Draft of Standard Test Method for

Cummins ISB Test[1]

1. Scope

1.1 This test method is commonly referred to as the Cummins ISB Test. The test method utilizes a modern medium-duty diesel engine equipped with exhaust gas re-circulation used to evaluate oil performance with regard to valve train wear.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parenthesis are for information only.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use. See A1 for general safety precautions.

2. Referenced Documents

2.1 ASTM Standards:

D 86 Standard Test Method for Distillation of Petroleum Products[4]

D 92 Standard Test Method for Flash and Fire Points by Cleveland Open Cup[4]

D 97 Standard Test Method for Pour Point of Petroleum Products[4]

D 129 Standard Test Method for Sulfur in Petroleum Products[4]

D 130 Standard Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test[4]

D 287 Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[4]

D 445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque

Liquids (and the Calculation of Dynamic Viscosity)[4]

D 482 Standard Test Method for Ash from Petroleum Products[4]

D 524 Standard Test Method for Ramsbottom Carbon Residue of Petroleum Products[4]

D 613 Standard Test Method for Cetane Number of Diesel Fuel Oil[5]

D 664 Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration[4]

D 1319 Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Absorption[4]

D 2500 Standard Test Method for Cloud Point of Petroleum Products[4]

D 2622 Standard Test Method for Sulfur in Petroleum Products by x-ray Spectrometry[6]

D 2709 Standard Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge[6]

D 2896 Standard Test method for Base Number of Petroleum Products by Potentionmetric Perchloric Acid Titration[6]

D 4485 Specification for Performance of Engine Oils[6]

D 4737 Standard Test Method for Calculated Cetane Index by Four Variable Equation[7]

D4739 Standard Test method for Base Number Determination by Potentiometric Titration[7]

D 5185 Standard Test Method for Determination of Additive Elements, Wear Metals, and Contaminants in Used Lubricating Oils and Determination of Selected Elements

in Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)[7]

D 5302 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation and Wear in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light Duty Conditions[7]

D 5967 Standard Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine[7]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[8]

E 344 Terminology Relating to Thermometry in Hydromometry[9]

2.2 Coordinating Research Council:

CRC Manual No. 12[10]

CRC Manual No. 18 (Revised May, 1994)[10]

3. Terminology

3.1 Definitions:

blind reference oil, n - a reference oil, the identity of which is unknown by the test facility. D 5844

blow-by, n — in internal combustion engines, the combustion products and unburned air-and-fuel mixture that enter the crankcase. D 5302

calibrate, v - to determine the indication or output of a measuring device with respect to that of a standard. E 344

heavy-duty, adj. – in internal combustion engine operation, characterized by average speeds, power output, and internal temperatures that are close to the potential maximum. D 4485

medium-duty engine, adj. – in internal combustion engines,??. D 4485

non-reference oil, n — any oil other than a reference oil, such as a research formulation, commercial oil or candidate oil. D 5844

non-standard test, n – a test that is not conducted in conformance with the requirements in the standard test method; such as running in an non-calibrated test stand or using different test equipment, applying different equipment assembly procedures, or using modified operating conditions. D 5844

reference oil, n – an oil of known performance characteristics, used as a basis for comparison. D 4485

sludge, n — in internal combustion engines, a deposit, principally composed of insoluble resins and oxidation products from fuel combustion and the lubricant, that does not drain from engine parts but can be removed by wiping with a cloth. D 5302

wear, n — the loss of material from, or relocation of material on, a surface. D 5302

Discussion – Wear generally occurs between two surfaces moving relative to each other, and is the result of mechanical or chemical action or by a combination of mechanical and chemical actions.

3.2 Descriptions of Terms Specific to This Standard:

3.2.1 crosshead, n — an overhead component, located between the rocker arm and each intake valve and exhaust valve pair, that transfers rocker arm travel to the opening and closing of each valve pair.

3.2.1.1 Discussion -- Each cylinder has two crossheads, one for each pair of intake

valves and exhaust valves.

3.2.2 exhaust gas re-circulation (EGR), n - a method by which a portion of engine's exhaust is returned to its combustion chambers via its inlet system.

3.2.3 overhead, n – in internal combustion engines, the components of the valve train located in or above the cylinder head.

3.2.4 tappet, n - in internal combustion engines, a valvetrain component, located between the camshaft and push rod, that transfers cam lobe travel to the rocker arm, opening and closing a pair of intake or exhaust valves.

3.2.5 valve train, n – in internal combustion engines, the series of components such as valves, crossheads, rocker arms, push rods, tappets and camshaft, which open and close the intake and exhaust valves.

4. Summary of Test Method

4.1 This test method uses a 2004 EPA emission compliant Cummins 5.9L ISB diesel engine. Test operation includes a 17-min. warm-up, an 80-h break-in, and 350 h in two stages. During stage A the engine is operated with retarded fuel injection timing to generate excess soot. During stage B the engine is operated at cyclic conditions to induce valve train wear.

4.2 Prior to each test, the engine is cleaned and assembled with overhead valve train components. All aspects of the assembly are specified.

4.3 A forced oil drain, an oil sample and an oil addition, are performed at the end of each 25-h period for the first 100-h of the test. Thereafter, oil samples shall be taken every 50-h. Oil additions are not made during the last 250-h of the test cycle.

4.4 The test stand is equipped with the appropriate instrumentation to control engine speed, fuel flow, and other operating parameters.

4.5 Oil performance is determined by assessing crosshead wear, tappet weight loss, cam profile wear, and adjusting screw wear at 3.25% soot.

5. Significance and Use

5.1 This test method was developed to assess the performance of a heavy-duty engine oil to control engine wear under operating conditions selected to accelerate soot production and valve train wear in a turbo-charged and inter-cooled four-cycle diesel engine with sliding tappet followers equipped with exhaust gas re-circulation hardware.

5.2 The design of the engine used in this test method is representative of many, but not all, modern diesel engines. This factor, along with the accelerated operating conditions shall be considered when extrapolating test results.

6. Apparatus

6.1 Test Engine Configuration:

6.1.1 Test Engine -- The Cummins ISB is an in-line six-cylinder medium-duty diesel engine with 5.9 L of displacement and is turbocharged, after-cooled, and has an overhead valve configuration. It features a 2004 emissions configuration with electronic control of fuel metering and common rail fuel injection. Obtain the test engine and the engine build parts kit from the supplier listed in A2.2. The components of the engine build parts kit are shown in Table A3.1.

6.1.2 Remote Oil Heat Exchanger and Adapter Plate — The stock oil heat

exchanger is removed from the engine and replaced with an adapter plate (Fig A4.1). A remote adapter is attached to the filter head as shown in Fig A4.2 to allow control of the oil temperature by directing the oil to flow thru a remote, tube and shell oil heat exchanger as shown in Fig. A4.3a. The oil lines to and from the remote oil heat exchanger and filter head can not be greater than one 1 meter in length. The lines to and from the remote oil heat exchanger and filter head are to be 25 mm inside diameter. The adapter plate, remote filter head adapter and remote oil heat exchanger can be obtained from the suppliers listed in X1.3.

6.1.3 Oil Pan Modification — Modify the oil pan as shown in Fig. A4.4. A modified oil pan can be obtained from the supplier listed in X1.2.

6.1.4 Engine Control Module (ECM) — Obtain the ECM from the supplier listed in A2.2. The ECM programming can be modified, using Cummins engineering tools, to provide retarded injection timing to increase soot generation and overhead wear. Some engine protection protocols will be disabled to insure that the test be run per the procedure. Instructions on how to disable the engine protection protocols, as well as, the use of the Cummins engineering tool requires prior authorization by Cummins Inc.

6.1.5 Air Compressor - The engine-mounted air compressor is not used for this test method. The air compressor is removed and the opening is covered by a plate, Cummins part number 3954567 which can be obtained from supplier X1.1.

6.1.6 Engine Inlet Air Heater – Remove the internal heating elements from the housing of the engine inlet air heater. Remove the lower factory installed

electrical terminal. Drill and tap this hole (1/8 NPT) for the inlet manifold pressure fitting.

6.2 Test Stand Configuration:

6.2.1 Engine Mounting — Install the engine so that it is upright and the crankshaft is horizontal.

Note 1: Caution -- The engine mounting hardware should be configured to minimize block distortion when the engine is fastened to the mounts. Excessive block distortion can influence test results.

6.2.2 Intake Air System– With the exception of the air filter and the intake air tube, the intake air system is not specified. A typical configuration is shown in Fig. A4.6. The air filter shall have a minimum initial efficiency rating of 99.2%. Install the intake air tube ~~(Fig A4.6) Need photo~~ at the intake of the turbocharger compressor. Construct the system to minimize airflow restriction. A method to cool the intake air is required.

Note 2: Difficulty in achieving or maintaining intake manifold pressure or intake manifold temperature, or both, could be indicative of insufficient or excessive restriction.

6.2.3 Aftercooler – A Modine after-cooler, P/N 1A012865, will be used for after-cooling. An installation photo of the cooler is shown in Fig A4.7a. The aftercooler can be obtained from the supplier listed in X.1.5.

6.2.4 Exhaust System – Install the exhaust tube (Fig A4.10) at the discharge flange of the turbocharger turbine housing. The piping downstream of the exhaust tube is not specified. A method to control exhaust back pressure is required.

6.2.5 Exhaust Gas Re-circulation System -- The components for the exhaust gas re-circulation system are installed by the manufacturer. Replacement parts can be obtained from the supplier listed in X.1.2.

6.2.6 Fuel Supply – The fuel supply and filtration system is not specified. The fuel consumption rate is determined by measuring the rate of fuel flowing into the day tank. A method to control the fuel temperature is required.

6.2.7 Coolant System – The system configuration is not specified. A typical configuration consists of a non-ferrous core heat exchanger, a reservoir (expansion tank) and a temperature control valve as shown in Fig. X2.3. Pressurize the system by regulating air pressure at the top of the expansion tank. The system should have a sight glass to detect air entrapment.

Note 3: Caution – Although the system volume is not specified, an excessively large volume can increase the time required for the engine fluid temperatures to attain specification. A system volume of 35 L or less (including engine) has proven satisfactory.

6.2.8 Pressurized Oil Fill System – The oil fill system is not specified. A typical configuration includes an electric pump, a 20-L reservoir, and transfer hose.

~~**6.2.9** External Oil System — Configure the external oil system according to Fig. A4.9. The external reservoir shall be Moroso P/N 22670 with baffles P/N 22670-170, which can be obtained from the supplier listed in X1.4. Insert 1P with a method to empty the bucket back into the sump.The three-way valve system is permissible.~~

6.2.9.1 Oil Sample Valve Location -- The oil sample valve shall be located on the return line from the external oil system to the engine. It is recommended that the

valve be located as shown in (Fig. A4.3).

6.2.9.2 Brass or copper fittings can influence used oil wear metals analyses and shall not be used in the external oil system.

6.2.10 Crankcase Aspiration – Vent the blow-by gas at the port located at the left rear of the flywheel housing as shown in (Fig. A4.4a). The vent line must proceed in a downward direction from the valve cover port into the

6.2.11 Blowby Rate — The flow rate device and system configuration is not specified. Install the system according to good engineering practice and operate the flow rate device according to manufacturer guidelines.

6.3 System Time Responses – The maximum allowable system time responses are shown in Table 1. Determine system time responses in accordance with the Data Acquisition and Control Automation II (DACA II) Task Force Report[12].

Table 1 Maximum Allowable System Time Responses

Measurement Type	Time Response (s)
Speed (RPM)	2.0
Torque	2.0
Temperature	3.0
Pressure	3.0
Flow	45.0

6.4 Oil Sample Containers — High-density polyethylene containers are recommended for oil samples.

Note 4: Precaution — Glass containers may break and may cause injury or

exposure to hazardous materials, or both.

6.5 Mass Balance — A balance is required to measure the mass of the crossheads, tappets, push rods, rocker lever sockets, rocker lever shafts and adjusting screws. An electronic or mechanical balance may be utilized. The balance shall have a minimum indication resolution of 0.1 mg.

7. Engine, Fluids and Cleaning Solvents

7.1 Test Oil -- Approximately 80 L of test oil is required to complete the test.

7.2 Test Fuel -- Approximately 8,000 L of ultra-low sulfur diesel fuel is required to complete the test. Purchase the fuel from the supplier listed in A2.1. The fuel shall have the properties and tolerances shown in A6.

7.3 Engine Coolant – Use pre-mixed Fleetguard Compleat PG. The coolant can be obtained from the supplier listed in X1.1.

7.4 Solvent – Aliphatic naphtha or equivalent.

7.5 Pentane – Clean Pentane used for cleaning components before measurement.

7.6 EnSolv® – Proprietary solvent that can be obtained from the supplier listed in X1.2

Note 5: Warning – Use adequate safety precautions with all solvents and cleaners.

8. Preparation of Apparatus

8.1 Cleaning of Parts:

8.1.1 General – The preparation of test engine components specific to the Cummins ISB test are indicated in this section. Use the Cummins service publications[13] listed in A7 for the preparation of other engine components. Take

precautions to prevent rusting of iron components.

8.1.2 Engine Block – The engine block is a parent bore type. This test does not require a complete teardown.

8.1.3 Rocker Cover and Oil Pan – Clean the rocker cover and oil pan. Use a brush as necessary to remove deposits. The internal plastic baffle in the RAC shall be remove before cleaning to allow complete removal of deposits under the RAC baffle and on the inner RAC surface. The baffle does not need to be resealed at the rear.

8.1.4 External Oil System -- Flush the internal surfaces of the oil lines and the external reservoir with solvent. Repeat until the solvent drains clean. Flush solvent through the oil pumps until the solvent drains clean.

8.1.6 Crosshead Cleaning and Measurement:

Note 6: Caution – Avoid handling the crossheads with bare hands, use Ensolv-compatible gloves or plastic covered tongs.

8.1.6.1 Inspect the crossheads, align in numerical order as etched from CPD, engrave with engine position (1I, 1E, 2I, 2E, etc), clean the crossheads with solvent. Use a non-metallic soft bristle brush if necessary. All engraving to be done on non-contact surfaces

8.1.6.2 Allow the crossheads to air dry, do not use compressed air.

8.1.6.3 Rinse the crossheads in pentane and allow to air dry, do not use compressed air.

8.1.6.4 Soak in EnSolv® for 30 minutes and allow to air dry, do not use compressed air. Ensolv-compatible gloves are recommended.

8.1.6.5 Measure crosshead mass to a tenth of a milligram (xxx.x mg) with flat pad

up and slot (and dot) to the right as viewed from the scale operator

8.1.6.6 If an electronic scale is used for mass measurement, then use the following procedure:

(a) Demagnetize (degauss) each crosshead prior to measurement

(b) Measure the crosshead twice, using two orientations 90° apart. If the difference between the two mass measurements is greater than 0.2 mg, the crosshead shall be demagnetized and the measurement process repeated.

8.1.6.7 Report the crosshead measurements on the form included in the TMC report package.

8.1.7 Tappet Cleaning and Measurement

Note 7: Caution – Avoid handling the tappets with bare hands, use Ensolv-compatible gloves or plastic covered tongs.

8.1.7.1 Inspect the tappets, align in numerical order as etched from CPD, engrave with engine position (1I, 1E, 2I, 2E, etc), engrave an A, then rotate 90 degrees and engrave a B, clean the tappets with solvent. Use a non-metallic soft bristle brush if necessary. All engraving to be done on non-contact surfaces

8.1.7.2 Allow the tappets to air dry, do not used compressed air.

8.1.7.3 Rinse the tappets with Pentane and allow the tappets to air dry, do not used compressed air.

8.1.7.4 Soak the tappets in Ensolve solvent, available from the supplier listed in X1.2, to cover the entire surface for 30 minutes.

8.1.7.5 Allow the tappets to air dry, do not used compressed air.

8.1.7.6 Measure the mass of each tappet, orienting the large circular flat surface in an upwards position and the engraved A to the front (facing the balance operator), to a tenth of a milligram (xxx.x mg).

8.1.7.7 If an electronic scale is used for mass measurement, then use the following procedure:

(a) Demagnetize (degauss) each tappet prior to measurement

(b) Measure the tappet twice, using two orientations, both with the flat face upwards, 90° apart. If the difference between the two mass measurements is greater than 0.2 mg, the tappet shall be demagnetized and the measurement process repeated

8.1.7.8 With the flat surface upwards, measure the tappet height in the center of the tappet face and report the dimension in mm

8.1.7.9 Using the PDI (Precision Devices Incorporated), microanalyzer 2000, capture a trace of the flat surface along the A plane and along the B plane.

8.1.7.10 Measure tappet stem diameter 15mm, 30mm and 45 mm from the flat surface and report the dimension in mm

8.1.7.11 Report the tappet measurements on the forms included in the TMC report package.

8.1.8 Camshaft Cleaning and Measurement

Note 8: Caution – Avoid handling the camshaft with bare hands, use gloves. Contamination can adversely affect the wear results.

~~**8.1.8.1**~~ The camshaft is pre-measured by the camshaft supplier,***Micrometer

measurements of lobes (ala Seq. III) details to be finalized. ~~no additional measurement or cleaning is required prior to running the test.~~

8.1.8.2 The reference or matrix camshaft will be sent back to the CPD and then to the supplier for post-measurement using an ADCOLE measurement machine. Candidate camshafts will be sent directly from the test lab to the cam supplier

8.1.9 Adjusting Screw Cleaning and Measurement

8.1.9.1 Remove the adjusting screws from the valve rocker levers and keep them in numerical order as etched by the CPD, inspect, note the etching from the CPD and engrave the rocker levers with (1I, 1E, 2I, 2E, etc), clean the adjusting screws with solvent. Use a soft bristle brush if necessary.

8.1.9.2 Allow the adjusting screws to air dry, do not use compressed air.

8.1.9.3 Rinse the adjusting screws with pentane and allow to air dry, do not use compressed air

8.1.9.4 Soak the adjusting screws in Ensolv® for 30 minutes

8.1.9.5 Allow the adjusting screws to air dry, do not use compressed air

8.1.9.6 Place the adjusting screw flat on the balance with the ball end to the right as viewed by the balance operator, measure adjusting screw mass to a tenth of a milligram (xxx.x mg).

8.1.9.7 If an electronic scale is used for mass measurement, then use the following procedure:

(a) Demagnetize (degauss) each adjusting screw prior to measurement

(b) Measure the adjusting screw twice, using two orientations 90° apart. If the

difference between the two mass measurements is greater than 0.2 mg, the adjusting screw shall be demagnetized and the measurement process repeated

8.1.10 Rocker Lever Shaft Cleaning and Measurement

8.1.10.1 Inspect the Rocker Lever Shafts, engrave with engine position (1I, 1E, 2I, 2E, etc), clean the Rocker Lever Shafts with solvent. Use a non-metallic soft bristle brush if necessary. All engraving to be done on end with factory alphanumeric stamping, non-contact surfaces

8.1.10.2 Allow the rocker lever shafts to air dry, do not use compressed air.

8.1.10.3 Rinse the rocker lever shafts in pentane and allow to air dry, do not use compressed air.

8.1.10.4 Soak in EnSolv® for 30 minutes and allow to air dry, do not use compressed air. Ensolv-compatible gloves are recommended.

8.1.10.5 Measure rocker lever shaft mass to a tenth of a milligram (xxx.x mg) with flat slot up and factory alphanumeric stamping to the right as viewed from the scale operator

8.1.10.6 If an electronic scale is used for mass measurement, then use the following procedure:

(a) Demagnetize (degauss) each rocker lever shaft prior to measurement

(b) Measure the rocker lever shaft twice, using two orientations 90° apart. If the difference between the two mass measurements is greater than 0.2 mg, the rocker lever shaft shall be demagnetized and the measurement process repeated.

8.1.10.7 Report the rocker lever shaft measurements on the form included in the

TMC report package.

8.1.11 Rocker Lever Socket Cleaning and Measurement

8.1.11.1 Inspect the Rocker Lever Sockets, engrave with engine position (1I, 1E, 2I, 2E, etc), clean the Rocker Lever Sockets with solvent. Use a non-metallic soft bristle brush if necessary. All engraving to be done on non-contact surfaces. Caution must be used removing the sockets from the ball end of the rocker levers, do not damage the plastic retainer.

8.1.11.2 Allow the rocker lever sockets to air dry, do not use compressed air.

8.1.11.3 Rinse the rocker lever sockets in pentane and allow to air dry, do not use compressed air.

8.1.11.4 Soak in EnSolv® for 30 minutes and allow to air dry, do not use compressed air. Ensolv-compatible gloves are recommended.

8.1.11.5 Measure rocker lever socket mass to a tenth of a milligram (xxx.x mg) with flat surface up

8.1.11.6 If an electronic scale is used for mass measurement, then use the following procedure:

(a) Demagnetize (degauss) each rocker lever socket prior to measurement

(b) Measure the rocker lever socket twice, using two orientations 90° apart. If the difference between the two mass measurements is greater than 0.2 mg, the rocker lever socket shall be demagnetized and the measurement process repeated.

8.1.11.7 Report the rocker lever socket masses on the form included in the TMC

report package.

8.1.12 Push Rod Cleaning and Measurement

8.1.12.1 Inspect the push rods, engrave with engine position (1I, 1E, 2I, 2E, etc), clean the push rods with solvent. Use a non-metallic soft bristle brush if necessary. All engraving to be done on, non-contact surfaces

8.1.12.2 Allow the push rods to air dry, do not use compressed air.

8.1.12.3 Rinse the push rods in pentane and allow to air dry, do not use compressed air.

8.1.12.4 Soak in EnSolv® for 30 minutes and allow to air dry, do not use compressed air. Ensolv-compatible gloves are recommended.

8.1.12.5 Measure push rod mass to a tenth of a milligram (xxx.x mg) with ball end to the right as viewed from the scale operator

8.1.12.6 If an electronic scale is used for mass measurement, then use the following procedure:

(a) Demagnetize (degauss) each push rod prior to measurement

(b) Measure the push rod twice, using two orientations 90° apart. If the difference between the two mass measurements is greater than 0.2 mg, the push rod shall be demagnetized and the measurement process repeated.

8.1.12.7 Report the push rod measurements on the form included in the TMC report package.

8.1.13 Cam Bore Measurement

8.1.13.1 Inspect the seven cam bore positions in the parent bore block. Position 1 is identified as the first bore toward the front of the block and it has a split

hydro-dynamic bearing insert. Positions 2-6 are bored in the cast iron block and do not contain bearing inserts. Position 7 is the rear most position and it has a split hydro-dynamic bearing inset.

8.1.13.2 Using a suitable inside diameter measuring instrument (such as a three point, snap bore gauge, measure each bore in the center and record the measurement in mm.

8.1.14 Tappet Stem Bore Measurement

8.1.14.1 Inspect the twelve tappet stem bore positions in the parent bore block. Position 1 is identified as the first bore toward the front of the block.

8.1.14.2 Using a suitable inside diameter measuring instrument (such as a three point, snap bore gauge, measure each bore in the center and record the inside diameter measurement in mm.

8.2 Engine Assembly:

8.2.1 General — Except as noted in this section, use the procedures indicated in the Cummins service publications (A7). Assemble the engine with the components from the Engine Build Parts Kit in numerical order, from front to rear (A3). Other non-kit components are available from the suppliers listed in X1.1 and X1.2.

8.2.2 Parts Reuse and Replacement -- Engine components may be reused or replaced at the discretion of the laboratory, except as per 8.2.5.

8.2.3 Build-Up Oil – Use Cummins Premium Blue (X1.1).

8.2.4 Coolant Thermostat -- The engine coolant thermostat shall be locked open to close off the bypass passage in the engine block.

8.2.5 New Parts – The parts listed below are contained in the Engine Build Parts Kit and are not reusable. Clean the parts prior to use. Replacement of any part listed below during a test will invalidate the test.

8.2.7.1 Rocker lever shafts

8.2.7.2 Rocker lever assemblies (exhaust and intake), complete with sockets

8.2.7.3 Tappets

8.2.7.4 Rocker lever sockets

8.2.7.5 Push rods

8.2.7.6 Valve crossheads

8.2.7.7 Camshaft

8.2.7.8 Test Oil Filter

8.2.8 The cylinder head, crankshaft, crankshaft bearings, pistons, piston rings, connecting rods, and connecting rod bearings may be replaced or changed at any time during the test or within the specified calibration period. The entire engine may be obtained from the CPD (A2.2) and replaced during a reference period as long as the engine completes a specified 80-hour break in cycle specified in section 10.

8.3 Operational Measurements:

8.3.1 Units and Formats – See Annex A8.

8.3.2 Instrumentation Calibration

8.3.2.1 Fuel Consumption Rate Measurement Calibration — Calibrate the fuel consumption rate measurement system before every reference oil test. Volumetric systems shall be temperature-compensated and calibrated against a mass flow

device. The flow meter located on the test stand shall indicate within 0.2% of the calibration standard. The calibration standard shall be traceable to national standards.

8.3.2.2 Temperature Measurement Calibration — Calibrate the temperature measurement systems at least once every six months. Each temperature measurement system shall indicate within ± 0.5 °C of the laboratory calibration standard. The calibration standard shall be traceable to national standards.

8.3.2.3 Pressure Measurement Calibration — Calibrate the pressure measurement systems at least once every six months. The calibration standard shall be traceable to national standards.

8.3.3 Temperatures

8.3.3.1 Measurement Location – The temperature measurement locations are specified in this section. The measurement equipment is not specified. Install the sensors such that the tip is located midstream of the flow unless otherwise indicated. The accuracy and resolution of the temperature measurement sensors and the complete measurement system shall follow the guidelines detailed in ??? available from the Test Monitoring Center.

8.3.3.2 Coolant Out Temperature — Install the sensor as shown in Fig A4.14.

8.3.3.3 Coolant In Temperature – Install the sensor on the right side of the engine on the inlet pipe to the coolant pump intake housing as shown in Fig A4.14a.

8.3.3.4 Fuel In Temperature — Install the sensor in the fuel pump inlet fitting as shown in Fig. A4.12.

8.3.3.5 Oil Gallery Temperature — Install the sensor at the metric straight thread

hole on the left front of the engine, near the ECM as shown in Fig. A4.11.

8.3.3.6 Intake Air Temperature – Install the sensor as shown on Fig A4.6Need new photo and more explicit specs on sensor location.

8.3.3.7 Intake Manifold Temperature — Install the sensor at the top of the aluminum snorkel on the air inlet tube as shown in Fig. A4.7. The insertion depth is to be 114 mm from the outside surface of the aluminum snorkel

8.3.3.8 Exhaust Temperature – Install the sensor as shown in Fig. A4.10.

8.3.3.9 Oil Sump Temperature – Install the sensor at an insertion depth of 60 mm from the outside pan boss identified as the Factory/OEM metric threaded hole as shown in Fig. A4.4.

8.3.3.10 Additional – Monitor any additional temperatures that the laboratory considers beneficial. Measurement of the EGR Cooler gas inlet and outlet and coolant inlet and outlet is highly recommended.

Note 9: Additional exhaust sensor locations are recommended, such as the exhaust ports and pre-turbine (front and rear). The detection of changes in exhaust temperature(s) is an important diagnostic.

8.3.4 Pressures:

8.3.4.1 Measurement Location and Equipment – The pressure measurement locations are specified in this section. The measurement equipment is not specified. The accuracy and resolution of the pressure measurement sensors and the complete measurement system shall follow the guidelines detailed in ASTM Research Report RR: D02-1218[11].

Note 10: Caution — A condensation trap should be installed at the lowest

elevation of the tubing between the pressure measurement location and the final pressure sensor for Crankcase Pressure, Intake Air Pressure, and Exhaust Pressure. Route the tubing to avoid intermediate loops or low spots before and after the condensation trap.

8.3.4.2 Oil Gallery Pressure — Measure the pressure at the metric straight thread fitting on the left front of the engine, located near the ECM as shown in Fig. A4.11.

8.3.4.3 Oil Filter Inlet Pressure — Measure the pressure at the 1/8-in. NPT port located on the remote oil filter assembly as shown in Fig. A4.3.

8.3.4.4 Oil Filter Outlet Pressure — Measure the pressure at the 1/8-in. NPT port located on the remote oil filter assembly as shown in Fig. A4.3.

8.3.4.5 Intake Manifold Pressure — Measure the pressure at the 1/4-in. NPT port located in the gutted air heater block at the top-front of the intake manifold as shown in Fig. A4.8.

8.3.4.6 Crankcase Pressure — Measure the pressure at the dipstick port located on the left side of the engine as shown in Fig. AX.X

8.3.4.7 Intake Air Pressure — Measure the pressure, flat wall, on the intake air tube as shown in Fig. A4.6

8.3.4.8 Exhaust Pressure After Turbo — Measure the pressure, flat wall, on the exhaust tube as shown in Fig. A4.10.

8.3.4.9 Fuel Pressure — Measure the pressure on the engine-mounted outlet of the fuel filter, as shown in Fig. A4.13.

8.3.4.10 Coolant Pressure – Measure the pressure on top of the expansion tank.

8.3.4.11 Additional – Monitor any additional pressures considered to be

beneficial. Measurement of the EGR cooler inlet and outlet coolant pressures and inlet and outlet gas pressure is highly recommended.

8.3.5 Flow Rate

8.3.5.1 Flow Rate Location and Measurement Equipment — The flow rate measurement locations are specified in this section. The equipment for the blow-by rate and the fuel rate are not specified. The accuracy and resolution of the flow rate measurement system shall follow the guidelines detailed in ??? ASTM Research Report RR: DO2-1218[11].

8.3.5.2 Blow-by — The device or type of system used to measure the blow-by flow rate is not specified. Use engineering judgment and the manufacturer's guidelines concerning the installation and use of the blow-by rate measurement device.

8.3.5.3 Fuel Flow — The fuel consumption rate is determined by measuring the fuel flowing to the day tank.

9. Engine/Stand Calibration and Non-Reference Oil Tests

9.1 General – Calibrate the test engine and the test stand by conducting a test with a blind reference oil[12]. Submit the results to the ASTM Test Monitoring Center (TMC) for determination of acceptance according to the Lubricant Test Monitoring System (LTMS)[12].

9.1.1 Because the ISB common rail engine is a parent bore block and is not completely rebuilt before each test, an engine is not referenced to a stand. The stand is calibrated for use with different ISB common rail engines as supplied from the CPD (X1.2).

9.3 New Test Stand -- A new test stand is defined as a test stand that has never been

calibrated or has not completed an acceptable reference oil test within 18 months of the end-of-test (EOT) date of the last acceptable reference oil test. Under special circumstances, such as industry-wide parts or fuel shortages, the TMC may extend the time period beyond 18 months. Perform the following to introduce a new test stand.

9.4 Engine/Stand Calibration Period:

9.4.1 Engine -- The calibration period is 18 months from the EOT date of the last acceptable reference oil test.

9.4.2 The TMC may schedule more frequent reference oil tests or extend the calibration period.

9.5 Change of Calibration Configuration – The laboratory may change the calibration configuration of a test stand according to the following:

9.6 Stand Modification and Calibration Status -- Modification of the test stand control systems or the conducting of any non-standard test, or both, can invalidate the calibration status. A non-standard test includes any test conducted under a modified procedure, non-procedural hardware, controller set-point modifications, or a combination thereof. The TMC should be contacted prior to any changes to determine the effect upon the calibration status.

9.7 Test Numbering System:

9.7.1 General — The test number has four parts, W-X-Y-Z. W represents the test stand number, X represents the run number for that stand and has a XXX format, Y represents the eight-digit serial number from the RAC label for that engine, and Z represents the number of test hours completed by that engine block prior to starting

the test and has a format XXXX. The hours on the engine value does NOT include the 80 hour break-in time nor does it include time for warm up and cool down run times. For example, test number 64-002-57216596-0350 indicates stand number 64, test number 002 for that stand, engine serial number 57216596, and the engine has 0350 test hours prior to starting this test on engine block 57216596. Every test start (reference oil and non-reference oil) will increment Y by one.

9.7.2 Reference Oil Tests – A reference oil test conducted subsequent to an unacceptable reference oil test will still increment Y by one and Z will increment for total test hours for that engine serial number.

9.7.3 Non-Reference Oil Tests -- No letter suffix will be added to Z for aborted or operationally invalid non-reference oil tests.

9.8 Reference Oil Test Acceptance:

9.8.1 Reference oil test acceptance and laboratory severity adjustment (SA) are determined in accordance with the LTMS[12].

9.9 Unacceptable Reference Oil Test:

9.9.1 It is recognized that some reference oil test results will not be within the LTMS acceptance limits. The laboratory, in conjunction with the TMC, shall attempt to determine the cause of the deviation. The TMC may solicit input from industry authorities to help determine the cause and extent of the problem.

9.9.2 If the laboratory is not within the LTMS acceptance limits and the TMC has determined that probable cause is isolated to an individual stand, then non-reference oil testing on other calibrated stands may continue.

9.9.3 If the laboratory is not within the LTMS acceptance limits and the TMC has

determined that probable cause involves more than one stand, then the TMC may declare the particular stands non-calibrated. Non-reference oil tests in progress at the time of the calibration status change are not effected.

9.9.3.1 The laboratory shall attempt to identify and correct the cause and conduct an acceptable reference oil test in at least one of the stands to demonstrate resolution of the problem.

9.9.4 The TMC will assign reference oil when satisfied that no particular problems exist or the problem has been resolved. The laboratory shall provide adequate documentation or findings, or both, to support the conclusions reached during this process. The conclusions shall be documented in the acceptable reference oil test report.

9.10 Reference Oil Accountability:

9.10.1 Laboratories shall provide a full accounting of the identification and quantities of all reference oils used. With the exception of the oil analyses required in section 11.6, perform no physical or chemical analyses of reference oils without written permission from the TMC. In such an event, include the written conformation and the data generated in the reference oil test report.

9.10.2 Retain used reference oil samples for 90 days from the EOT date.

9.11 Non-Reference Oil Tests:

9.11.1 This test method incorporates the use of a Severity Adjustment (SA) for non-reference oil test results. A control chart technique described in the LTMS is used to determine if a significant bias exists for tappet, rocker lever socket, rocker lever shaft, push rod and crosshead mass loss, average sludge, or oil filter plugging, cam lobe

wear or combination thereof. When calibration results indicate a significant bias, an SA is determined according to the LTMS and applied to the non-reference oil test result. The SA and the adjusted result are reported on Fig. **A9.2.** The SA will remain in effect until a new SA is determined from subsequent calibration tests.

9.11.2 Last Start Date -- A non-reference oil test may begin provided the warm-up is started prior to the expiration of the calibration period (9.4).

10. Test Procedure

Introduction

Move to Section 4

The ISB was developed to evaluate the durability and reliability of the camshaft and tappet interface when run with different lubricating oils. This is a two-stage test with the first 100 hours run at steady-state with retarded timing to generate soot and the final 250 hours cycling at different load and speed conditions. The duration of the test is three hundred and fifty (350) hours.

General Information

If not previously performed, the 80-hour break-in cycle must be run before installing test parts and using the engine for testing purposes. See Engine Break-In Procedure.

Test Fuel shall also be used for the 80-hour break in, an additional 2,925 L to used to complete the 80-hour break-in for new engines.

Specifications of Apparatus

10.1 Test Engine – 5.9L ISB MY04, CPL 8123. This engine is certified to meet EPA 2004 emissions standards

Engine specification

Fuel system	Common Rail
CPL	8123
Low idle	750 RPM (ECM), 800 RPM for test
High idle	3,000 RPM
Rated	224 kW (300 HP) @ 2,600 RPM
Torque peak	813 Nm (600 lbf-ft) @ 1,600 RPM

10.6 Engine Break-in Procedure

Break-in test cycle – The following sequence consists of 15-minute cycles run for a total of 80 hours. Unless otherwise stated changes in load and speed are to be done at a rapid rate. This break-in cycle is only required for first time use engines only. The engine is installed in almost an "as-received" condition. The OE oil cooler may be left installed as received, OE fuel filter and peripherals are allowed. Make sure to block open the thermostat for this procedure. See Table 3. USE PREMIUM BLUE.

Table 3. Break-in Cycle

Sub Cycle	Load	**Speed**	Time (Sec)
1.	0 %	800 RPM	144
2.	800 Nom	1,600 RPM	36
3.	800 Nom	2,600 RPM	360
4.	0 %	3,000 RPM	36
5.	800 Nom	2,600 RPM	144
6.	800 Nom	Lug from 2,600 RPM to 1,600 RPM	36
7.	800* Nom	1,600 RPM	108
8.	0 %	3,000 RPM	36

* During step 7, turbo surge conditions may occur in the induction system requiring torque to be reduced about 3-8%

1. Start engine warm-up procedure

2. Specific test conditions (Table 2)

Pre test Cycle

1. Engine Oil Fill Procedure – Pressure charge the engine with 14.5 kg of lubricant to be evaluated (this includes oil in the filter from supplier X1.1.)
2. Cam and Tappet Break-in
   - Start the engine and idle (no load) the for no more than 10 seconds to check for leaks
   - Run the engine at 3,000 RPM, no load for 30 seconds (5-sec ramp allowed)

3. Engine Warm-up procedure

   Run the engine at 1,300 RPM, no load for 2 minutes, start the external oil adder pump.
   Increase engine to 1,300 RPM and 200 Nm for 5 minutes.
   Increase engine to 1,300 RPM and 400 Nm for 5 minutes.
   Increase engine to 2,600 RPM and 600 Nm for 5 minutes.

4. For flush step, operate at 1,600 RPM and 440 Nm for 15 minutes
5. Drain oil for 30 minutes, replace filter with non test filter, filter to be supplied by X1.1 and repeat steps 1,3 and 4

6. Drain oil for 30 minutes and verify valve lash per repair manual, remember to use EGR lash adjustment method.
7. Charge engine with 14.5 kg of lubricant to be evaluated filling the test oil filter (PN 3937736 obtained from CPD X1.2).

Table 2. Test conditions

Test Parameter	Stage A	Stage B	Units	Limits
Time, h	100	250***		
Engine speed	1,600	Varies	RPM	± 10
Torque	Resultant	Varies	Nm	
Fuel Rate	20.0	Varies	kg/hr	± 0.3
Coolant out temp	99	99**	Deg. C.	± 3
Coolant reservoir pressure	99-107	99-107	kPa	
Intake manifold pressure	Resultant	Varies	kPa	
Intake manifold temp	68	68**	Deg. C	± 2
Inlet air temp	25-35	25-35**	Deg. C.	
Turbine inlet temp	Resultant	Varies	Deg. C.	
Oil pan temp	110	110**	Deg. C.	± 2
Oil pressure	Resultant	Varies	kPa	
Intake air restriction	94-98	Varies	kPa abs	
Exhaust back pressure	107	Wide open	kPa abs	± 1
Fuel temp	40	40	Deg. C.	± 2
Fuel inlet restriction	*	*	kPa	
Fuel return restriction	*	*	kPa	

* Maintain to avoid cavitation at high pressure fuel pump

** May vary due to cyclic conditions

*** Stage B length is determined by test time. A minimum of 32,000 cycles shall be completed for the test to be valid.

10.7. Engine shut down procedure

From Stage A:
Decrease engine to 1300 RPM and 400 Nm rated load for 1 minute.
Decrease engine to 1300 RPM and 200 Nm rated load for 1 minute.
Run the engine at 0% throttle and no load for 2 minutes.

From Stage B:
Run the engine at 1300 RPM and 200 Nm for 2 minutes
Run the engine at 0% Throttle and no load for 2 minutes.

10.8 350- h Test Procedure

1. Stage A: Four, twenty-five hour (25) check interval

   Check the external oil adder indicated oil weight and record oil weight in grams

   Test oil sample - 120 ml purge from the sample valve as shown in Fig A4.3 (returned to external oil adder reservoir after sample is taken). 120 ml oil sample is taken from the sample valve which is post oil filter and replaced with 120ml of new oil. Suggested oil analysis include non-additive wear metals, TBN, TAN, D445 Vis, TGA Soot. (also suggested for Stage B)

Perform a forced drain and oil addition of 1,000 g to bring back to original full mark (set full mark based on recorded oil adder weight at 4 test hours)

Specific Test Conditions

Stage A –

Run at retarded timing (-12 to -16) to generate 3.25% +/- 0.25% soot at 100 hours. Use Cummins engineering tool to change final timing as indicated on engineering tool display. Oil samples are taken and soot values established prior to forced oil additions. Oil samples taken every 25 hours with forced oil addition. At the 100 h oil add, after topping off to full mark in the external oil adder, close the oil adder suction valve, allow the auxiliary oil pumps to empty the oil adder and force the oil into the engine sump/pan, then the external oil adder valves are closed for Stage B and the external oil adder pump is turned off. (This can be done in the final minutes while the engine is still operating at Stage A conditions).

Stage B –

The test cycle time is twenty-eight (28) seconds in duration. This cycle is repeated for 250 hours. Return timing to factory set default (native timing). Using Cummins engineering tools software, (run from default code and data mode which can be commanded by F7). Oil samples (118 ml) are taken every 50 hours, discarding 30 ml purge. No fresh oil replacement or additions allowed throughout Stage B. Stage B length is based on test time. A minimum of 32,000 cycles shall be completed for the test to be valid. The cycle counter advances at the completion of the last low idle step.

Parameter	Duration	Speed (RPM)	Load (Nm)
Accelerate to rated	2.5 s		
Rated speed	6.0 s	2,600*	WOT (800 nominal)
Decelerate to idle	2.0 s		
Low idle	1.0 s	800 ± 25	No load excitation
Accelerate speed	2.5 s	1,600 minimum	550 minimum
Decelerate to low idle	2.0 s		
Low idle	1.0 s	800 ± 25	No load excitation
Accelerate speed	2.5 s	1,600 minimum	550 minimum
Decelerate to low idle	2.0 s		
Low idle	1.0 s	800 ± 25	No load excitation
Accelerate speed	2.5 s	1,600 minimum	550 minimum
Decelerate to low idle	2.0 s		
Low idle	1.0 s	800 ± 25	No load excitation

*Engine speed average (6 seconds) to be 2,600 +/- 50 RPM.

Post-test

Measure all pre-test parts
Retain EOT oil sample

Data Collection Minimums for Stage A
Snapshot of all data every 6 minutes.

Data Collection Minimums for Stage B

At least every 12 cycles, capture snapshot of all data 1s before end of rated speed stage (5 s into 2,600 RPM step)

Every 1,000 cycles two (minimum) full consecutive traces of speed and load at 10 Hz.

11. Calculations, Ratings and Test Validity

11.1 Crosshead Mass Loss -- Use the procedure shown in 8.1.6 to determine individual EOT crosshead mass. Report the crosshead measurements and calculations on Fig. A9.5.

11.1.1 Separate the crossheads into intake and exhaust groups.

11.1.2 Calculate the mass loss for each crosshead (pre-test - post test).

11.2 Adjusting Screw Mass Loss -- Use the procedure shown in 8.1.9 to determine individual EOT adjusting screw mass. Report the adjusting screw measurements and calculations on Fig. A9.5.

11.2.1 Separate the adjusting screws into intake and exhaust groups.

11.2.2 Calculate the mass loss for each adjusting screw (pre-test - post test).

11.3 Tappet Mass Loss -- Use the procedure shown in 8.1.7 to determine individual EOT tappet mass loss. Report the tappet loss measurements and calculations on Fig. A9.5

11.3.1 Separate the tappets into intake and exhaust groups.

11.3.2 Calculate the mass loss for each tappet (pre-test - post-test).

11.4 Rocker Lever Shaft Mass Loss -- Use the procedure shown in 8.1.10 to determine individual rocker lever shaft EOT mass loss. Report the rocker lever shaft measurements and calculations on Fig. A9.5.

11.4.1 Separate the rocker lever shafts into intake and exhaust groups.

11.4.2 Calculate the mass loss for each rocker lever shaft (pre-test - post test).

11.5 Rocker Lever Socket Mass Loss -- Use the procedure shown in 8.1.11 to determine individual EOT rocker lever socket mass loss. Report the rocker lever socket measurements and calculations on Fig. A9.5.

11.5.1 Separate the rocker lever sockets into intake and exhaust groups.

11.5.2 Calculate the mass loss for each rocker lever socket (pre-test - post test).

11.6 Push Rod Mass Loss -- Use the procedure shown in 8.1.12 to determine individual EOT push rod mass loss. Report the push rod measurements and calculations on Fig. A9.5.

11.6.1 Separate the push rods into intake and exhaust groups.

11.6.2 Calculate the mass loss for each push rod (pre-test - post test).

11.7 Sludge Ratings:

11.7.1 Rate the rocker arm cover sludge with the plastic baffle in its original position and the oil pan sludge according to CRC Manual No. 12[10] at the locations specified in Figs. A10.1 and A10.2, respectively, and report on Fig. A9.10.

11.7.2 Average the rocker arm cover sludge and oil pan sludge ratings. Report as Average Sludge Rating on Fig. A9.7.

11.8 Oil Analyses -- Analyze the oil samples for viscosity at 100°C, wear metals (iron, copper, lead, chromium, aluminum), TAN, TBN, and %soot (TGA) according to the schedule and methods shown in A12 and report on Fig. A9.17.

11.9 Oil Consumption — Using a mass balance methodology, sum the weight of the oil consumed for the test and report on Fig A9.2 for a non-reference oil test or

on Fig A9.3 for a reference oil test.

11.10 Fuel Analyses — Report the analyses provided by the fuel supplier on Fig. A9.18. Report the analyses of the final batch if more than one fuel batch was used.

11.10.1 Additional Analyses -- Perform the following analyses on the 1 L new and EOT fuel samples, and report on Fig. A9.18.

11.10.1.1 API Gravity at 15.6 °C (60 °F), Test Method D287 or equivalent

11.10.1.2 Total Sulfur, % wt., Test Method D129 or equivalent

11.11 Assessment of 28-second Cycle Validity Data will be collected at an acquisition rate of at least 10 Hz and the resulting plot of Speed (RPM) and Torque versus time. The resulting plot of the cycle will indicate that the engine achieved the conditions set forth in the test procedure.

11.12 Assessment of Operational Validity – Determine operational validity according to Annex A13. (Test must complete no less than 32,000 cycles during Stage B within the 250 hours to be operationally valid)

11.13 Assessment of Test Interpretability — A non-reference test is non-interpretable when the 100 h soot is less than 3.0% or more than 3.5%. Interpretability is reported on Fig. XXX

12. Test Report

12.1 Report Forms – Report the test results in the format shown in A9. The data dictionary is shown in X3.

12.2 Reference Oil Test — Send forms A9.1, A9.3 - A9.7, A9.17, and A9.19, and any other supporting information, to the TMC[14] by facsimile or electronic

transmission within five days of the EOT date for test acceptance determination. Reference oil test reports should be mailed or electronically transmitted to the TMC within 30 days of the EOT date.

12.2.1 Electronic Transmission of Test Results — Use ASTM Data Communications Committee Test Report Transmission Model (Section 2-Flat File Transmission Format)[12].

13. Precision and Bias (TBD)

ANNEXES

(Mandatory Information)

A1. Safety Precautions

A2. Mandatory Supplier List

A3 Engine Build Parts Kit

A4. Sensor Locations and Special Hardware

A5. External Oil System

A6. Fuel Specification

A7. Cummins Service Publications

A8. Specified Units and Formats

A9 Report Forms

A10. Sludge Rating Forms

A11. Oil Analyses

A12Operational Validity

A1. SAFETY PRECAUTIONS

A1.1 The operating of engine tests can expose personnel and facilities to safety hazards. Personnel trained and experienced with engine testing should perform the design, installation, and operation of test stands.

A1.2 Guards (shields) should be installed around all external moving, hot, or cold components. Design the guard to contain the energy level of a rotating component should the component break free. Fuel, oil, coolant and electrical wiring should be properly routed, guarded, grounded and kept in good order.

A1.3 The test stand should be kept free of oil and fuel spills and tripping hazards. Containers of oil or fuel, or both, should not be permitted to accumulate in the testing area. Fire fighting equipment should be immediately accessible. Normal precautions should be observed whenever using flammable solvents for cleaning purposes.

A1.4 Safety masks, glasses, or hearing protection, or a combination thereof, should be worn by personnel working on the test stand. No loose or flowing clothing, including long hair or other accessory to dress, should be worn near rotating equipment. Personnel should be cautioned against working alongside the engine and driveline while the engine is running.

A1.5 Interlocks should automatically shutdown the engine when an anomaly in any of the following occur: engine or dynamometer coolant temperature, engine oil pressure, dynamometer field current, engine speed, exhaust temperature, excessive vibration or when the fire protection system is activated. The interlock should include a method to cut off the fuel supply to the engine at the injector pump (including the

return line). A remote fuel cut off station (external to the test stand) is recommended.

A1.6 Employ other safety precautions as required by regulations.

A2. MANDATORY SUPPLIER LIST

A2.1 Obtain the test fuel shall from the supplier listed below:

Chevron-Phillips Petroleum

Type: Dyed, PC-10 (15 ppm S)

A2.2 Obtain the test engine, the engine build parts kit, and the ECM from the CPD listed below. Direct questions or correspondence concerning Cummins test parts to the CPD listed below.

Test Engineering, Inc.

12718 Cimarron Path

San Antonio, TX 78249-3423

Phone: (210) 690-1958

Fax:(210) 690-1959

A3. ENGINE BUILD PARTS KIT

Table A3.1 Engine Build Parts Kit

Description	Part Number	QTY
Camshaft	3954099	1
Tappet	3947759	12
Crosshead	3943626	12
Push Rod	3941253	12
Rocker Shaft	3935892	12
Rocker Lever, Intake (short)	3937219	6
Rocker Lever, Exhaust (long)	3937220	6
Rocker Support	3941559	6
Oil Pan Seal	3959797	1
Rear Seal	4890833	1
Test Oil Filter	3937736	1
Rocker Cover Seal	3954324	1
Lift Pump	3955116	1

A4. SENSOR LOCATIONS AND SPECIAL HARDWARE

A4.1 Figure Description:

A4.1.1 Oil Heat Exchanger Bypass Plate (Fig. A4.1)

A4.1.2 Remote Filter Head Adapter (Fig A4.2)

A4.1.3 Remote Oil Filter (Fig A4.3)

A4.1.3a Remote Oil Cooler (Fig A4.3a)

A4.1.4 Oil Pan Modifications (Fig A4.4 and Fig A4.5)

A4.1.4a Blowby Elbow to Blowby Barrel (Fig A4.4a)

A4.1.5 Intake Air System (Fig A4.6, Fig A4.6a, Fig A4.7, and Fig 4.8)

A4.1.6 Aftercooler Installation (Fig A4.9)

A4.1.7 Exhaust System (Fig A4.10)

A4.1.8 Oil Gallery Temperature and Pressure (Fig A4.11)

A4.1.8a Crankcase Pressure Measurement Point (Fig A4.11a)

A4.1.9 Fuel Temperature (Fig A4.12)

A4.1.10 Fuel Pressure (Fig A4.13)

A4.1.11 Coolant Temperature Outlet (Fig A4.14)

A4.1.11a Coolant Temperature Inlet (Fig A4.14a)

A4.1.12 Entire Test Installation (Fig A4.15)

FIG A4.1

FIG A4.2

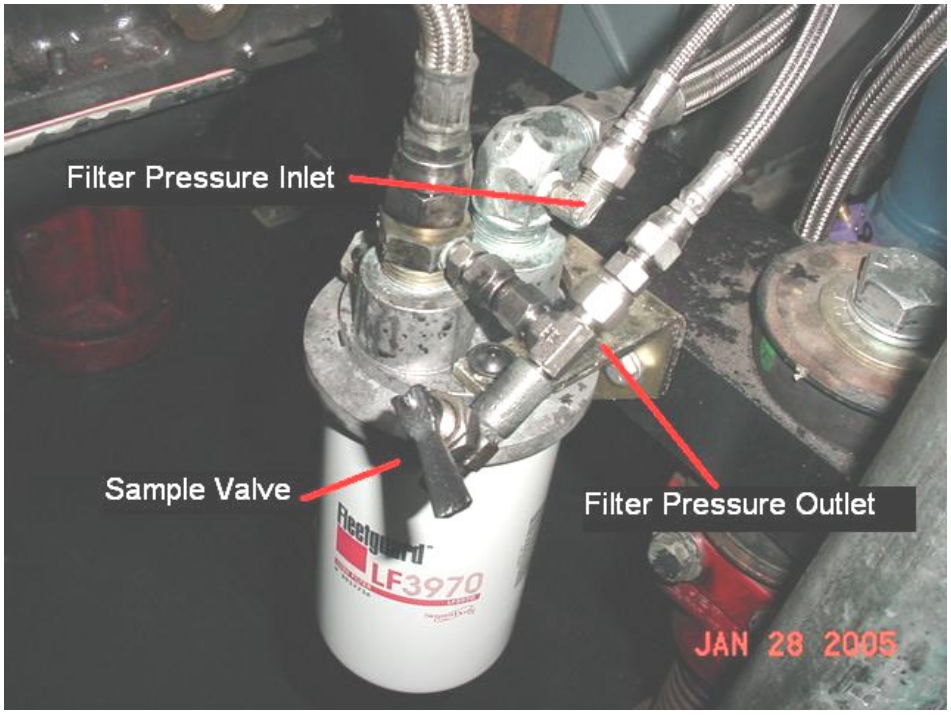

FIG A4.3

FIG A4.3a

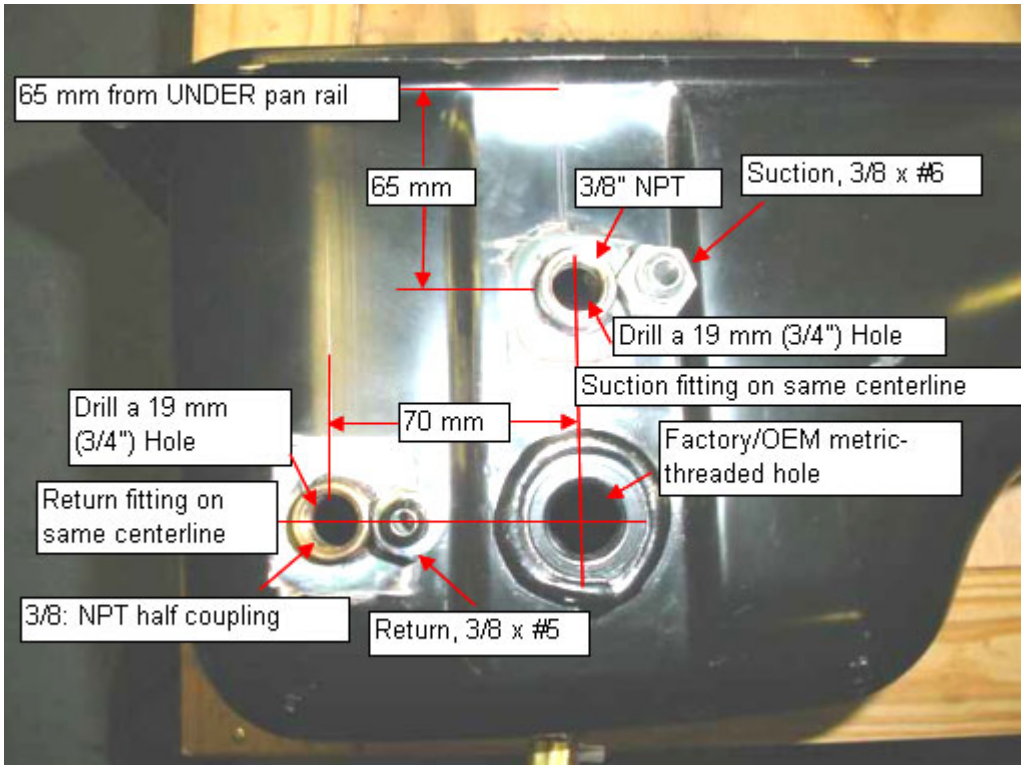

FIG A4.4

FIG A4.4a

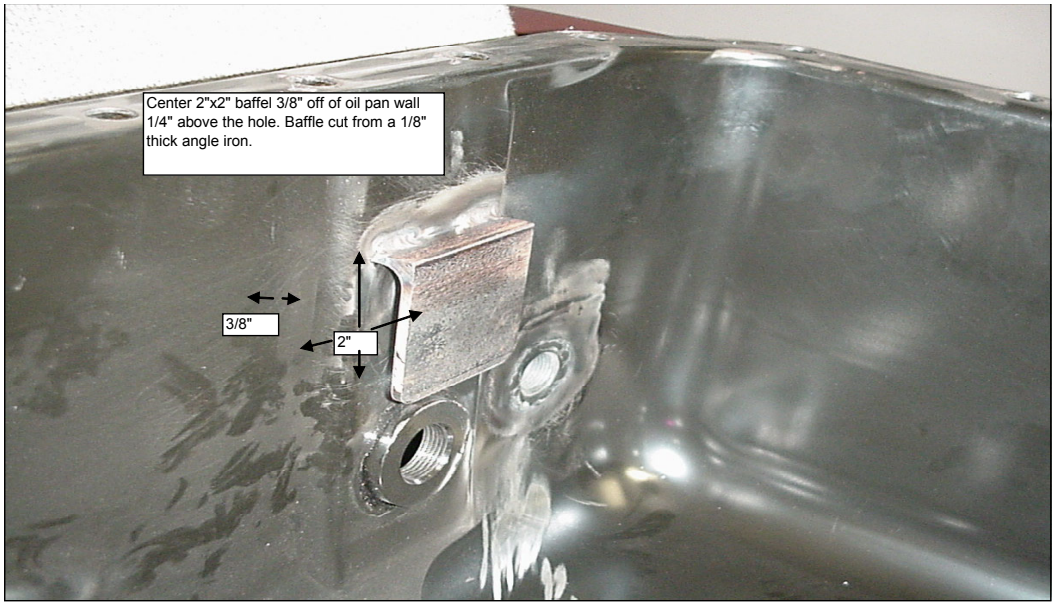

FIG A4.5

FIG A4.6

FIG A4.6a

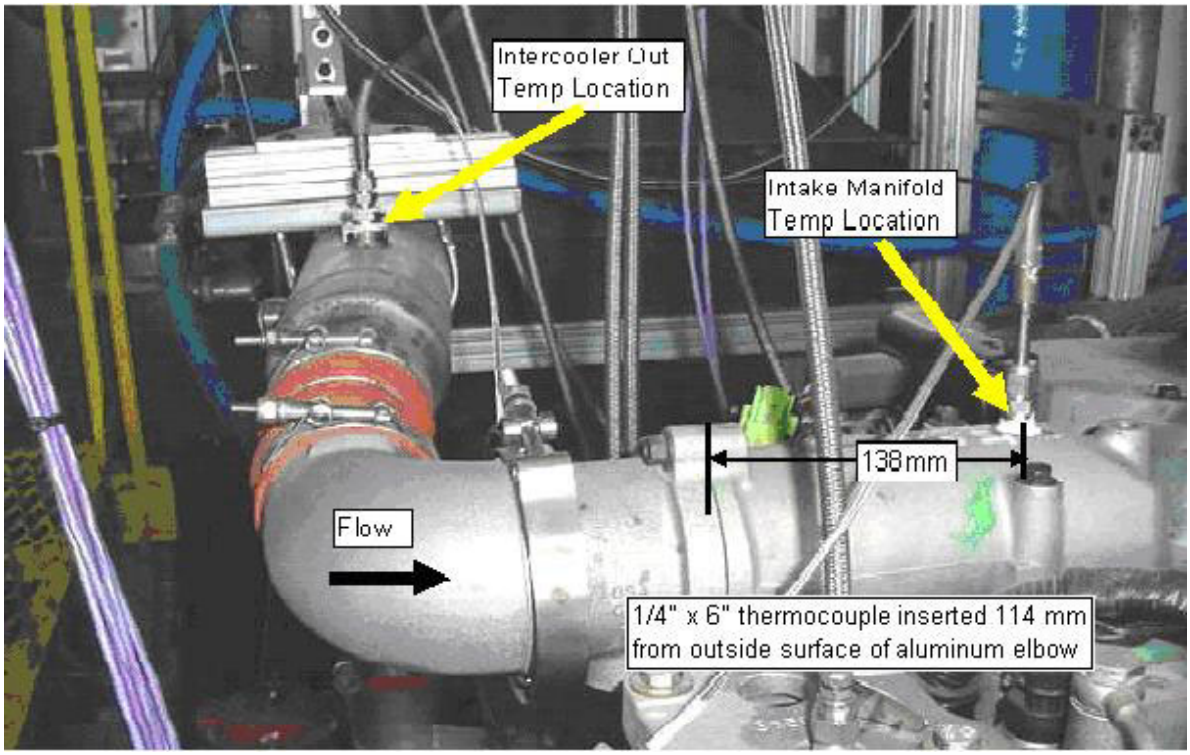

FIG A4.7

FIG A4.8

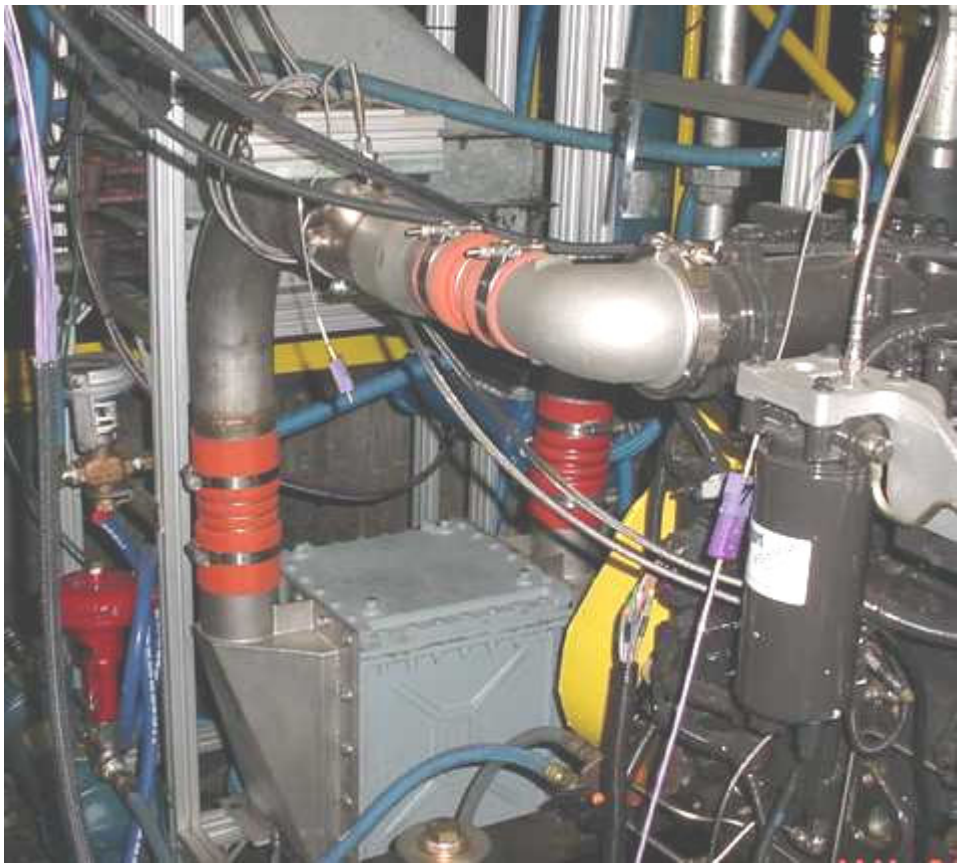

FIG A4.9

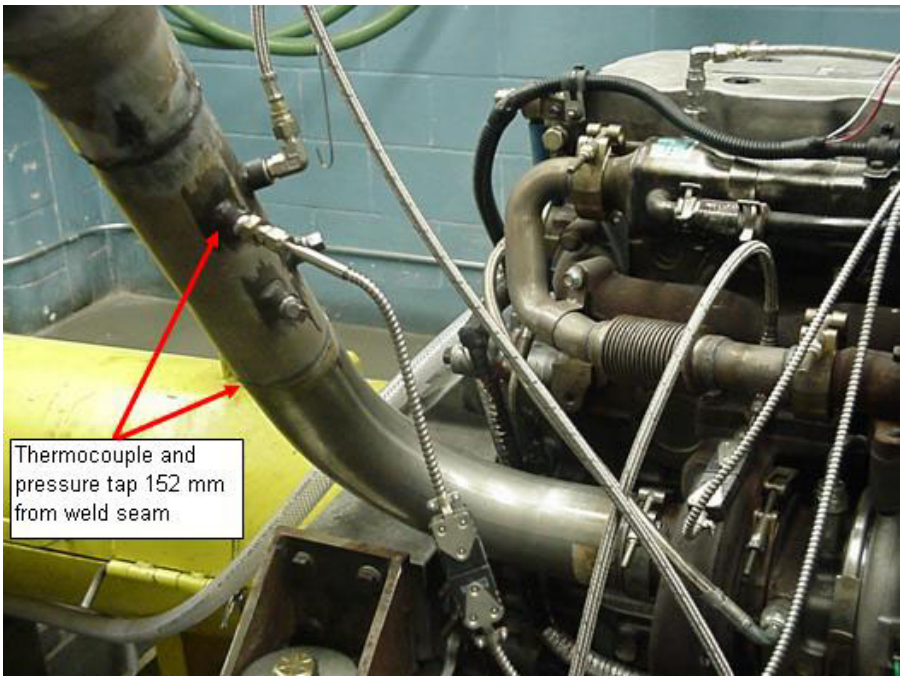

FIG A4.10

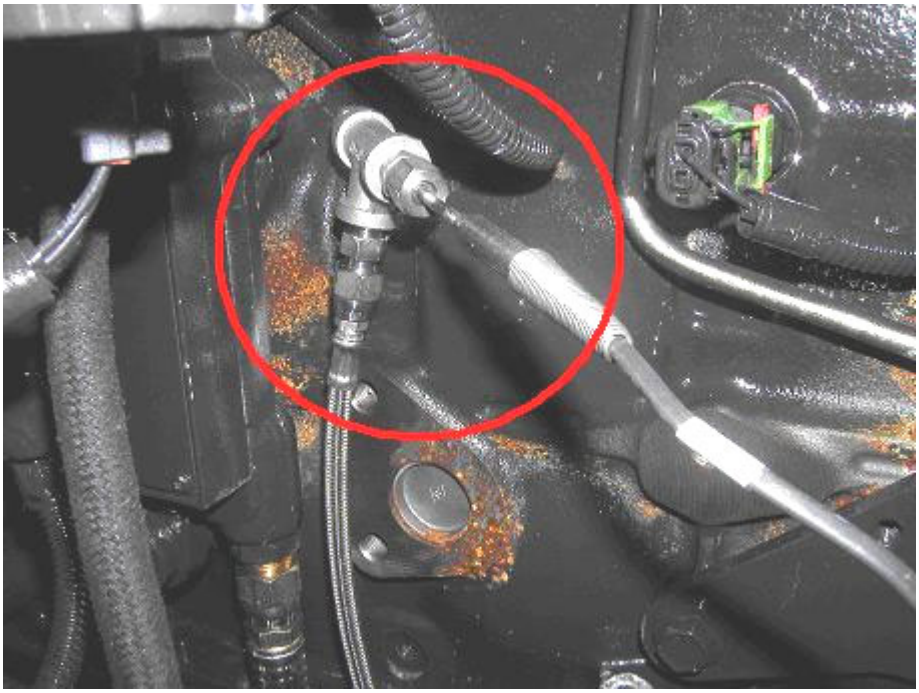

FIG A4.11

FIG A4.11a

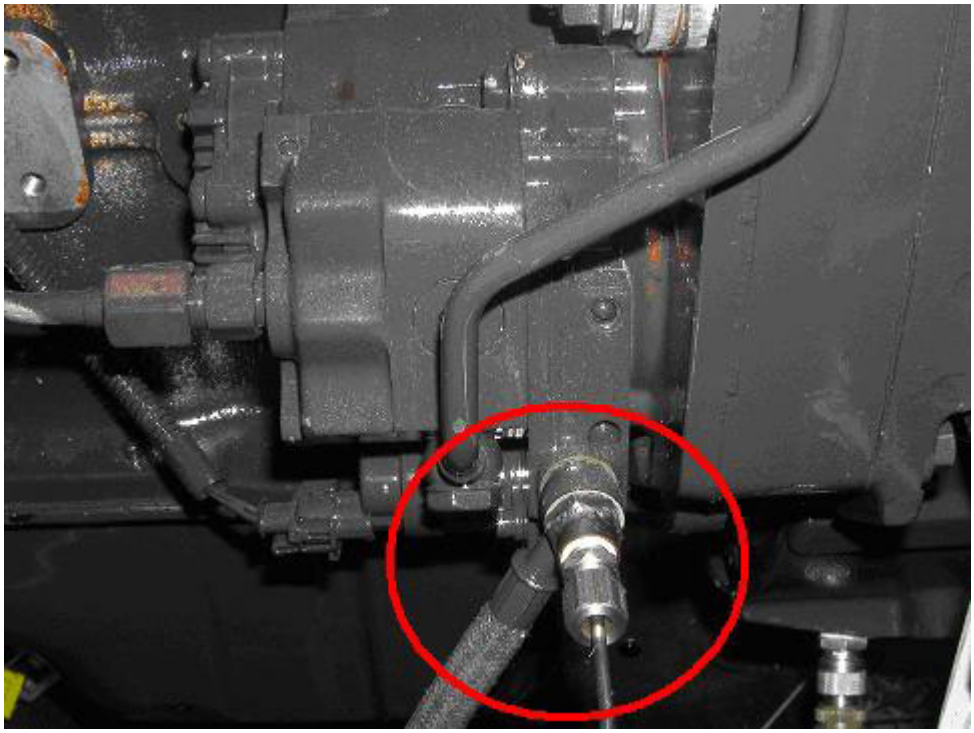

FIG A4.12

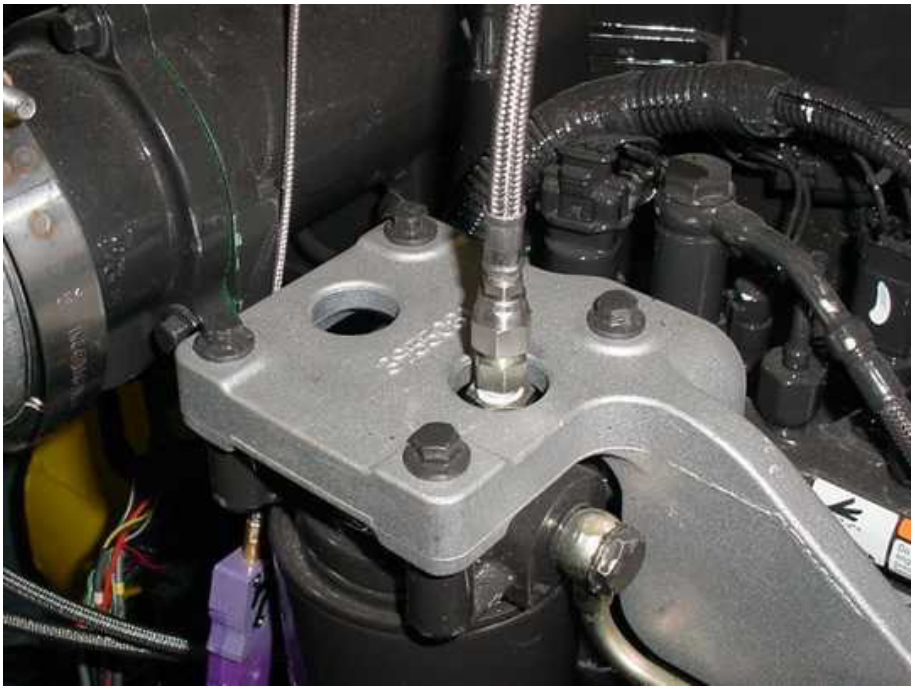

FIG A4.13

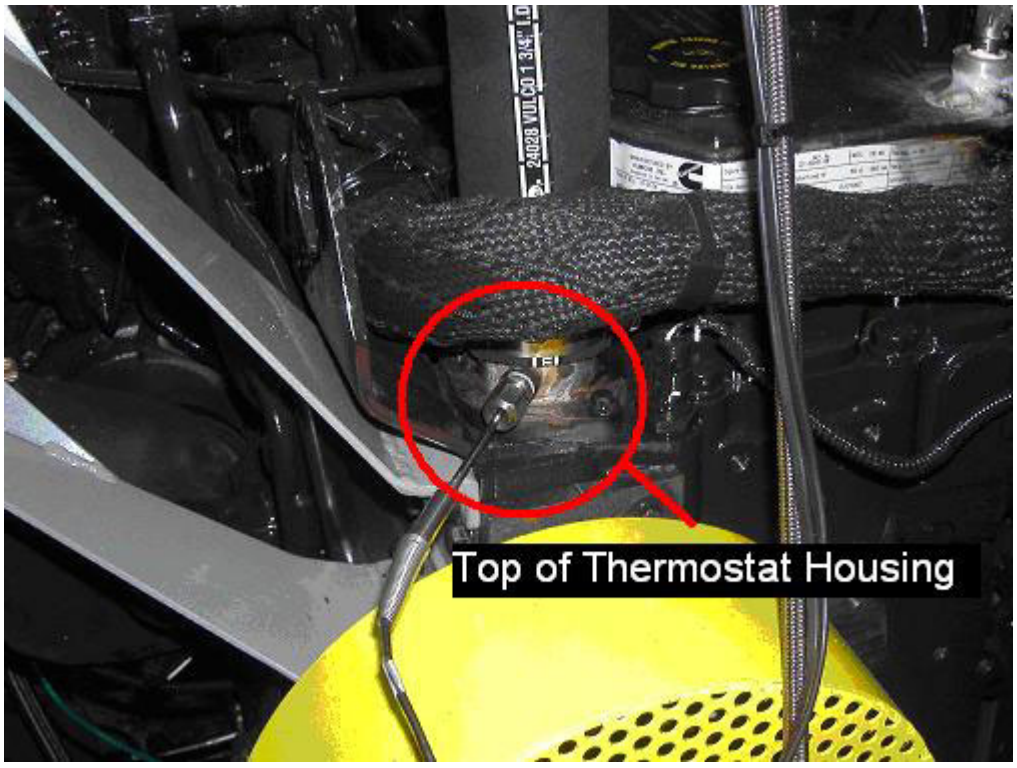

FIG A4.14

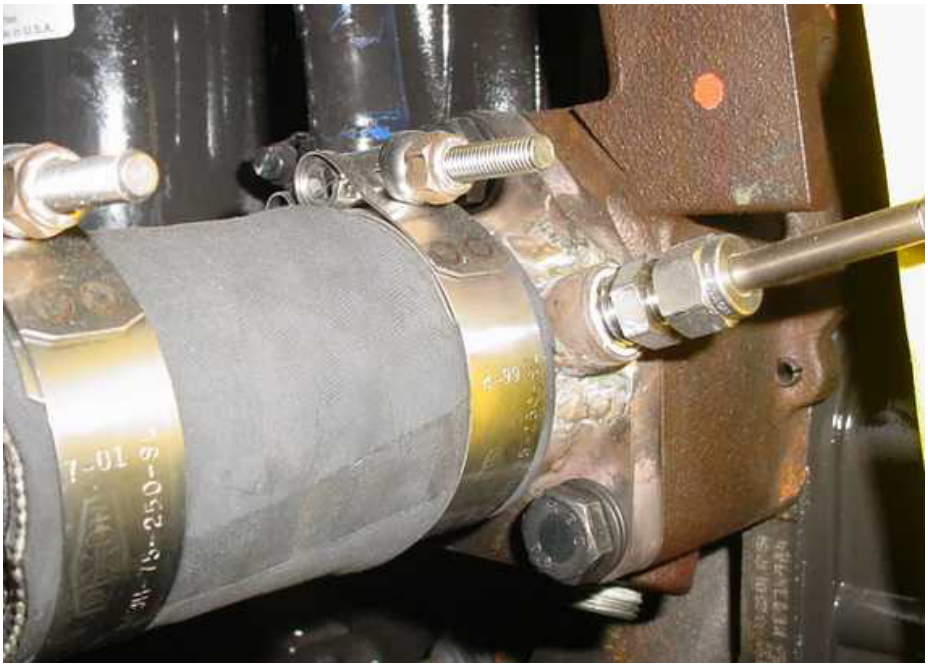

FIG A4.14a

FIG A4.15

A5. EXTERNAL OIL SYSTEM

A5.1 Figure Description:

A5.1.1 External Oil System (Fig. A5.1)

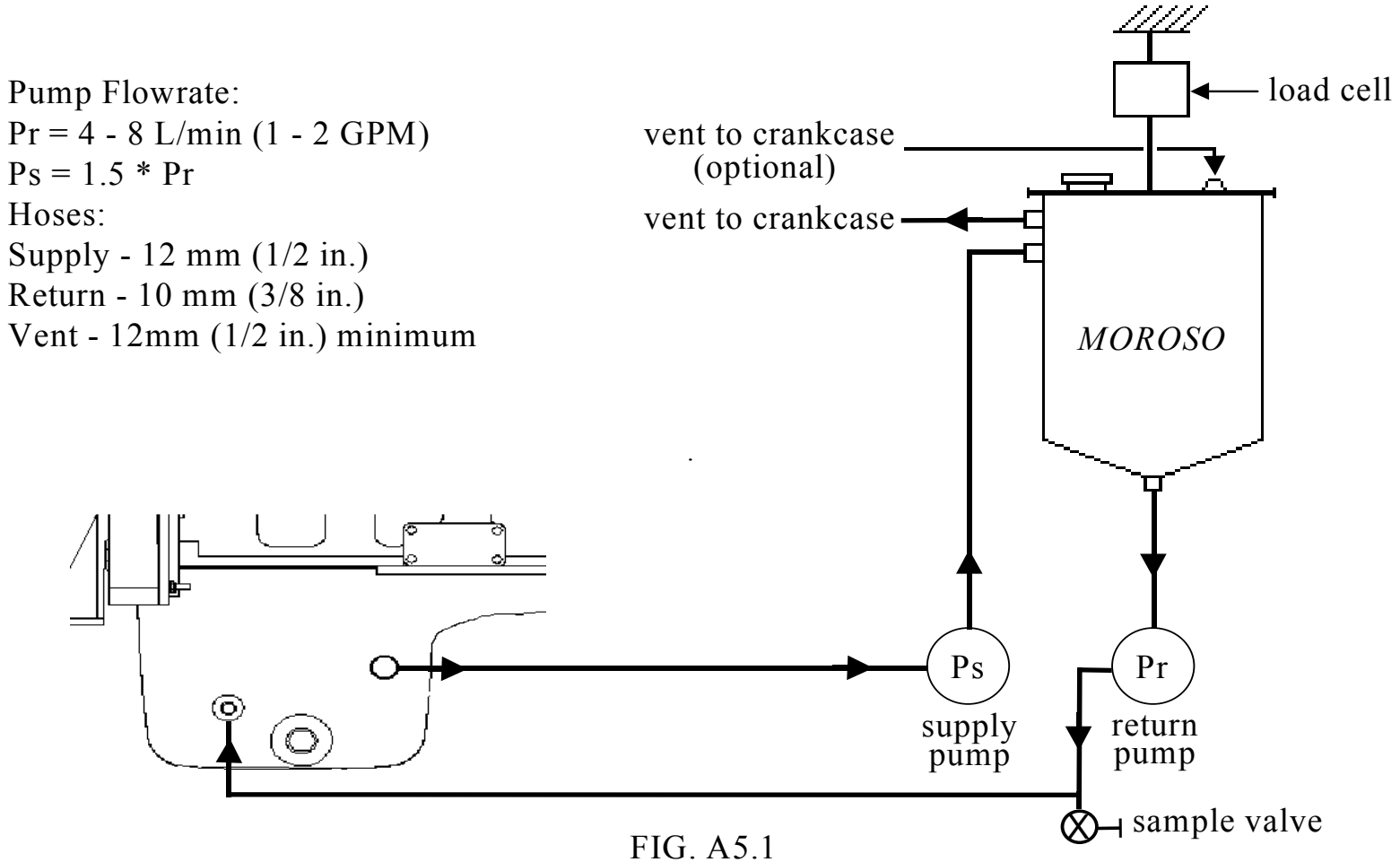

FIG. A5.1

A6. FUEL SPECIFICATION

A7. CUMMINS SERVICE PUBLICATIONS

A7.1 General preparation techniques, as well as, engine specifications, component specifications and torque values for Cummins ISB engines are detailed in the Cummins publication titled, Troubleshooting and Repair Manual ISB^{e} and ISB (Common Rail Fuel System) Series Engines, Bulletin No. 4021271, printed June 30, 2004.

A8. SPECIFIED UNITS AND FORMATS

A8.1 Specified Units:

A8.1.1 The parameters in this test method are specified in metric units except for pipe fittings, tubing and tubing fittings. Pipe fittings, tubing and tubing fittings are available worldwide and are not interchangeable with metric-sized equivalents because of differences in thread dimensions, therefore, no metric conversion is stated. The ports are standard straight thread and are not interchangeable with metric-sized equivalents.

A8.1.2 Test Report — Record operational parameters according to Table A8.1. Report test results in the units and with the significant digits shown in Table A8.2. Round test results in compliance with Practice E29.

A8.1.3 Measurements and Conversions — With the exceptions noted in A8.1.1, all parameters have been specified in S.I. units. The intent of this test method is to measure all parameters directly in S.I. units. If parameters are measured in inch-pound units, then the laboratory shall be able to demonstrate to the TMC that the measurements are within the tolerance after conversion to S.I. units.

Note A8.1: Caution -- Significant error can occur due to rounding or tolerance stacking, or both, when converting from inch-pound units to S.I. units.

Table A8.1 Minimum Resolution of Recorded Measurements

Parameter	Record data to Nearest
Speed	1 r/min
Power	1 kW
Torque	1 N•m
Fuel Flow	0.1 kg/hr
Coolant In Temperature	0.1 °C
Coolant Out Temperature	0.1 °C
Fuel In Temperature	0.1 °C
Oil Gallery Temperature	0.1 °C
Intake Air Temperature	0.1 °C
Exhaust (Tailpipe) Temperature	1 °C
Intake Manifold Pressure	0.1 kPa
Crankcase Pressure	0.01 kPa
Exhaust Pressure	0.1 kPa

Table A8.2 Significant Digits for Test Results

Parameter	Round off to Nearest
Mass Loss	0.1 mg
Sludge	0.1 merit
Filter Plugging	1 kPa

A8.2 Specification Format — Specifications are listed in three formats: 1) target 2) target and range, and 3) range with no target.

A8.2.1 Target – A target specification has no tolerance, therefore, the only acceptable value is the target. A representative specification format is xx.xx (target). For example, the oil pan oil charge is listed as 14.5 kg.

A8.2.1.1 A parameter with a target shall not be intentionally calibrated or controlled at a level other than the target.

A8.2.2 Target and Range – A target and a range specification implies the correct value is the target and the range is intended as a guide for maximum acceptable variation about the mean. A representative specification format is xx.xx ± x.xx (target ± range). For example, the engine speed is 1600 ± 10 r/min.

Note A8.2: The mean of a random sample should be equivalent to the target. Operation within the range does not imply that parameter will not bias the final test results.

A8.2.3 Range with No Target – A range with no target specification is used when 1) the parameter is not critical and control within the range is sufficient or 2) the measurement technique is not precise, or both. A representative specification format is xx.xx - xx.xx ($range_{low}$ – $range_{high}$). For example, the coolant system pressure is 99 – 107 kPa.

A9. REPORT FORMS

A9.1 Figure Description:

A10. SLUDGE RATING FORMS

A10.1 Figure Description:

A11. OIL ANALYSES

	Parameter				
Sample Hour	Metals[A]	TAN[B]	TBN[C]	Vis @ 100 °C[D]	TGA Soot[E]
0	X	X	X	X	X
25	X			X	X
50	X	X	X	X	X
75	X			X	X
100	X	X	X	X	X
150	X	X	X	X	X
200	X	X	X	X	X
250	X	X	X	X	X
300	X	X	X	X	X
350	X	X	X	X	X

[A] D 5185 (Copper, Iron, Lead, Chromium, Aluminum)

[B] D 664

[C] D 4739 and D 2896

[D] D 5967 Annex 3 or D 445

[E] D 5967 Annex 4

APPENDIXES

(Non Mandatory Information)

X1. Non-Mandatory Suppliers List:

X1.1 Available from a Cummins approved parts distributor.

X1.2 Available from the CPD listed below:

Test Engineering, Inc.

12718 Cimarron Path

San Antonio, TX 78249-3423

Phone: (210) 690-1958

Fax:(210) 690-1959

Table X1.2 Non-Kit Parts Available from the CPD

~~**X1.3 External Oil Cooler supplied by ITT Standard**~~

X1.4 The Moroso oil tank (P/N 22667) and baffles 22670-170 can be obtained from:

Moroso Performance Products Inc.

80 Carter Dr.

P.O.Box 1470

Guilford, CT 06437

Phone (203) 453-6571

Fax (203) 453-6906

X.1.5 The Modine aftercooler (P/N 1A012865) can be obtained from:

Modine

X3. Data Dictionary

X3.1 Data Dictionary Repeating Field Specifications

X3.2 Data Dictionary

Cummins ISB Footnotes

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.0B on Automotive Lubricants. Current edition approved XXX. Published YYYY.

[2] American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

[3] The ASTM Test Monitoring Center will update changes in this test method by means of Information Letters. Information letters may be obtained from the ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206-4489, Attention: Administrator.

[4] Annual Book of ASTM Standards, Vol 05.01

[5] Annual Book of ASTM Standards, Vol 05.04

[6] Annual Book of ASTM Standards, Vol 05.02

[7] Annual Book of ASTM Standards, Vol 05.03

[8] Annual Book of ASTM Standards, Vol 14.02

[9] Annual Book of ASTM Standards, Vol 14.03

[10] Available from the Coordinating Research Council, Inc., 219 Perimeter Parkway, Atlanta, Georgia 30346.

[11] Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[12]Available from the ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206-4489, Attention: Administrator.

[13] Available from a Cummins parts distributor

[14] ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206-4489 Phone: (412) 365-1000, Fax: (412) 365-1047