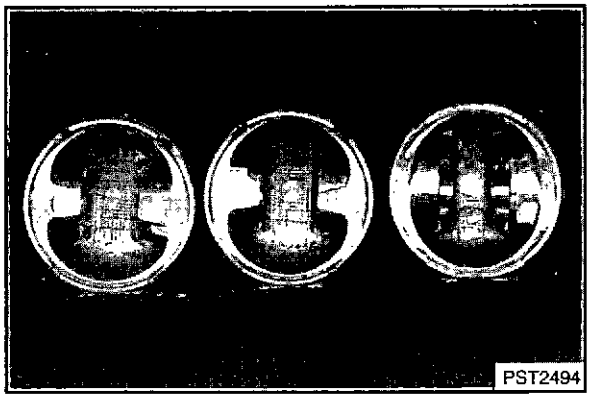
- Connecting rods are steel forgings
  - The crankshaft end is split at a 45° angle to allow clearance for installation or removal through the cylinder bore.
  - Location of the split also reduces conn rod bolt loading when the rod is pulling the piston down on the intake stroke.
- Two types of connecting rods are used in the ***POWERTECH*** 4.5 L and 6.8 L engines
  - Conventional type rod, similar to the rod in the Series 300 engines, is used with naturally aspirated and some turbocharged engines.
  - A new rod for high output turbocharged engines has a tee-pee shape at wrist pin end which allows piston to be designed *heavier above the pin boss area.*
  - Connecting rod weight is reduced at the piston end. This reduces the reciprocating mass which helps reduce engine vibration.
- Precision machined, non-symmetrical tongue and groove joints assure proper cap installation for a high integrity joint
- "Torque-Turn" method is used to tighten rod bolts for maximum reliability of the joint
- Connecting rod bolts are not reusable and must be replaced at each service
- Connecting rod is marked **FRONT** for proper orientation to the piston
- Lubricate con rod bolt threads and washer face by dipping them in engine oil and install using procedure described in CTM104
- ***POWERTECH*** 4.5 L and 6.8 L connecting rod bolts are metric

PISTONS

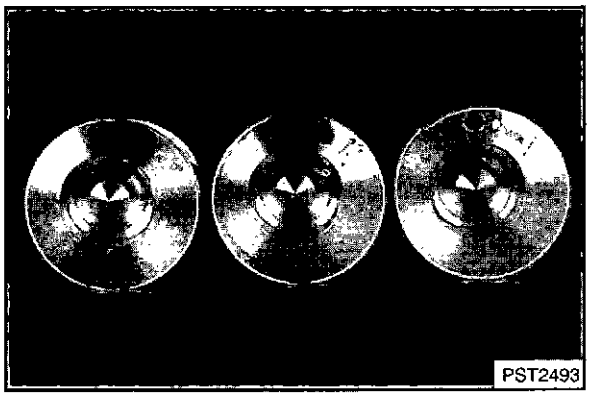
- Three different piston designs are used in the ***POWERTECH*** 4.5 L and 6.8 L engines
  - One piston, designed for the conventional rod, is used in **naturally aspirated** engines.
    - The top ring on this piston is located the same as the turbo piston but the diameter of the land above the top ring provides .35 mm (.014 in.) clearance to the cylinder wall.
    - Pin boss bores on this piston are round with side reliefs for lubrication
  - A second piston, designed for the conventional rod, is used in **turbocharged** engines
    - This piston has a reduced diameter land above the top ring that has .86 mm (.034 in) clearance to the cylinder wall for increased carbon clearance and more effective gas pressure sealing of the top ring.
    - This piston has ovalized pin bores that give more support to the pin under load.
    - The bores are also bell mouthed to improve pin to piston support with less distortion of the piston.
  - A third piston, designed for use with the tee-pee rod, is used in **high output turbocharged engines.**
    - This piston is made with ovalized and bell mouthed pin bores.
    - The piston is very robust in the area directly above the rod and wrist pin.
- Pistons are cast of high-grade aluminum alloy with internal ribbing at high load areas
- Pistons have a re-entrant bowl swirl chamber in the top that creates a turbulence during the compression stroke to enhance mixing of the fuel and air for more complete burning of the fuel-air mix
- The re-entrant bowl varies in depth on each of the three pistons and has a single leading edge except in areas where the piston is heavily loaded directly beneath the edge. In these areas a double lip edge is used to reduce stress
- Piston skirt is cam ground (oval) to allow for expansion variation as it becomes heated in operation
- The word "**FRONT**" is stamped in ink on top of the piston and embossed in the piston at the pin boss area. This ensures proper positioning with the connecting rod and the re-entrant bowl relative to the injection nozzle



G.C. No. 51



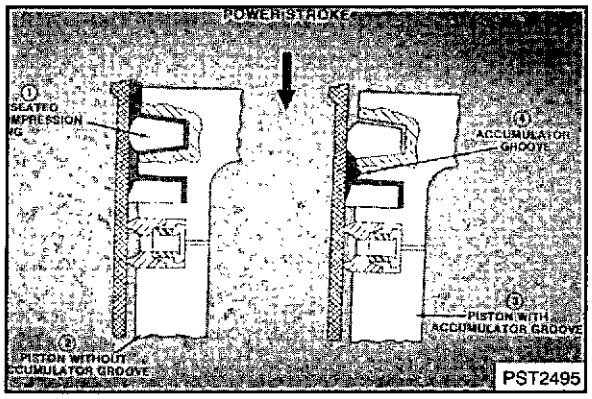
G.C. No. 52



G.C. No. 53

PISTONS (Cont'd)

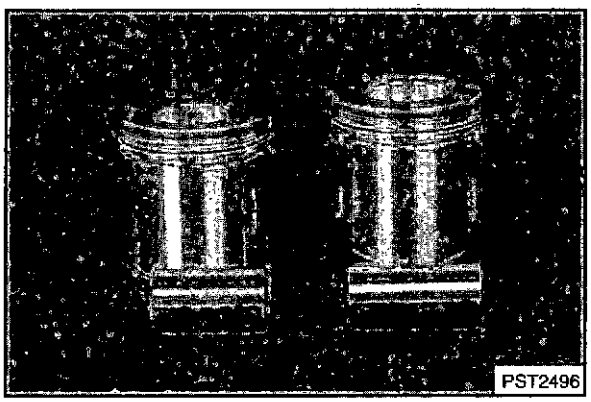
- A Ni-Resist (nickel, steel alloy) top compression ring carrier is cast integrally in the piston. This improves top ring groove wear life by providing characteristics of a cast iron piston in areas where it is needed
- All pistons have the re-entrant bowl design which contributes to more complete burning of the fuel and reduced emissions
- Pistons have an accumulator groove located in the land between the first and second ring
  - This groove provides a space to lower the pressure beneath the top ring.
  - This has a stabilizing effect on the top ring to keep it seated against the cylinder liner
- The oil control ring groove has drain holes to pass the oil back to the crankcase



G.C. No. 54

PISTON PINS

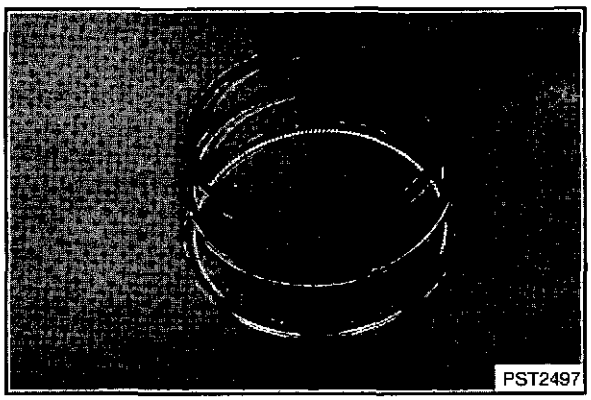
- There are two new pins for the three new pistons
- The same pins are used in the naturally aspirated and turbocharged engines and a different pin is used in the high output engines with tee-pee rods
- The pins are shorter than those used in the Series 300 engines
  - Shorter pins result in weight reduction at the piston and..
  - Less engine vibration
- Pins are the "Full Floating" design and retained with snap rings
  - Snap rings have square and rounded edges
  - Installed with the square edge toward liner
- Piston and pin are lubricated by spraying oil into the pin area



G.C. No. 55

PISTON RINGS

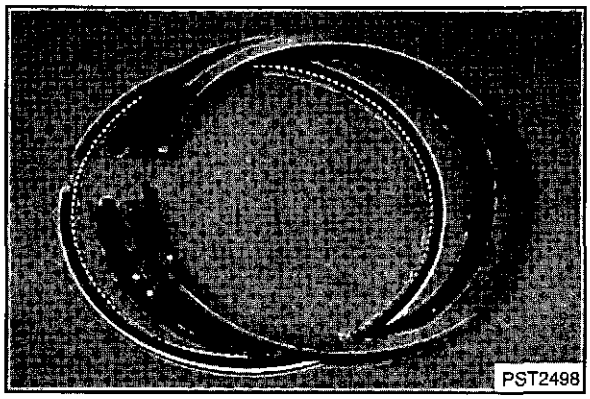
- Two different ring sets are used on the three piston designs
- Top or first ring
  - Pistons used with conventional connecting rod (non tee-pee) have a keystone shaped top ring that has a 6 degree angle
  - Steel ring
  - Plasma coated
  - Barrel faced
  - Pistons used with tee-pee connecting rod have a keystone shaped top ring that has a 15 degree angle
  - Ductile iron ring
  - Plasma coated
  - Barrel faced
- Second and third ring
  - All three piston designs use the same second and third (oil) ring
  - The second ring is cast iron, rectangular shape and has a taper-faced liner contact surface.
  - The third ring is a cast iron, double rail oil control ring with a round expander spring.
  - Rails are chrome plated and ground for smoothness and conformability to increased wear life.
- Plasma coating used on all top rings is of molybdenum, nickle and chrome to provide maximum wear life



G.C. No. 56

PISTON RING MARKINGS AND INSTALLATION PROCEDURES

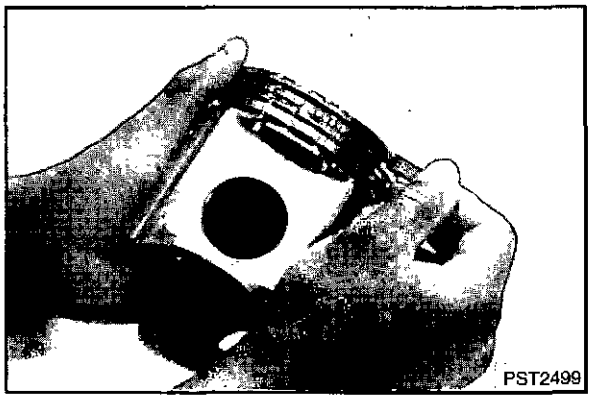
- Pip marks are used to identify ring location and direction of installation
  - One pip mark means it is the ring closest to the top of the piston,
  - Two pip marks mean it is the second ring from the top of the piston.
  - The pip mark or marks on any ring should face the top of the piston.
- Some piston ring suppliers do not place "pip" marks on the sides of the ring
  - In such instances the ring packaging material may contain the proper instructions for locating the ring.
  - If no information is available the proper location and direction can usually be determined by the shape of the ring.
  - The keystone-shaped top ring fits the number one ring-groove and may be non-directional unless noted.
  - Second ring is rectangular and has a taper-faced and is installed so the sharp outside edge of the ring faces the bottom of the piston.
  - The third ring, called the oil control ring, is symmetrical and non-directional.
- Always consult the CTM104 regarding ring location identifiers
- Oil control ring coil expander ring joint should be located 180 degrees (opposite) from the ring gap. This prevents the possibility of the ring gap getting stuck on the expander
- Install rings on piston with ring gaps over the pin bores and staggered 180 degrees. This method keeps the ring gaps off the thrust surfaces during break-in



G.C. No. 57

RING GROOVE WEAR CHECK

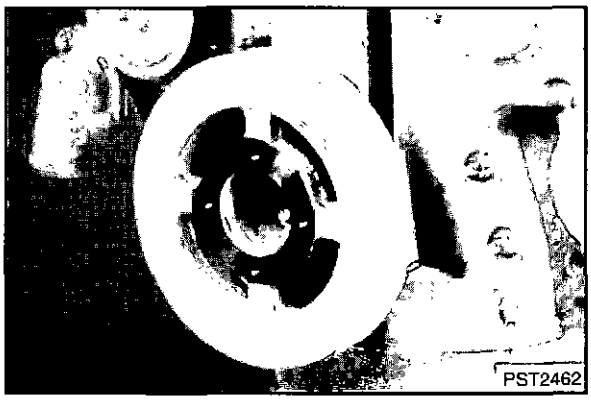
- Use a ring groove wear gauge to check wear of the keystone ring groove (top groove). Gauge shoulders should not contact the ring land
- Check the second and third ring groove using a new ring and a feeler gauge. See CTM104 (group 10) for wear allowance



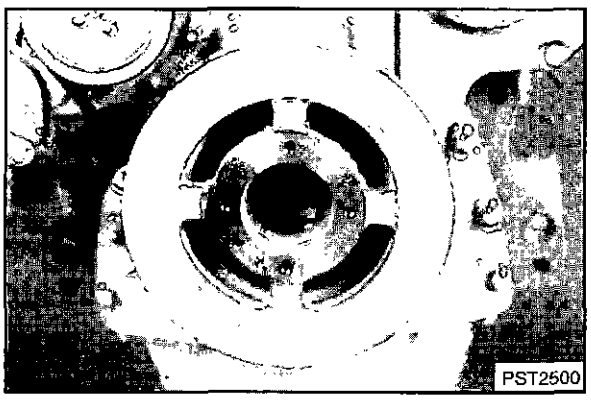
G.C. No. 58

TORSIONAL VIBRATION DAMPER CONSTRUCTION, FUNCTION AND SERVICE

- In operation, the front of an in-line six-cylinder engine crankshaft is accelerating and decelerating relative to the flywheel
- The crankshaft is being twisted in alternate directions at high frequency which is referred to as torsional vibration
- To absorb some of the torsional forces a vibration damper is fitted to the nose of the crankshaft
  - The damper is similar to a small flywheel at the outside area called the inertia ring.
  - The inertia ring is on a rubber mounting that holds the ring semi-restricted so that its rate of slowing down and speeding up is slower than that of the crankshaft.
  - This action has a dampening affect that reduces twisting of the crank.
- Failure of the damper can cause failure of the crankshaft so it is important that the damper be checked for run-out and loosening from the rubber mount. See CTM104 for checking and replacement procedures
- The damper is to be replaced after five years of service or 4500 hours use
- Replace damper at any major overhaul or if the crankshaft is replaced
- Crankshaft damper is a rubber mounted inertia mass connected to a hub
- Crankshafts have a natural resonant frequency
- On 6-cylinder engine crankshaft, torsional impulse frequencies are induced when the engine is running



G.C. No. 59



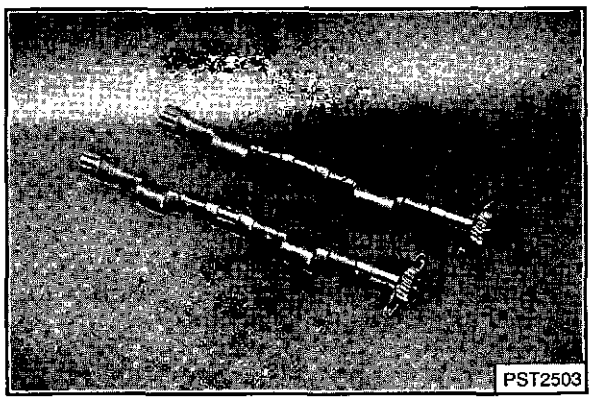
G.C. No. 60

TORSIONAL VIBRATION DAMPER CONSTRUCTION, FUNCTION AND SERVICE (Cont'd)

- When the two frequencies are in resonance, the combined vibration could over stress the crankshaft and in time, cause the crank to fail
- The inertia mass of the damper acts like a fly-wheel (counter-weight) in that it reduces the crankshaft stresses to a safe limit by absorbing some of the high frequency vibration and torsional stresses
- Some John Deere 6-cylinder engine applications use a semi-viscous damper. This does not apply to; the 6076 nor the 6076 (s/n 500,000 - up)
- With that damper design the inertia mass of the damper is able to slip freely within the viscous fluid as higher torsion's are felt
- Do run-out check to determine condition of damper
- The damper is not repairable, it must be replaced
  - If run-out exceeds limits or can be shifted by hand
  - At recommended service period 5 years or 4500 hours
  - At any major over-haul, or if the crankshaft is changed
  - After any gear train failure
  - If the engine has suffered a broken camshaft
- Do not beat or hammer on the inertia ring as the rubber may become damaged and render the damper useless
- Do not clean the damper with cleaning solvents or any petroleum products as the rubber may be damaged

BALANCER SHAFTS

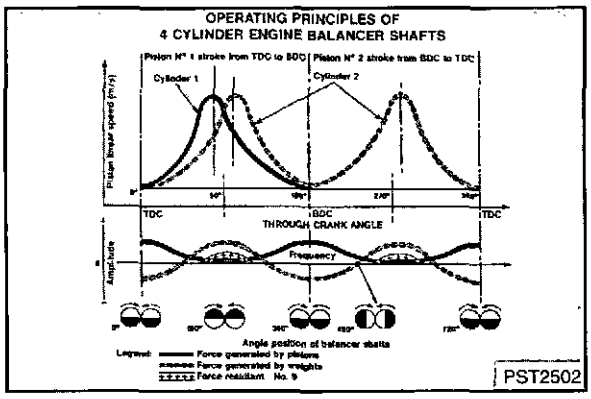
- Balancer shafts are only used on the 4-cylinder engines since they are of no benefit on any other multi-cylinder John Deere engine
- Two different weight balancer shafts are used on the ***POWERTECH*** 4.5 L engines
  - The lighter of the balancers (identified by reduced size offset weight) is used on engines that use non tee-pee connecting rods.
  - The heavier balancers are used in applications with tee-pee rods.
  - Balancer shafts may have bolt-on weights in initial production
- Balancer shaft bushings have been made larger in diameter so balancers with bolt-on weights are no longer required



G.C. No. 61

4-CYLINDER BALANCING THEORY OF OPERATION

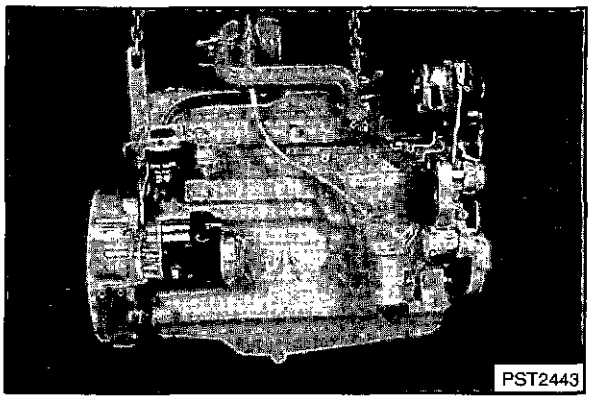
- Two counter rotating shafts
- Turn at twice crankshaft speed
- Vertical reciprocating force created at twice engine rpm by piston and rod motion on the crankshaft
- Primary vibration is removed by crank and conn/rod assembly
- Secondary vibration is removed by the balancer shafts
- General information on balancer shafts
  - Balancer shafts bearing journals are directional lapped and marked for location.
  - Right and left hand side... do not reverse
  - *Apply grease to bushings on assembly*



G.C. No. 62

AUXILIARY DRIVE

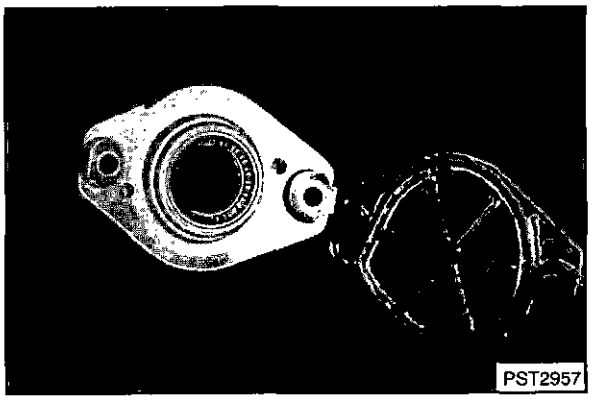
- The gear auxiliary drive is integrated into the front cover of the engine and is standard equipment
- The drive is rated at 37 kW (50 hp) for intermittent use and 30 kW (40 hp) for continuous use at 2500 engine rpm
- Auxiliary drive speed is 0.97 times crankshaft speed and rotates clockwise as viewed from rear of engine
- The auxiliary drive has a unique front plate and gear cover
- A direct tapered shaft drive can be used with:
  - Air compressors
  - Power steering pumps
  - Low pressure hydraulic pumps
- Thrust isolators with 9 tooth or 13 tooth spline for use with SAE "A" or "B" flange are available
- Offset drives available for accessories that require greater radial flange to block clearance:
  - With 13 tooth spline
  - For SAE B hydraulic pumps and air compressor flanges



G.C. No. 63

THRUST ISOLATOR

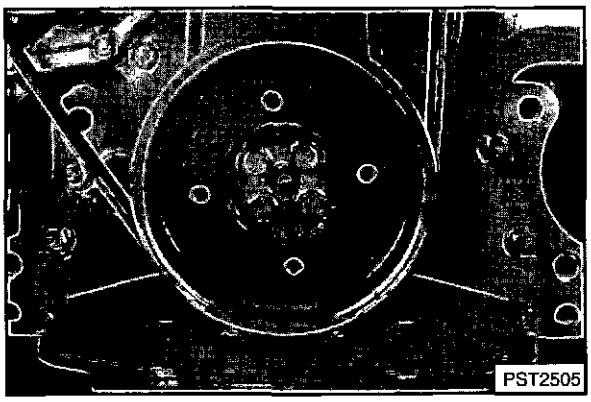
- A thrust isolator with an SAE A or B splined shaft drive is available for use with the auxiliary drive where hydraulic pumps or other devises need it
- The bearings in the thrust isolator are pressure-lubricated from the engine oil galley by an external lube line



G.C. No. 64

ACCESSORY DRIVE OPTIONS

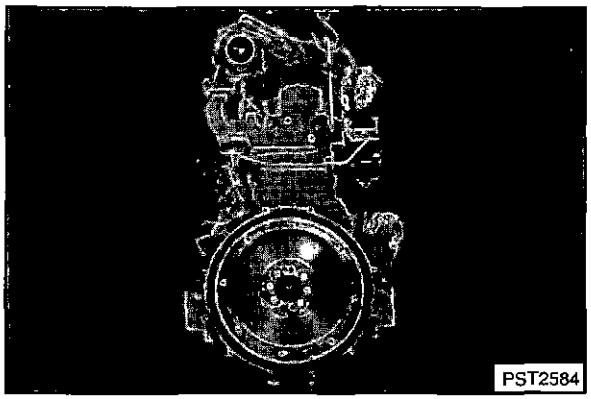
- Multiple accessory drives allow these engines to provide what the application requires
- Add-on crankshaft pulleys with one, two and three 1/2 inch belt grooves
- Add-on waffle plate drive for front mounted pump
- Mounting bracket for Nippondenso or similar 4-bolt side mount air conditioner compressor



G.C. No. 65

FLYWHEELS AND FLYWHEEL HOUSINGS

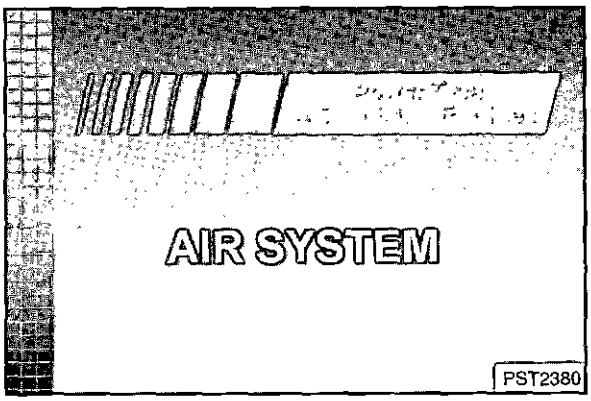
- Two new flywheel options are available on these engines
  - Flywheel that can be used with a 10 inch or 11.5 inch over center clutch in an SAE #3 housing.
  - Flywheel that provides a 10 inch over center clutch in an SAE #3 housing.
  - The same size clutch in an SAE #4 housing has been retained from the Series 300 engines.
- Flywheels are attached to the crankshaft using 6 bolts. The attaching hardware and threaded bores in the crankshaft are now metric
- Two "push-off" threaded bores for ease of flywheel removal
- Mechanical tachometer drives are no longer offered on the ***POWERTECH*** 4.5 L and 6.8 L engines
- Only electronic tachometers are being offered
- Notches at top and bottom of flywheel housing provide clearance for flywheel removal
- Refer to CTM104 for flywheel service procedures and safe handling methods



G.C. No. 66

THE FUNCTION OF THE AIR SYSTEM

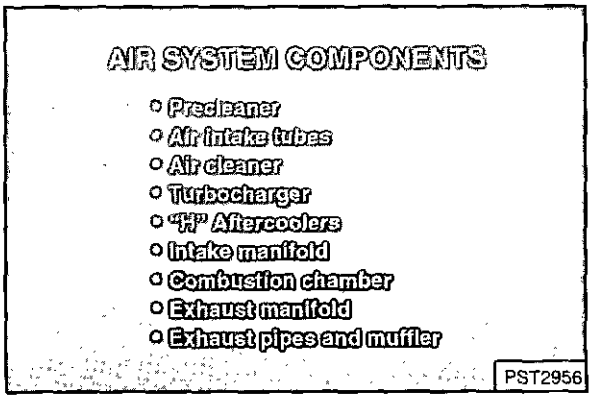
- Combustion - supplies sufficient clean air for the combustion process
- Cylinder scavenging - flushes residual exhaust gases and heat from cylinder
- Crankcase ventilation allows blowby gases to escape from crankcase



AIR No. 1

AIR SYSTEM COMPONENTS AND AIR FLOW

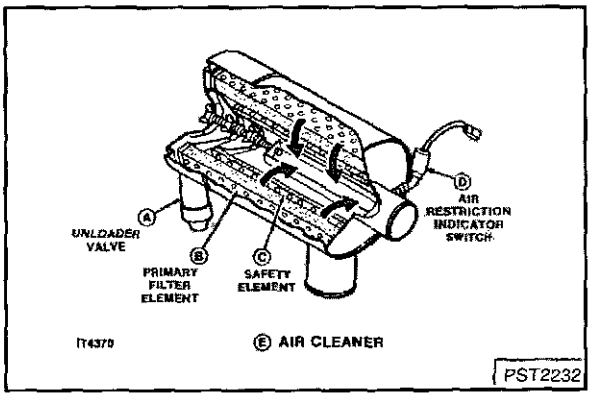
- Precleaner
- Air intake tubes
- Air cleaner
- Turbocharger
- Aftercooler
- Intake manifold
- Combustion chamber
- Exhaust manifold
- Exhaust pipes & muffler
- Discuss system maintenance as recommended in Operation and Maintenance Manual



AIR No. 2

AIR CLEANER OPERATION

- Piping and attachments
  - Inlets should be located to provide air with a temperature as close to ambient air temperature as possible.
  - Inlet piping or air cleaner should not be located near hot areas of the engine.
  - Piping design must provide minimum flow restriction. Pipe between the air cleaner and engine is the primary concern. Piping upstream from cleaner must also provide the lowest possible restriction
  - Avoid sharp bends, small pipe diameter, long pipe runs. Steel, aluminum, molded plastic or smooth I.D. fiberglass acceptable. Joint seals must be positive.



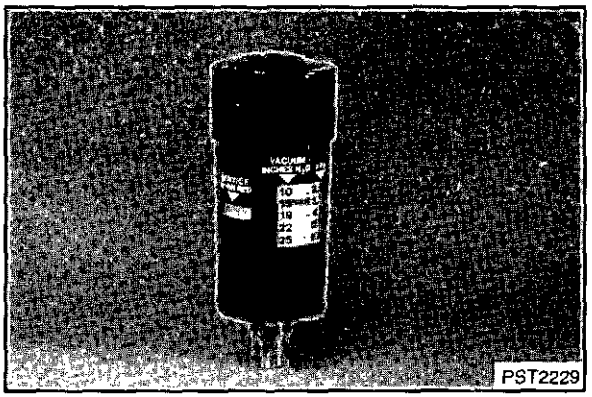
AIR No. 3

AIR CLEANER OPERATION (CONT'D))

- Discuss operating principles of a typical air filter assembly
  - Housing
  - Safety element
  - Primary element
  - Dust cup
- Discuss maintenance intervals
  - Recommended service interval monitor is the restriction indicator
  - Maximum allowable air inlet restriction is
    - 3 kPa (12 in.) water - clean
    - 6.25 kPa (25 in.) water- dirty
    - Measured 50-100 mm (2 to 4 in.) ahead of turbocharger or intake manifold inlet.
  - John Deere's primary filter elements can be washed with non- sudsing detergent soap
    - Dry
    - Check for holes
  - Automotive application filters (not in the John Deere system) are usually non-washable.
  - Replace yearly or as recommended by manufacturer.
  - Filter canisters with unloading valves should be emptied daily.

RESTRICTION INDICATORS

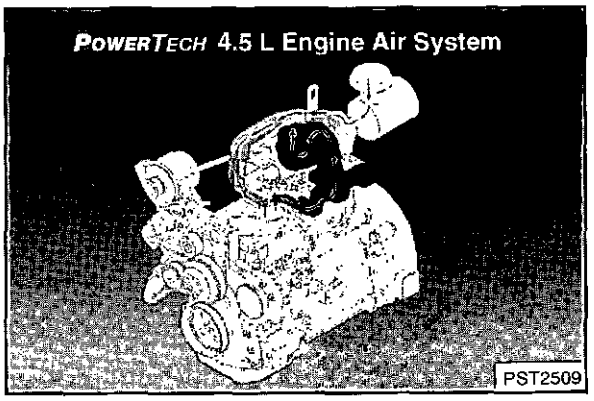
- Filter indicator used with dry-type air cleaners
  - Component parts
    - Housing
    - Indicator window
    - Piston
  - Purpose
    - Indicates air filter restriction.
    - Visual indicator of developing problem.
- Filter indicator function
  - Calibrated in inches of Water (or in. Hg)
    - Various manufacturers
    - See manufacturer for specific values
    - 1 in. Hg (Mercury) = 13.58 in. H20 (Water)
  - Black flag - no significant restriction.
  - Colored flag showing
    - Restriction limit has been reached.
    - Observation during operation will tell when limit near or warn of large holes in system.
  - Can be filter outlet mounted or remote located.



AIR No. 4

AIR-TO-AIR AFTERCOOLING

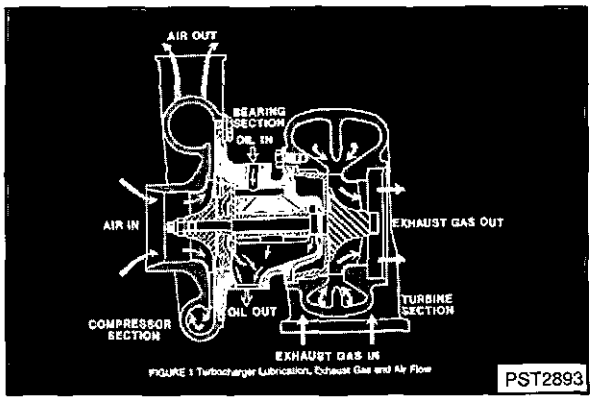
- Signified by model designation "H" (air-to-air)
- Exhaust manifold temperatures on "H" models are about the same as "T" versions. Though power output is 50-100% higher on the "H" models, manifold temperature is similar to that of the "T"
- Exhaust manifold temperatures of the "H" engine indicate that internal components experience thermal stress loads similar to "T" models which operate at lower power levels



AIR No. 5

TURBOCHARGERS

- Garrett turbochargers used
- Point out internal components
  - Turbine wheel housing with scroll, used for higher wheel speeds as a result of nozzle velocity effect
  - Center section
    - Turbine shaft and wheel assembly
    - Heat shield
    - Turbine end seal
    - Floating bearing assembly. Snap ring at the turbine end and thrust bearing at compressor end.
    - Supply pressure oil and pressure free drain-back oil
    - Thrust bearing
    - Seal
    - Compressor wheel and nut
  - Compressor housing
    - Compressor range is broadened to accommodate increased torque rise
    - Turbos are physically larger. Requires new manifolding and hardware.
  - Exhaust Housing
    - Smaller
    - Wheel smaller - turns faster
    - Accommodates low end torque
- Operation
  - Exhaust gas from cylinders enters turbine housing driving turbine wheel
    - Turbine responds to load on engine
    - Typical speeds from 60,000 to 180,000 rpm full load
    - Bearings run about 1/2 turbocharger speed.



AIR No. 6

TURBOCHARGERS (Cont'd)

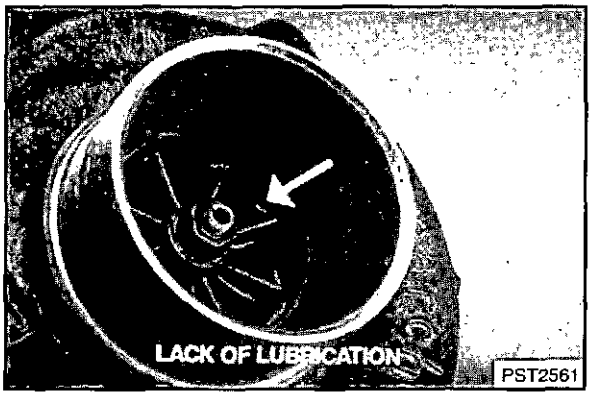
- Gasses leave large end of turbine housing and pass through muffler to atmosphere.
- Air from the air cleaner enters large opening of compressor housing.
- Air is compressed as it passes through compressor wheel, leaving by smaller opening into the intake manifold.

- Operating a Turbocharged Engine
  - Starting
    - Pre-lube if installing a replacement turbocharger or unit has been unused for a long period.
    - Leave throttle in idle position 30 seconds after start to assure oil flow to turbocharger.
  - Stopping
    - Idle engine a few minutes before shutdown to cool down and slow down.
    - Hot shutdown from high load reduces life, due to progressive slight damage at each occurrence.
  - Shipping
    - Cap inlet and outlet to prevent spinning from air flow during open transport.
    - Turning with a lack of lube oil, results in destruction.

- Most DSD (Authorized Diesel Service Dealer) shops provide turbocharger rebuilding service

LACK OF LUBRICATION FAILURE

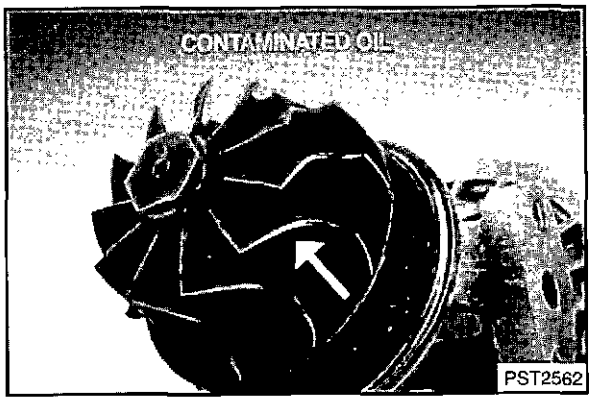
- Bearing wear
- Discuss housing and wheel contact
- Leads to failure



AIR No. 7

CONTAMINATED LUBE FAILURE

- Examine bearing to identify cause
- Allows housing and wheel contact
- Evidenced by grooving of the bearings
- Usually closes off oil passages in bearing



AIR No. 8

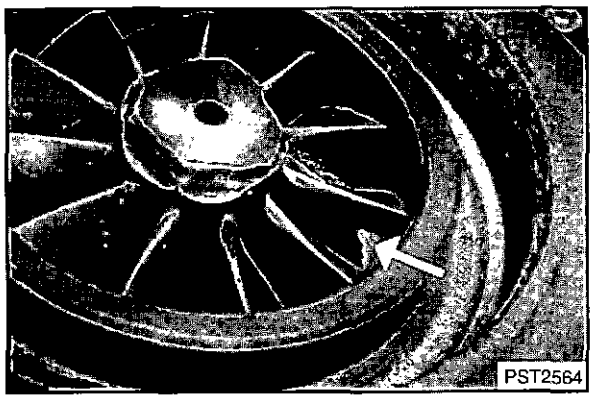
FOREIGN OBJECT DAMAGE

- Typical entry of foreign object (loose washer) damage
- Usually still present, find and remove
- *Soft material (shop rag) will usually bend the vanes backwards*

AIR No. 9

FOREIGN OBJECT DAMAGE TURBINE SIDE

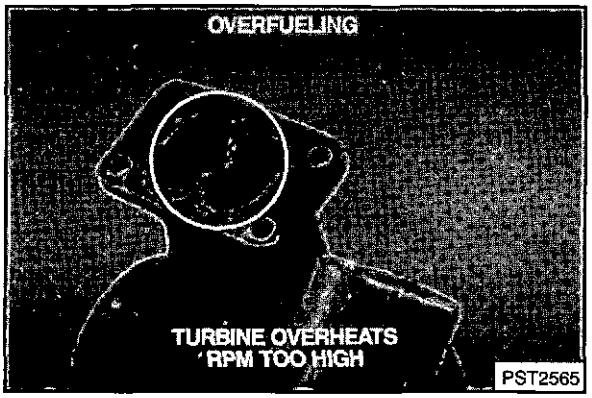
- Debris from engine
- *Weld slag*
- Uniform wheel damage



AIR No. 10

OVERFUELING FAILURES

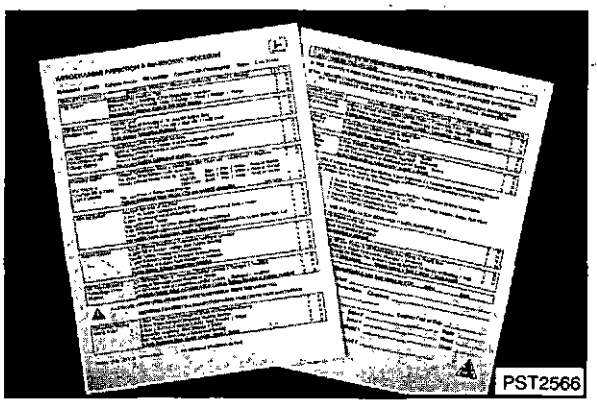
- Continued overheating leads to metal meltdown
- Probable causes
  - Tampering with injection pump setting
  - Failure to change fuel or derate at high altitude



AIR No. 11

INSPECTION AND DIAGONSTIC PROCEDURE

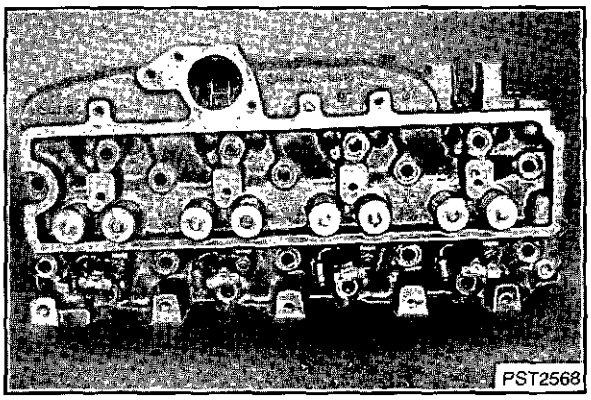
- Review inspection sheet
  - Related systems - Turbocharger component review
  - Turbocharger and engine information requirements
  - Pass out and review with class



AIR No. 12

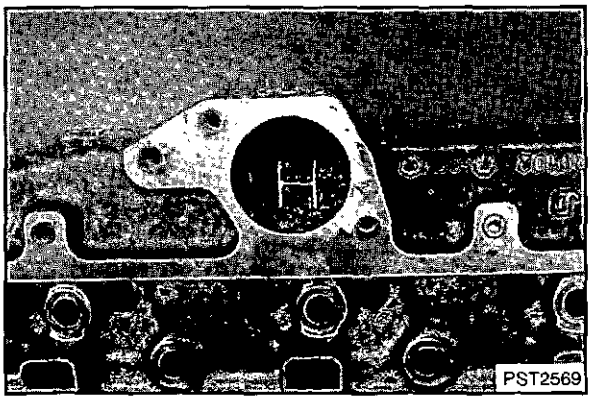
INTAKE MANIFOLD

- The intake manifold is integral to the cylinder head



AIR No. 13

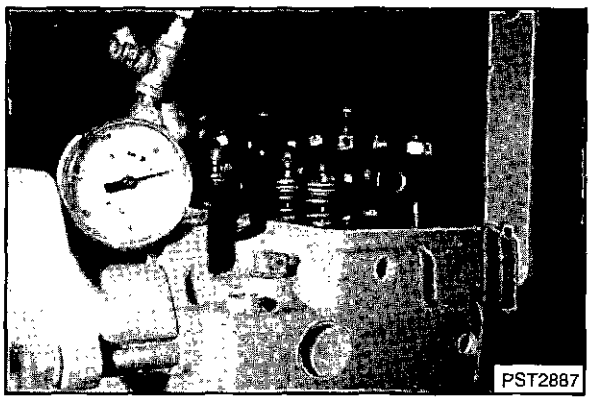
- There are heads with two different intake manifold configurations
- These create different swirl characteristics in the intake air
  - They are identified by an "H" (high swirl) or an "M" (medium swirl) cast in the inlet passage
  - The head for any engine is selected to provide the best combustion characteristics



AIR No. 14

COMPRESSION CHECK

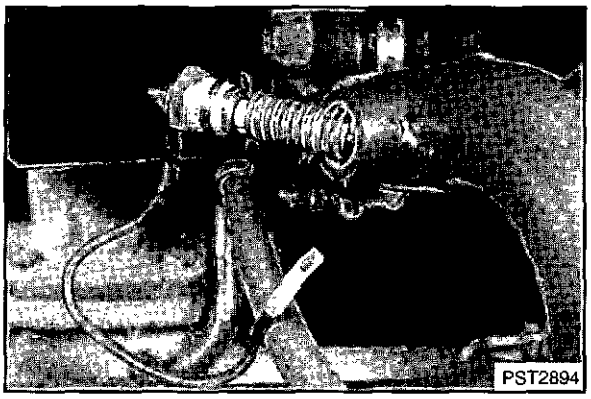
- Compression of ratio...volume in cylinder at start of compression compared to fully compressed stroke
- Compression efficiency increase air-to-fuel mixture...thereby creating more power
  - Limits do exist
  - Check for ratio in CTM
- Compression check
  - Run engine for 15 minutes .. warm up
  - Remove injection nozzles
  - Install test gauge JD01679 (D14550BA)
  - Turn crankshaft at 150 rpm for 10-15 seconds
  - Take reading ... compare all readings and check CTM for desired results
  - Shows if desired air flow is present (350 kpa/50 psi max variation between cylinders)



AIR No. 15

OPTIONAL STARTING AID

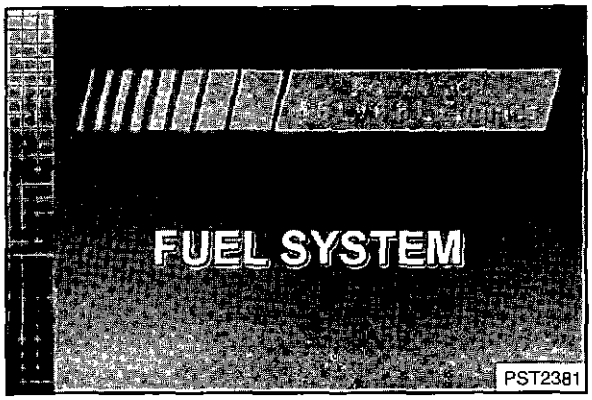
- A 12 volt, 700 watt heating element is installed in the air pipe between the turbocharger and the intake manifold. The element heats the intake air for easier cold weather starting.
- The pre-heater is to be used at temperatures below 5 °C (23 °F).
- ***Starting fluid is not used for cold weather starting.***



AIR No. 16

BASIC FUNCTIONS OF THE FUEL SYSTEM

- The proper performance of the John Deere Diesel engine is a function of a properly designed fuel system
- To be able to develop full rated engine power, have proper throttle response and maintain satisfactory fuel injection equipment operation:
  - Supply adequate quantities of clean fuel to and from the engine
  - Deaerates the fuel
- Store and supply adequate quantity per operational shift demand
- Cooling and lubrication of the fuel system components



FUEL No. 1

FUEL REQUIREMENT SPECIFICATIONS

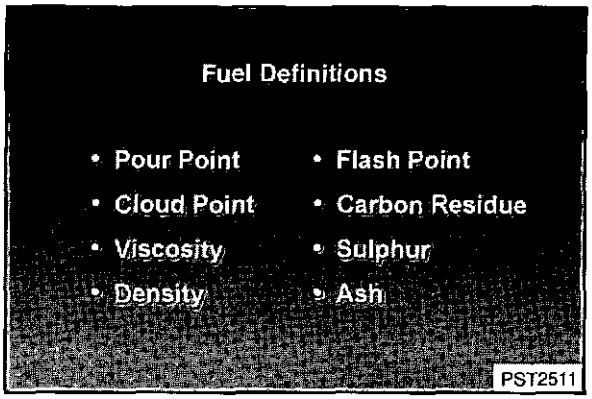
- Grades of diesel fuel;
  - Number 1 diesel
    - High speed engines
    - Wide variations in loads and speeds
    - Low fuel temperatures
    - 100°F flash point
  - Number 2 diesel
    - High speed engines
    - Relatively high loads and uniform speeds
    - Less volatility than D-1 fuel
    - 125°F flash point
- Cetane
  - Scale used to represent the ignition quality of diesel fuel (Similar to octane rating)
  - 100 is top of cetane scale and allows for creation of good ignition at lowest temperature
  - Paraffin (wax) increases cetane rating
  - 40 is John Deere minimum

		Temperature	
		Below Freezing	Above Freezing
Elevation	Above 1524 m 5000 feet	#1 Diesel Fuel	#1 Diesel Fuel Naturally Aspirated #2 Diesel Fuel All Others
	Below 1524 m 5000 feet	#1 Diesel Fuel	#2 Diesel Fuel

FUEL No. 2 PST2118

FUEL DEFINITIONS

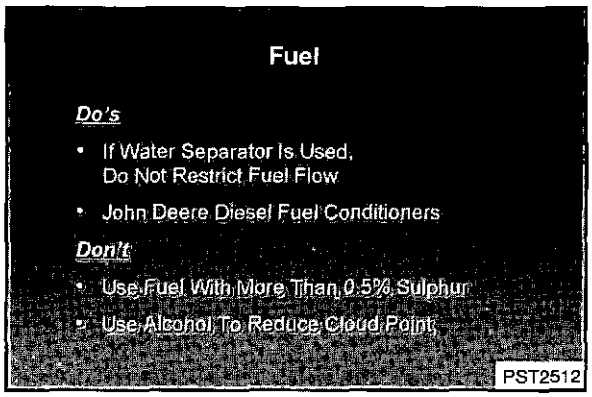
- Pour point
  - Lowest point at which fuel will pour
  - Proportional to cetane rating
- Cloud point
  - Prior to pour point paraffin (wax) forms into crystals
  - Clogs filters and system [-13 °C/-12 °C (8 °F/10 °F)]
- Viscosity
  - If too low creates more maintenance
  - If too high will create high injections pressure
- Density
  - The more dense it is, the higher the heat content
- Flash point
  - Point at which it will ignite
- Carbon residue
  - Carbon left after evaporation and chemical decomposition of liquid sulphur
  - Not to exceed 0.5%, will lead to creation of sulfuric acid (ash)
  - Metallic soap and abrasive solids



FUEL No. 3

SERVICE TIPS

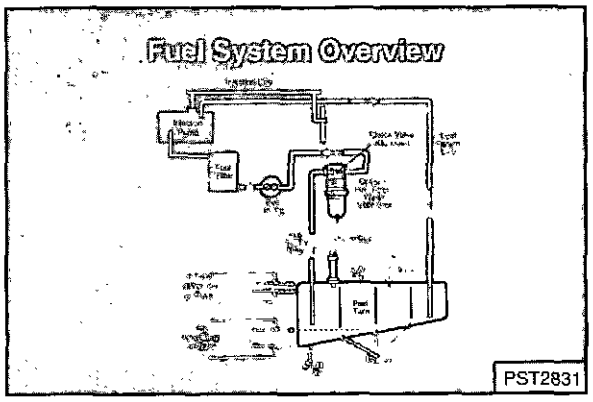
- Sulphur content;
  - Recommend less than 0.5%
  - If higher, reduce oil change intervals per Operation and Maintenance Manual
  - Doesn't allow H_2SO_4 (sulfuric acid to form)
- Water content
  - Water separators can be used, do not restrict fuel flow
  - Test for water on a regular basis
- Additives;
  - John Deere anti-gel will reduce cloud point (do not use alcohol)
  - John Deere fuel conditioner is available to keep fuel stable and microbe free



FUEL No. 4

FUEL SYSTEM COMPONENTS

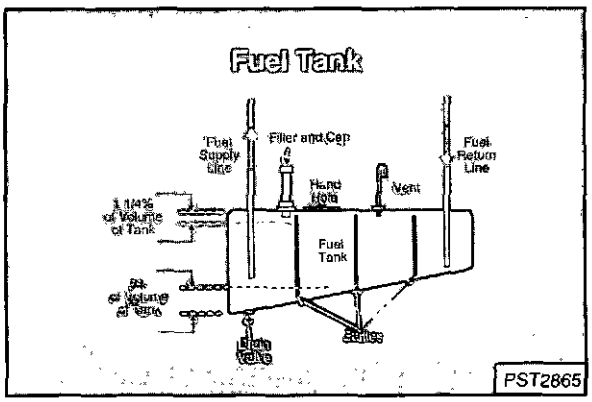
- *Fuel tank(s)*
- Supply Pump
- Supply & Return Lines
- Fuel Filter
- Fuel Injection Pump & Governor
- Fuel Injection Nozzles
- Fuel Return Lines
- Fuel Shut-Off



FUEL No. 5

FUEL TANK(S)

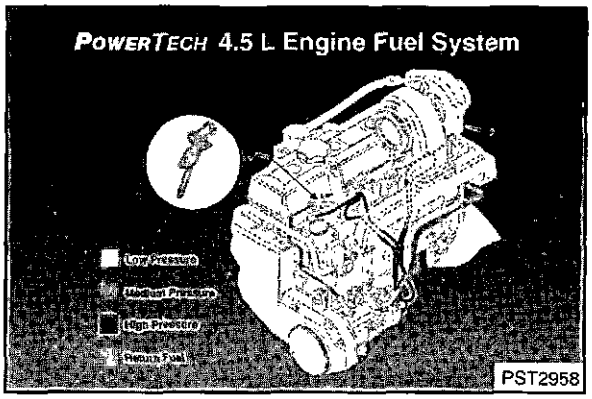
- Must not be made of galvanized metal
- Allow 5% of total volume for condensation and contaminants
- Should have drain plug
- Allow 1.25% for expansion, 1/8 in. vent tube
- Baffles to prevent sloshing
- Capacity for average 10 hour working period
- *Filler neck vented to avoid fuel back pressure*
- Separate suction and return lines to prevent hot fuel recirculation
- Fuel system return line should be baffled, if necessary, so that return fuel does not cause air entrainment in the fuel at the suction point
- The fuel should be returned above the operating level of the fuel when using elevated tanks
- On installations where the tank is lower than the engine, the fuel return line should extend below the fuel in the tank to prevent drain back



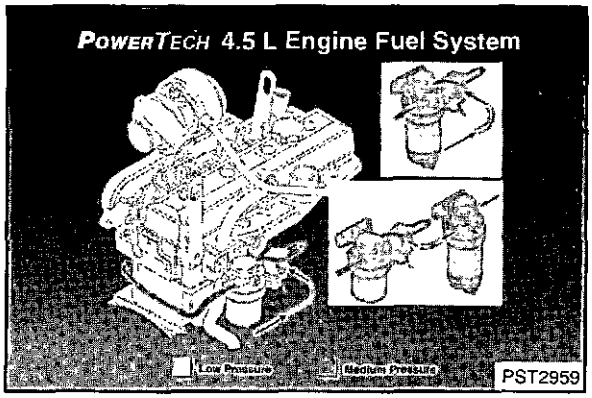
FUEL No. 6

FUEL FLOW

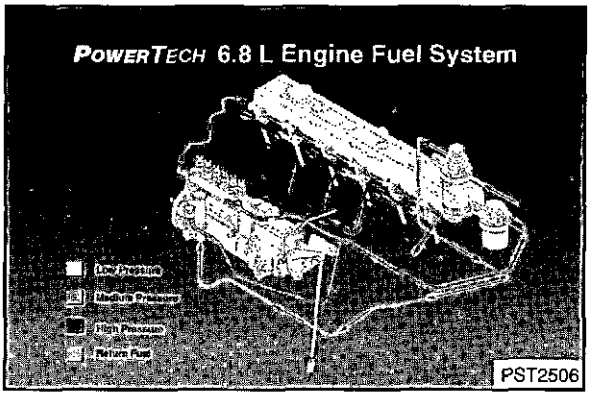
- From tank to supply pump
- Supply pump to water separator (optional) to fuel filter
- Filter to fuel injection pump
- Pump to injector
- From injectors and fuel injection pump to return to tank



FUEL No. 7



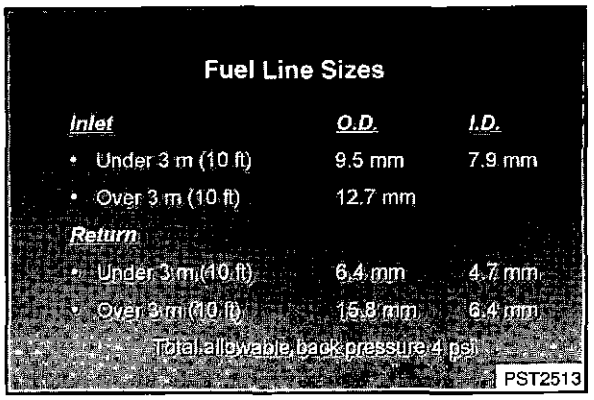
FUEL No. 8



FUEL No. 9

FUEL LINES

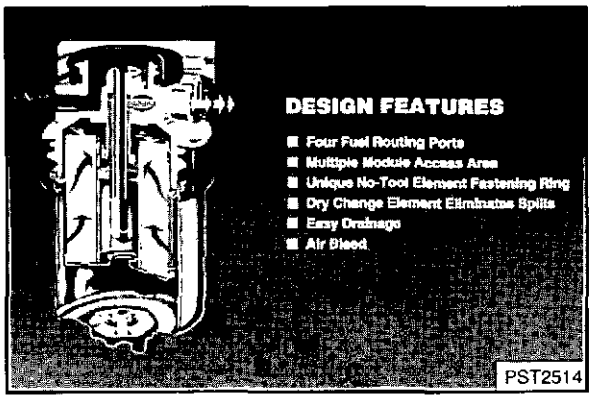
- Inlet fuel lines
  - Under 3.0 meters (10 ft), use 9.5 mm (3/8 in.) O.D. and 7.9 mm (5/16 in.) I.D. hose
  - Over 3.0 meters (10 ft), use 12.7 mm (1/2 in.) O.D. and 11 mm (7/16 in.) I.D. hose
  - For remote mounted filter line size
    - Measure from supply pump filter to injection pump
    - Then determine size required by measuring pressure
- Return fuel lines
  - Use on rotary pumps and return lines under 3 meters (10 ft) use 6.4 mm (1/4 in.) O.D. and 4.7 mm (3/16 in.) I.D. hose
  - In-line pumps/rotary pumps with line lengths over 3 meters (10 ft) use 15.8 mm (5/8 in.) O.D. and 6.4 mm (1/4 in.) I.D. steel tubing
  - Back pressure allowed at distribution pump
    - 2 psi - in-line
    - 4 psi - total
  - Return line should be 19 mm (3/4 in.) to 25 mm (1 in.) from bottom of tank to avoid hard-starting from siphoning of fuel



FUEL No. 10

STANADYNE FUEL FILTER

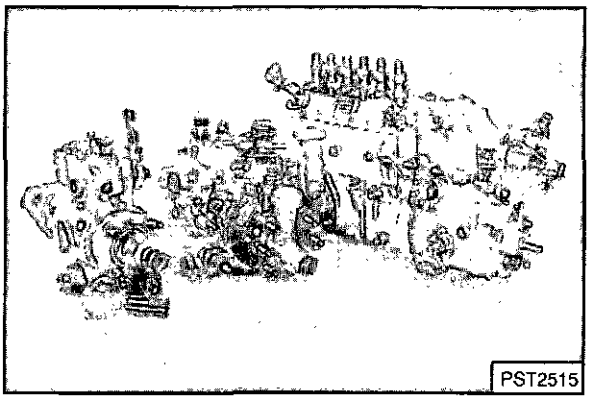
- Components;
  - Permanently Mounted Base
  - Paper Filter Element
  - Separation Area
  - Locking Ring
  - Air Bleed
  - Canister
  - Water Drain
- Operating pressure - 30 psi (207 kpa)
- Flow path
  - Trace path through filter
  - Maintenance
    - Replace as recommended
    - Bleed air if system opened



FUEL No. 11

FUEL INJECTION PUMPS

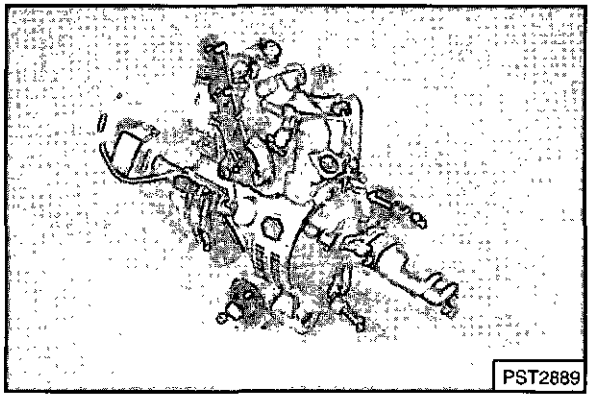
- Stanadyne
  - Model DB2 for 60 kW (80 hp) industrial engines
  - Model DB4-LLA (Light Load Advance) for OEM generator drive engines
  - Cold start advance
  - Used on the lowest horsepower engines
- Lucas
  - Model DP201 w/o aneroid
  - Model DP 203-LLA (Light Load Advance) with aneroid
  - Cold start advance
  - Used on the medium horsepower engines
- Nippondenso
  - Model A
  - Used on the highest horsepower engines



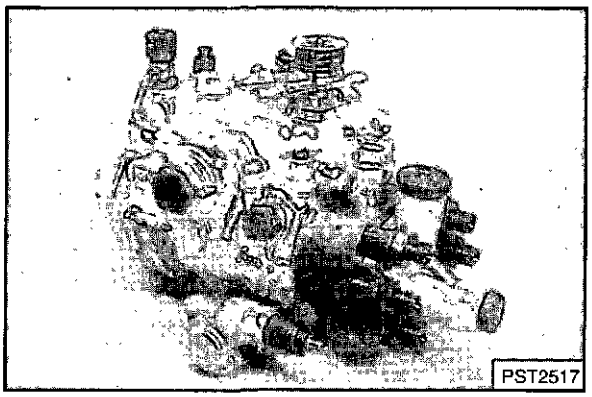
FUEL No. 12

ROTARY INJECTION PUMPS

- Types
  - Stanadyne
  - Lucas
- Characteristics
  - Cold advance (CA)
  - Opposed pumping plungers
  - Inlet metering
  - Positive displacement
  - Self-lubricated and cooled
  - Variable-speed governor
  - Light load advance (LLA)
- Features exterior
  - Return check valve fitting
  - Solenoid shut-off control
  - Energized-to-run (most applications)
  - Serial number plate
  - Advance mechanism
  - Hydraulic head
    - High pressure discharge fittings must not be allowed to loosen
    - If leakage occurs, replace (never use sealant or try to tighten)
  - Aneroid
  - Cold start advance switch
- Option codes - 1600 group
  - Many options exist in fuel injection system, check the option manual and match up the requirements to the unit needs
  - Mechanical governor 0% droop is not available.
  - An electronic governor may be purchased from outside source (Barber Coleman)
  - Other options ... hardened parts for use with jet fuels



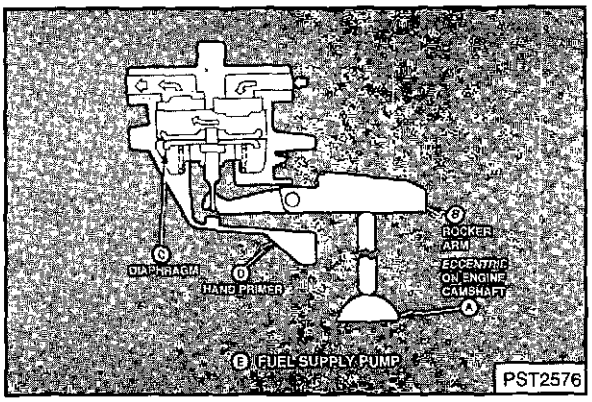
FUEL No. 13



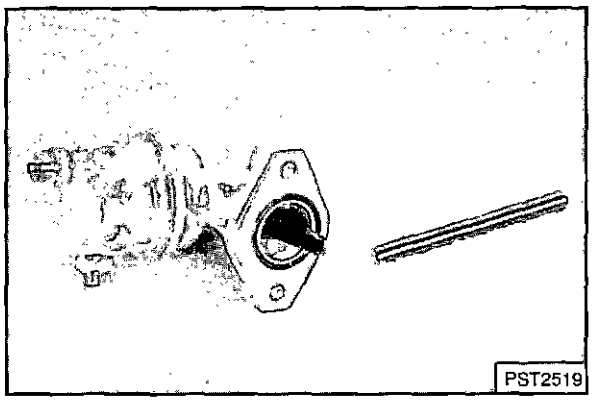
FUEL No. 14

FUEL SUPPLY PUMP

- Driven by engine camshaft
- Supply pumps are non-repairable
- Pressure test to determine vacuum at inlet and outlet
  - Numbers are not as important as speed of gauge operation
  - Slow gauge movement indicates good pump
  - Fast or no movement indicates defective pump
- If supply pump is higher than 1 m (3.28 ft) above fuel supply, an electric supply (boost) pump is required



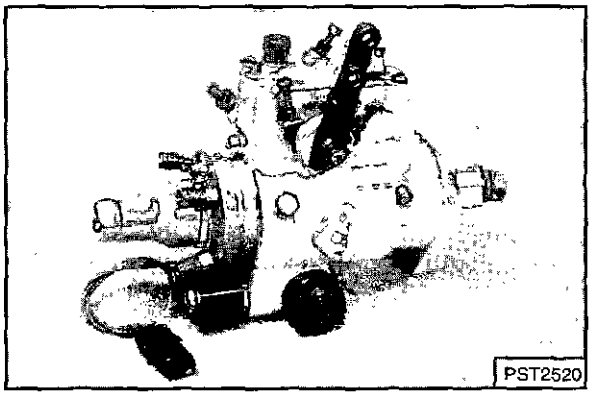
FUEL No. 15



FUEL No. 16

STANADYNE LIGHT LOAD ADVANCE (LLA) - DB4 PUMPS

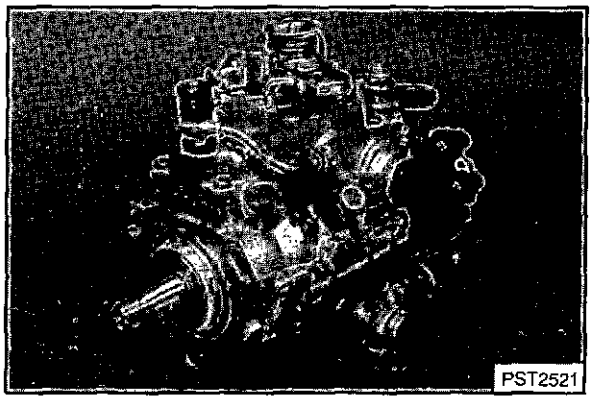
- This is a speed advance pump but also provides additional advance in light load conditions
- This light load advance overcomes the characteristic of the rotary pump where beginning of injection is delayed as the plunger fill (load) is decreased
- This feature is one of the things that allow a rotary pump to be used on an emissions-certified engine
- The pump also has cold-start advance which keeps the pump fully advanced until the engine coolant temperature reaches 50 °C (122 °F)
- A thermo-switch in the coolant manifold closes a solenoid valve in the advance mechanism at higher temperatures



FUEL No. 17

LUCAS DP 203 LIGHT LOAD ADVANCE (LLA) PUMPS

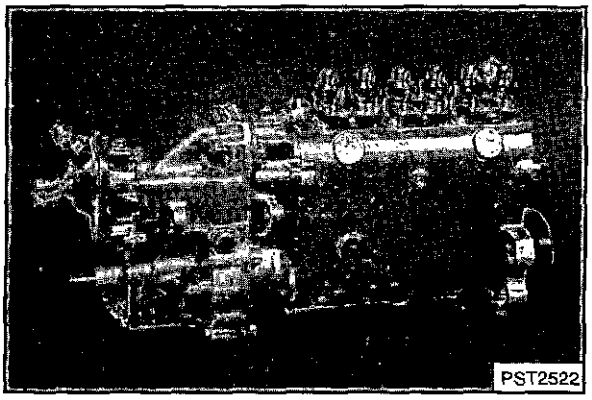
- These pumps have the light-load and the cold-advance similar to the Stanadyne LLA-DB4
- In addition, there is an optional aneroid to modulate fuel delivery during acceleration and low-speed full-load conditions



FUEL No. 18

NIPPONDENSO PUMPS

- These in-line pumps have a constant beginning of injection so they do not require the light-load and cold-start advance mechanism used on the rotary pumps
- An aneroid limits the fuel delivery (rack travel) during acceleration and low-speed, full-load operations



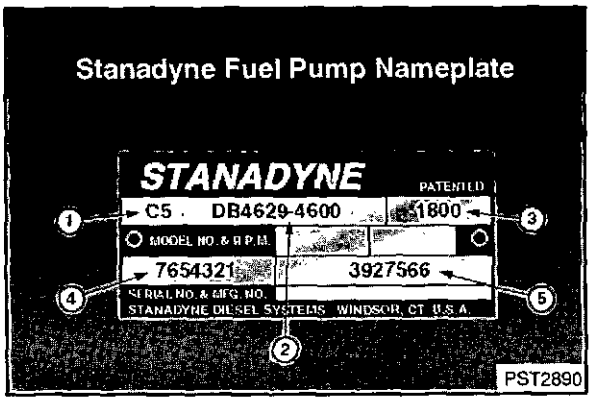
FUEL No. 19

PUMP SERIAL NUMBER PLATES

- The number stamped on the type-plate attached to the pump housing identifies the type and model of pump
- Pumps with identical build but with different settings, dependent on engine application, are further identified by the setting code stamped underneath the serial number

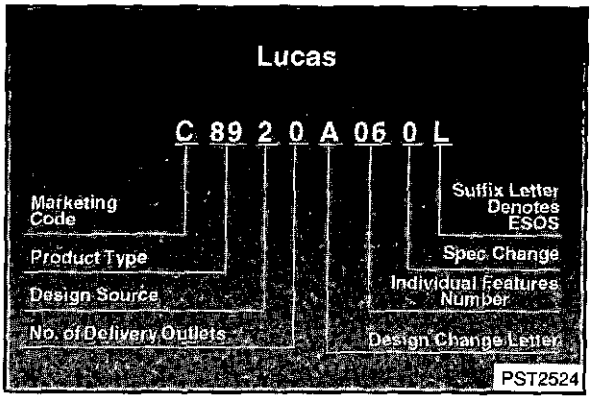
STANADYNE PUMPS

- (1) Date Code-Reference Stanadyne Service Bulletin 439
- (2) Model Number:
  - DB - "B" version of "D" series pump
  - 4 - Number of Pumping Plungers
  - 6 - Number of Engine Cylinders Served
  - 29 - Abbreviation of Plunger Diameter
    - 25 - .250" (6.35 mm)
    - 27 - .270" (6.86 mm)
    - 29 - .290" (7.37 mm)
    - 31 - .310" (7.87 mm)
  - 4600 - Specification Number
    - Determines selection of parts and adjustments for a given application.
    - Must be included in any reference to the pump.
  - Model numbers may be abbreviated on nameplates (e.g. - DB4-4600)
- (3) Rated or High idle Engine RPM (See Individual Specification)
- (4) Serial Number
- (5) Customer Part Number



FUEL No. 20

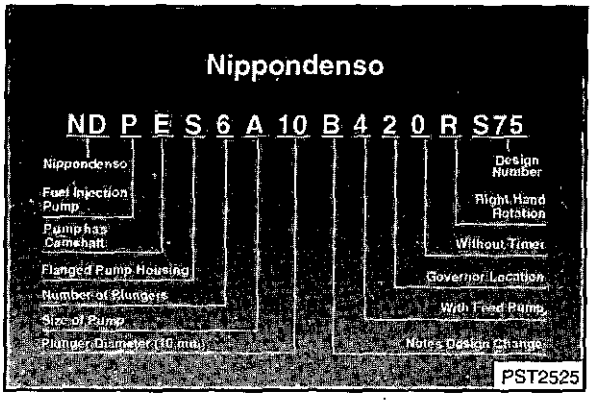
LUCAS PUMPS



FUEL No. 21

- C8920A060L
  - C - Marketing code
    - C = Spain
    - No letter = U.K.
  - 89 - Product type (DP200)
  - 2 - Design source
    - 0 = USA
    - 1 = Korea
    - 2 & 3 = U.K.
    - 4 = France
    - 5 = Spain
    - 6 = Brazil
    - 7 = India
    - 8 = Poland
    - 9 = Japan
  - 0 - No. of delivery outlets
    - 0 = 4 cylinder
    - 1 = 6 cylinder
    - 2 = 3 cylinder
    - 3 = 4 cylinder
    - 4-9 = to be allocated
  - A - Design change letter
  - 06 - Individual features number
  - 0 - Change to the individual specification affecting arts interchangeably, but not fit or function of the pump
  - L - Suffix letter denotes the type of ESOS fitted

NIPPONDENSO PUMPS

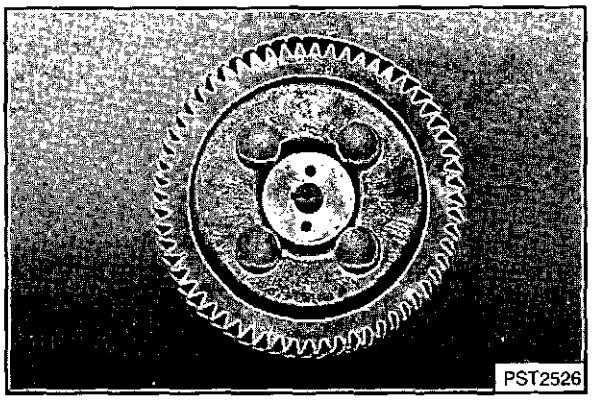


FUEL No. 22

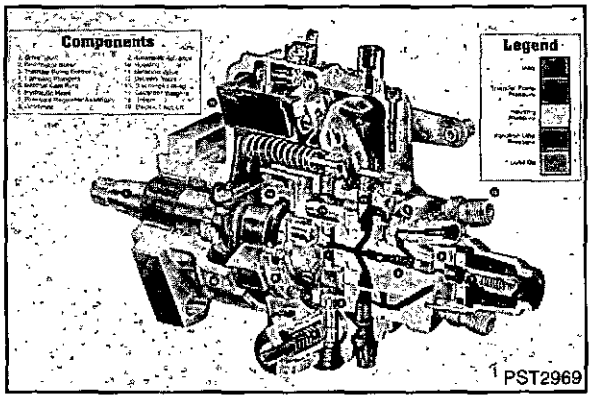
- ND-PES6A10B312RS75
  - ND - Manufactured by NIPPONDENSO
  - P - Fuel Injection Pump
  - E - Injection pump has a camshaft
  - S - With flange cast on pump housing
  - 6 - Number of plungers
  - A - Size of pump
  - 10 - Plunger diameter in mm (10 mm)
  - B - Denoting design change
  - 4 - With feed pump, camshaft assembly notch is engraved on the right end of the camshaft or.....
    - 3- With feed pump, camshaft assembly notch is engraved on the left end of the camshaft
  - 2 - Governor is installed to the right side of pump housing
    - 1- Governor is installed to the left side of pump housing
  - 0 - Without timer
    - 1- Timer is installed to left side of pump housing
    - 2- Timer is installed to right side of pump housing
  - R - Right hand rotation (viewed from drive end)
    - L- Left-hand rotation
  - S75 - Design number

INTERNAL ROTARY PUMP COMPONENTS

- Drive components
  - Drive shaft
    - Gear driven
    - *Two internal seals*
    - Supported by a bearing
  - Distributor rotor
    - Rotates in hydraulic head
    - Pumping plungers compress fuel for final injection
  - Vane-type transfer pump
- Compression components
  - *Internal cam ring tracks lobes for compression process*
  - End plate houses the fuel inlet connection, strainer, and transfer pump pressure regulating valve
  - Governor assembly speed control of the pump balanced by the governor spring and throttle lever
  - Automatic advance controls beginning of fuel delivery



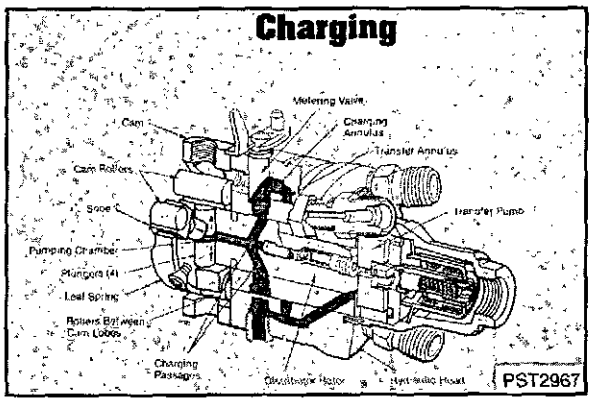
FUEL No. 23



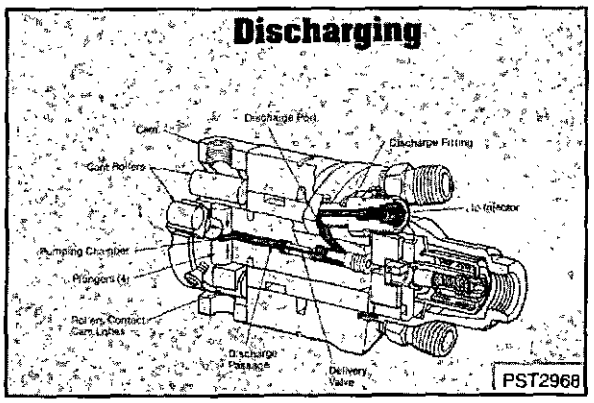
FUEL No. 24

ROTARY PUMP OPERATION

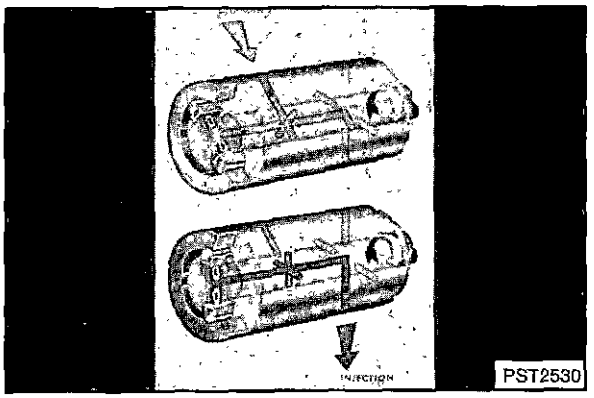
- Fuel flow
  - Fuel is drawn in through inlet strainer
  - Vane pump creates flow and pressure
  - Metered flow from transfer pump is bypassed to fuel tank via. the pump housing
  - Pump pressure increases with speed
  - Fuel is forced through a drilled passage to annulus and on to the metering valve
  - Position of metering valve is controlled by the governor and regulates flow to charging ring
  - When inlet passage indexes with charging ports in hydraulic head the fuel flows to pumping cylinder
  - Inlet closes and compression begins as cam lobes force plungers together
  - Rotor port aligns with injector port
  - As pressure increases, injection begins
  - Return fuel acts as a lubricant for pump
- Charging cycle
  - Inlet passages in rotor and hydraulic head are indexed
  - Enough fuel to meet power demand flows into the pumping chamber
  - Maximum fuel delivery is limited by leaf spring adjustment
  - As shaft rotates;
    - The inlet slots are closed,
    - Rollers contact cam lobes
- Discharge cycle
  - Discharge passage comes into registry
  - Compressed fuel is forced out the axial passage to the injection nozzle
  - Injection continues till top of cam lobe is reached
  - Pressure drops and allows nozzle to close



FUEL No. 25



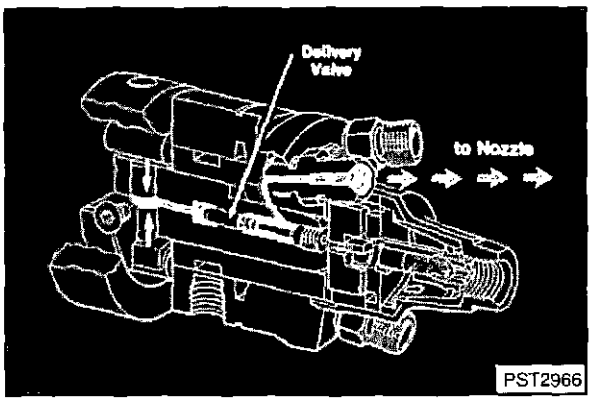
FUEL No. 26



FUEL No. 27

DELIVERY VALVE

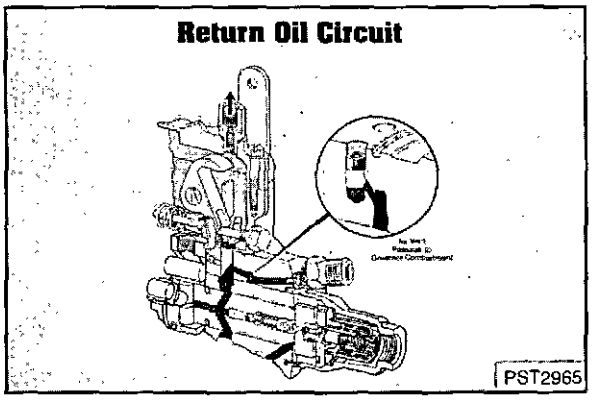
- Control static line pressure
  - Ensures nozzle closure
  - Creates smoother running engine
- Has no seat, only a shoulder to limit travel
- Stanadyne - Same valve housed in rotor , used for all cylinders
- Lucas - similar valve is located in each nozzle outlet fitting
- Operation
  - At injection start, fuel pressure lifts valve in its bore
  - This allows fuel to go to injection nozzle
  - Nozzle valve opens to allow injection
  - As injection ends, cam rollers pass full fuel compression point
  - Fuel retracts from delivery cavity and lets injection nozzles close
  - This lowers the line pressure to the nozzles, preventing nozzle drip



FUEL No. 28

RETURN FUEL CIRCUIT

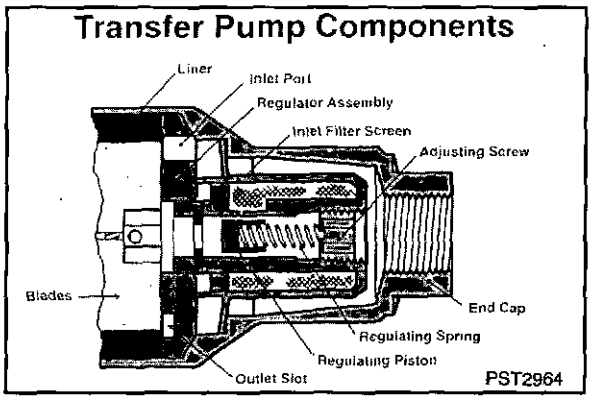
- Cavity in hydraulic head accepts excess (returned) fuel
- Upper half of this chamber connects to vent passage and returns excess fuel to housing interior
- It is restricted by a vent wire
- If air enters system it returns to fuel tank
- Return fittings
  - Mounts on top of housing
  - Has spring loaded check valve
  - Housing pressures are 3 to 12 psi (15 psi at high altitude)
  - Check valve removal
    - Drop in housing pressure
    - Causes fuel advance 1-1/2 to 2°
    - Loss of governor control
    - Rough idle
    - Slight pumping pressure increase
    - "Down-hill surge"
  - Plugged valve
    - Increases housing pressure
    - Will oppose plunger action
    - Causes hard-to-start or no-start situations



FUEL No. 29

END PLATE OPERATION

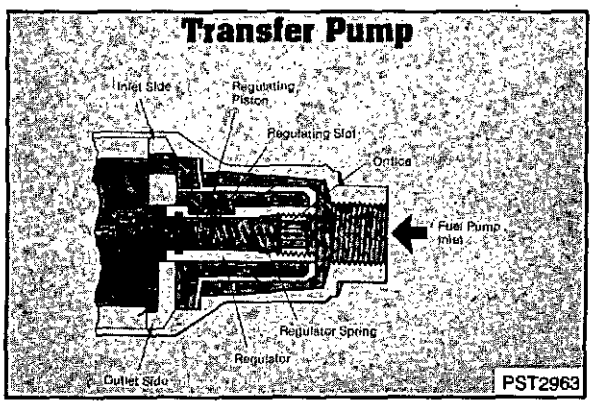
- Function;
  - Fuel inlet
  - Houses pressure regulating valve
  - Houses bypass spring which allows fuel to bypass pump during hand priming
  - Covers the transfer pump
  - Absorbs end thrust of drive and governor
- Operation;
  - Fuel flows through inlet during priming function
  - After engine start-up, fuel flows to the pump



FUEL No. 30

VISCOSITY COMPENSATION

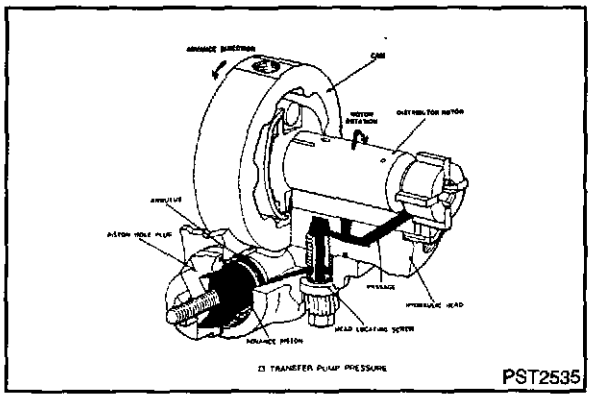
- Function;
  - Offset pressure changes caused by varying fuel viscosities or temperature
  - Helps to offset other leakages in system
- Operation;
  - The thin plate (sharp-edged orifice) behind the pressure regulating valve compensates for the effect of viscosity on the valve



FUEL No. 31

AUTOMATIC ADVANCE

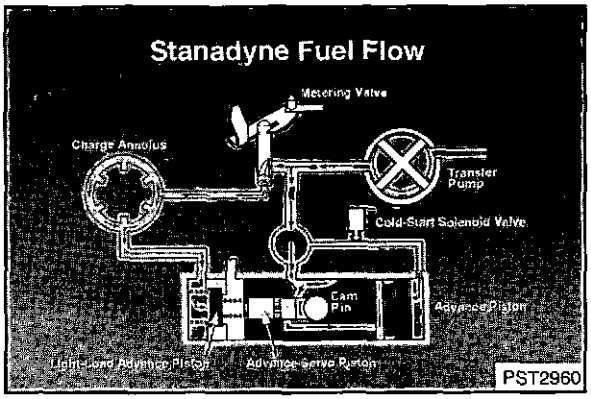
- Purpose - Advance or retard fuel delivery to obtain best pressure and combustion throughout speed and load range



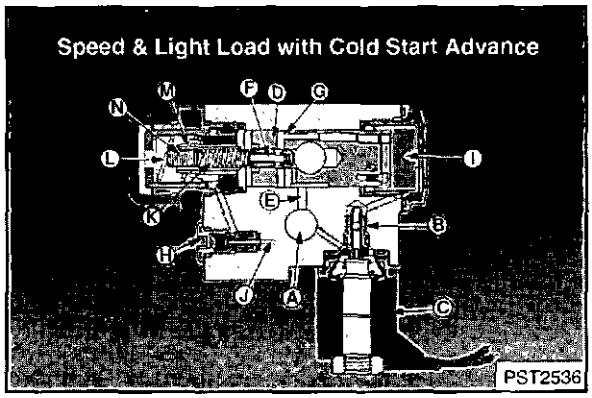
FUEL No. 32

STANADYNE AUTOMATIC ADVANCE

- Transfer pump pressure is fed to the advance mechanism through the head locating screw (A)
- Pressure can also go to an optional cold-start solenoid valve (B)
- The cold start solenoid (C) is not activated in normal operation
- Transfer pump pressure is directed to the advance piston (D) through the cross passage (E)
  - Moves servo valve (F) to the left, opening a second cross drilled passage (G)
  - Fuel flows through the passage to the right end of the advance piston (D)
  - Moving the advance piston to the left advancing injection
- Amount of advance is determined by movement of the servo valve (F) against the servo valve spring (K)
- The position of the servo valve (F), and thus the advance of the advance piston (D) is determined by the transfer pump ,pressure (speed)
- Charge pressure (J) sensed at the charge annulus acts on the light- load piston (M) through the load advance orifice screw (H)
- This pressure is behind the metering valve, so will increase as the load increases and the metering valve passes more fuel to the pumping plungers of the injection pump.
- When the pressure is highest during full load, the light load advance piston (M) containing the load advance adjusting screw (N), is forced to the right, limiting the servo valve (F) and advance piston (D) movement to the left.
- This is because the transfer pump pressure can no longer overcome the spring pressure against the servo valve (F) and flow is stopped to the right end of the advance piston (D) and timing is retarded
- LLA = LIGHT LOAD ADVANCE
  - When the load is reduced and pressure drops behind the light load advance piston (M) because less fuel is passing the metering valve, the servo valve spring (K) pressure is reduced and the servo valve (F) is allowed to move to the left.
  - This allows full advance piston (D) movement to the left.
  - This additional advance movement in the light load situation (partial piston plunger filling) gives the injection pump about the same beginning of injection as in the full-load conditions

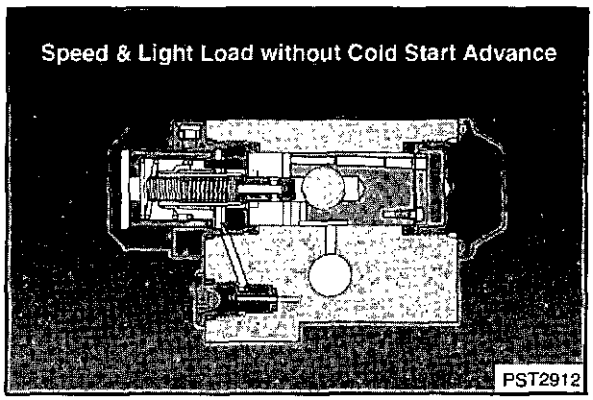


FUEL No. 33



FUEL No. 34

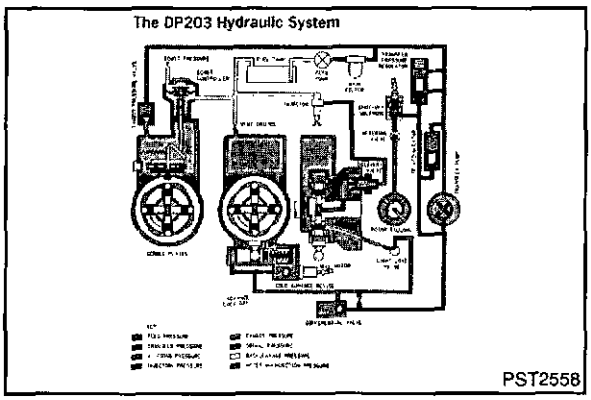
STANADYNE AUTOMATIC ADVANCE (Cont'd)



FUEL No. 35

- CSA = COLD START ADVANCE
  - Coolant temperature is sensed at thermostat housing
    - If the coolant temperature is below 50 °C (122 °F+} the solenoid valve (B) in the advance circuit is opened
    - This directs transfer pump pressure to the cold start piston (I) forcing the advance piston (D) to the fully advanced position
    - When the coolant temperature rises above the activation temperature. the solenoid valve (B) closes and the advance is again controlled by the speed and load advance mechanism.

LUCAS AUTOMATIC LIGHT LOAD ADVANCE



FUEL No. 36

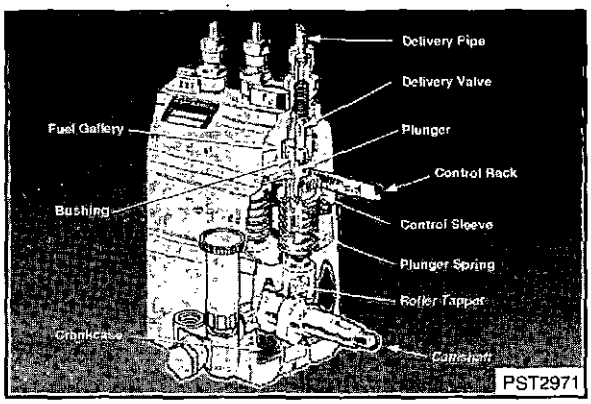
- Light load advance provides advanced timing at part load conditions to reduce engine emissions and maintain smooth engine operation
- Transfer pump pressure goes to the advance area through a differential valve and orifices
- Differential valve is adjustable by ADS (Association of Diesel Specialist) shops to calibrate the advance to specifications
- Pressure acting on the left side of the advance piston forces it to right, advancing the timing of the pump
- The metering valve has two notches:
  - One for metering fuel to the pumping plungers and a second notch for controlling pressure at the timing advance mechanism.
  - The second notch is opened at full load and by-passes fuel out of the advance circuit to retard timing.
- At light loads a smaller opening of the notch results in less fuel by-passing and higher pressure at the advance piston to advance timing of the injection pump
- CSA = COLD START ADVANCE
  - The wax motor (acts like a solenoid) valve is closed at start-up to prevent pressure from entering the retard or right side of the advance piston where the retard spring is located.
  - This allows pressure on left side of advance piston to provide full advance
  - When coolant temperature reaches 50 °C (122 °F+) the wax motor opens the valve allowing pressure fuel to assist the spring in moving the advance piston to the left, retarding the timing to normal operating condition.

LUCAS AUTOMATIC LIGHT LOAD ADVANCE (Cont'd)

- ANEROID OPERATION
  - Limits fuel delivery (smoke at low speed, full load) and during acceleration
    - Used on higher horsepower engines
    - Activated by turbo boost pressure
    - Mechanical linkage moves scroll plates that limit pumping plunger travel to control fuel delivery

INTERNAL COMPONENTS OF IN-LINE PUMP

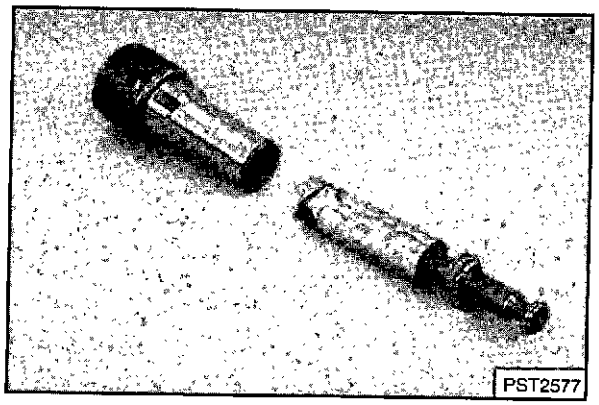
- Pump housing
  - Internal camshaft driven from engine gear train
  - Camshaft supported by 3 built-in bearings (aluminum bearing in center)
  - Must always pre-lube new or repaired pump prior to starting engine ... small feed oil line insufficient for "dry" start-up oil supply (lube-fill hole on side) camshaft area is pressure lubed with engine oil during normal operation
  - Roller tappet rides on cam
  - Tappet pushes upwards against plunger valve held in positive contact with the cam by spring and seat
  - Plunger valve fits through control sleeve
  - Control sleeve connects to fuel rack for metering purposes
  - Plunger operates inside of a barrel
  - Barrel is secured by the delivery valve holder
- CAUTION:
  - Always use two wrenches to replace fuel pressure lines.
  - Hold the delivery valve holder in place while breaking loose or tightening a fuel line.
- Operation;
  - From the filter, fuel enters the gallery area above the plunger and sleeve ... an outlet restriction (overflow) valve maintains gallery pressure at 130-180 KPa (20-26 psi)
  - Cam moves plunger upward, trapping the fuel at some point
  - Spill deflectors across from the port opening deflect fuel flow in gallery and prevent gallery erosion
  - As pressure builds, pump delivers fuel through delivery valve, line and nozzle to engine cylinder
  - Fuel rack moves from governor end into pump (towards the drive end) to increase fuel delivery



FUEL No. 37

FUNCTION OF PLUNGER AND BARREL ("P AND B")

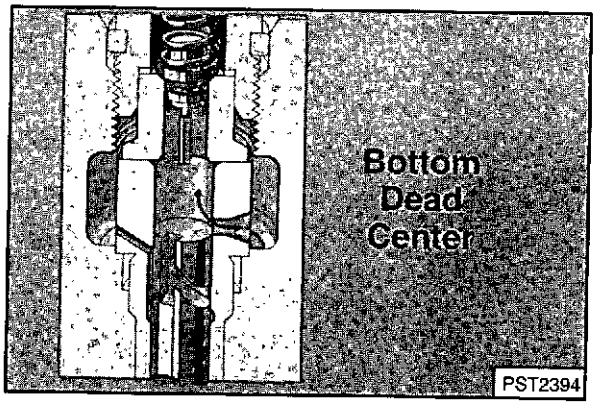
- Parts are matched set
- Vertical groove in shoulder of barrel returns fuel that leaks past plunger to the spill port and ultimately into gallery
- Controls timing and metering function
- This is accomplished through the two helixes and the port in the sleeve
- Precisely lapped set - clearances approximately 0.002 mm (0.00008 in.)
- Lubricated by fuel oil
- Operates at a constant stroke as the camshaft lifts them



FUEL No. 38

FUEL ENTRY INTO PLUNGER AND BARREL AT BOTTOM OF PLUNGER STROKE

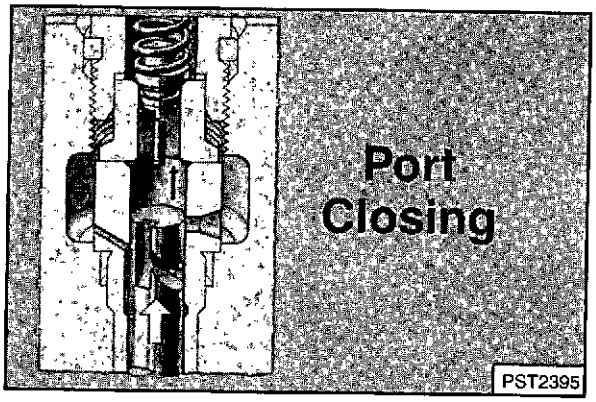
- Position before delivery
- When plunger is at bottom dead center then supply fuel from the gallery enters the barrel chamber



FUEL No. 39

INJECTION TIMING AND PRESSURIZATION

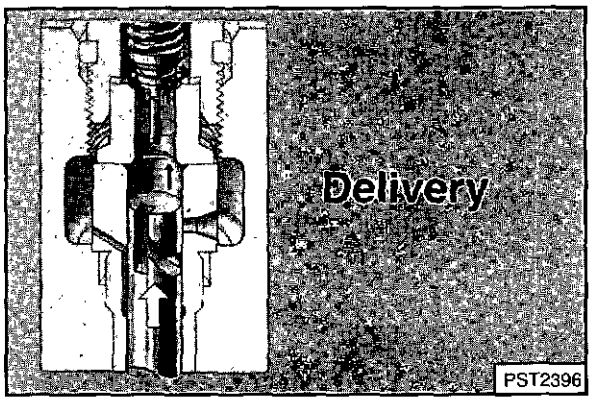
- Port closure closes spill ports and traps the fuel
- Pressure increases prior to delivery
- Begins injection



FUEL No. 40

FUEL DELIVERY FROM PLUNGER ASSEMBLY

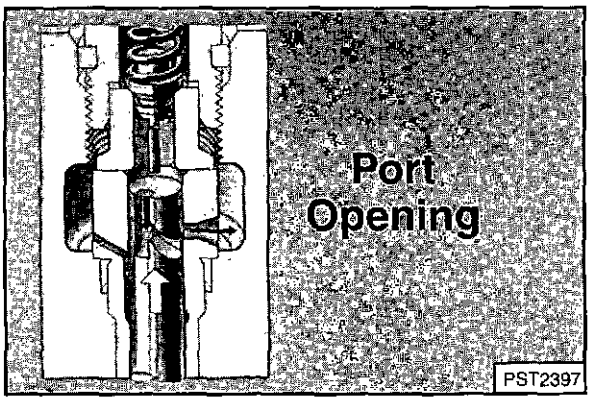
- Spill ports are closed
- Fuel pressure increases
- Delivery valve forced off its seat
- Delivers fuel as long as port is closed
- *High injection pressures make controlling secondary injection, injection line cavitation and hydraulic (fuel flow) stability difficult*
  - Pressure waves dampened by the snubber valve to prevent secondary injection
  - Residual line pressure is maintained to prevent cavitation and assure consistent fuel metering cycle-to-cycle



FUEL No. 41

FUNCTION OF LOWER HELIX. END OF INJECTION OR PORT OPENING

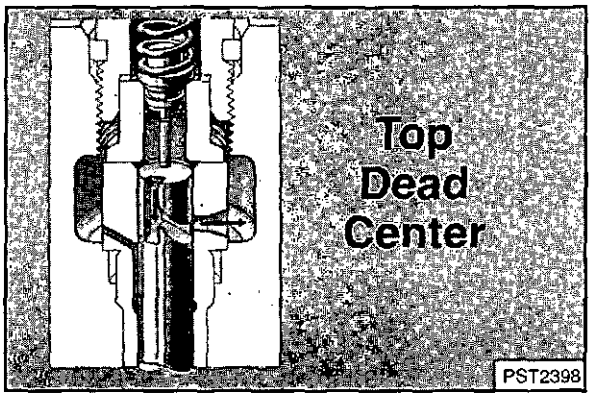
- Plunger moves up to uncover spill port
- Fuel no longer trapped (this is where gallery erosion occurs, so hardened screws or sleeves are used to deflect fuel) residual line pressure is approximately 685 - 1370 KPa (100 - 200 psi) below nozzle cracking pressure
- Pressure drops
- Injection ends
- *Port opening is adjustable on test bench*
- Low power and poor idling complaints are the effects of improper adjustment



FUEL No. 42

EFFECTIVE PLUNGER STROKE VS. TOTAL PLUNGER STROKE

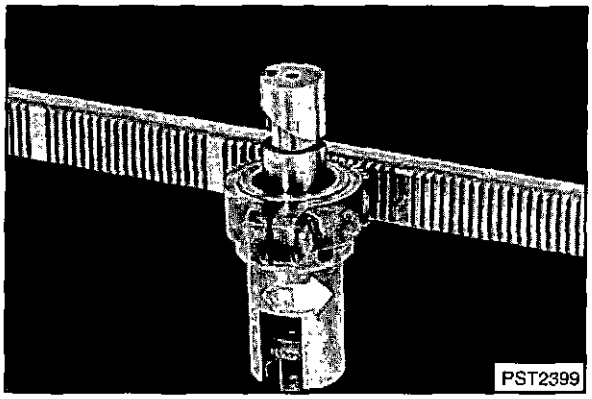
- Plunger completes its stroke going up
- Returns to bottom of stroke, recharging with fuel
- Relate difference between effective stroke (period of time at which injection takes place) versus total stroke
- This is the timing and pressurizing function



FUEL No. 43

MATCH-UP OF CONTROL RACK TO CONTROL SLEEVE

- Controls plunger rotation
- One common rack controls all cylinders.
- By rotating plunger, we alter effective stroke

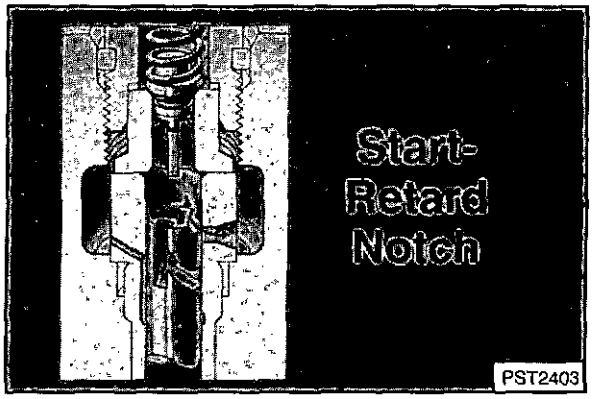


FUEL No. 44

FUNCTION OF START RETARD NOTCH

- Aids in cold starts by delaying injection to hottest point of piston travel up in the compression stroke
- This is full rack position
- Currently use a 2.5° (pump degrees) notch on AS2500, P3000 and P7100 pumps
- Larger volume fuel is provided. While delaying injection timing, it provides for approximately 5° engine retard before injection takes place
- Starting magnet and spring force holds rack in "full fuel"
- The smaller notch has been beneficial to starting as it improves run-up time to magnet pull off
- Adds extra fuel above normal max. (approximately 0.10 mm more rack, or 10 mm^3 per stroke, more fuel volume delivered)
  - On electronic pumps, the rack is positioned for starting by command from the controller (i.e., no magnet)

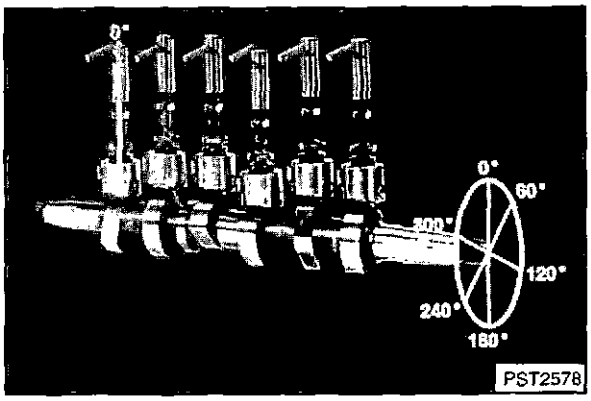
Note: Improper governor adjustment can result in this "full rack" position during normal operation which could result in overheating the engine.



FUEL No. 45

PUMP CALIBRATION PROCESS

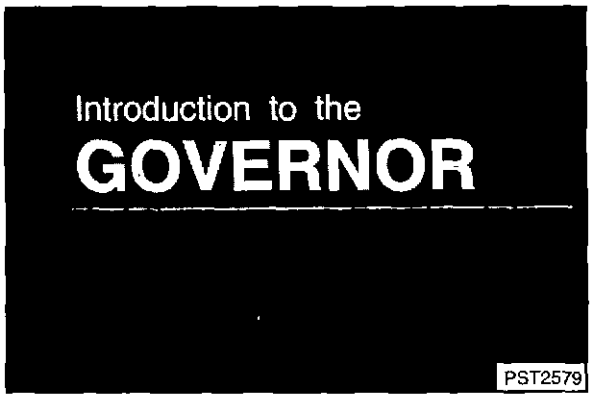
- No.1 cam lobe is positioned to specified lift
- Barrel is adjusted vertically to obtain port closure at that point
- Remaining cylinders adjusted in like manner at exactly 60° intervals
- This calibration adjustment requires a test stand, special tools and master nozzle set



FUEL No. 46

FUEL INJECTION PUMP GOVERNOR

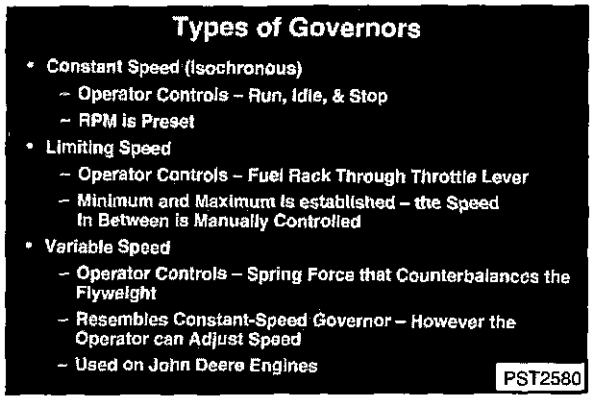
- The governor is a speed sensitive mechanism that matches the fuel input to the power requirements in an attempt to maintain a constant engine speed



FUEL No. 47

THREE TYPES OF GOVERNORS

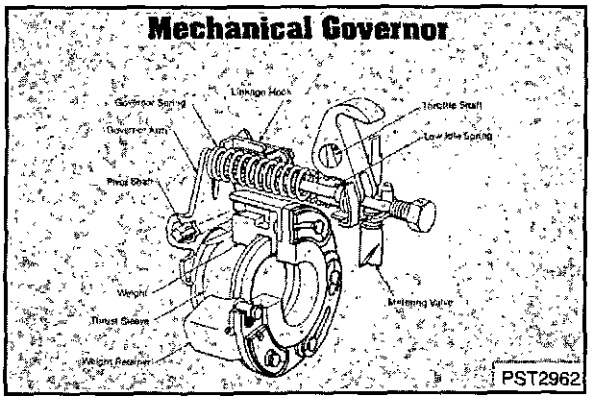
- Constant speed governor features
  - Operator has the choice of run, idle, or stop positions
  - Operating rpm is preset by the technician
- Limiting speed governor feature
  - Governor controls at idle
  - Governor control from maximum no-load (high idle) to maximum full-load range
  - Operator has direct control of fuel rack through movement of throttle lever
- Variable speed governor feature
  - These are used on John Deere mechanical governed engines
  - Operator has throttle control of spring pressure
  - Governor controls full range rpm, from idle to maximum no-load



FUEL No. 48

GOVERNOR ASSEMBLY

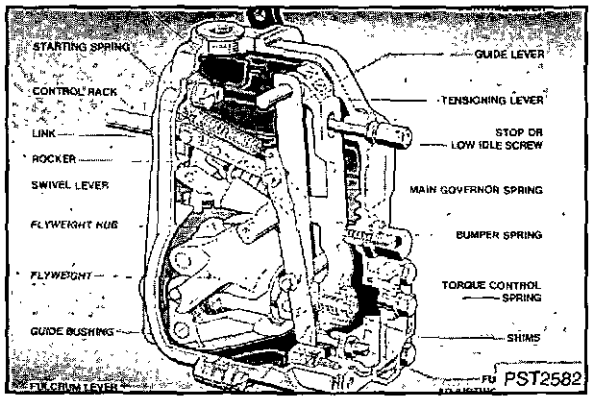
- Function
  - To counterbalance the demand for fuel with the ability of the pump to supply it at all speed levels
- Components
  - Weights
  - Weight retainer
  - Thrust sleeve
  - Governor spring
  - Low idle spring
  - Linkage hook
  - Guide stud
  - Throttle arm
  - Metering valve
- Operation
  - Spring force working against weight force
  - Put metering valve "in" or "out" of fuel
  - Low idle spring makes small adjustments (low end of speed range weight force is low)
  - Spring force is manually controlled by throttle shaft linkage in regulating engine speed



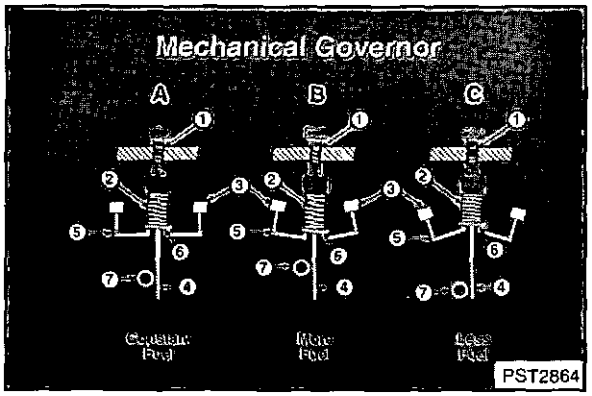
FUEL No. 49

OPERATING PRINCIPLES OF THE MECHANICAL GOVERNOR

- These simple, basic components make up a *governor*:
  - A weight assembly driven by the engine at varying speeds. They are pivoted so they can swing in and out freely. On John Deere engines the weight assembly is attached to the pump camshaft and is rotated at one-half engine speed.
  - When rotating, the force of the spring opposes movement of the weights.
  - And in the governor housing, a mechanical linkage is connected to control the fuel rack movement
- Explain movement of components as speed varies:
- Three basic components in the governor assembly are required to control fuel delivery and maintain engine speed. They are:
  - Flyweights
  - *Main governor spring ...and,*
  - Some form of linkage to a fuel controller
- **The flyweight assembly** is attached to the injection pump camshaft. It therefore, rotates whenever the camshaft rotates and does so at 1/2 the engine crank shaft speed. When the flyweight assembly rotates it creates a centrifugal *and* mechanical force. As speed goes up, so does the centrifugal force
- **The main governor spring** is required to maintain a constant fuel delivery, thus a constant engine speed. The fuel delivery becomes constant when the main governor spring force and centrifugal/mechanical force from the flyweights become equal
- **Linkage mechanism** is required to transfer the mechanical movement created by the governor main spring and flyweight assembly to a fuel control device - a fuel rack
- The illustration demonstrates three general fuel delivery examples:
  - **A. Constant speed has been established.**
    - The screw (A) at the top simulates a throttle lever moved to the high idle position and engine has a load applied and is at a rated full-load speed
    - Spring (2) and flyweight (3) have established equal forces at (6) and a full delivery is controlled by a fuel rack (4)
    - Engine runs at steady speed in any particular range



FUEL No. 50



FUEL No. 51

OPERATING PRINCIPLES OF THE MECHANICAL GOVERNOR (Cont'd)

- **B. An increase in engine load**
  - The increased load reduces engine speed, thus the flyweight speed is reduced, lowering weight centrifical force, at this moment spring (2) has more force then centrifical from the flyweights, at this moment the weights move inward through pivot point (5). At the same time, the fuel linkage (7) to the fuel delivery device (4) moves down to increase fuel delivery.
  - This increase in fuel to the engine will provide speed recovery and attempt to reach a position as illustrated at "A"
- **C. Load decrease and engine speed increases**
  - When speed increases flyweight forces become greater than the preset main governor spring force
  - The spring is compressed at contact point (6) from the weights by pivot point (5) the attached fuel linkage moving the fuel rack to a reduced fuel delivery, thus engine reaction will be to slow down due to the reduced fuel delivery and establish a positions as illustration(A)

- **Speed droop**
  - At some specific engine speed, an applied load will cause engine speed to drop. The engine is momentarily not getting enough fuel to overcome the additional load.
  - At this point, weights swing in and the spring moves the governor linkage and fuel rack to increase fuel delivery. The governor spring is allowed to extend, slightly decreasing its force. As spring force weakens, this allows the governor weights to balance spring force with the fuel rack to a greater fuel delivery and so, carry the increased load. This speed difference is called "droop," and the weights/spring interaction is necessary for inherent mechanical governor stability.
- **Throttle operation**:
  - Throttle movement alters spring force.
  - Governor assembly, as a whole unit now, reacts to this change in spring force.
  - In the variable speed governor, when the operator moves the throttle lever, he/she is only changing governor spring pressure. The governor does the rest, and reacts according to speed change.
  - If you were to put a lock nut on the throttle screw (in the slide), it becomes in essence, a constant speed governor.

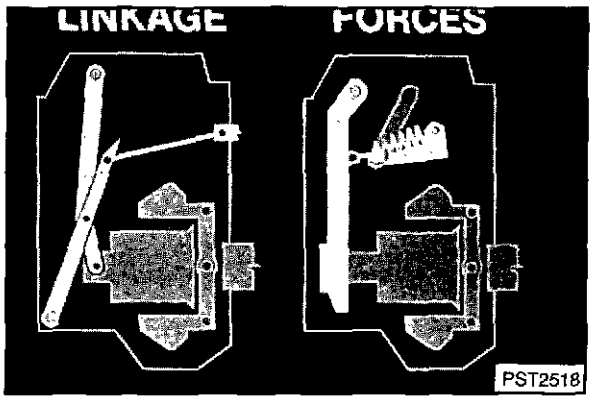
TERMINOLOGY ASSOCIATED WITH GOVERNORS

- Idle speeds
  - The low idle is the lowest governed speed of engine with no-load (also referred to as "minimum no-load")
  - High idle is the highest governed rpm (W.O.T.) with no-load (also referred to as "maximum no-load")
- Maximum full-load speed
  - The maximum governed rpm (W.O.T.) at full-load, full fuel input (also referred to as "dead rack" position)
  - In this position, you are up against the full-load stop on the governor
- Roll or Hunt - an instability in engine speeds evidenced by reoccurring highs and lows in rpm generally occurs at low or maximum no-load
  - Repeated oscillation or speed variations (these could occur through no fault of governor)
  - If governor is responsible, hunting will stop if throttle is blocked in a fixed position
  - If oscillation still continues with the throttle blocked, the governor is not at fault
- Speed droop
  - An inherent characteristic of a mechanical governor
  - The difference (or loss) of speed typically occurs between maximum no-load and maximum full-load
  - The loss of speed is necessary to get a fuel correction
  - Expressed normally in percentages such as "3-5% governor", "7-12% standard governor"
  - Electronic or isochronous governors correct to tighter tolerances that approach or maintain zero droop

FUEL No. 52

INTERNAL GOVERNOR COMPONENTS FOR IN-LINE PUMP

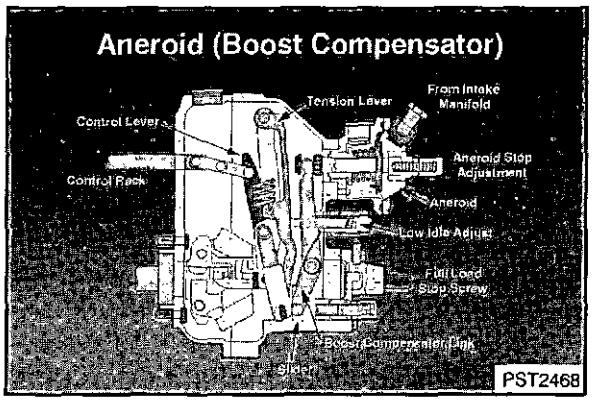
- A set of weights
- A main spring
- The weights and spring work against each other through the linkage and controls the action and reaction of each other to control the fuel rack



FUEL No. 53

LOW SPEED ADJUSTMENT

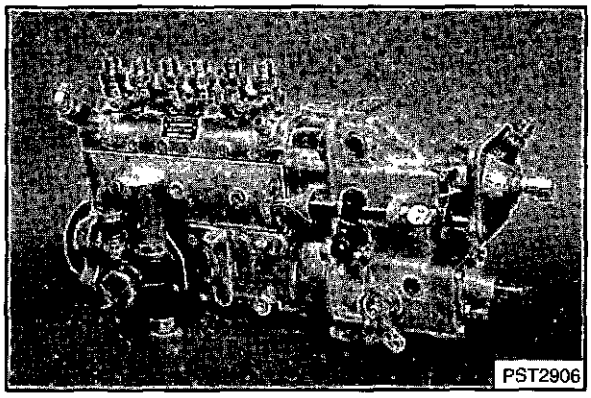
- Idle adjustment
- Turning in increases idle speed
- Rear of governor housing, on engine adjustment
  - Back-out bumper screw
  - Set 20-30 rpm below sped with low idle screw
  - Bring rpm back up 20-30 rpm with bumper screw
- Bumper screw function and adjustment
  - Located below idle screw
  - Cushions "off travel" of tensioning lever at idle and maximum no-load
  - Adjustment
    - With bumper backed out, set idle 20-30 rpm low
    - Increase idle to specification with bumper screw



FUEL No. 54

HIGH IDLE SPEED ADJUSTMENT (MAX NO-LOAD)

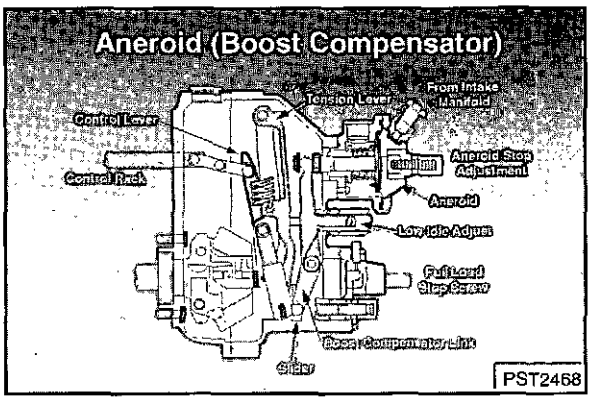
- External adjustment, screw and locknut which is located on the side of the governor
- Screwing out increases high idle (max no-load) speed
- High idle setting will not smooth out any other governor misadjustment and it will cause plunger and bushing wear



FUEL No. 55

ANEROID

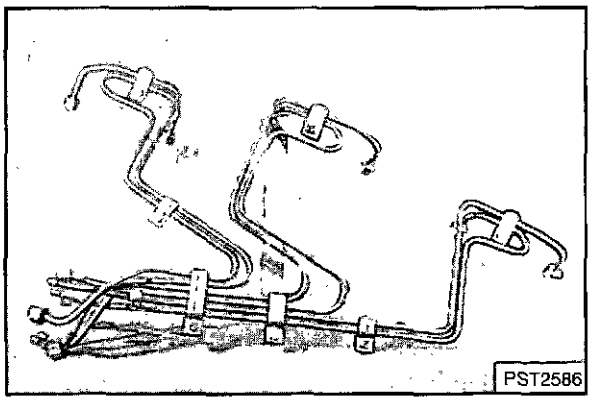
- Aneroid receives turbo boost pressure from the intake manifold
- When pressure is low, the aneroid spring moves the boost compensator link and slider to limit governor linkages and rack travel
- When pressure increases the diaphragm moves linkage and slider to allow full rack travel
- This feature limits fuel delivery (smoke) at low idle, full load and during acceleration



FUEL No. 56

REVIEW FUEL LINES

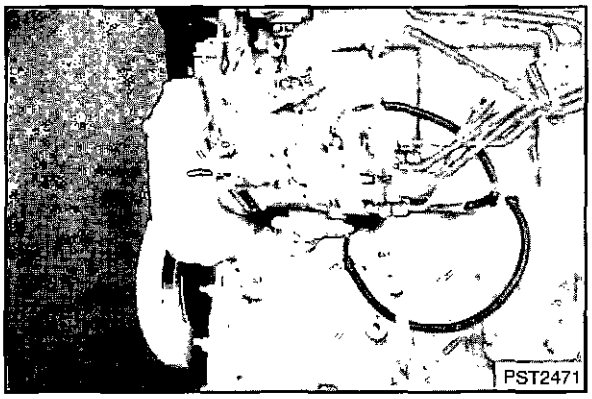
- Design
  - Lines are all the same length ... different *bends to accommodate space require*ments
  - If line fails, replace it. Do not attempt to braze or weld it
  - *Clamps are important .. if removed or loos*ened return to same location ... vibration control
- Service
  - Injection line nuts have critical torque, do not overtighten
  - Do not disturb pump discharge fittings
  - Always replace with lines of same size
  - Hold discharge and nozzle fittings with a second wrench when tightening lines. This will reduce possibility of damage to pump and nozzles.



FUEL No. 57

TIMING ROTARY PUMPS

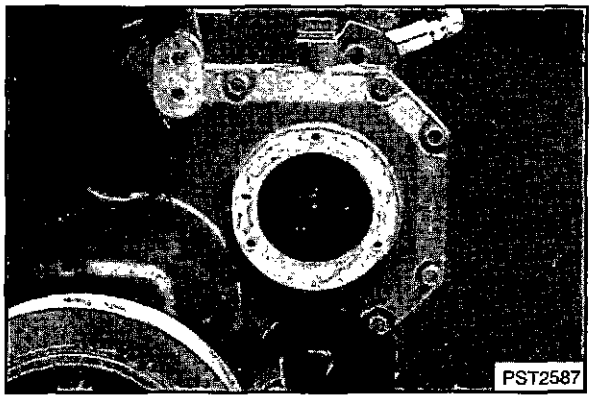
- Setting...static method
  - Loosen pump mounting bolts
  - Locate marks on flange and plate
  - Lineup both marks
  - Retighten pump mounting bolts
  - Removal of timing window will invalidate pump warranty
  - If necessary to remove front plate refer to CTM104 (group35) for proper steps
- Dynamic method
  - See CTM104 (Group 35) for proper use of Time Trac® equipment



FUEL No. 58

TIMING IN-LINE PUMP

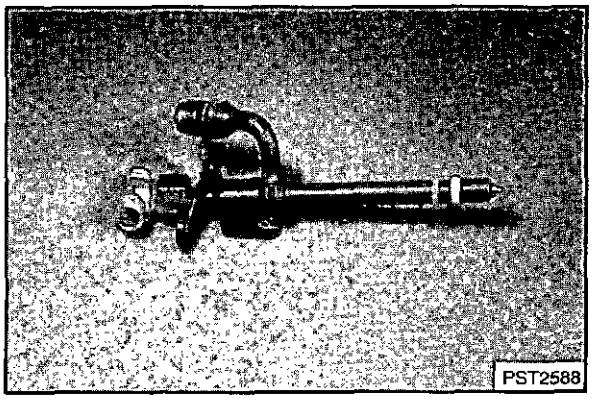
- Install timing pin in pump
- Position and lock engine with no. 1 piston at top-dead-center, compression position
- Position pump drive gear so that slots in gear line up with capscrew holes in pump flange and round hole with timing pin
- Tighten drive gear to pump hub capscrews to specified torque
- Remove timing pin from pump



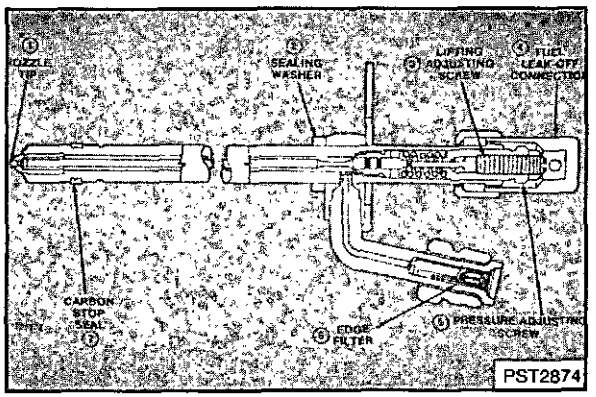
FUEL No. 59

FUEL INJECTION NOZZLES

- 9.5 mm nozzles are used
  - Inward opening
  - Valve seats in nozzle tip
  - Fuel pressure overcomes spring pressure and lifts valve to deliver
  - Spring and adjustment screw can change the opening pressure
  - Body has carbon dam Teflon seal to maintain compression
  - Has upper nylon washer-controls position in cylinder head
  - Has built-in edge type filter
  - Fuel/return leak-off connection
  - Review CTM 104 (Group 35) for opening pressure ... valve lift ... valve leakage
  - Don't intermix nozzles
  - Never lubricate nozzle tip. It will ruin seal and cause carbon buildup



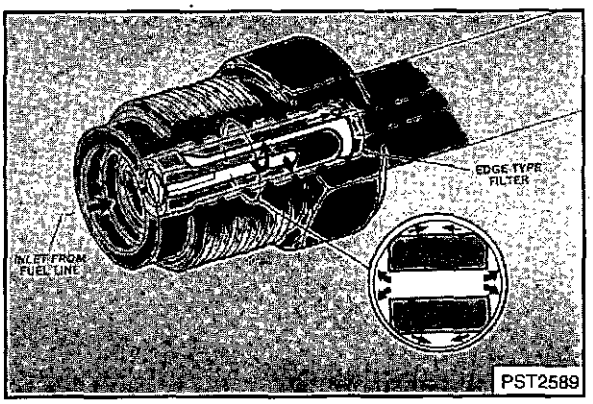
FUEL No. 60



FUEL No. 61

EDGE FILTER

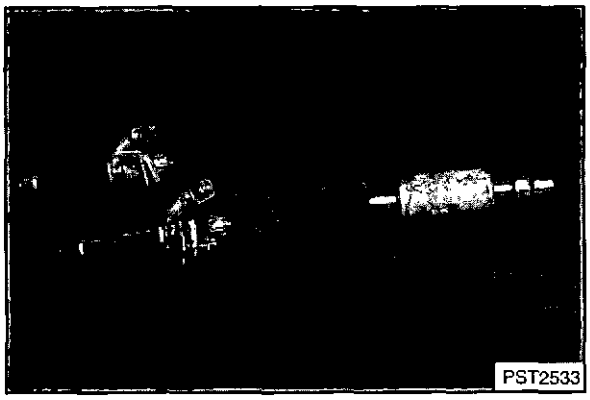
- *Integral part of injection nozzle*
- Function;
  - *Breaks down solid impurities*
  - To pass through orifice in nozzle tip
- Fuel must pass the edge type filter
  - Any debris of a solid nature large enough to plug the nozzle is held at the filter edge
  - Pressure pulses usually break the debris down to a size that will pass filter



FUEL No. 62

NOZZLE REMOVAL

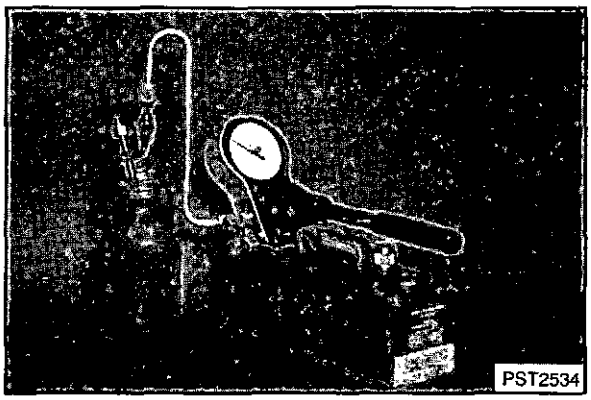
- Review CTM104 (Group 35) removal method
  - Loosen leak-off lines
  - Disconnect leak-off lines
  - Remove spacer
  - Remove from head with nozzle puller
- Never use screwdriver for pry during removal
- Allow new carbon dam seal to sit at room temp (80 °F) for two hours
- Reinstall with new seals



FUEL No. 63

NOZZLE TEST

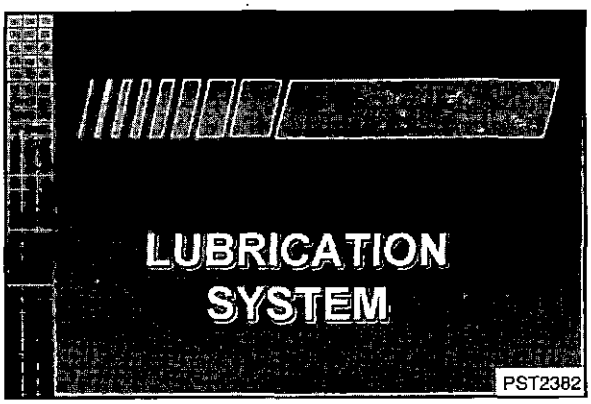
- Describe test procedure
  - Select correct fitting, do not force threads
  - Observe spray pattern
  - "Chirp" or "chatter" test
  - Stem and guide wear ... timed leakage
  - Check "popping" pressure
  - Check valve seat
- Test and adjust in the shop



FUEL No. 64

LUBRICATION SYSTEM

- The lubrication system consists of the following:
  - Oil pump
  - Oil filter
  - Pressure regulating valve
  - By-pass valve
  - Oil cooler
  - Spray nozzles



LUBE No. 1

ENGINE LUBE OIL REQUIREMENTS

- Reduce Friction & wear
  - Keep a protective oil film on moving parts
  - Provides an effective wear film on heavily loaded surfaces
- Cool moving parts
  - Largely responsible for piston cooling
  - Resist decomposition when contact hot surfaces - Resist high temperatures
  - Flow easily at low temperatures
- Help seal the power cylinders
  - Combustion pressures may exceed 18,000 kPa (2600 psi)
  - Help the piston ring seal these pressures in the cylinder
  - Oil film on rings and cylinder walls
- Keep parts clean
  - Prevent corrosion and rusting
  - Keep soot and other microscopic solids in suspension
  - Prevents or minimizes the formation of piston deposits
  - Prevent ring sticking
  - Prevent sludge formation
  - Resist breakdown after prolonged wear

LUBE No. 2

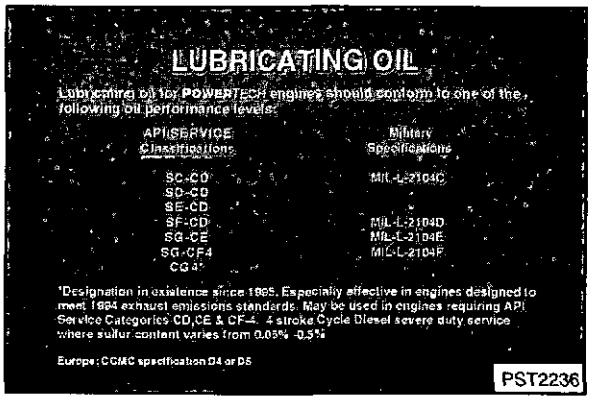
JOHN DEERE'S ENGINE OIL PERFORMANCE REQUIREMENTS

- Found in Operation and Maintenance Manual
- John Deere engines are designed to operate with oil sump temperature as high as 121° C (250° F)
- Higher output engines are equipped with oil coolers to maintain oil temperature below this limit
  - Recommended API spec oils are CG-4; CF-4; or CE/SF (severe duty diesel engine service) formerly MIL-L-2104E
- John Deere PLUS-50™ (15w-40) has a nominal 0.98% ash level with a TBN of 10. It is an excellent high lubricity, engine lubricant
- The John Deere series of engines can tolerate ash levels up to 1-1/2%, use oils with less than 1%
- Engine shipped "wet" with break-in engine oil (No API classification assigned): special-blend/ additives to allow for power cylinder "wear-in" without scuffing, while protects valve & gear train from abnormal wear
  - Service part No. TY22041 (1 gallon)
  - Service part No. TY22042 (55 gallon)
  - Maximum of 2-100 hour break-in oil (with filter) changes is recommended if operating at light loads
  - Excellent for non-John Deere engines
  - Rings & liners establish good wear pattern for maximum performance & extended life
  - Change oil and filter after 100 hours
  - Can be used at second fill but changed after 100 hours
- When engine is thoroughly broken-in:
  - Drain out break-in oil
  - Replace filter and refill with
  - TORQ-GARD® (15W40) or TORQ-GARD SUPREME® (SAE30)
  - Thereafter, replace oil and filter at recommended change intervals

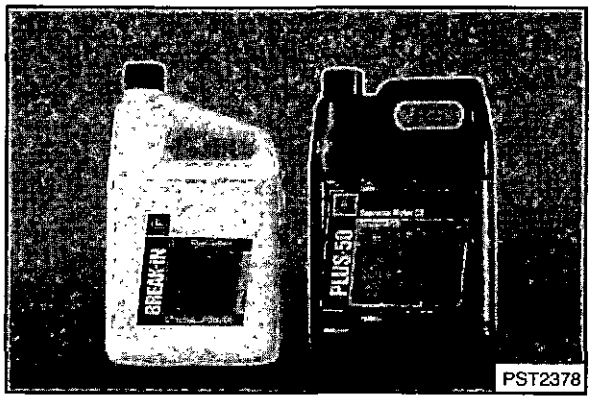
Note: PLUS -50® (SAE30) replaced by TORQ-GARD SUPREME® SAE30 (meets API CG-4 specs). John Deere no longer recommends extended oil drain using single viscosity oils.

- PLUS-50 is an exclusive John Deere formulated oil. It meets/exceeds current recommendations for every engine manufacturer. Recommended for all engines requiring API classification of CG--4 or later

Service Note: TORQ-GARD SUPREME PLUS-50® **must not** be used (*not even for make-up*) fill until engine is completely broken in. The excellent lubricity of this oil will not allow new rings to seat.



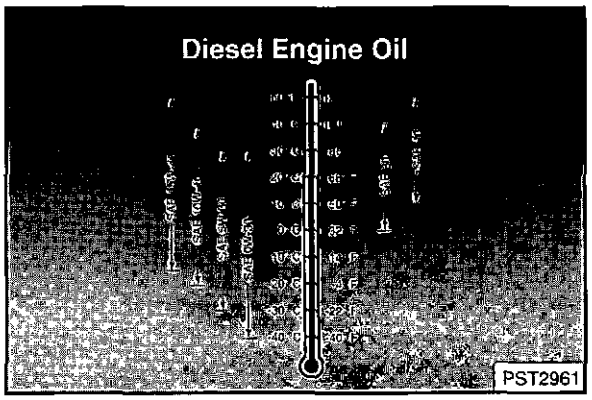
LUBE No. 3



LUBE No. 4

JOHN DEERE ENGINE OIL VISCOSITY REQUIREMENTS

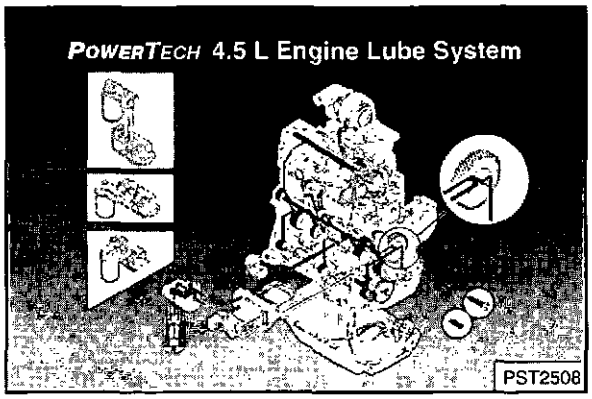
- Requirements always stated in engine Operation and Maintenance Manual
- Different viscosities recommended for various ambient temperature ranges
- Multi-viscosity for colder ambient air temperature ranges
- Single viscosity recommended for hotter ambient temperatures



LUBE No. 5

OIL FLOW

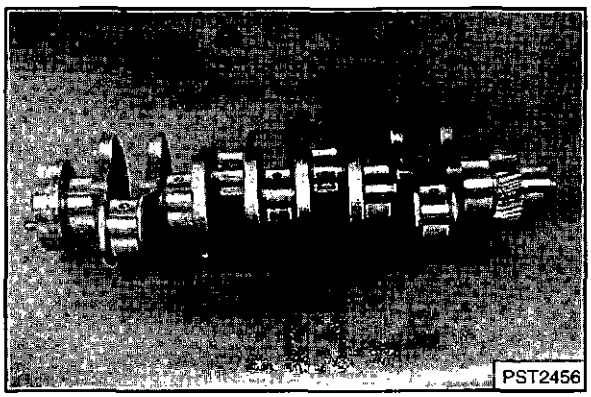
- Lube System
  - Internal force feed and splash type
  - Crankshaft driven, positive displacement, gear oil pump
  - System bypass valve
  - Pressure regulating valve
  - Filter bypass valve (in filter)
- Main lubrication supply
  - Crankshaft main bearings
  - Connecting rods
  - Balance shafts (4-cylinder)
  - Idlers (bottom splash-lubed)
  - Camshaft bores
  - Piston cooling jets
  - Rocker arm assembly
  - Turbocharger



LUBE No. 6

OIL PATH THROUGH CRANKSHAFT

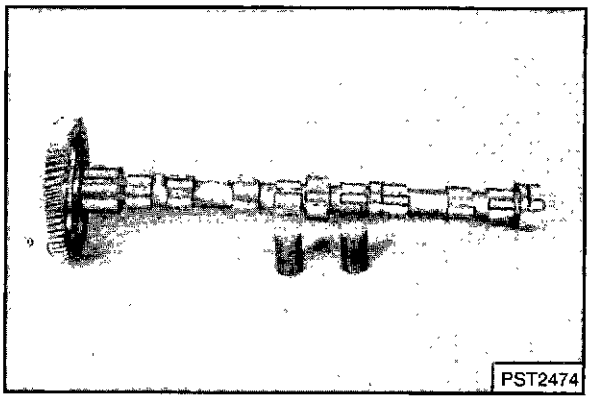
- Oil flows from main to rods
  - Block hole mates with hole in journal
  - Transfers to rods journal
  - Oil lubes pistons and cylinders
  - Each rod and main is lubed separately
- Rear main is lubed from main oil gallery
  - Saran (4-cylinder)... No. 4 main feeds No. 4 rod
  - Dubuque (4-cylinder)...No.5 main feeds No. 4 rod



LUBE No. 7

ROCKER ARM LUBRICATION

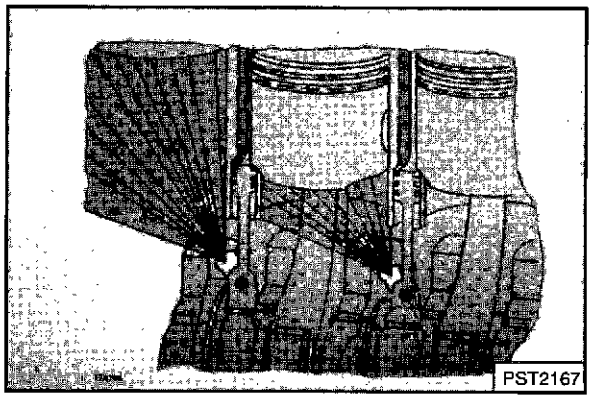
- Rear journal of camshaft is slotted
- Slot receives pressurized oil as slot indexes with pressurized oil gallery
- Pressure feeds oil up to rocker arm shaft to lubricate rockers and valves



LUBE No. 8

PISTON COOLING

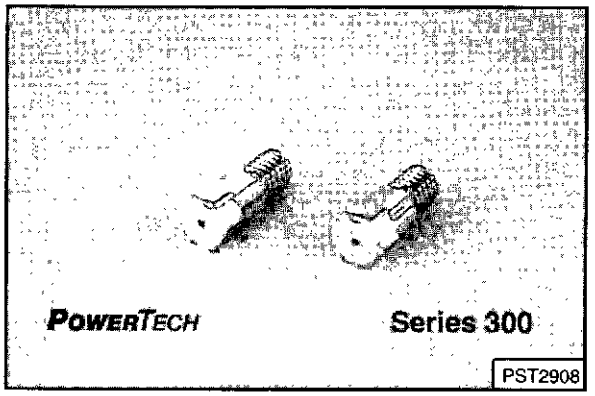
- Cooling jets
  - Located in block webbing, between bearing supports
  - Sprays oil to cool piston and lube wrist pin



LUBE No. 9

- Orifice size
  - Predetermined size
  - If not reinstalled at rebuild, will result in oil pressure drop

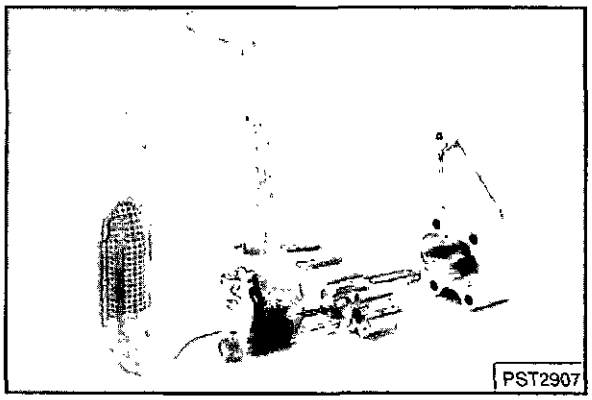
Note: ***POWERTECH*** 4.5 L and 6.8 L engines cooling jets have a 1.32 mm (.052 in.) orifice. Series 300 cooling jet orifice is 1.02 mm (.040 in.)



LUBE No. 10

OIL PUMP AND PICKUP TUBE

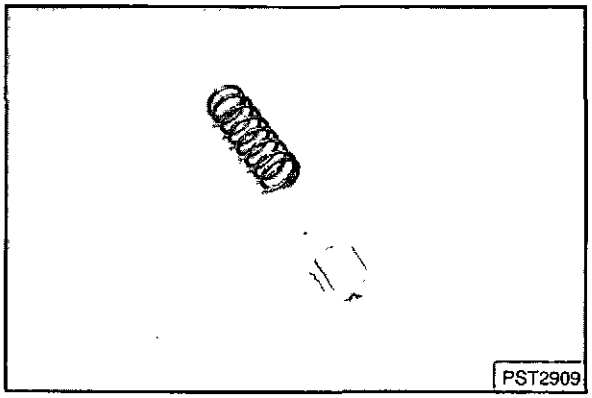
- 18 gpm at 2500 rpm
- Gear driven from lower idler gear
- Different pick-up tubes for different oil pans



LUBE No. 11

OIL BYPASS VALVE

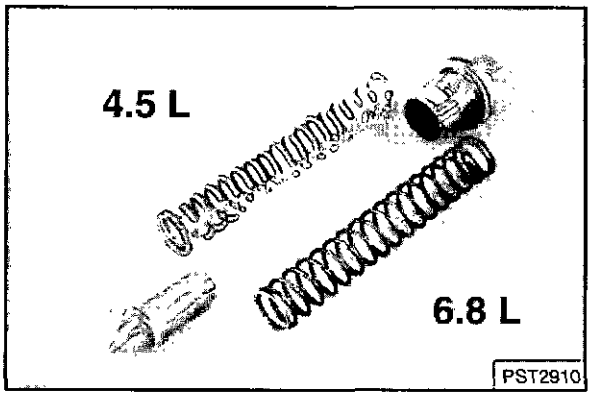
- Purpose
  - Valve is composite material
  - To allow cold oil to bypass filter and cooler
  - Avoid rapid rises in pressure
  - Reduces lag time in getting oil to bearings during cold weather start-up
- General information
  - Located between pump and main gallery
  - Nonadjustable spring pressure
  - Spring installed under cover plate
  - Take care not to cock at installation
  - Must remove timing gear cover and plate to access



LUBE No. 12

PRESSURE REGULATING VALVE

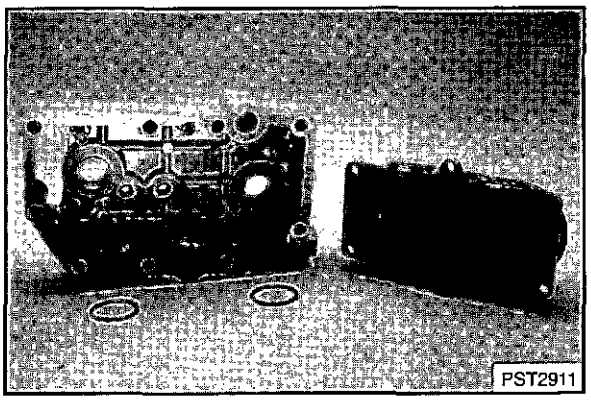
- Purpose
  - To maintain oil pressure within desired operating range
- Located after the oil filter in the lube circuit
  - Behind timing gear cover
    - Externally serviceable
  - Spring tension is "only" adjustment--do not use shims
- There are two springs
  - One for 4-cylinder and one for 6-cylinder engines to provide proper pressure for each
  - Check specifications for definite range and operating temperature
- 4 cylinder spring is color coded white



LUBE No. 13

OIL COOLER

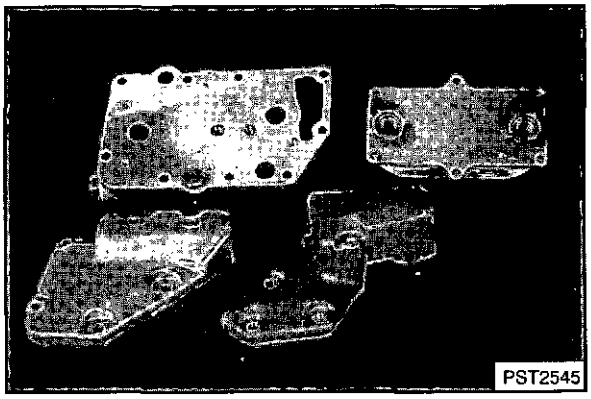
- Plate type oil cooler is mounted in coolant cavity of cylinder block
- Four different capacity oil coolers are used depending on the cooling requirements of the application. Three, five, seven and nine plate oil coolers are used in the ***POWERTECH*** engines



LUBE No. 14

OIL CONDITIONING HOUSING

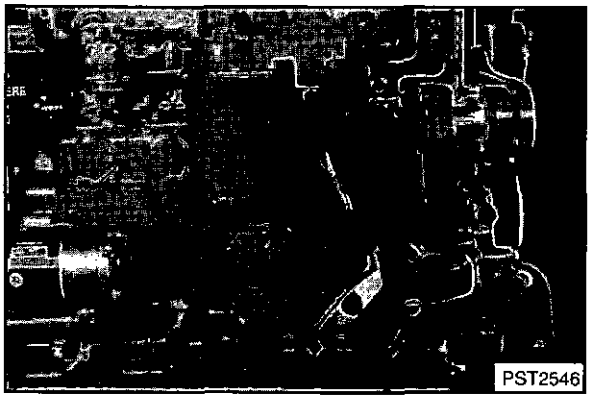
- The oil conditioning housing bolts to the side of the engine block and contains the oil cooler and has the oil filter housing attached to it
- Oil comes into the oil conditioning housing from the engine oil pump
- Oil passes through the cooler and is directed to the oil filter housing that is attached to the oil conditioner housing



LUBE No. 15

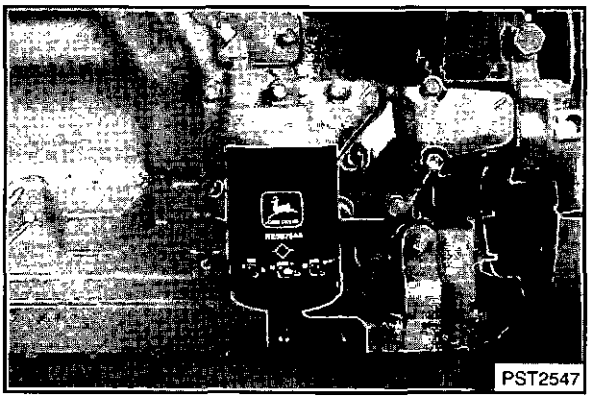
OIL FILTER HOUSINGS

- The oil filter can be located on either side of the engine
- The filter can be positioned high on the right side of the engine if the auxiliary drive will not be used



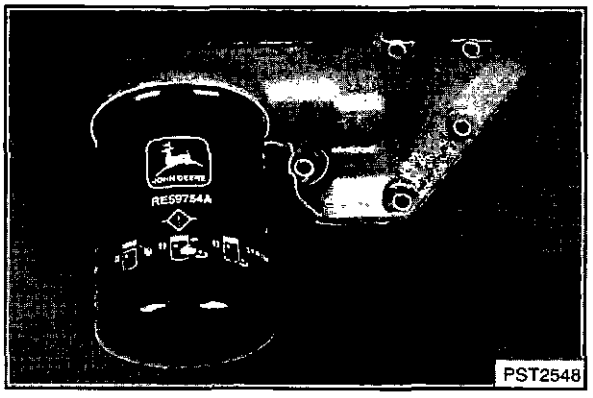
LUBE No. 16

- Filter housing can be mounted perpendicular to the oil conditioner housing. This position is required if a large starter is to be mounted on the four cylinder engine



LUBE No. 17

- Filter housing can be mounted parallel to the side of the engine at the low mount position

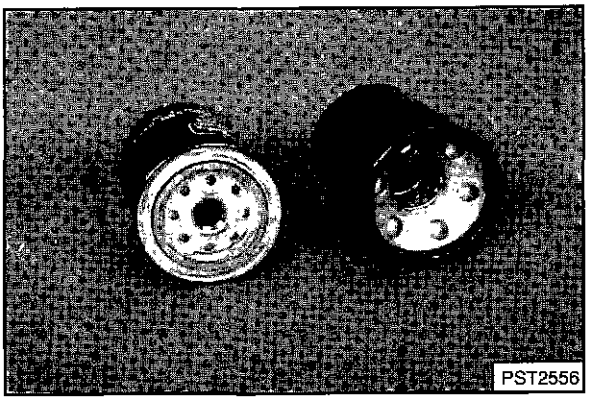


LUBE No. 18

- Filter can be mounted on the left side of the engine or remotely mounted with flexible hoses connected to adaptor on the oil conditioning housing

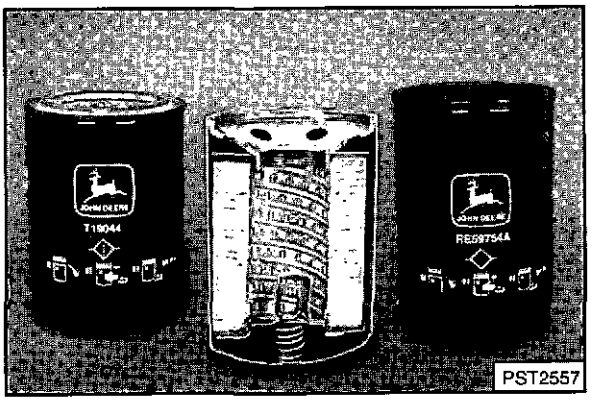
OIL FILTER

- A new RE59754 spin on type oil filter is used on the Powertech engines
- The new filter has larger passages to reduce flow restriction and a deep concave on the thicker mounting plate to prevent filter can flexing in cold weather start-up conditions



LUBE No. 19

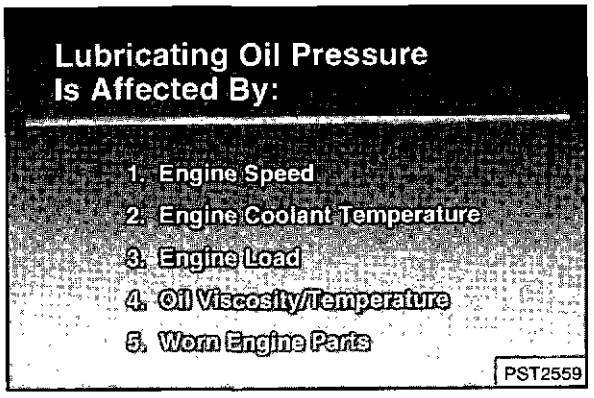
- The filter has a built in by-pass valve to allow oil flow should the filter become plugged
- Filter has no wrench flats to cause metal fatigue and cold weather restriction
- These filters have been thoroughly tested to give maximum protection on these engines



LUBE No. 20

ELEMENTS THAT AFFECT LUBE PRESSURE

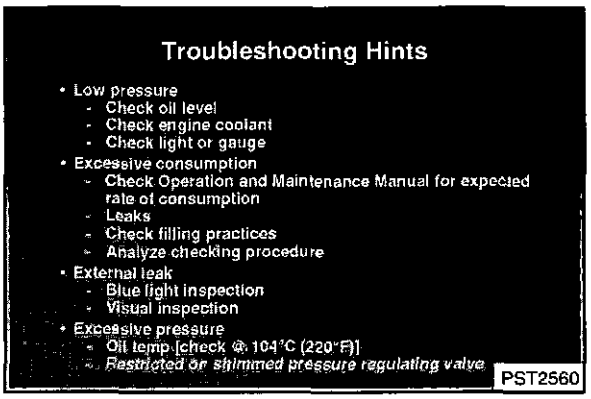
- Engine speed
- Engine coolant temperature
- Engine load
- Oil viscosity/temperature
- Worn engine parts



LUBE No. 21

TROUBLESHOOTING HINTS

- Low pressure
  - Check oil level
  - Check engine coolant
  - Check light or gauge
- Excessive consumption
  - Check Operation and Maintenance Manual for expected rate of consumption
  - Leaks
  - Check filling practices
  - Analyze checking procedure
- External leak
  - Blue light inspection
  - Visual inspection
- Excessive pressure
  - Oil temp [check @ 104°C (220°F)]
  - Restricted or shimmed pressure regulating valve

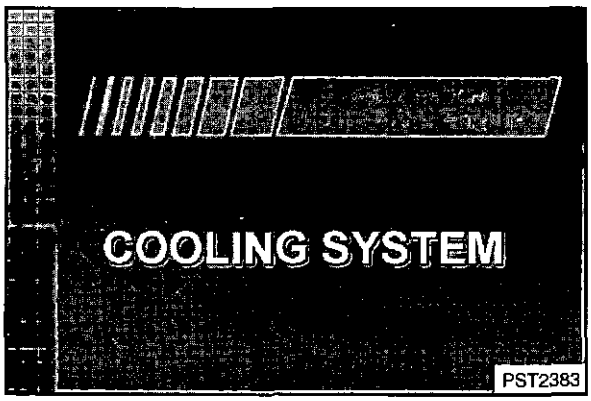


LUBE No. 22

NOTES

PURPOSE OF THE COOLING SYSTEM

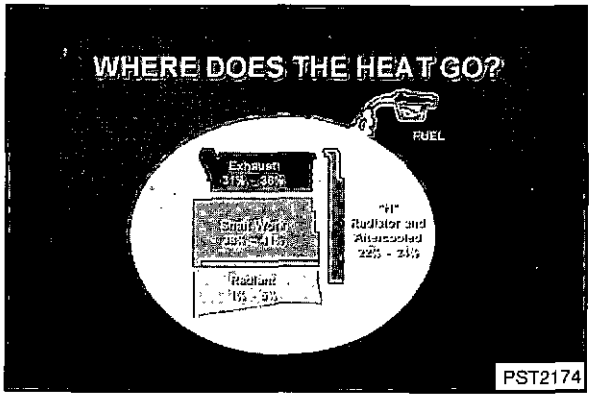
- The purpose of the cooling system is to control temperature of the engine within the range of highest operating efficiency
- Internal combustion, heat engines produces heat energy during combustion of fuel
- Adequate cooling is, therefore, essential to engine life
- Engine cooling system is closely related to lube and exhaust systems
- Need to maintain engine at normal operating temperatures



COOL No. 1

WHERE DOES THE HEAT GO?

- These ***POWERTECH*** 4.5 L and 6.8 L engines must dissipate the heat energy they generate
- Approximately 1/3 is rejected to coolant
  - Amount depends on engine load
  - Usually about 1/4 to 1/3 of energy of fuel burned
- Approximately 1/3 to crankshaft work output
- Approximately 1/3 goes up the exhaust; also some losses from radiation



COOL No. 2

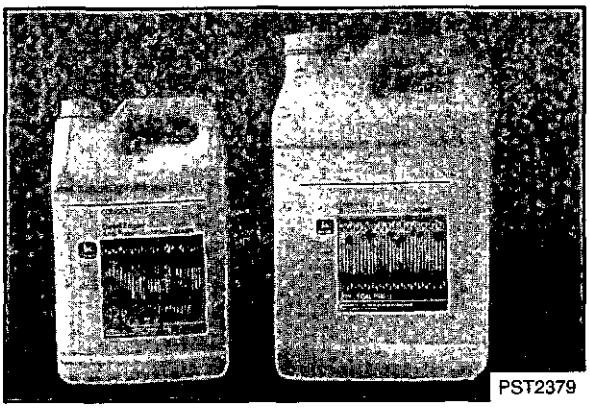
COOLANT RECOMMENDATIONS FOR ALL JOHN DEERE ENGINES

- Recommend John Deere Antifreeze/Summer Coolant
- Available in:
  - Concentrate:
    - Mix with good quality water to obtain the proper freeze point protection.
  - Prediluted (ready-to-use):
    - Contains 50% demineralized water; *freeze point of* -37 °C (-34 °F)
    - Both forms contain coolant conditioner (SCA); anti-corrosion additives & anti-foaming agents
  - Excellent protection from liner pitting, scalling, corrosion and gelling
- **Concentrate:** 1-gal (TY16034) or 55 gal **Prediluted:** 2-1/2 gal (TY16036) or 55 gal
- Excellent for use in ALL engine cooling systems requiring a coolant conditioner - Supplement Coolant Additive (SCA)
- List recommendation which include the importance of using "John Deere Liquid Coolant Conditioner" (TY16004 -16 oz. or TY16005-1/2 gal.) marketed by John Deere
- Engine coolant is marketed in Europe as "John Deere Cool-Gard™ "

COOLANT RECOMMENDATIONS

- Always use a properly inhibited coolant
- Do not use soluble oil
- Maintain the prescribed inhibitor strength
- Always follow the manufacturer's recommendations on inhibitor usage and handling
- If freeze protection is required, always use a permanent antifreeze
- Re-inhibit antifreeze with a recommended non-chromatic inhibitor system
- Do not use methoxy propanol base antifreeze in any John Deere engine. Will damage liner seals
- Do no use an antifreeze containing sealer additives
- Use extreme care when removing the radiator

COOL No. 3


PST2379

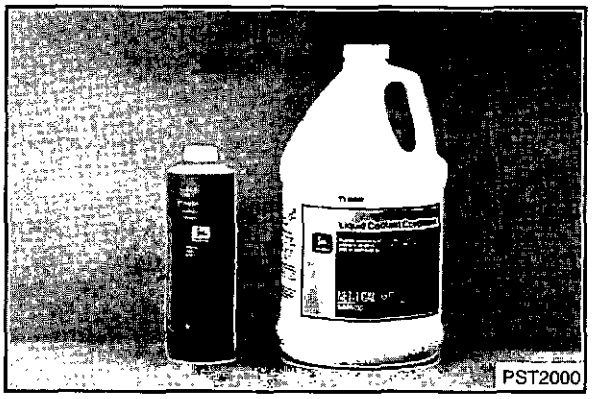
COOL No. 4

COOLANT CONDITIONER

- Refer to Operation and Maintenance Manual for information on John Deere's liquid coolant conditioners and replenishment intervals
- Added to a mixture of soft water and antifreeze (preferably 50/50) or 100% soft water
- Plain water without inhibitors should not be used as coolant
  - Only clean water low in chemical impurities should be used to mix with coolant
  - The natural corrosive action of water on metals is undesirable
- Where antifreeze is used, ethylene glycol (E.G.) or propylene glycol (P.G.) formulated to ASTM D4985 with low silicate content and compatible with supplemental coolant additives (SCA's) base shall be used. It protects against cylinder liner cavitation erosion, coolant system corrosion and scale
- Concentrated antifreeze/summer coolant mixed with good quality water should be changed every 24 months or 2000 hours
- Prediluted antifreeze/summer coolant should be changed every 36 months or 3000 hours
- Deere's "Liquid Coolant Conditioner" is a complete corrosion inhibitor
  - Excellent compatibility with other conditioners with silicate which could cause dropout problems
  - Corrosion protection for metals (i.e., iron, copper, aluminum)
  - Protects against solder bloom and increases the life of sensors and gaskets of cooling system

Service Note:

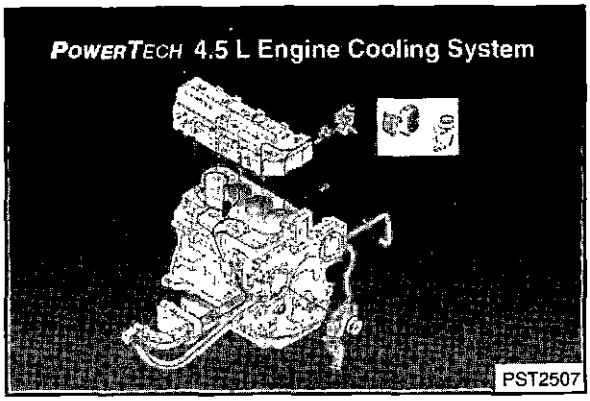
- Liquid coolant conditioner RE23182 was a DCA-2 additive.
  - It is not compatible with current TY16036 (DCA-4)
  - Same manufacturers
  - Different chemical properties
  - DO NOT INTERMIX *or* USE FOR MAKEUP to reinhibit system
- Limited shelf life of 2 years
  - Sunlight affects the chemicals stored in clear plastic bottles



COOL No. 5

COOLANT FLOW THROUGH THE ENGINE

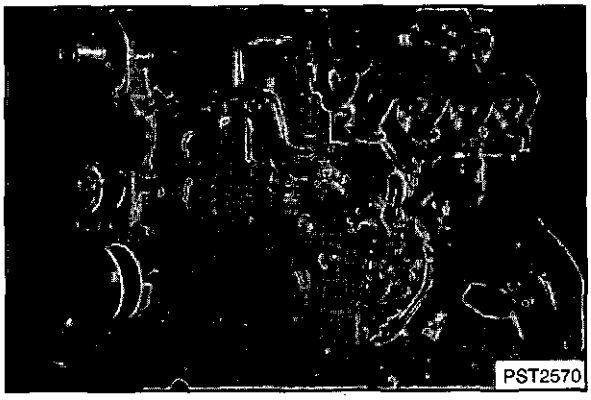
- Coolant flows
  - From the bottom of the radiator
  - Through the water pump
  - Into the oil cooler housing where it cools the engine lubricating oil
  - The coolant then flows through the integral water manifold in the side of the block which distributes the coolant throughout the block and cylinder head
- Coolant extracts the heat from the liners and passes on through the cylinder head, past the thermostats to the top of the radiator
- As the coolant passes through the radiator heat is removed and the coolant is again ready to complete another cooling cycle
- Engines that are emissions certifiable generally have higher heat rejection than uncertified models
- Top tank (radiator) allowable temperature is increased from 99 °C (210 °F+) to 105 °C (221 °F+)



COOL No. 6

BYPASS TUBE

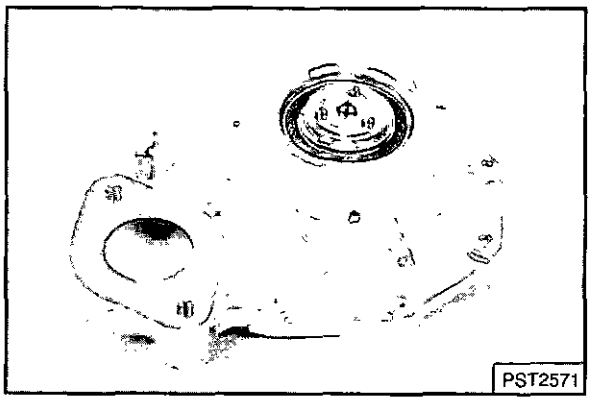
- A steel tube runs from the thermostat housing to the water pump to carry the thermostat bypass flow
- This limited coolant flow allows the engine to warm up quickly and prevents hot spots



COOL No. 7

WATER PUMP

- A new cartridge type water pump is mounted in the aluminum front gear cover and uses the cover cavity as the pumping area for the impeller
- Two impeller sizes, two drive pulleys and two driven pulley sizes are offered
- The **flow capacity** of the water pump **is controlled** by **impeller size** drive pulley and driven pulley size
- The rotating assembly, which includes the pump cover, impeller and bearing is removable from the aluminum front gear cover
- Rotating assembly of the water pump can be rebuilt as service parts are available

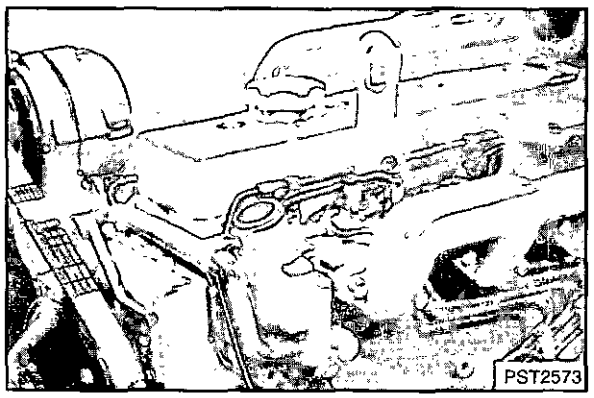


COOL No. 8

COOL No. 9

THERMOSTAT COVERS

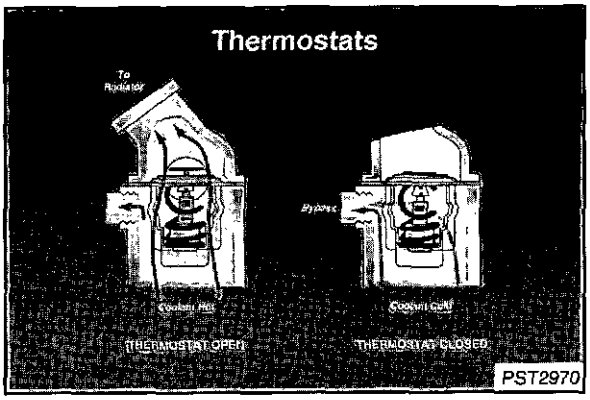
- An 82 °C (180 °F) thermostat fits directly into the cylinder head and is held in place by the thermostat cover
- The heat-sensing portion of the thermostat goes into the cylinder head
- The thermostat covers have internal lugs which interfere if backward installation is attempted
- Standard thermostat covers has one sensor port
- Optional cover has three sensor ports
- Thermostat should be installed with jiggle pin at top to improve deaeration of coolant



COOL No. 10

THERMOSTAT FEATURES

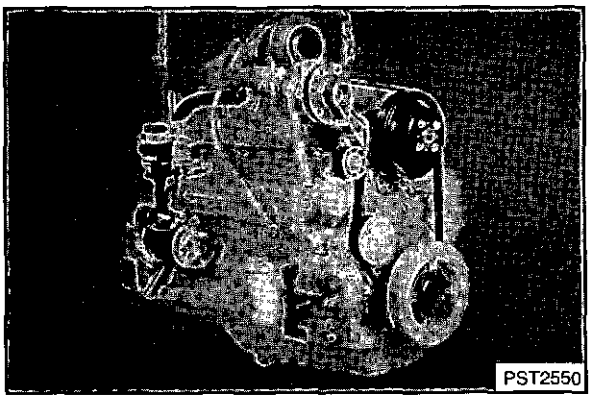
- 82 °C (180 °F+) thermostat is standard
- Operation;
  - Wax, granular copper, or liquid ether actuator
  - Heat forces expansion and opens valve
  - As heat is expelled actuator cools and closes valve
  - Temperature to open valve is stamped on strap
- Components;
  - Valve
  - Valve seat
  - Return spring
  - Spring strap holder
  - Power actuator



COOL No. 11

POLY-VEE BELT DRIVE

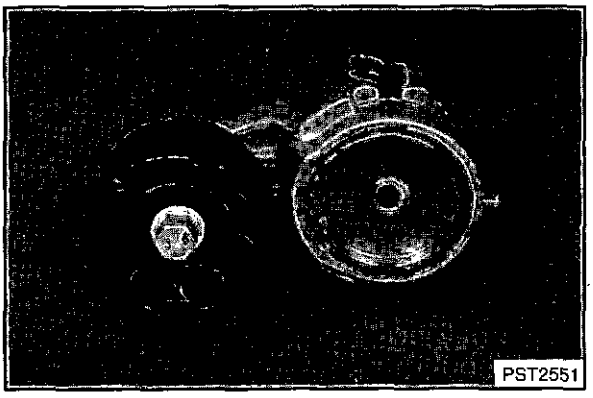
- The water pump, fan and alternator are driven by a ribbed poly-vee belt
- The belt can transmit more power than a conventional "vee" belt at the same tension
- After extended periods of use the belt may exhibit cracks perpendicular to the ribs
- Replacement is not required until the ribs show signs of chunks falling out
- In severe operating conditions the belt is expected to increase belt life considerably over that of a conventional "vee" belt



COOL No. 12

SELF-ADJUSTING BELT TENSIONER

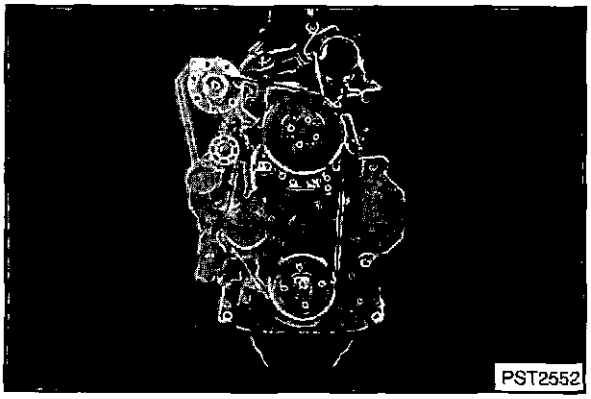
- A self-adjusting tensioner for the poly-vee belt
- The tensioner maintains proper tension for the life of the belt
- Spring loaded potion of the tensioner is a sealed unit and must be replaced as an assembly
- Idler sheave uses sealed and lubricated bearings and is replaceable
- Idler attaching bolt is left hand threaded so it will not loosen when a wrench is used to relieve belt tension



COOL No. 13

FAN DRIVE

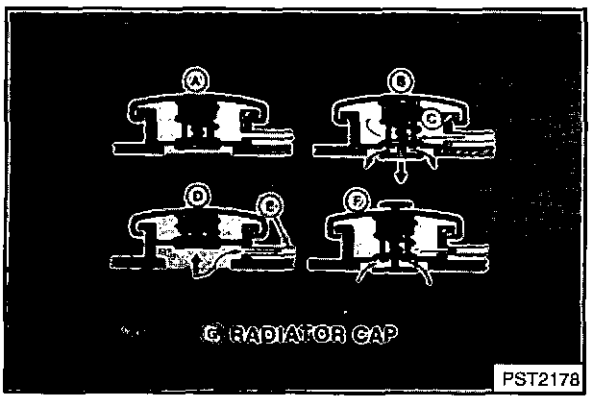
- Driven by an 8 groove poly-vee belt
- Increased fan power capability
- Fan is separated from the water pump and can now be driven at speeds the application requires
- Standard-duty and heavy-duty bearing options
- Fan support mounts directly to front gear cover and may be turned upside down to provide a total of 15 standard fan heights
- Six standard fan drive ratios are available by changing pulley size
  - 1.34:1
  - 1.20:1
  - 1.12:1
  - 1.00:1
  - 0.93:1
  - 0.83:1
- Three more than was available on Series 300



COOL No. 14

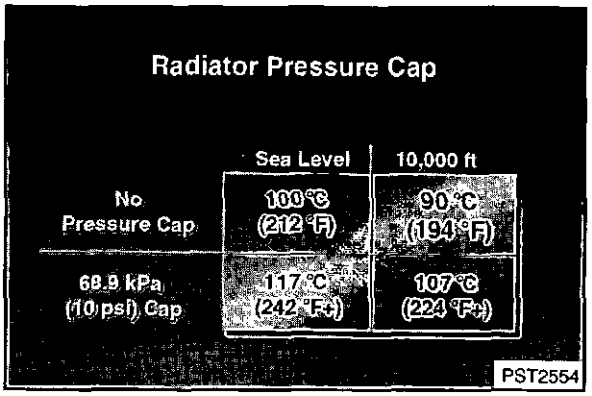
RADIATOR PRESSURE CAP

- Functions;
  - Pressure control device
  - Keeps coolant clean and contained
  - Vacuum prevention, avoids collapsing tubes
  - Cover for radiator system
  - Increases operating temperatures
- (A) Radiator cap at rest
  (B) & (C) Warm coolant is cooling down and vacuum has opened vacuum relief
  (D) & (E) Coolant is warming and pressure has opened pressure relief
  (F) Cap with mechanical pressure relief for pre-removal



COOL No. 15

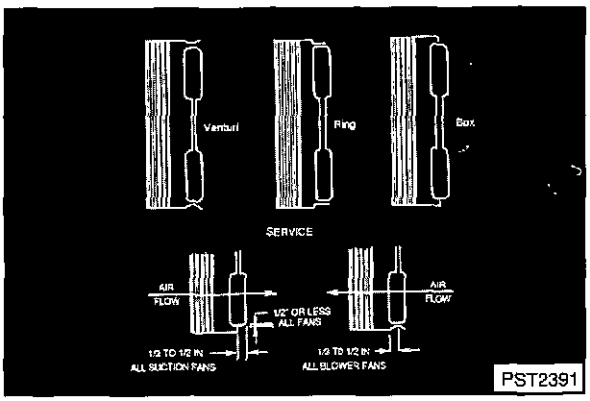
- Operation;
  - -1.67 °C (3 °F) added for each 6.89 kPa (1 psi) increase
    Example:
    100 °C (212° F+) 68.9 kPa x 1.67 °C = 117 °C (242° F+) boiling point
  - ***POWERTECH*** 4.5 L and 6.8 L engine use a 6.9 kPa (10 psi) pressure cap
  - Heavy concentration of ethylene glycol will increase the boiling point



COOL No. 16

TYPES OF FANS

- Suction type
  - Pulls air through radiator
  - Pushes air over engine
  - Smaller fan and radiator
  - *Machine motion aids air flow*
- Blower type
  - Pulls air across engine
  - Pushes air through radiator
  - Slow moving vehicles
  - Avoids drawing in contaminants to radiator



COOL No. 17

FAN SELECTION

- Most efficient ... largest fan diameter turning at slowest possible speed
- *Fan position ... optimum distance is 60 mm* (2-1/2 inches) from radiator core

FAN SELECTION

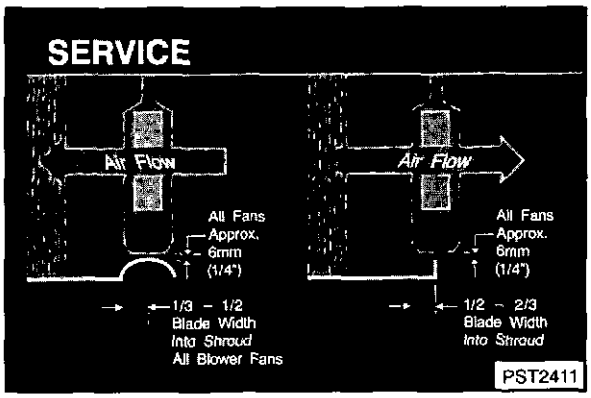
- Most Efficient - Largest Fan Diameter Turning at Slowest Possible Speed
- Position
  - 60 mm (2.5 in.) from Radiator core
  - 6 mm (.25 in.) between Blade Tip and Shroud

PST2553

COOL No. 18

FAN-TO-SHROUD SPACING

- Fan shrouds ensures efficient directed air flow *through radiator*
  - Suction fan ... 1/2 to 2/3 of blade pitch is inside shroud or 1/2 to 1/3 is outside
  - Blower type ... 1/3 to 1/2 blade pitch is inside shroud or 1/2 to 2/ 3 is outside
- Clearance between fan blade tip and shroud should be 6 mm (1/4 inch)



COOL No. 19

TROUBLESHOOTING TIPS

- Overheating ... simplest to most complicated
  - Loose or broken fan belt
  - Dirty radiator
  - Low coolant level
  - Defective radiator cap
  - Collapsed lower radiator hose
  - Low oil level
  - Overloaded engine
  - Air intake blocked
  - Excessive air intake temperature
  - Defective head gasket
  - Faulty water pump or plugged weep hole
  - Plugged coolant line
  - Improper grade of fuel
  - Too much fuel delivery
  - Incorrect timing
- Too cold
  - Inoperative sending unit
  - Faulty radiator cap
  - Faulty thermostat

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COOL No. 20

NOTES

DSEGETG350
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