Test Monitoring Center
A Program of ASTM International
203 Armstrong Drive, Freeport, PA 16229, USA
www.astmtmc.org
412-365-1000

Sequence IX Information Letter 23-1
Sequence Number 5
June 5, 2023

TO: Sequence IX Surveillance Panel

SUBJECT: Addition of Appendix X2, Oil Aging for LSPI

During the March 23, 2023 Sequence IX Surveillance Panel Conference Call, the panel agreed to add to the procedure a means by which to construct a stand for aging oil to be used in an aged LSPI test, as well as the procedure for conducting the aging process. Since conducting LSPI on aged oil is not in any category, this information was added as an appendix.

The attached new sections are all included as Appendix X2. These revisions modify ASTM Test Method D8291 and are effective with the issuance of this letter.

/s/*M. D. Deegan*
Michael Deegan
FCSD, Service Product Development, SEO
Ford Motor Company

Jeffrey A. Clark
Executive Director
ASTM Test Monitoring Center

Attachment
c: http://www.astmtmc.org/ftp/docs/gas/sequenceix/procedure_and_ils/il23-1-ix.pdf

Distribution: Email

Revises D8291-21

Appendix X2.
Oil Aging and LSPI testing of Aged Engine Oil

X2.1 This appendix details the setup of engine oil aging stands, engine preparations, test operations during aging and modifications to the conduct of Sequence IX test to accommodate testing of aged oil.

X2.1.1 The test engine is completely rebuilt before each test and essentially all aspects of assembly are specified in detail. The piston-ring gaps are increased to increase the level of crankcase blowby, to age the oil. The crankcase ventilation system for the oil aging test is configured in the stock/production configuration.

X2.1.2 The oil aging process includes an engine break in schedule, with oil changes, after which the test runs 72 hours steady state at Sequence X Stage 2 test conditions. The test is conducted at steady state rpm/load and the engine is shut-down every 24 hours for oil level checks.

X2.1.3 The aging cycle is used to simulate approximately 4000 miles of vehicle operation.

X2.2 Apparatus

X2.2.1 *Test Engine:*

X2.2.1.1 The test engine is a Ford 2.0 L, spark-ignition, four-stroke, four-cylinder, gasoline, turbocharged, direct-injection (GTDI) engine[1], with dual overhead camshafts driven by a timing chain, four valves per cylinder, and electronic fuel injection.

X2.2.1.2 *Table X2.1* lists the engine part numbers.

X2.2.1.3 Configure a test stand to accept the test engine. Suggested fixing brackets are shown in Fig *X2.8*

X2.2.2 *Reusable Engine Parts and Fasteners:*

X2.2.2.1 *Tables X2.2* and X2*.3* provide the part numbers and descriptions for the reusable engine parts and fasteners, respectively.

X2.2.2.2 All engine parts, other than the 'Parts to be Replaced Each Test' (see X2.4.3), can be used provided they remain serviceable (see *Tables X2.2* and X2*.3*).

a) Crankshaft, connecting rods, pistons, camshafts, cylinder blocks, cylinder-head assemblies, and timing assemblies can be re-used provided they remain serviceable. However, keep these parts together as a set.

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[1] The engine is based on the Ford Motor Co. 2012 Explorer engine, and a completely assembled new test engine is available from Ford Component Sales, Ford Motor Co., 290 Town Center Dr., Dearborn, MI 48126.

Table X2.1 Assembled Test Engine

Ford Service Part Number	Ford Engineering Part Number	Description
BB5Z-6006-A	**BB5E-6006-AD** **DA8E-6006-BB**	**2.0L ENGINE ASY LB**

Table X2.2 Reusable Engine Parts

Ford Service Part Number	Ford Engineering Part Number	Description
1S7Z6507B	1S7G6507D7G	**VALVE – INLET**
1S7Z6514AA	1S7G6514AE	**RETAINER - VALVE SPRING**
1S7Z6518AA	1S7G6518AD	**KEY, VALVE SPRG**
1S7Z8501A	1S7G8501BD	**PUMP ASY – WATER**
8W9Z6C287A	AG9E6C287AA	**TAPPET ASY, FU PMP**
AG9Z6010B	AG9E6010A34B	**CYLINDER BLOCK**
AG9Z6135B	AG9E6135AA	**PIN – PISTON**
AG9Z6140A	AG9G6140BA	**RETAINER - PISTON PIN**
AG9Z6200D	AG9E6200CD	**ROD – CONNECTING**
AG9Z6250A	AG9E6A268AB	**CAMSHAFT, LH (EXHAUST)**
AG9Z6303A	BB5E6300A33A	**CRANKSHAFT ASY**
AG9Z6505A	AG9E6505AA	**VALVE – EXHAUST**
AG9Z6600B	AG9E6600AB	**PUMP ASY – OIL**
AG9Z6A785A	AG9G6A785CA	**SEPARATOR ASY – OIL**
AG9Z9350B	AG9E9D376AB	**PUMP ASY – FUEL**
AG9Z9P847A	AG9G9P847AA	**BRACKET, FUEL INJ CLIP**
BB5Z2A451C	BB5E2A451BD	**PUMP ASY – VACUUM**
BB5Z6019C	BB5E6019AF	**COVER - CYLINDER FRONT**
BB5Z6250A	BB5E6A267AB	**CAMSHAFT, RH (INTAKE)**
BB5Z6881A	BB5E6881AD	**ADPT OIL FILTER**
BB5Z6K269A	DB5E6K269AA	**COUPLING - PUMP DRIVE**
BB5Z9F593B	BB5E9F593BA	**INJECTOR ASY**
CJ5Z6049C	CJ5E6C032AC	**CYLINDER HEAD ASY**
CJ5Z6513A	CJ5E6513AA	**SPRING – VALVE**
CJ5Z6582A	CJ5E6K271BG	**COVER - CYLINDER HEAD**
CJ5Z6K254A	CJ5E6C271AA	**TENSIONER, OIL PUMP DRIVE**
CJ5Z6M280A	CJ5E6B297AA	**SOLENOID - ENGINE VARIABLE TIMING**
CJ5Z9D280A	CJ5E9D280BF	**MANIFOLD ASY - FUEL SUPPLY**
CJ5Z9D440A	CJ5E9B374BC	**COVER - FUEL PUMP**
CM5Z6652A	CM5E6652AA	**GEAR, OIL PUMP DRIVE**
CM5Z6A895A	CM5E6A895AA	**CHAIN ASY - OIL PUMP DRIVE**
CYFS12Y2	CB5E12405AA	**SPARK PLUG**
AG9Z-6108-H	AG9E-6110-AC2 (Batch Code BC2)	**PISTON- STD**
CJ5Z6256B	CJ5E6C524AD	**SPROCKET - CAMSHAFT, LH**

CJ5Z6268A	CJ5E6268AA	**BELT/CHAIN – TIMING**
CJ5Z6306A	CJ5E6306AB	**GEAR – CRANKSHAFT**
CJ5Z6C525A	CJ5E6C525AD	**SPROCKET - CAMSHAFT, RH**
CJ5Z6K254B	CJ5E6K254AA	**TENSIONER - TIMING CHAIN**
CJ5Z6K255A	CJ5E6K255AB	**ARM - TIMING-CHAIN TENSIONER**
CJ5Z6K297A	CJ5E6K297AB	**GUIDE, TIMING CHAIN**
W500221S437	W500221S437	**BOLT - HEX.HEAD**
W500224S437	W500224S437	**BOLT**
W500300S437	W500300S437	**BOLT**
W500301S437	W500301S437	**BOLT**
W500310S437	W500310S437	**BOLT - HEX.HEAD**
W500313S437	W500313S437	**BOLT**
W500328S437	W500328S437	**BOLT**
W500414S442	W500414S442	**BOLT**
W503275S437	W503275S437	**BOLT - HEX. HEAD – FLANGED**
W505531S442	W505531S442	**SCREW**
W506976S442	W506976S442	**SCREW**
W520214S440	W520214S440	**NUT**
W700115S437	W700115S437	**SCREW AND WASHER ASY**
W701183S300	W701183S300	**DOWEL – BUSH**
W701219S437	W701219S437	**BOLT**
W702426S303	W702426S303	**BOLT - HEX.HEAD**
W702492S437	W702492S437	**STUD**
W702700S437	W702700S437	**STUD**
W703383S437	W703383S437	**BOLT**
W703643S430	W703643S430	**BOLT**
W703649S300	W703649S300	**PIN**
W704474S437	W704474S437	**STUD**
W706282S430	W706282S430	**BOLT**
W706284S437	W706284S437	**BOLT**
W706487S437	W706487S437	**BOLT-OIL COOLER FILTER**
W711261S437	W711261S437	**BOLT**
W711574S439	W711574S439	**STUD**
W712022S430A	W712022S430	**BOLT - HEX.HEAD**
W713095S403	W713095S403	**NUT**
W715323S300	W715323S300	**WASHER - COPPER, T/C OIL LINE**
W715638S443	W715638S443	**STUD**
W715848S437	W715848S437	**BOLT**
W716137S437	W716137S437	**BOLT**
W716735S437	W716735S437	**BOLT**
W716841S900	W716841S900	**PIN, BELL HOUSING**
1L5Z6379AA	W706161S300	**BOLT**
1S7Z6A340AA	1S7G6K340BC	**BOLT, CRK SHFT PULLEY**
1S7Z6K282AA	1S7G6K282AB	**BOLT, CHAIN TEN**
AG9Z6065A	AG9G6065BA	**BOLT - HEX.HEAD, CYL HEAD**
AG9Z6345A	AG9G6345AC	**BOLT - BEARING CAP - HEX. HEAD**
BB5Z6214A	BB5E6214CA	**BOLT - CONNECTING ROD**

CV6Z6279A	CV6E6279AA	**BOLT, CAMSHAFT**

X2.2.2.3 Test the flowrate of the positive crankcase ventilation (PCV) valve before each test to ensure it meets the required flowrate (see X2.3.*6.2(d)*). The PCV valve stays with the test stand as long as it remains within serviceable test limits.

X2.2.2.4 Correct damaged threads in the block with commercially available thread inserts.

X2.2.3 Required New Engine Parts for Each Test:

X2.2.3.1 Part numbers and descriptions for new engine parts (referred to as the "Test Parts") and gaskets are listed in Tables X2.3 and X2.4, respectively.

X2.2.3.2 Use new piston rings for each test.

X2.2.3.3 Do not modify or alter test parts without the approval of the LSPI Oil Aging Sub-Group, membership of the Sequence X Surveillance Panel.

X2.2.4 Additional Related Parts and Tools:

X2.2.4.1 The part numbers and descriptions of the Test Stand Setup Parts and Special Parts are listed in Tables X2.5 and X2.6, respectively. With a few noted exceptions, they can be reused for numerous tests provided they remain serviceable.

X2.2.4.2 Engine parts can be replaced during the test, provided the reason for replacement is not oil related and does not affect the oil.

Table X2.3 Gaskets / Seals

Current Ford Service Part Number	Ford Engineering Part Number	Description
CJ5Z6079D	CJ5E6079AC	**KIT - GASKET**
1S7Z6571EA	1S7G6A517BG	**SEAL - VALVE STEM EX**
1S7Z6840AA	1S7G6A636AD	**GASKET, OIL FILTER ADPT**
1S7Z6B752AA	1S7G6B752AC	**GASKET, OIL SEP**
1S7Z6K301BA	1S7G6A321AA	**SEAL - CRANKSHAFT REAR OIL**
1S7Z8507AE	1S7G8507AF	**GASKET - WATER PUMP**
3M4Z6625AA	3M4G6625AA	**GASKET, OIL PMP P/U TUBE**
3M4Z8255A	3M4G8K530AB	**GASKET, T/STAT HSG**
3S4Z6571AA	3S4G6A517AA	**SEAL - VALVE STEM INT**
9L8Z9E936A	9L8E9E936AA	**GASKET, T/B**
AA5Z9E583A	AA5E9E583AA	**SEAL, FU PUMP**
AG9Z9P431A	AG9G9P431AA	**GASKET, T/C COOL LINE**
BB5Z2A572B	BB5E2D224BB	**GASKET - VACUUM PUMP**
BB5Z6584A	BB5E6K260AB	**GASKET, CAM COVER**
BB5Z6L612A	BB536L612AA	**GASKET, EXHAUST**
BG9Z9229A	BG9E9U509AB	**KIT - "O" RING, FU INJ**
BR3Z6C535B	BR3E6P251BA	**SEAL - VALVE VCT**
CB5Z9276A	CJ5E9A420BA	**GASKET, FU PUMP CVR**
CJ5Z6051A	CJ5E6051EC	**GASKET - CYLINDER HEAD**

CJ5Z6N652A	CJ5E6N652AA	**GASKET, T/C OIL DRAIN LINE**
CJ5Z8255A	CJ5E8255AA	**SEAL - THERMOSTAT**
CJ5Z9439A	CJ5E9439AA	**GASKET - INTAKE MANIFOLD**
CJ5Z9448A	CJ5E9448BA	**GASKET, EX MANIFOLD**
CM5Z6700A	CM5E6700AB	**SEAL ASY - CRKSHAFT OIL - FRT**

Table X2.4 Test Parts Replaced Each Test

Current Ford Service Part Number	Ford Engineering Part Number	Description
1S7Z6378AA	1S7G6378AB	**WASHER,CRK DIAMOND CRUSH**
AG9Z-6148-A	AG9E-6148-AA	**KIT-PISTON RING**
6M8Z6278A	6M8G6278AA	**WASHER, CAM, DIAMOND CRUSH**
7T4Z9601A	7T439601AA	**ELEMENT ASY - AIR CLEANER**

X2.2.5 Special Service Tools:

X2.2.5.1 A list and part numbers of special tools for crankshaft alignment and timing are shown in Table X2.7. The tools are available from a Ford dealership and are designed to aid in performing several service items. The specific service items that require special tools to perform the functions indicated (if not self-explanatory) are listed in relevant sections below.

X2.2.6 Specially Fabricated Engine Parts:

X2.2.6.1 The following specially fabricated engine parts are required in this test method:

(a) The intake-air system can be fabricated. However, use the stock 2012 Explorer air-cleaner assembly and mass air flow (MAF) sensor listed in Table X2.5.

b) Use the stock oil pan (same as used in the Sequence IX test) as shown in Figs. X2.1A & X2.1B. Modify the oil pan to include the additional drain hole according to the diagram in Figure X2.1A.

The oil pan should have three baffles installed. If the front “C” shaped baffle is installed, remove it. Reinstall the three screws and tighten. Figure X2.1B shows the three baffles used in the Aging test as installed and the location of the screws reinstalled after the “C” shaped baffle was removed (red circles).

NOTE 1—Sources for some materials and information are provided in Appendix X1.

X2.2.6.7 Other Special Equipment:

(a) Use an appropriate air-conditioning system to control the temperature and pressure of the intake air to meet the requirements listed in Tables X2.10 & X2.11.

(b) Use an appropriate fuel-supply system.

(c) Use the control and data acquisition system described in Annex A10.

(d) Use an appropriate exhaust system to control the pressure and monitor the temperature of the exhaust gases listed in Tables X2.11, X2.13 and X2.15.

X2.2.6.8 Driveline:

(a) Use the flywheel, clutch, pressure plate, bell housing, and clutch spacer listed in Table X2.7 (see also X1.24).

Table X2.5 Test Stand Set Up Parts List

Current Ford Service Part Number	Ford Engineering Part Number	Description
AG9Z9D930B	AG9T9H589BE	**WIRE ASY, FE INJ**
1S7Z12A699BB	1S7A12A699BB	**SENSOR - ENGINE KNOCK**
6M8Z6C315AA	6M8G6C315AB	**SENSOR - CRANKSHAFT POSITION - CPS**
8F9Z9F472A	8F9A9Y460AB	**SENSOR ASY, MAF**
8V2Z12B579A	8V2112B579AA	**SENSOR ASY**
9L8Z6G004E	9L8A6G004BC	**SENSOR ASY, CYL HD TMP**
AA5Z9A600B	AA539A600AD	**CLEANER ASY - AIR**
AE5Z6A228A	AE5Q6A228AA	**PULLEY ASY - TENSION BELT**
AE5Z8620A	AE5Q6C301AA	**V-BELT**
AG9Z6K679A	AG9G6K679BC	**PIPE - OIL FEED, T/C**
AG9Z6K868A	CJ5E6K868AA	**VALVE ASY, ENG PST OIL COOL**
AG9Z6L092A	AG9G6K677BC	**HOSE - T/C OIL DRAIN**
AG9Z8555A	AG9G8A506BB	**HOSE - WATER INLET, T/C**
AG9Z9F479A	AG919F479AB	**SENSOR ASY, MAP**
AS7Z6B288A	AS7112K073AA	**SENSOR - CAMSHAFT POSITION**
BB3Z6A642A	BB3E6A810AA	**KIT ENGINE OIL COOLER**
BB5Z11002C	BB5T11000AA	**STARTER MOTOR ASY**
BB5Z5A231A	BB535A281AA	**CLAMP - HOSE, T/C TO EXH**
BB5Z6C640A	BB536K863CE	**CONNECTION - AIR INLET T/B END**
BB5Z6C640B	BB536K863DF	**CONNECTION - AIR INLET, I/C END**
BB5Z6C646C	BB536C646CD	**DUCT - AIR, TURBO END**
BB5Z6C646D	BB536C646DF	**DUCT - AIR, INTERCOOLER END**
BB5Z6C683A	BB5E6L663AA	**FILTER ASY (T/C SCREEN)**
BB5Z9647A	BB539647AB	**BRACKET, AIRBOX**
BB5Z9661A	BB539643AA	**COVER, AIRBOX**
BB5Z9B659B	BB539F805DE	**HOSE - AIR, TURBO END**
BB5Z9B659E	BB539F805CG	**HOSE - AIR, AIR BOX END**
BM5Z9F972A	BM5G9F972BA	**SENSOR - FUEL INJECTOR PRESSURE**
BR2Z9E499A	BR2E9E499AA	**CONNECTOR, VAC CONTRL, T/C**
CB5Z6K682F	CB5E6K682BF	**TURBO CHARGER**
CB5Z8592A	CB5E8592AB	**CONNECTION - WATER OUT, T/C**
CB5Z8K153B	CB5E8B535AC	**TUBE - WATER OUTLET**
CB5Z9424D	CB5E9424AF	**MANIFOLD ASY - INTAKE**
CB5Z9S468C	CB5E9S468AF	**HOSE, EMS (VAC HARNESS)**
CJ5Z9J323B	CJ5E9J323BC	**TUBE ASY FE PMP TO FE MAN**
CM5Z12029A	CM5E12A366CA	**COIL ASY - IGNITION**

CP9Z9E926A	CM5E9F991AD	**THROTTLE BODY AND MOTOR ASY**
D4ZZ7600A	D4ZA7120AB	**SLEEVE, PILOT BEARING**
DU5Z12A581U	DU5T12C508UE	**WIRE ASY, ENGINE MAIN**
YS4Z6766A	YS4G6766DA	**CAP ASY - OIL FILLER**
5M6Z8509AE	5M6Q8509AE	**PULLEY - WATER PUMP**
AG9Z6312B	AG9E6D334AA	**PULLEY - CRANKSHAFT**
BB5Z-6675-A	BB5E-6675-AA	**PAN ASSY - ENGINE OIL**
CJ5Z-6675-D	CJ5E-6675-AD	**PAN ASSY - ENGINE OIL**
E4FZ-6731-AB	9U2J-6731-HD Motorcraft FL-400S	**FILTER – ENGINE OIL**

Table X2.6 Special Parts List

Part number[A,B]	Description	
VH002-2	TUBE, PICK UP	
OHTVH-005-1	HOUSING, FLYWHEEL	
OHTVH-006-1	FLYWHEEL, MODIFIED, 2.0L	
VH006-8	CLUTCH, ASSY. W/ PRESSURE PLATE	
VH006-8-1	CLUTCH	
VH006-8-2	PLATE, PRESSURE	
OHTVH-007-1	HARNESS, DYNO, 2.0L	
OHTVH-008-1	INLET, COOLANT	
VH008-1	CLIP, RETAINER, SENSOR, COOLANT INLET	
VH008-2	SEAL, COOLANT INLET	
OHTVH-009-1	OUTLET, COOLANT	
VH009-6	SEAL, COOLANT OUTLET	
OHTVH-011-1	SHIM, CLUTCH PRESSURE PLATE	
M-6026-23BSBP	Ford Racing Balance Shaft Delete Kit	
MSI-41/55S-22	MSI Driveshaft	

[A] OHT denotes OH Technology [13]
[B] MSI denotes Machine Service Inc.[2]

TABLE X2.7 Special Service Tools

Description	Ford P/N
Camshaft alignment tool	303-1565
Crankshaft TDC timing peg	303-507
Crankshaft sensor alignment tool	303-1521

(b) Use the driveshaft listed in Table X2.6.

X2.2.6.9 Special Engine Measurement and Assembly Equipment:

(a) General:

1) Items routinely used in the laboratory and workshop are not included.

2) Use any special tools or equipment shown in the 2012 Explorer service manual for assembly.

3) A list of these tools is provided in Table X2.7.

[2] Machine Services Inc., 1000 Ashwaubenon Street Green Bay, WI 54304.

4) Complete any assembly instructions not detailed in Section 8 according to the instructions in the 2012 Explorer Service Manual.

b) Piston-ring positioner:

1) Use the piston-ring positioner to locate the piston rings from the cylinder block deck surface by 38 mm (Fig. X2.6). This allows the compression rings to be positioned in a consistent location in the cylinder bore for the ring-gap measurement.

c) Piston-Ring Grinder—A ring grinder is required for adjusting ring gaps. The Sanford piston-ring grinder.[9] has been found suitable.

X2.2.7. Reagents and Materials

X2.2.7.1 Degreasing Solutions:

a) Degreasing Solvent—Mineral spirits meeting the requirements of Specification D235, Type II, Class C for Aromatic Content (0 to 2) volume %, Flash Point (61°C, min) and Color (not darker than +25 on Saybolt Scale or 25 on Pt-Co Scale). (Warning-Combustible-Health hazard-see appropriate SDS). A Certificate of Analysis is required for each batch of solvent.

b) Chemtool B-12 , —(Warning-Combustible-Health hazard-see appropriate SDS)

c) Acqueous Detergent Solution—Prepare from a commercial laundry detergent. Tide[6] has been found suitable for this purpose.

d) Heptane C^7H^{16} —is a recommended cleaning agent for final rinsing of some special test components. (Warning – Flammable-Health hazard-see appropriate SDS).

X2.2.7.2 Test Fuel—Use EEE Lube Certification test fuel ,[9] for each test. (Warning—Flammable. Health Hazard.) A Sequence X Surveillance Panel approved EEE test fuel Specification of Analysis is available on the TMC Website.

X2.2.7.3 Test Oil —A minimum 27.6 liters of test oil is required.

a) Three charges of 4.6 kg each (13.8 kg total) are required for the Aging phase of this test

b) Two charge of 4.2 kg each (8.4 kg total) of fresh oil are also required to flush the engine during the LSPI test run afterwards (section X2.5.13)

X2.2.7.4 Engine Coolant—Use only Dex-Cool concentrate mixed 50/50 with deionized water or premixed 50/50.

X2.2.7.5 Sealing Compounds:

a) Silicon-based Sealer—Use as needed on the contact surfaces between the rear-seal housing and the oil pan and the front cover and cylinder block, cylinder head and oil pan. Motorcraft TA-357 is preferred. Use silicon-based sealer sparingly because it can elevate the indicated silicon content of the used oil.

b) Motorcraft Gasket Maker TA-16 or equivalent—Use between the 6th intake and exhaust camshaft cap and the cylinder head.

c) Non-silicon Liquid or Tape Thread Sealers—Use as needed on bolts and plugs.

d) Thread Sealant—Use Loctite 565.

X2.2.7.7 Engine Build Up Oil—Use EF-411 as engine assembly oil.

X2.3. Preparation of Apparatus

X2.3.1 *Engine Parts Cleaning:*

X2.3.1.1 *Ultrasonic Cleaner Preparation:*

a) The TierraTech model MOT-400 N[3,] (capacity 400 L) has been found suitable.

b) Add solution once the ultrasonic cleaner reaches a minimum of 60 ºC (140 °F).

1) Use Brulin AquaVantage 815 GD and 815 QR-NF solutions with a volume fraction of 12.5 %.

2) Mix these solutions to give a volume fraction of 50 %. For the TierraTech Model 400N, the quantities involved are 25 L of each solution. Quantities will be different for a different capacity unit.

3) Change the soap and water solution at least after every 25 h of use.

X2.3.1.2 *Engine Parts for Ultrasonic Cleaning*—the following engine parts are subjected to ultrasonic cleaning:

(a) *Cylinder Block*—Remove oil jets and main bearings.

(b) *Bare Pistons without Wristpins*—Remove the piston compression and oil rings. A new set of piston rings is used for every test.

(c) *Bare Cylinder Head*—Remove valve-train components.

(d) *Modified Oil Pan—refer to figure X2.1A and X2.1B*

(e) *Front Cover*.

X2.3.1.3 *Procedure for Ultrasonic Cleaning*:

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[3] The sole manufacturer of this equipment known to the committee at this time is TierraTech, 701 N Bryan Rd., 78572 Mission, TX. Tel: +1 956 519 4545; sales@tierratech.com.

(a) *Bare Pistons without Wristpins:*

(1) Place the bare pistons without wristpins into the ultrasonic cleaner for 30 min maximum. A nylon brush may be used to scrub the pistons and remove heavy deposits. Do not leave the pistons in the ultrasonic cleaner longer than 30 min.

NOTE 2—Leaving the pistons in the ultrasonic cleaner longer than 30 min can remove the skirt coating on the piston sides.

(b) After 30 min, remove the pistons and immediately spray with hot water, then with Degreasing Solvent (**Warning-**Combustible-Health hazard-see appropriate SDS) and leave to air-dry.

(c) Repeat steps (a) and (b) until all the piston deposits have been removed.

X2.3.1.3 (a) *Other Parts*—Clean all the other parts listed in X2.3.*1.2* as follows:

(1) First rinse the parts with aqueous detergent solution (see X2.2.*7.1 c*) followed by a hot-water rinse.

(2) Then place the parts in the ultrasonic parts cleaner apparatus for 30 min.

(3) After 30 min, remove the parts and immediately spray with hot water, then with Degreasing Solvent (**Warning-**Combustible-Health hazard-see appropriate SDS) and leave to air-dry.

X2.3.1.4 *Degreasing*—Spray clean the following components with Degreasing Solvent, (**Warning-**Combustible-Health hazard-see appropriate SDS) then blow out with pressurized air, and leave to air-dry:

(a) Camshafts and all valve-train components;

(b) Intake manifold/throttle body (not being separated);

(c) Fuel-pump housing with piston;

(d) Vacuum pump and oil screen;

(e) Turbo oil feed line oil screen located in the engine block (do not clean the inside of the turbocharger);

(f) Oil pump;

(g) Valve cover;

(h) Turbocharger oil lines;

(i) Oil separator (PCV housing on the cylinder block);

(j) Oil pick up tube;

(k) Oil squirters/jets;

(l) Crankshaft;

(m) Connecting rods and pins;

(n) Camshaft sprockets and crankshaft gear.

X2.3.1.5 *Cleaning of Other Components:*

(a) *VCT solenoids*—Spray with degreasing solvent, (**Warning-**Combustible-Health hazard-see appropriate SDS) then blow out with pressurized air, and leave to air-dry.

(b) *Turbocharger Intake and Outlet*—Lightly wipe down with degreasing solvent, (**Warning-**Combustible-Health hazard-see appropriate SDS).

(c) *Injectors*—Wipe off carbon build up.

(d) *Timing Chain*

X2.3.2 *Cylinder Deglazing for New & Rebuild:*

X2.3.2.1 Use a silicon carbide, grit flexible cylinder hone Flex Hone Model GB31232[4,] and Pneumatic Honing Drill, Westward ½ in. Reversible Air Drill, 500 r/min, 600 kPa (90 psig) max, Model 5ZL26G[4,] to deglaze the cylinder walls (see X2.3.*13* and *Figs. X2.2 & X2.3)*.

X2.3.3 *PCV Valve Flowrate Device:*

X2.3.3.1 Use this device to verify the flowrate of the PCV valve before the test and to measure the degree of clogging after the test.

X2.3.3.2 Fabricate the device according to the details shown in *Fig. X2.4*.

X2.3.3.2.(a) The device shall have a full-scale accuracy of 5 % and a resolution of 0.05 L/s.

X2.3.3.2. (b) The inlet-flowrate meter shall calibrate to within 5 % of the standard (pre-calibrated) orifices at the pressure differentials stamped on the orifices.

X2.3.4 *Preparation of Miscellaneous Engine Components:*

X2.3.4.1 *Area Environment of Engine Build-Up and Measurement:*

X2.3.4.1. (a) The ambient atmosphere of the engine build-up and measurement areas shall be reasonably free of contaminants.

X2.3.4.1.(b) Maintain a relatively constant temperature (within ± 3 °C) to ensure acceptable repeatability in the measurement of parts dimensions.

X2.3.4.1.(c) Maintain the relative humidity at a nominal maximum of 50 % to prevent moisture forming on cold engine parts that are brought into the build-up or measurement areas,

X2.3.5 *Throttle Body*:

X2.3.5.1 Clean the butterfly and bore of the throttle body with carburetor cleaner Chemtool B12 (**Warning-**Combustible-Health hazard-see appropriate SDS) and air-dry before each test.

(a) Do not disassemble the throttle body as this will cause excessive wear on the components.

(b) There is no specific life for the throttle body. The clearance between the bore and the butterfly will, however, eventually increase and render the body unserviceable.

(c) Discard the throttle body when the clearance becomes too great to allow control of speed, torque, and air-fuel ratio.

[4] The sole source of supply of this equipment known to the committee at this time is W.W.Grainger, Inc., www.grainger.com.

X2.3.6 *PCV Valve Cleaning and Measurement:*

X2.3.6.1 Clean the PCV valve by spraying the inside of the valve with Chemtool B12 (**Warning-** Combustible-Health hazard-see appropriate SDS) until the solvent comes out clear.

X2.3.6.2 Measure and record the flowrates of the PCV valve with the calibrated flow device described in *Fig. X2.4*.

(a) Measure the flowrate at 27 kPa and 60 kPa vacuum.

(b) Because of the hysteresis in the PCV valve spring, make the vacuum adjustments in one direction only.

(c) Measure the flowrate twice and average the readings.

1) Correct the actual flow measurements to 65.5 °C and 100.7 kPa using the formula:

corrected flow = uncorrected flow * 1.8338 (barometer / (air temp + 273)) ^ 0.5

$$F_C = 1.8338 * F_A\left[\left(P_{baro}\right)/\left(T_{AIR} + 273\right)\right]^{0.5} \qquad (1)$$

where:

F_C = the corrected flow rate, L/min,

F_A = the actual flow rate, L/min,

P_{baro} = the barometric pressure in the measurement area, kPa (absolute),

T_{AIR} = the air temperature in the measurement area, °C.

X2.3.6.2. (d) Reject any PCV valve that does not exhibit an average flowrate of 36 L/min to 54 L/min at 27 kPa and 19 L/min to 21 L/min at 60 kPa.

X2.3.7 *Drive System for Water Pump*—The water-pump drive is shown in X2.5. Use only the pulleys and belt provided in the test stand set-up parts list (*Table X2.5*) for the crankshaft pulley, water-pump pulley, tensioner, and six-groove belt shown in *Fig. X2.5*.

X2.3.8 *Oil Separator* — Clean with Degreasing Solvent (**Warning-**Combustible-Health hazard-see appropriate SDS) and allow to air dry.

X2.3.9 *Assembling the Test Engine:*

X2.3.9.1 *General*—Use the long block obtained from the supplier.[5]

a) Disassemble the long block in accordance with the 2012 Explorer workshop manual.

b) Required new parts and reusable parts are listed in *Tables X2.2* and X2.4.

X2.3.10 *Parts Selection*—Instructions concerning the use of new or used parts are detailed in X2.2 to X2.6.

X2.3.11 *Gaskets and Seals*—Install new gaskets and seals during engine assembly.

[5] The sole source of supply of this block known to the committee at this time is Ford Component Sales, Ford Motor Co., 290 Town Center Dr., Dearborn, MI 48126.

X2.3.12 *Block Preparations*—Inspect block, including oil galleries for debris and rust.

X2.3.12.1 Remove any debris or rust that is found.

X2.3.12.2 Remove oil gallery plugs.

X2.3.12.3 Removal of coolant jacket plugs is left to the discretion of the laboratory.

X2.3.13 *Deglazing Procedure***:**

X2.2.13.1 *General*—Carry out deglazing after ultrasonic cleaning for both new and used engines under the following conditions to achieve a per cylinder average surface roughness (*Ra*) of 9_{Ra} to 13_{Ra} (0.178 µm to 0.330 µm) or (7 µin to 13 µin) and 30º ± 5º crosshatch. Use a Mitutoyo SJ-410 profilometer for the surface finish measurements.

a) Mount the engine block on an engine stand or suitable fixture so it is secure and will not move during the deglazing operation.

b) Rinse cylinder bores with Degreasing Solvent (**Warning-**Combustible-Health hazard-see appropriate SDS).

c) Deglaze cylinder bores using the drill and hone shown in *Figs. X2.3* and *X2.2* (see also X2.2.*2*).

d) Run the drill at 500 r/min horizontal drill speed for 25 vertical strokes to 35 vertical strokes over an elapsed time of 20 s to 25 s. Ensure a steady supply of lubricant is supplied during each stroke.

e) Use a 50/50 ratio of Degreasing Solvent (**Warning-**Combustible-Health hazard-see appropriate SDS) and EF411 as the hone lubricant.

(f) Clean cylinders after honing deglazing with warm/hot water or hot water and detergent (Tide[6] has been found suitable) using a brush, then oil cylinders with EF411.

(g) Replace ball hone after deglazing a maximum of 24 engine blocks.

X2.3.14 *Crosshatch Measurement Procedure***:**

X2.3.14.1 *Apparatus*—Use the following:

a) *HatchView Software*. [7]

b) *USB microscope*.

c) *Computer System*—Minimum requirements: Windows XP, Vista or Windows 7 (32 or 64 bit), an available USB 2.0 port is required for live "video" viewing.

X2.3.14.2 *Preparation*:

a) Clean the cylinder of any oil or residue from honing to maintain consistency of measurements.

b) Adjust the focus of the camera while the face of the camera is placed against the cylinder wall.

[6] The sole source of supply of this product known to the committee at this time is Procter & Gamble Co., 1 P&G Plaza, Cincinnati, OH 45202. Tel: +1 513 983 1100.

[7] The sole source of supply of this software known to the committee at this time is Digital Metrology, https://digitalmetrology.com/solution/hatchview.

c) Set camera resolution to 640 x 480 and 30 frames per second (fps).

d) Use the identification feature available in the program to title the image with cylinder number and test number.

X2.3.14.3 *Measurement*:

a) Take the measurement at the rear-most longitudinal position of each cylinder.

b) Using a ruler, take the measurement 38.1 mm (1.5 in.) down from the top of the cylinder deck.

c) The measurement shall be between 25° to 35° with a target of 30°.

X2.3.15 *Crankshaft Preparation:*

X2.3.15.1 Clean the crankshaft as described in X2.3.1.4.

X2.3.15.2 Measure the horizontal and vertical diameters of the main and connecting rod journals, the bearing inside diameter and clearance, and verify that they meet the service limits.

X2.3.15.3 Polish the crankshaft with 400 grit aluminum oxide utility cloth while it is still lightly coated in Degreasing Solvent (**Warning-**Combustible-Health hazard-see appropriate SDS) 3M utility cloth 314D[8] has been found to be suitable.

X2.3.15.4 Give a final finish with 600 grit crocus cloth.

X2.3.15.5 Clean with Degreasing Solvent (**Warning-**Combustible-Health hazard-see appropriate SDS) as described in X2.3.1.4 for the final time.

X2.3.16 *Piston and Rod Assembly:*

X2.3.16.1 Clean the pistons as described in X2.3.1.3.(a).

X2.3.16.2 Measure piston, piston pin and pin-rod-hole diameters to ensure they meet service limits.

X2.3.16.3 Install the pistons on the connecting rods following the procedure in the 2012 Explorer workshop manual.

X2.3.17 *Piston Rings:*

X2.3.17.1 *Ring Gap Adjustment*:

a) Clean the piston rings by spraying them with Chemtool B12 (**Warning-**Combustible-Health hazard-see appropriate SDS) carburetor cleaner to remove the factory coating. Wipe the piston rings with EF411.

b) Typically a multi-laboratory median gap of 2.057mm (0.081in) for the top ring and 2.184mm (0.086in) for the second ring have proven to produce acceptable blowby levels with used pistons and a surface finish and crosshatch pattern as achieved in *section X2.3.13.* Ensure that the delta between the top and second ring gaps are within 0.127mm (0.005 in) +/- 0.0254mm (0.001in).

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[8] The sole source of supply of this product known to the committee at this time is 3M United States, 3M Center, St. Paul, MN 55144-1000. Tel: 1-888 364 3677; www.3m.com.

c) To achieve an average blowby of 65 L/min to 75 L/min, an adjustment may be necessary immediately before or after the 24 h measurement

d) A 1.5 h blowby value of at least 70 L/min is recommended. The 24 h to 72 h blowby average shall fall within 65 L/min to 75 L/min.

e) Ring gap adjustments are not allowed once the test has resumed after the 24 h blowby reading.

f) Place the ring 38 mm (1.5 in.) from the deck, using the piston-ring setter (see *Fig. X2.6*).

X2.3.17.2 *Piston-Ring Cutting Procedure:*

a) Cut the top and second compression-ring gaps to the required gap using a ring grinder. The Sanford Piston Ring Grinder[9,] has been found suitable with a 3/16 in. (4.76 mm) ring cutting burr P/N 74010020[10,9] rotated at a rated speed of 3450 r/min.

b) Remove equal amounts from both sides of the gap. Make final cuts on the down stroke only.

c) Cut the ring with a maximum increment of 0.125 mm until the desired ring gap is achieved.

d) After the rings are cut, remove the ring from the cutting tool, deburr using a Sunnen soft stone P/N JHU -820[11,9] , and wipe with a dry towel.

X2.3.17.3 *Installation:*

a) Install the oil-control rings and the compression rings on the pistons with the gaps located over the piston pin.

b) Position the gaps at approximately 180° intervals, with the top compression-ring gap toward the rear.

c) Install the rings using a ring spreader tool, keeping the rings' surfaces parallel to the ring groove in the piston.

d) If any rings require replacement, measure and record the new ring gap(s).

X2.3.18 *Cylinder-Bore Measurements:*

X2.3.18.1 Measure the cylinder bores with the bearing caps in place and torqued.

X2.3.18.2 Clean the bores with a dry rag. The bores shall be clean and dry when they are measured.

X2.3.18.3 Use a bore-gauge micrometer, along with the bore ladder (see *Fig. X2.7*) to determine the diameter of the cylinders at the top, middle, and bottom.

X2.3.19 *Assembling the Test Engine:*

X2.3.19.1 Assemble the engine according to the instructions in the 2012 Explorer service manual unless specified herein.

X2.3.19.2 *Cylinder block:*

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[9] The sole source of supply of this equipment known to the committee at this time is Sanford Mfg. Co., 300 Cox St., PO Box 318, Roselle, NJ 07203.

[10] The sole source of supply of this equipment known to the committee at this time is M.A.Ford Mfg. Co., Inc., 7737 Northwest Blvd., Davenport, IA 52806. www.maford.com.

[11] The sole source of supply of this equipment known to the committee at this time is Sunnen Inc., 7910 Manchester, St Louis, MO 63143.

a) Remove the heater-hose tube from the block (see *Fig. X2.13*) and plug with a 3.2 mm (5/8 in.) freeze plug coated in room-temperature-vulcanizing (RTV) silicone.

X2.3.19.3 *Piston Installation*:

a) Install piston and rod assemblies in the appropriate cylinders, taking care to ensure rings are not damaged during installation.

b) Wipe the cylinders with EF-411.

c) Install the pistons and connecting rods with the notches facing the rear.

d) Install the rod-bearing caps and torque according to the procedure in the 2012 Explorer workshop manual.

X2.3.19.4 *Oil System Components:*

a) Use production configuration for all oil-system components in the engine with the exception of the oil pan (see X2.3.*1.2.d*), shown in *Fig. X2.1A and X2.1B*.

X2.3.19.5 *Cylinder Head Installation:*

a) Heads may be reused, provided they remain within service limits.

b) Disassemble heads and inspect for any debris or other deleterious materials and remove as necessary.

c) Clean the cylinder head in the ultrasonic cleaner as described in X2.3.1.2.(c).

d) Determine valve-guide clearance at the top and middle of the heads on the transverse side of the guide.

e) Reject any heads that exceed the service limits shown in the 2012 Explorer workshop manual.

f) Measure and record spring free length and spring load at a compressed height of 28.7mm for the intake and exhaust valve springs.

g) Verify the compressed spring load is 460 N ± 21 N. Reject any springs not meeting this criteria.

h) Assemble the cylinder heads in accordance with the service manual. The valves are lapped before installation and new intake and exhaust valve seals are installed.

i) Set the valve lash according to the procedure in the workshop manual and record the valve lash.

X2.3.19.6 *Chain and Camshaft Installation Procedure:*

a) Install camshaft and timing chain according to the procedure in the 2012 Explorer workshop manual.

b) If using the Ford camshaft alignment tool P/N 303-1565[12], ensure it does not bind in the slots at the rear of the camshafts. It should be loose after the timing-chain installation is complete. Ensure the camshaft positioning tool is flat before installing.

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[12] Available from any Ford or Lincoln dealer.

c) Use a spanner on the harmonic balancer or a flywheel lock to hold the crankshaft while performing this installation. Alternatively, use the crankshaft positioning TDC timing peg Ford P/N 303-507[12] to hold the crankshaft in place

d) Install the timing chain with the lettering on the black link facing forward. This ensures the chain is installed in the same orientation in the event it is removed and reinstalled during the test.

e) Coat the timing chain with test oil every time it is installed in the engine other than the pre break-in installation. Coat the timing chain with EF-411 when it is first installed before break-in.

f) Install the chain tensioner and guides according to the 2012 Explorer workshop manual.

g) After the tensioner is installed and the pin is pulled from the tensioner to release the tensioner arm, do not move or apply any force to the tensioner arm.

X2.3.19.7 *Balance Shaft Housing:*

a) Do not install the balance shaft housing; it cannot be used with the test oil pan.

b) Remove the balancer and plug the oil passage with a Ford Racing Balance Shaft Delete Kit (Ford Performance P/N M-6026-23BSBP).

X2.3.19.8 *Oil Pan and Baffle:*

a) Install the oil pan with the baffle configuration as shown in *Figs. X2.1A & X2.1B*.

b) Install the oil pan according to the procedure in the 2012 Explorer service manual.

X2.3.19.9 *Water Pump, Water-Pump Drive:*

a) Install the water pump and pulley, the crankshaft pulley, and the tensioner according to the 2012 Explorer service manual. These are the only components needed to drive the water pump. All other production front-end, accessory-drive components do not need to be installed.

b) Do not use the engine to drive any external engine accessory other than the water pump.

c) Pull back tensioner and install water pump drive belt (see Fig. X2.5).

X2.3.19.10 *Engine Cooling System:*

a) Coolant inlet and outlet housings are available from OH Technologies [13]

b) Do not install the thermostat.

c) Plumb the external coolant system (see *Figs. X2.16 and X2.17*).

d) Measure coolant flowrate with a meter having an accuracy of ± 1 %.

e) Use a radiator cap to limit the system pressure to 105 kPa.

f) Pressurize the coolant system to 70 kPa ± 10 kPa at the top of the coolant reservoir.

g) Control the flowrate and outlet temperature of the engine coolant in accordance with the specifications listed in *Table X2.11*.

h) Cyclic ramping specifications are detailed in *Table X2.12*.

i) Prior to running each reference calibration test, inspect the engine-coolant system components, external to the engine, and clean as needed.

j) The coolant side of the system typically does not need cleaning, but the process-water side may need routine cleaning. While a specific flushing technique is not specified, ensure it includes the use of a commercial descaling cleaner.

X2.3.19.11 *Cylinder Block Oil Separator:*

X2.3.19.11.(a) Install a PCV valve in the oil separator on the side of the engine block.

X2.3.19.12 *Oil-Cooling System:*

a) Use the production oil cooler (P/N BB3Z-6A642-A) attached to the oil-filter adapter.

b) Use process water on the coolant side to control the oil temperature.

c) Control oil temperature by a valve on the inlet line of the process water to adjust the flow of process water through a feedback loop from the location of the oil gallery thermocouple (see *Fig. X2.9 and X2.10*).

X2.3.20 *Test Stand Installation:*

a) *General*—Functions that are to be performed in a specific manner or at a specific time in the assembly process are noted.

X2.3.20.2 *Test Engine*:

a) Mount the engine on the test stand so that the flywheel friction face is 0.0° ± 0.5° from vertical.

b) Use four motor mounts (Quicksilver P/N 6628A 2) as shown in *Figs. X2.20 and X2.21*.

c) Suggested designs for the mount brackets are shown in Fig. *X2.8*.

d) The engine shall be at 0.0° ± 0.5° roll angle.

X2.3.20.3 *Flywheel:*

a) Obtain the flywheel from OH Technologies[13, 9]

b) Lightly coat the flywheel bolts with Loctite 565 to prevent any oil from seeping out of the holes.

c) Torque the flywheel to 108 N·m to 115 N·m. OTC flywheel holding tool (P/N 303-103) [14] has been found suitable to hold the flywheel while torquing the flywheel bolts.

X2.3.20.4 *Clutch and Pressure Plate:*

a) Obtain the clutch, pressure plate and spacer from OH Technologies [13]

b) Put the flat side on the clutch toward the engine.

c) Put the OHTVH-001-1 spacer between the flywheel and pressure plate.

d) Torque the pressure plate bolts to 25 N·m to 33 N·m.

e) Replace each clutch after every 6 runs.

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[13] The sole source of this equipment known to the committee at this time is OH Technologies, 9300 Progress Pkwy., Mentor, OH 44060.

[14] A recommended source of supply of this tool known to the committee at this time is Tool Source.com 1-888-220-8350.

X2.3.20.5 *Driveshaft:*

a) *General*—Use 1410 series flanges and grease th driveline before every test.

b) *Driveline Specifications*—These are as follows:

(1) Driveshaft angle degree: 1.5° ± 0.5°;
(2) Installed length from flange to flange: 450 mm to 790 mm;
(3) 1410 series flanges; 1550 joints;
(4) Driveshaft stiffness: 0.1° to 0.3°/136 N·m (100 ft·lbf).

X2.3.20.5.(c) P/M MSI-41/55S-22 from Machine Services Inc.[2] (see *Table X2.6* and *X2.5.2.3*) has been found to be a suitable driveshaft.

X2.3.20.6 *Dynamometer*—Use Midwest dynamometer model 1014A[16].

X2.3.20.7 *Exhaust System and Gas Sampling Fittings*:

(a) *Fig. X2.22* shows a typical exhaust system and fittings for backpressure probes, O_2 sensors and thermocouple.

(b) Construct exhaust components from either solid or bellows pipe/tubing. Other types of flexible pipe are not acceptable.

(c) Use the backpressure probes until they become unserviceable.

1) If the existing probes are not cracked, brittle, or deformed, clean the outer surface and clear all port holes.

2) Check the probes for possible internal obstruction and reinstall the probes in the exhaust pipe.

3) Stainless steel probes are generally serviceable for several tests; mild steel probes tend to become brittle after one test.

(d) Any leaks in the connections to the sample probe will result in erroneous readings and incorrect air-fuel ratio adjustment. **(Warning—**Exhaust gas is noxious.)

X2.3.20.8 *Fuel Management System:*

(a) Use the fuel injectors for a maximum of 6 tests.

(b) Inspect the O-rings to ensure they are in good condition and will not allow fuel leaks. Replace if necessary.

(c) Install the fuel injectors into the fuel rail and into the cylinder head.

(d) A schematic of the fuel system is shown in *Fig. X2.11*.

X2.3.20.9 *Powertrain Control Module (PCM):*

(a) To run this test, use the engine PCM provided by Ford Motor Company[15]

(b) The PCM contains a calibration developed for this test. Use a PCM that contains the calibration U5J0110D1VEPfn13_78_2.

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[15] The sole source of supply of this equipment known to the committee at this time is Ford Motor Company, 17225 Federal Drive, Ste. 200 Room P029, Allen Park, MI 48101.

(c) The PCM power shall come from a 13.5 V ± 1.5 V battery or a power supply that does not interrupt/interfere with proper PCM operation. Connect the PCM battery/power supply to the engine wire harness with an appropriate gage wire of the shortest practical length so as to maintain a dc voltage of 12 V to 15 V and minimize PCM electrical noise problems.

(d) Ground the PCM ground wire to the engine. From the same ground point, run a minimum two gage wire back to the battery negative to prevent interruption/interference of the PCM operation.

(e) The power supply can also be used for the lambda measuring devices.

X2.3.20.10 *Spark Plugs:*

(a) Install new Motorcraft CYFS-12-Y2 spark plugs[15] These come pre-gapped.

(b) Torque the spark plugs to 9 N·m to 12 N·m.

(c) Do not use anti-seize compounds on spark-plug threads.

X2.3.20.11 *Crankcase Ventilation System:*

(a) Use PCV system as shown in Fig X2.28

(b) *System Description:* The crankcase ventilation system is routed the same as the production system. Fresh air is drawn in through the camshaft cover and down into the crankcase through the oil drain back passages in the cylinder head, block, and the front cover. The fresh air and blowby gases are evacuated from the crankcase through the oil separator attached to the left side of the engine block which is fitted with a PCV valve. The hose on the separator assembly connects the crankcase to the intake manifold just above the throttle body incorporating an in-line shut-off valve for use during blowby measurements.

X2.3.20.12 *Intake Air Components:*

(a) Install the fresh air tube, air cleaner assembly, and air filter.

(a) Modify the air cleaner assembly to accept fittings for the inlet-air-temperature thermocouple and pressure tap as shown in *Fig. X2.24*.

X2.3.20.13 *Water-to-Air Turbocharger Intercooler:*

a) Use a water-to-air intercooler capable of achieving the required air charge temperature in Table X2.11 and an average system pressure loss less than 3 kPa.

b) The intercooler accumulates significant amounts of blowby condensate during each test. Spray-clean the air side of the intercooler with Degreasing Solvent, (**Warning-**Combustible-Health hazard-see appropriate SDS) then rinse with hot water, and allow to air-dry before each test. Clean the water side of the intercooler with commercial Aqua Safe descaler[16].

c) *Intercooler Tubing:*

[16] Available from various retailers.

(1) Fabricate the intake-air system from the turbocharger to the intercooler with stainless steel tubing having an internal diameter (ID*)* of 51 mm and from the intercooler to the throttle body with stainless steel tubing having an ID of 64 mm. The tubing length is not specified but should be the appropriate length to achieve the required air-charge temperature and system-pressure loss.

(2) Locate the manifold absolute pressure and temperature (MAPT) sensor 305 mm ± 25 mm from the intake surface of the throttle body and the thermocouple for the intake-air-charge temperature 25 mm downstream from the MAPT sensor.

(3) Place the post-intercooler turbo boost pressure measurement probe a minimum of 305 mm upstream from the MAPT sensor.

(4) Place the pre-intercooler turbo boost pressure measurement probe a minimum of 130 mm downstream from the turbocharger outlet.

(5) A typical installation is shown in *Fig. X2.14*. The intercooling tubing measurements and instrumentation are shown in *Fig. X2.15*

X2.3.20.14 *External Hose Replacement:*

a) Inspect all external hoses used on the test stand and replace any hoses that have become unserviceable.

b) Check for internal wall separations that could cause flow restrictions.

c) Check all connections to ensure security.

X2.3.20.15 *Wiring Harness:*

a) Two wiring harnesses are used on the test stand - a dynamometer harness[13,] **Error! Bookmark not defined.** that connects to the stand power and PCM (see *Fig X2.30*) and an engine harness [13] (see *Fig X2.31*). The stand harness receives a constant dc voltage of 12V to pins 4 and 8 and 12V switched to pin 1.

X2.3.20.16 *Electronic Throttle Controller:*

a) *General*— The throttle is controlled using simulated accelerator pedal position signals. The dynamometer wiring harness is supplied with an Accelerator Pedal Position jumper cable with un-terminated pigtail leads.

b) Connect two voltage command signals, Acc Pos Sensor 1 and Acc Pos Sensor 2, to the Accelerator Pedal Position jumper cable. The voltage control ranges for each signal are shown in *Table X2.8*. The wiring schematic and pin-out description for this connection are shown in *Fig. X2.27*. Run the voltage signals through a voltage isolator otherwise interference will occur between the laboratories Data Acquisition & Control (DAC) system and the Engine Control Unit (ECU) and throttle control will be erratic.

Table X2.8: Accelerator Position Sensor Control Ranges

Command Signal	Operating Range, dc voltage	Min Signal (Idle), dc voltage	Max Signal (WOT), dc voltage
Acc Pos Sensor 1	0 V to 5.0 V	0.75 V (15 %)	4.25 V (85 %)
Acc Pos Sensor 2	0 V to 2.5 V	0.375 V (15 %)	2.125 V (85 %)
Note: Acc Pos Sensor 2 should always equal 50 % of Acc Pos Sensor 1			

X2.3.21 *Engine Fluids (Supply/Discharge Systems):*

X2.3.21.1 *Air supply system:*

a) Ensure the supply system is capable of delivering 110 L/s of conditioned air, while maintaining the intake/air pressure, temperature, and humidity specified in Table X2.11. The test stand intake air duct system is not specified.

X2.3.21.2 *Dew Point:*

a) Measure the dew point either in the main system duct or at the test stand. If measured in the main system duct, verify the dew point periodically at the test stand.

b) Maintain the duct surface temperature above the dew point temperature at all points downstream of the humidity measurement point to prevent condensation and loss of humidity level.

X2.3.21.3 *Fuel System:*

a) A schematic diagram of a typical fuel-supply system is shown in *Fig. X2.11*.

b) Supply an excess volume of fuel to the fuel rail at all times. The engine has a closed loop fuel system so excess fuel goes into the loop back to the heat exchanger.

c) Deliver the fuel to a high-pressure, engine-driven pump that boosts the pressure and supplies the fuel to the fuel rail.

d) Maintain the fuel temperature to the fuel rail below 50 °C.

e) To ensure good supply to the high-pressure fuel pump, maintain the fuel pressure to the fuel pump above 448 kPa ± 35 kPa. Ensure the fuel pressure is constant at all steady-state conditions to ensure good speed, power, and air-fuel ratio control

X2.3.21.4 *Fuel Details:*

a) *General*— Use EEE Lube Certification test fuel[17]**Error! Bookmark not defined.**. Approximately xxx L is required for each test. (**Warning**—Flammable. Health Hazard.) A Sequence X Surveillance Panel approved EEE test fuel Specification of Analysis is available on the TMC Website.

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[17] The sole source of supply of this product known to the committee at this time is Haltermann Solutions, P.O. Box 0429, Channelview, TX 777530-0429, USA. Tel: +1 800 969 2542; www.haltermansolutions.com.

b) The laboratory storage tank may be filled with subsequent batches of fuel. A new batch of fuel may be added to existing fuel in the tank. The fuel batch that is reported for a test is the last fuel batch that was added to the tank before the test started.

c) A certificate of analysis accompanies each batch. Maintain a record of a certificate of analysis for each batch.

X2.3.21.5 *Engine Oil*:

(a) The test oil sample shall be uncontaminated and representative of the lubricant formulation being evaluated.

(b) A minimum of 27.6 L (7.3 gallons) of new oil is required to complete the test. A 30 L (~8 gallon) sample of new oil is normally provided to allow for inadvertent losses.

X2.3.22 *Temperature Measurement:*

X2.3.22.1 *General:*

(a) Temperature-measurement locations for the ten required temperatures are specified (see X2.23.2) allowing reasonable opportunity for adaptation of existing test stand instrumentation.

(b) Use thermocouples that are calibrated to ± 0.5 °C (see X2.23.3).

(c) Use only original equipment manufacturer (OEM) temperature sensors for electronic engine control (EEC) inputs.

(d) All thermocouples, except the intake-air thermocouple, shall be premium and sheathed. The intake-air thermocouple may be an open-tip type.

(e) The diameter of the thermocouples shall be 3 mm.

(f) Thermocouples, wires, and extension wires shall be matched to perform in accordance with the special limits of error as defined in ANSI MC96.1

X2.3.22.2 *Temperature Sensor Locations:*

(a) *Coolant Inlet*—Install the sensor in the coolant inlet on the engine (see OHTVH-008-1 in *Fig. X2.17*) perpendicular to the run. Install sensor with the tip in the center of the stream of flow (see *Fig. X2.16*).

(b) *Coolant Outlet*—Install the sensor in the coolant outlet on the engine (see OHTVH-009-1 in *Fig X2.17*) perpendicular to the run. Install sensor with the tip in the center of the stream of flow (see *Fig. X2.16*).

(c) *Engine-Oil Gallery Inlet*—Install the tip of the thermocouple sensor 13mm ± 1mm at the center of the flow stream in the external oil-filter adapter (see *Fig. X2.9, X2.10 and X2.19*) through the hole for the oil-pressure switch (not used). Install a tee to accept this temperature sensor and attach the oil-pressure and sample lines.

(d) *Engine-Oil Filter Inlet* —Install the tip of the sensor at the center of the cross fitting attached to the side opposite from the engine-oil inlet-temperature sensor on the oil-filter adaptor. Modify the adapter with a 1/8in. NPT drilled and tapped hole to access the oil passage (see *Fig. X2.18 and X2.19*).

(e) *Intake Air*—Install the tip of the thermocouple midstream in the air cleaner box downstream of the filter (see *Fig. X2.24*). Insertion depth shall be 37 mm ± 2 mm.

(f) *Fuel*—Install the sensor in the fuel line before the high-pressure pump.

(g) *Air Charge*—Install the sensor in the intercooler outlet tube 25 mm ± 2 mm downstream from the MAPT sensor (see *Fig. X2.15*). Locate the tip at the center of the flow.

(h) *Pre-intercooler*—Install a sensor in the tube between the turbocharger and the intercooler (see *Fig. X2.14*).

(i) *Exhaust*—Install a sensor 140 mm ± 12 mm downstream on the exhaust flange (see *Fig. X2.22*).

X2.3.22.3 *Thermocouple Calibration:*

(a) Calibrate all thermocouples prior to a reference oil test. The temperature measurement system shall indicate within ± 0.5 °C of the laboratory calibration standard. The calibration standard shall be traceable to National Institute of Standards and Technology[18] (NIST).

X2.3.23 *Pressure Measurement:*

X2.3.23.1 *General*:

a) Pressure-measurement locations for each of the ten required quantities are specified in X2.3.*23.2*, allowing reasonable opportunity for adaptation of existing test stand instrumentation.

b) The accuracy and resolution of the pressure-measurement sensors and the complete pressure measurement system shall meet the requirements of the Data Acquisition and Control Automation (DACA) II Task Force Report[19].

c) Replace pressure sensors that are part of the EEC system only with Ford-specified equipment.

d) In accordance with good engineering practice, incorporate tubing between the pressure tap locations and the final pressure sensors' condensate traps. This is particularly important in applications where low air pressures are transmitted by means of lines that pass through low-lying trenches between the test stand and the instrument console.

X2.3.23.2 *Pressure Sensor Locations:*

a) *Manifold Absolute Pressure (MAP)*—Measure the manifold absolute pressure at the port downstream of the throttle-body on the front side of the intake manifold (see *Fig X2.15*).

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[18] National Institute of Standards and Technology, 100 Bureau Drive, Stop 2300, Gaithersburg, MD 20899-2300. www.nist.gov.

[19] Available from the ASTM Test Monitoring Center, 203 Armstrong Drive, Freeport, PA. 16229 Attention Director. Also available on the website at https://www.astmtmc.org

b) *Engine Oil*—Measure oil-pump pressure in the external oil-filter adapter (see *Fig. X2.9, X2.18 and X2.19*) through the hole for the oil pressure switch (not used). Install a tee to accept the temperature sensor and attach the oil pressure line.

c) *Coolant*—Measure engine-coolant pressure at the top of the coolant reservoir as shown in *Fig. X2.17*.

d) *Fuel*—Measure fuel pressure in the lower pressure fuel line at the exit of the stand fuel pump.

e) *Crankcase*—Measure crankcase pressure at the dipstick tube (see *Fig. X2.20*).

f) *Exhaust Gas*—Measure the exhaust back pressure with the exhaust gas sampling probe located 76 mm ± 12 mm downstream of the exhaust flange (see *Fig. X2.22*). A sensor capable of absolute or gauge measurement corrected with barometric pressure reading is recommended. Install a condensate trap between the probe and sensor to accumulate water present in the exhaust gas.

g) *Inlet Air*—Measure inlet-air pressure in the air cleaner downstream of the air filter (see *Fig. X2.24*).

h) *Pre-intercooler—*Measure the pre-intercooler pressure with the exhaust gas sampling probe located 155 mm ± 25 mm downstream of the turbocharger flange (see *Fig. X2.15*).

i) *Boost (Post-Intercooler)—*Measure the post-intercooler pressure with the exhaust gas sampling probe located downstream of the intercooler and at least 305 mm upstream of the MAPT sensor (see *Fig. X2.15*).

j) *Cylinder Head Oil*—Measure cylinder-head pressure at the oil gallery plug on the left side of the cylinder head next to the belt tensioner.

X2.3.23.3 *Calibration of Pressure Sensors:*

a) Calibrate all pressure measurement sensors prior to a reference oil test.

b) The MAP pressure measurement system shall indicate within 0.1 kPa of the laboratory calibration standard.

c) The calibration standard shall be traceable to NIST[35].

X2.3.24 *Flowrate Measurement:*

X2.3.24.1 *General:*

a) Flowrate measurement for each of the two required quantities are detailed in X2.3*.24.2*.

X2.3.24.2 *Flowrate Measurement Locations:*

a) *Engine Coolant*—Determine the engine coolant flowrate using a flow meter with a mass flow accuracy of ± 1 % (see Fig. X2*.16*). A suitable coolant flow meter is available from Micro Motion[20].

1) Take precautions to prevent air pockets from forming in the lines to the pressure sensor. Transparent lines or bleed lines, or both, are beneficial in this application.

[20] Emerson Automation Solutions, Micro Motion, 7070 Winchester Circle, Boulder, Co 80301 +1 800522 6277; www.emersonprocess.com.

2) Ensure that the manufacturer's requirements for orientation and straight sections of pipe are installed immediately up- and down-stream of the flow meter.

X2.3.24.2.(b) *Fuel*—Measure fuel flowrate in kg/h on the low-pressure fuel system before the high-pressure engine fuel pump. A suitable fuel flow meter is available from Micro Motion[20],

X2.3.24.3 *Calibration of Flowrate Devices:*

a) Calibrate the flow meters used in the measurement of fuel flowrate and the engine-coolant flowrate prior to a reference oil test. Calibrate as installed in the system at the test stand with the test fluid. Calibrate secondary by a volume/time method at test operating conditions.

X2.3.25 *Blowby Flowrate:*

X2.3.25.1 Measure the blowby flowrate using a sharp-edged orifice meter.

a) Details of the crankcase ventilation system as used for on-test conditions are shown in X2.28. The critical aspects are detailed below:

1) The hose used to connect the valve cover vent port to the inlet air tube shall have an ID of ¾ in. No part of this hose shall be lower than the valve cover vent, and there shall be no sags or dips in the hose that can retain fluid.
2) Use stainless steel for all wetted materials of pipes, tubing, and fittings.
3) Use Tygon PTFE hose or equivalent hose rated for use with fuel for all wetted materials of hoses.
4) The original equipment PCV valve is flow tested and installed in the oil separator attached to the side of the engine block. The functioning PCV valve is connected to the intake manifold through a 2-way valve used as a switching device during blowby measurements.

X2.3.25.2 The measurement system routes the blowby into the atmosphere through an external, sharp-edged orifice meter cart type system. (see Fig. X.12)

a) Determine the blowby flowrate by measuring the differential pressure drop across the sharp-edged orifice using an inclined manometer or differential pressure sensor. The differential pressure drop sensor shall have a range from 0 kPa to 1 kPa.

b) Fabricate the sharp-edged orifice assembly that is specifically designed for blowby flowrate measurement in strict compliance with the specifications that are available from the TMC.

c) The complete orifice assembly (P/N RX-116-169-A1) can also be purchased from OH Technolgies[28, 9] who will provide additional information.

d) The assembly contains five orifices. The 9.525 mm orifice is generally satisfactory for the range of blowby flowrates encountered.

X2.3.25.3 Allow 1 min for the flow to stabilize before recording the blowby flowrate. Maintain crankcase pressure during blowby measurement using the blowby cart bleeder valve to maintain crankcase pressure at the dipstick tube at 0.0 kPa ± 0.025 kPa. Measure and record the blowby flowrate for a period to allow for an accurate average flowrate to be obtained. This can be up to the full 15 minute measurement period.

X2.3.25.4 Calculate the blowby flowrate and correct the value to standard conditions (38°C, 100 kPa) using the formula:

corrected Flow = uncorrected flow * (3.11 * P / (T+273))^0.5 where P is in kPa and T is in °C

X2.4. Stand Calibration

X2.4.1 *General:*

X2.4.1.1 Annex A2 describes calibration procedures using the TMC reference oils, including their storage and conditions of use, the conducting of tests, and the reporting of results.

X2.4.1.2 Annex A3 describes maintenance activities involving TMC reference oils, including special reference-oil tests, special use of the reference-oil calibration system, donated reference-oil test programs, introducing new reference oils, and TMC information letters and memoranda.

X2.4.1.3 Annex A4 provides information regarding new laboratories, the role of the TMC regarding precision data, and the calibration of test stands used for non-standard tests.

X2.4.1.4 Calibrate the test stand by conducting a test with a blind reference oil (see A2.2). Submit the results to the TMC as described in A2.6. Determine the acceptability of a reference-oil test according to the LTMS.

X2.4.2 *New Test Stand*—A new test stand is one that has never been calibrated or has not completed an acceptable reference-oil test within 24 months of the EOT date of the last acceptable reference-oil test. Perform a calibration as described in X2.4.1.4 to introduce a new test stand.

X2.4.3 *Stand-Calibration Period*—The calibration period is normally 180 days or after completing 15 non-reference oil tests, whichever comes first. However, calibration time periods may be adjusted by the TMC. Additionally, any test terminated with 26 test hours or less will not be counted towards the 15 allowed runs. Any non-reference oil test started within 180 days of the previous calibration test is considered within the calibration period, provided the X allowed non-reference oil tests that have been completed since the previous calibration test in the stand are not exceeded.

X2.4.4 *Stand Modification and Calibration Status*—Stand-calibration status will be invalidated by conducting any non-standard test or modification of the test and control systems, or both. A non-standard test is any test conducted under a modified procedure, or using non-procedural hardware, or using controller-set-point modifications, or any combination thereof. Any such changes terminate the current calibration period. A reference test is required before restarting the current calibration period (see A2.2.2). If changes are contemplated, contact the TMC beforehand to ascertain the affect on the calibration status.

X2.4.4.1 Test stands may also conduct testing per Test Method D8291 (Sequence IX) or Test Method D8279 (Sequence X) and still maintain calibration. Returning a stand to conducting Sequence D89291 LSPI Oil Aging in accordance with the test method will not require a reference test, provided that the calibration period and number of tests have not been exceeded. Ensure that instrumentation calibration requirements are met when changing test methods.

X2.4.4.2 Stand-calibration status may be invalidated by conducting any non-standard test or modification of the test and control systems, or both. A non-standard test is any test conducted using a modified procedure, non-procedural hardware, modified test duration, or any combination thereof. Any such changes may terminate the current calibration period. If changes are contemplated, contact the TMC beforehand to ascertain the effect on the calibration status.

X2.4.5 *Test-Numbering System:*

X2.4.5.1 *Acceptable Tests*—The test number shall follow the format *AAA-BB-CCC* where:

AAA represents the test stand number,

BB represents the number of tests since last reference, and

CCC represents the total number of tests on the stand.

As an example, 95-5-100 represents the 100th test on stand 95 and the fifth test run since the last reference.

a) Consecutively number all tests on a given stand.

b) For a reference test, *BB* would be 0.

X2.4.5.2 *Unacceptable or Aborted Tests*—If a calibration test is aborted or the results are outside the acceptance limits, the *CCC* portion of the test number for subsequent calibration test(s) shall include a letter suffix. Begin the suffix with the letter A and continue alphabetically until a calibration test is completed within the acceptance limits. For example, if three consecutive unacceptable calibration test are completed on the same test stand, and the test stand number of the first test is 95-0-100 the next two test numbers would be 95-0-100A and 95-0-100B. If the results of the next calibration test are acceptable, the test number 95-0-100C would permanently identify the test and appear on future correspondence.

a) The completion of any amount of operational time on tests other than calibration tests will cause the test number to increase by one.

b) Add no letter suffix to the test number of tests other than calibration tests.

X2.5. Test Procedure

X2.5.1. *Pre-Test Procedure and Engine Break-In:*

X2.5.1.1 *General*—The pre-test procedure comprises an engine break-in schedule as described in *Table X2.9*. The break-in procedure has 12 steps and is 8.25 h long. Use 30 second (0:00:30) ramp times between steps, ramp times are counted as part of the 8.25 h. There are three oil charges, Initial Fill, Oil Flush 1, and Oil Flush 2 (Final Test Charge) with the oil being drained each flush.

X2.5.1.2 Prime and install a new oil filter (Motorcraft FL-400S) and charge the engine with 4600 g (total) of test oil.

X2.5.1.3 Start the engine as described in X2.*5.2.1* and initiate Step 1 of the break-in as listed in *Table X2.10*.

X2.5.1.4 The controlled quantities and their values during break-in are listed in Table 3. All other controls are left wide open/free flowing. The engine does not produce enough heat in the early steps to reach all target temperatures. All controlled quantities shall be on target at the beginning of Step 4.

TABLE X2.9 Oil Aging Test Break-in Schedule

Step	Engine Speed, r/min	Torque, N·m	Time per stage, h:min	Total Time, h:min
Charge engine with 4600g Total, new test oil and new primed oil filter				
1	Idle	0	0:30	0:30
2	1500	38	0:30	1:00
3	2000	72	0:30	1:30
4	2500	111	0:30	2:00
5	3000	135	0:30	2:30
6	3000	150	3:15	5:45
7	2000	72	0:15	6:00
8	3250	155	0:15	6:15
9	3500	155	0:15	6:30
10	3750	155	0:15	6:45
11	4000	155	1:15	8:00
Bring engine to idle for 5 min and shutdown.				
Oil Flush 1: Shut engine down and drain used test oil and remove oil filter. Add 4600g Total, new test oil and install a new primed oil filter.				
12	Idle	0	0:15	8:15
Oil Flush 2: Shut engine down, drain used test oil and remove oil filter. Add 4200g of the 4600g Total Charge, (retaining 400g for calibration check, see 10.1.7.8), new test oil and install a new primed oil filter.				

X2.5.1.5 The laboratory ambient atmosphere shall be reasonably free of contaminants. The temperature and humidity levels of the operating area are not specified. A fan is allowed to divert air toward the turbocharger during break-in only.

X2.5.1.6 During the break-in, check the PCM system operation, check for leaks in the various systems, and purge air from the cooling systems.

TABLE X2.10 Oil Aging Test Break-in Controlled Quantities

Quantity	Units	Value
Coolant Out Temperature	°C	85 ± 0.5
Oil Gallery Temperature	°C	100 ± 0.5
Inlet Air Pressure (gauge)	kPa	0.05 ± 0.02
Air Charge Temperature	°C	37 ± 0.5
Inlet Air Temperature	°C	30 ± 0.5

X2.5.1.7 Perform Oil Flush 1 at the end of Break-in Step 11.

a) Shutdown the engine as described in X2.5.4.1, drain the used oil, remove the used oil filter and allow the oil to drain.

b) Measure out 4600 g of new test oil, use a portion to prime a new oil filter and install it on the engine.

c) Charge the engine with the remaining new test oil.

d) Start the engine as described in X2.5.2.2.(a).

e) Initiate Step 12 of the Break-in schedule (see *Table X2.10*).

f) At the end of Step 12, perform Oil Flush 2. Retain 400g of new oil charge for use during dip stick calibration (See X2.5.7.4) or dip stick confirmation check (See X2.5.1.7.(i)).

g) For each new test, a dipstick calibration or confirmation check needs to be performed during the final test oil charge to determine the 4200 g and 4600 g oil levels. See X2.4.7.4 for calibration or X2.4.1.7.(j) for confirmation check.

h) Start the engine as described in X2.5.2.1, run at idle for 5 min, and then shut down the engine as described in X2.5.4.1.

i) After the engine has been shut down for 20 min ± 2 min, record the dipstick level in millimeters to ensure it reaches the 4200g level on the dipstick. Add the 400g retained new oil charge from X2.4.1.7.(h) to confirm the 4600 g level mark on the dip stick. These marks are determined during the dipstick calibration (X2.4.7.4).

(j) Break-in and the initial oil level measurement are now completed and the test procedure described in Test Sequence, X2.5.3 can be initiated.

k) No makeup oil is allowed during the oil aging test.

X2.5.2 *Engine Start-up Procedures:*

X2.5.2.1 *Normal Engine Start-up:*

a) *General*—Use this procedure each time the engine is started.

b) Turn on the ignition, safety circuits, fuel-management system and fuel pump. Ensure the intake-air supply duct is connected.

c) Crank the engine. The engine should start within 4 s.

1) Because the engine has a crankshaft-driven oil pump, cranking oil pressure might be low.

2) If used, disable a low oil-pressure ignition shutoff during engine starting to allow the engine to start even though the oil pressure is low. The use of such a shutoff switch could lead to excessive cranking time to start the engine.

d) If starting difficulties are encountered, do not crank the engine excessively. Perform diagnostics to determine the reason the engine will not start (for example, ignition problems, or insufficient or excess fuel). **Warning—**Excessive cranking times can promote additional fuel dilution of the test oil and can adversely affect the test result. In addition to other precautions, do not attempt to pour gasoline into the intake-air horn.

X2.5.2.2 *Start-Up After Oil Leveling Period:*

a) *General*—Follow this procedure each time an engine start-up is performed after an oil leveling period.

b) Start the engine as described in X2.5.4.1, idle for 5 min, then ramp to test conditions for 30 min as shown in *Tables X2.11 & X2.12*. The 5 min of idle does not count toward the total test time.

c) the test timer starts at the beginning of the ramp to test conditions. (Except after unscheduled shutdowns see X2.5.2.3)

X2.5.2.3 *Start-Up After Unscheduled Shutdown*—Follow the procedure detailed below each time an engine start-up is performed after an unscheduled shutdown:

a) *To Return to test conditions*—Start the engine as described in X2.4.2.1, idle for 5 min, then ramp to test conditions for 30 min using the ramp as described in *Table X2.12*. Once test conditions are reached resume the total test timer from where they left off before shutdown

X2.5.3 *Test Sequence:*

X2.5.3.1 After completion of the engine break-in (see X2.4.1), carry out the test procedure shown in *Tables X2.11 & X2.12*.

X2.4.3.2 *General Description*—The test is a steady state test as shown in *Table X2.11* run for a total of 72 hours.

X2.4.3.3 Perform oil level measurement every 24 hours. Extract an oil sample only at EOT oil level. The oil level measurement and sampling procedure, which is described in X2.4.7, does not count toward test time.

X2.5.3.6 *End of Test Procedures:*

a) *Final Drain*—Drain the engine coolant after the completion of the last test cycle.

b) *Engine Disassembly*—During disassembly, ensure the original location of the parts can be identified with respect to either the cylinder number, valve location, bearings, etc.

X2.5.4 *Engine Shutdown Procedures:*

X2.5.4.1 *Scheduled Shutdown Procedure:*

a) *General*—Scheduled shutdowns include those that occur during engine break-in and oil leveling. Follow the procedure described here each time a scheduled shutdown is performed.

b) Bring the engine speed to idle. Allow flow valves and all temperature valves, to open to maximum to cool the engine down.

c) Switch the ignition off.

d) Turn off power to the ignition power source.

e) Turn off fuel and coolant pumps.

f) Reduce the intake-air pressure to atmospheric.

Table X2.11Aging Test Operational Parameters

Parameter	Units	Value
Time	Hrs	72
Engine Speed	r/min	2500 ± 5
Torque	Nm	128 ± 2
Oil Gallery Temperature	°C	100 ± 0.5
Coolant Out Temperature	°C	85 ± 0.5
Coolant Flowrate	L/min	70 ± 2
Inlet Air Pressure (gauge)	kPa	0.05 ± 0.02
Coolant Pressure (gauge)	kPa	70 ± 2
Inlet Air Temperature	°C	32 ± 0.5
Exhaust Back Pressure (absolute)	kPaA	107 ± 2
Air Charge Temperature	°C	30 ± 0.5
Air Fuel Ratio (AFR), Lambda	*unitless*	1 ± 0.05
Humidity	g/kg	11.4 ± 1.0
Blowby	L/min	65 to 75

Table X2.12 Oil Aging Test Schedule

		Estimated Elapsed Time, h[4]
Startup & Ramp to aging conditions	5 minute idle 30 s speed and flow ramps.	30 min

	3 min to 3.5 min torque ramp. 30 min oil and coolant temperature ramp.	
Aging Conditions (segment 1)	Test run at aging conditions (see Table X2.11)	24 h
Ramp to oil leveling	30 s speed / torque and flow ramps to idle conditions. Total 5 min cool down	5 min
Startup & Ramp to aging conditions	30 s speed and flow ramps. 3 min to 3.5 min torque ramp. 30 min oil and coolant temperature ramp.	30 min
Aging Conditions (segment 2)	Test run at aging conditions (see Table X2.11)	24 h
Ramp to oil leveling	30 s speed / torque and flow ramps to idle conditions. Total 5 min cool down	5 min
Startup & Ramp to aging conditions	30 s speed and flow ramps. 3 min to 3.5 min torque ramp. 30 min oil and coolant temperature ramp.	30 min
Aging Conditions (segment 3)	Test run at aging conditions (see Table X2.11)	24 h
Ramp to oil leveling and End of aging	30 s speed / torque and flow ramps to idle conditions. Total 5 min cool down	5 min
Ramping Conditions		
Torque Ramp to Aging conditions	30 s 75 N·m to 85 N·m 90 s 55 N·m to 60 N·m 150 s to 180 s 48 N·m to 52 N·m	

Torque Ramp to oil leveling	Linear ramp down from test condition to Idle.	
Oil Temperature ramp to Aging Conditions	Reach 75 °C by 12.5 min ± 2 min. Reach 100 °C ± 0.5 °C by 25 min ± 2 min. Remaining time used to stabilize at 100 °C ± 0.5 °C	30 min
Coolant Out Temperature ramp to aging conditions	Reach 65 °C by 12.5 min ± 2 min. Reach 85 °C ± 0.5 °C by 25 min ± 2 min. Remaining time used to stabilize at 85 °C ± 0.5 °C	30 min
Ramps to oil leveling and shutdown not specified.		

[A] Transition times are not included in test time, only time at aging conditions is used for test time.

X2.5.4.2 *Unscheduled Engine Shutdown*—Follow this procedure each time an unscheduled engine shutdown is performed:

a) Stop test timer when ramp down starts.

b) Ramp down to idle in 30 s and allow flow valves and all temperature valves, to open to maximum to cool engine down.

c) Allow the engine to idle for a total of 2 min, the 30 s ramp down counting as part of the 2 min. Shut the engine down after 2 min.

d) Switch the ignition off.

e) Turn off fuel and coolant pumps.

f) Reduce the intake-air pressure to atmospheric.

X2.5.4.3 *Unscheduled Downtime*—The oil leveling periods of 25 min ± 2 min are the only scheduled shutdowns allowed during the test. The test can, however, be interrupted to perform necessary maintenance. Note all unscheduled downtime on the Supplemental Operational Data Form of the final test report.

X2.5.4.4 *Resumption of Test Time After Unscheduled Shutdown*—After an unscheduled shutdown, test time does not begin until the engine has reached operating conditions. On start-up, idle for 5 min, then ramp to test speed and load in 30s.

X2.4.5 *Blowby Flowrate Measurement:*

X2.4.5.1 *General*—Every, 24 hours, as shown in *Table X2.11*, measure and record the blowby flowrate.

a) The engine shall be stable and operating at normal operating conditions.

b) The installation of the blowby flowrate measurement apparatus is described in *Fig.X2*.12

c) The procedure for measuring blowby flowrate is described in section X2.4.*5.2.*

d) Complete only one set of blowby flowrate measurements.

e) Under special circumstances additional blowby flowrate measurements can be performed to determine or verify a problem with the flowrate measurement apparatus or the engine.

f) Record additional blowby flowrate measurements and an explanation of the reason for the additional measurements. Include these data in the supplemental operational data in the final test report.

X2.4.5.2 *Blowby Cart Procedure:* (*See Fig. X2.12*)

a) Connect the blowby measurement device to the pressurized air source.

b) Connect the blowby apparatus flow line to the 3-way valve located between the valve cover and intake tube.

c) Position the 2-way valve in between the PCV and throttle body to keep air from entering the throttle body.

d) Position the 3-way valve to divert the blowby gas through the blowby sharp edged orifice meter.

e) Record the differential pressure across the blowby meter orifice, the blowby gas temperature, and the barometric pressure.

f) After completing the measurements, return the engine to normal operating configuration.

1) First, reposition the 3-way valve and 2-way valve to ensure porting of the intake vacuum to the engine PCV.

2) Then disconnect the blowby apparatus hose from the closed port of the 3-way valve.

g) Calculate the blowby flowrate and correct the value to standard conditions (38°C, 100 kPa) using the formula;

$F_C = F_A\,(3.11 * P_{baro} / (T_{Air}+273))$^0.5

where:

F_C = the corrected flow rate, L/min,

F_A = the actual flow rate, L/min,

P_{baro} = the barometric pressure in the measurement area, kPa (absolute),

T_{AIR} = the air temperature in the measurement area, °C.

X2.5.6 *Parameter Logging*

X2.5.6.1 Refer to *Tables X2.13* and 14 for parameter logging information.

X2.5.6.2 Fuel flowrate and exhaust temperature are monitored parameters. Both are good indicators of proper engine operation. Their typical uncontrolled ranges are given in *Table X2.15*.

X2.5.7 *Oil Level and Consumption:*

X2.5.7.1 *General*—Carry out oil level measurements at intervals of 24 h to insure the appropriate oil quantity is still in the engine. If the oil level is below the 4200 g dipstick mark, at any point before the EOT oil level, contact the test engineer to discontinue test due to insufficient oil quantity.

X2.5.7.2 *Sampling: only sample oil at EOT*

X2.5.7.3 *Oil Level Measurement:*

a) Shut-down the engine according to shutdown procedure (X2.5.*4.1* scheduled shutdown or X2.5.*4.3* unscheduled shutdown).

b) Record the dipstick level in millimeters 20 min ± 2 min after the engine is shutdown.

X2.5.7.4 *Oil Dipstick Calibration*

a) For the first run on a new engine after the break in and flushes are complete (X2.5.1.12). Measure out 4200 g of new test oil, use a portion to prime a new oil filter and install it on the engine.

b) Start the engine as described in X2.5.2.1, run at idle for 5 min, and perform oil level measurement (X2.5.7.3)

c) Mark the dipstick at this millimeter point to show 4200 g level for this engine.

d) Measure out 400 g of new test oil and add test oil to the engine for a total charge of 4600 g.

e) Start the engine as described in X2.5.2.1, run at idle for 5 min, and perform oil level measurement (X2.5.7.3).

f) Mark the dipstick at this millimeter point to show the 4600 g level for this engine.

g) The dipstick for this engine is now calibrated. This dipstick must remain with this engine for any subsequent aging procedures run on this engine. When this engine is removed from service a new dipstick calibration must be performed for the new engine.

h) Dipstick calibration time will not be counted as test time.

X2.5.7.5 Restart the engine as described in X2.5.*2.2* and proceed with running the aging cycle.

X2.5.8 *General Maintenance:*

X2.5.8.1 The scheduled shutdown periods of 30 min during oil leveling provide (limited) opportunity for engine and stand maintenance.

X2.5.8.2 In addition, the test can be shutdown at any convenient time to perform unscheduled maintenance. However, minimize the duration of such a shutdown. Report any unscheduled shutdown on the Supplemental Operational Data Sheet.

X2.5.9 *Special Maintenance Procedures*

X2.5.9.1 *General*—Functions that require special maintenance procedures are listed in this section. These maintenance procedures are specifically detailed because of their effect on test validity or because they require special care while being completed.

TABLE X2.13 Parameter Logging

	TEST POINT	UNITS
Controlled	Engine speed	r/min
	Engine torque	N•m
	Coolant-out temperature	ºC
	Oil-gallery temperature	ºC
	Air-charge temperature	ºC
	Inlet-air temperature	ºC
	Inlet-air pressure (gauge)	kPa
	Exhaust back pressure (absolute)	kPa
	Fuel temperature	ºC
	Humidity	g/kg
Monitored	Fuel flowrate	kg/h
	Manifold absolute pressure (MAP)	kPa
	Boost pressure (absolute)	kPa
	Barometric pressure (absolute)	kPa
	Oil-gallery pressure (gauge)	kPa
	Oil-head pressure (gauge)	kPa
	Oil-filter-in temperature	ºC
	Exhaust temperature	ºC
	Crankcase pressure (gauge)	kPa
	Fuel pressure (gauge)	kPa
	Power	kW
	Pre-intercooler air pressure (absolute)	kPa
	Ambient temperature	ºC
	Coolant-In temperature	ºC
	Coolant pressure (gauge)	kPa
	Coolant flowrate	L/m
	Lambda (λ)	unitless
PCM CAN BUS Channels	Ignition timing advance for #1 cylinder	° CA
	Absolute throttle position	%
	Engine-coolant temperature	ºC
	Inlet-air temperature	ºC
	Equivalence ratio (lambda)	unitless
	Absolute torque value	%
	Intake-manifold absolute pressure	kPa
	Fuel-rail pressure (gauge)	kPa
	Accelerator pedal position	%
	Boost absolute pressure - raw value	kPa
	Turbocharger waste gate duty cycle	%
	Actual Intake (A) camshaft position	°
	Actual exhaust (B) camshaft position	°
	Intake (A) camshaft position actuator duty cycle	%
	Exhaust (B) camshaft position actuator duty cycle	%
	Charge air cooler temperature	º C

Table X2.14 PCM Quantity Logging Information

Mode	PID Number (Hex)	Parameter Description	Type	Bytes	Scale	Offset	Minimum	Maximum	Units
1	47	Absolute Throttle Position B	Unsingned Numeric	1	0.392156863	0	0	100	%
1	0E	Ignition Timing Advance for #1 Cylinder	Unsingned Numeric	1	0.5	-64	-64	63.5	°
1	11	Absolute Throttle Position	Unsingned Numeric	1	0.392156863	0	0	100	%
1	5	Engine Coolant Temperature	Unsingned Numeric	1	1	-40	-40	215	˚C
1	0F	Intake Air Temperature	Unsingned Numeric	1	1	-40	-40	215	˚C
1	34	Equivalence Ratio (Lambda)	Unsingned Numeric	2	3.0518E-05	0	0	2	undefined/not used
1	43	Absolute Load Value	Unsingned Numeric	2	0.392156863	0	0	25700	%
1	0B	Intake Manifold Absolute Pressure	Unsingned Numeric	1	1	0	0	255	kPa
22	318	Actual Intake (A) Camshaft Position Bank 1	Signed Numeric	2	0.0625	0	-2048	2047.9375	°
22	319	Actual Intake (B) Camshaft Position Bank 1	Signed Numeric	2	0.0625	0	-2048	2047.9375	°
22	461	Charge Air Cooler Temperature Bank 1 Sensor 1- Raw	Signed Numeric	2	0.015625	0	-512	511.984375	˚C

Table X2.15 Typical Uncontrolled Ranges for Fuel Flowrate and Exhaust Temperature

Quantity, unit	Stage 2
Fuel flowrate, kg/h	8.0 to 8.5
Exhaust temperature, °C	640 to 680

X2.5.9.2 Check the oil level before performing any maintenance requiring removal of the front cover or rear seal housing to determine if the oil level is above the pan rail.

a) Use a clean container to catch the oil removed from the pan.

b) Before restarting the test, return the oil to the engine after the maintenance is completed.

X2.5.10 *Blowby Flowrate Adjustment:*

X2.5.10.1 The average blowby flowrate for the readings from 24 to 72 h of the test shall fall within the range 65 L/min to 75 L/min as listed in *Table X2.11*

X2.5.10.2 A blowby adjustment can only be carried out anytime during the test at the laboratory's discretion. However, only one blowby adjustment is allowed.

X2.5.10.3 The blowby measurement taken after break in (3.5 h to 3.75 h) provides a good indication how the blowby will perform for the rest of the test. Typically a blowby flowrate greater than 70 L/min will provide the necessary blowby flowrate for the remainder of the test to achieve an average blowby flowrate of 65 to 75 L/min

a) Adjust the blowby by changing the ring gaps or replacing piston rings, if necessary.

b) Ring gaps shown in *Table X2.12* typically produce the blowby flowrate values less than 70 L/min. However, these gaps can be adjusted as necessary to achieve the correct blowby level.

c) Use the ring cutting procedure outlined in X2.3.*17.2.(a)* to adjust the ring gap.

X2.5.10.4 *High Blowby Flowrate Adjustment*—Reduce high blowby flowrate by replacing the compression rings with new rings that have smaller ring gaps. Ensure that the ring-gap stagger remains at 0.127 mm ± 0.0254mm (0.005 in. ± 0.001in.)

X2.5.10.5 *Low Blowby Flowrate Adjustment*—Increase low blowby flowrate by increasing the ring gaps of the compression rings. Measure ring gaps to determine existing ring gaps and ring gap stagger. Maintain the same ring-gap stagger.

X2.5.11 *Engine Disassembly and Reassembly for Maintenance (Before End of Test):*

X2.5.11.1 *Engine Assembly and Disassembly*—Adhere to the procedures in section *X2.3.9*

a) When the engine is disassembled for maintenance, drain as much test oil as possible from the oil pan into a clean container, and retain that oil for installation in the engine after reassembly.

b) Take precautions to ensure the oil is not contaminated and that deposits are not disturbed on any parts.

c) Place all parts in or over clean drain pans to collect oil that drains off while maintenance is being performed.

d) Place the timing chain in a separate container to prevent it from getting contaminated.

X2.5.11.2 *Engine Reassembly:*

a) During reassembly, lubricate the engine parts with used drained test oil.

b) Do not use EF-411 oil or new test oil to lubricate parts during engine reassembly.

c) After the engine has been reassembled, reinstall the used test oil removed from the oil pan and collected from the engine parts during disassembly and maintenance.

d) Do not add any new test oil to the pan.

TABLE X2.16 Recommended Blowby Readings

Test Hours	Recommended average blowby reading, L/min
1.5	≈68-77
3.5 to 3.75	≈76
23.5 to 23.75	≈76
47.5 to 47.75	65 to 75
71.5 to 71.75	65 to 75

TABLE X2.17, Suggested Piston Ring Gaps

Top piston ring gap	See Sec. X2.3.17.1.(b)
2nd piston ring gap	See Sec. X2.3.17.1.(b)

X2.5.12 *EOT Oil Drain*

X2.5.12.1 It is essential to obtain 4200 grams of aged oil from the EOT drain of the aging test; this is the initial test charge for the LSPI test. Oil can be retrieved from using the following three methods.

a) *Standard oil drain*

1) Drain the engine's oil from the lower of the two drain ports on the oil pan into a clean container. Rotate the engine as necessary.

b) *Oil filter oil retrieval*

1) Remove the oil filter. Drain the filter into a clean container. Do not crush the filter element, as this could contaminate the oil drain

c) *Vacuum method*

1) Fashion the device as shown in Fig X2.29.

2) Ensure the empty canister is clean. Attach the rubber hose using a clamp to the oil filter threaded nipple area (where the oil filter was removed). Apply an air hose to the air quick disconnect located on the canister pipe lid. While applying air pressure, oil will be extracted from the oil cavities and deposited in the canister. Once the oil stops flowing, disconnect the air pressure and remove the canister lid to retrieve the oil.

X2.5.13 With the oil drain, conduct a Sequence IX test with the following exceptions:

X2.5.13.1 Use the new, unaged oil for the flushes in Section 11 of D8291 (this method)

X2.5.13.2 Follow the remaining sections of D8291 for conducting the sequence IX test on the oil aged in accordance with this Appendix.

X2.5.13.3 Report Sequence IX test results on the Aged oil on the report forms described in X2.8.1.

X2.6. Diagnostic Data Review, Oil Aging

X2.6.1 *General*—The PCM quantities listed in this section can directly influence the test results or can be used to indicate normalcy of other quantities. This section outlines significant characteristics of specific engine operating quantities.

X2.6.2 *Engine Torque:*

X2.6.2.1 Engine torque, which is controlled should remain relatively constant throughout a test and from test-to-test. Large differences in engine torque could be indicative of control or engine problems.

X2.6.3 *Fuel-Consumption Rate:*

X2.6.3.1 Although fuel-consumption rate is not a specifically controlled parameter it is used as a diagnostics tool and should remain relatively constant throughout the test.

X2.6.4 *Exhaust Gas Component Levels:*

X2.6.4.1 *General*—The lambda (λ) value in the exhaust gas determines the characteristics of combustion that occur during the test and can be used to determine the normalcy of combustion and any significant changes in combustion that occur throughout a particular test.

b) Lambda is controlled by the program in the PCM. No adjustments can be made to change the exhaust-gas lambda.

c) If the lambda value differs from that given in X2.11, check the PCM and test-cell control system. Correcting a fault in the PCM and test-cell control system is the only way to achieve the correct lambda value.

X2.6.5 *Crankcase Pressure:*

X2.6.5.1 *General*—Crankcase pressure is a function of blowby flowrate and PCV-valve flowrate.

X2.6.5.2 High crankcase pressure is usually caused by high-blowby flowrate or a significant loss of PCV-valve flowrate. Incorrect three-way valve plumbing or port plugging also promotes high-crankcase pressure.

X2.6.5.3 Low- or negative-crankcase pressure might be caused by low-blowby flowrate or a restriction of vent air to the PCV valve.

X2.6.6 *Oil Pressure:*

X2.6.6.1 *General*—The oil pressure is a function of oil viscosity and operating temperature.

X2.6.6.2 The oil pressure should remain consistent throughout the test, unless the oil exhibits a significant change in viscosity.

X2.6.7 *Oil-Temperature Differential:*

X2.6.7.1 *General*—The oil-temperature differential is primarily a function of oil flowrate and oil viscosity and is normally stable throughout the test. It can change if the oil viscosity changes significantly during the test.

X2.8.8 *Coolant-Temperature Differential:*

X2.6.8.1 *General*—The coolant temperature differential is primarily a function of the coolant flowrate and is normally stable throughout the test.

X2.6.8.2 Large variations in the differential can be caused by coolant flowrate or temperature measurement errors.

X2.7. Test Results

X2.7.1 *Oil Analyses*—Analyze the fresh oil and the EOT sample as follows and report the results on Form 6 of the standardized report form set[21] (Available from the ASTM website, https://www.astmtmc.org)).

X2.7.2.1. *Metals Concentrations*—Using Test Method D5185, determine the mass fraction of the following 15 elements: aluminum, boron, calcium, chromium, copper, iron, lead, manganese, molybdenum, potassium, phosphorus, silicon, sodium, tin and zinc. Report the results in mg/kg.

X2.7.2.2. *Fuel dilution*- Measure by gas chromatography by Test Method D3525. Report in % mass.

X2.7.2.3. *Total Base Number (TBN)*—Measure by Test Method D4739. Report in gKOH/g.

X2.7.2.4. *Total Acid Number (TAN)*— Measure by Test Method D664. Report in gKOH/g.

X2.7.2.5. *Kinematic Viscosity (KV)*—Measure at 40 °C and 100 °C by Test Method D445. Report in mm^2/s

X2.7.2.6. *Soot Concentration*—Measure by thermogravimetric analysis (TGA) by Test Method D5967, Annex A4. Report

in % mass.

X2.72.7. *Oxidation*- Measure by Fourier Transform Infrared Spectroscopy (FT-IR) by Test Method D7414. Report in

$A.cm^{-1}/mm$

X2.7.2.8. *Nitration*- Measure by Fourier Transform Infrared Spectroscopy (FT-IR) by Test Method D7624. Report in Abs/cm

X2.8. Report

X2.8.1 For reference oil results, use the standardized report form set available from the ASTM TMC[21] and data dictionary for reporting test results and for summarizing operational data.

X2.8.1.1 Fill out the report forms according to the formats shown in the data dictionary.

X2.8.1.2 Transmit results to the TMC within 5 working days of test completion.

X2.8.1.3 Transmit the results electronically as described in the ASTM Data Communications Committee Test Report Transmission Model (Section 2 — Flat File Transmission Format) available from the ASTM TMC. Upload files via the TMC's website.

X2.8.2 Report all reference oil test results, whether aborted, invalidated, or successfully completed, to the TMC.

X2.8.3 *Deviations from Test Operational Limits*—Report all deviations from specified test operational limits.

X2.8.4 *Precision of Reported Units*—Use the Practice E29 rounding-off method for critical pass/fail

[21] Available on the ASTM TMC website: www.astmtmc.org

test result data. Report the data to the same precision as indicated in data dictionary.

X2.8.5 In the space provided, note the time, date, test hour, and duration of any shutdown or off-test condition. Document the outcome of all prior reference oil tests from the current calibration sequence that were operationally or statistically invalid.

X2.8.6 If a calibration period is extended beyond the normal calibration period length, make a note in the comment section and attach a written confirmation of the granted extension from the TMC to the test report. List the outcomes of previous runs that may need to be considered as part of the extension in the comment section.

X2.9. Precision and Bias

X2.9.1 *Precision:*

X2.9.1.1 Test precision is established on the basis of operationally valid reference-oil test results monitored by the TMC.

X2.9.1.2 *Intermediate Precision Conditions*—Conditions where test results are obtained with the same test method using the same test oil, with changing conditions such as operators, measuring equipment, test stands, test engines, and time.

NOTE 4—Intermediate precision is the appropriate term for this test method, which defines more rigorous within laboratory conditions.

a) *Intermediate Precision Limit (ip)*—The difference between two results obtained under intermediate precision conditions that in the long run, in the normal and correct conduct of the test method, exceed the value shown in Table X2.18 in only one case in twenty. When only a single test result is available, the intermediate precision limit can be used to calculate a range (test result ± intermediate precision limit) outside of which a second test result would be expected to fall about one time in twenty.

X2.9.1.3 *Reproducibility Conditions*—Conditions where test results are obtained with the same test method using the same test oil in different laboratories with different operators using different equipment.

a) *Reproducibility Limit (R)*—The difference between two results obtained under reproducibility conditions that would, in the long run, in the normal and correct conduct of the test method, exceed the values in Table X2.18 in only one case in twenty. When only a single test result is available, the reproducibility limit can be used to calculate a range (test result ± reproducibility limit) outside of which a second test result would be expected to fall about one time in twenty.

14.2 *Bias*—No estimate of bias for this test method is possible because the performance results for an oil are determined only under specific conditions of the test and no absolute standards exist.

Table X2.18 Test Precision for the Oil Aging Test

Quantity, units	Intermediate Precision		Reproducibility	
	$S_{ip}{}^{D}$	*ip*	$S_R{}^{D}$	*R*
Average Number of Pre-Igintions	0.4406	1.2212	0.4406	1.2212
Maximum Number of Pre-Ignitions	0.4406	1.2212	0.4406	1.2212

15. Keywords

15.1 engine oil; turbocharger,-blowby, oil aging

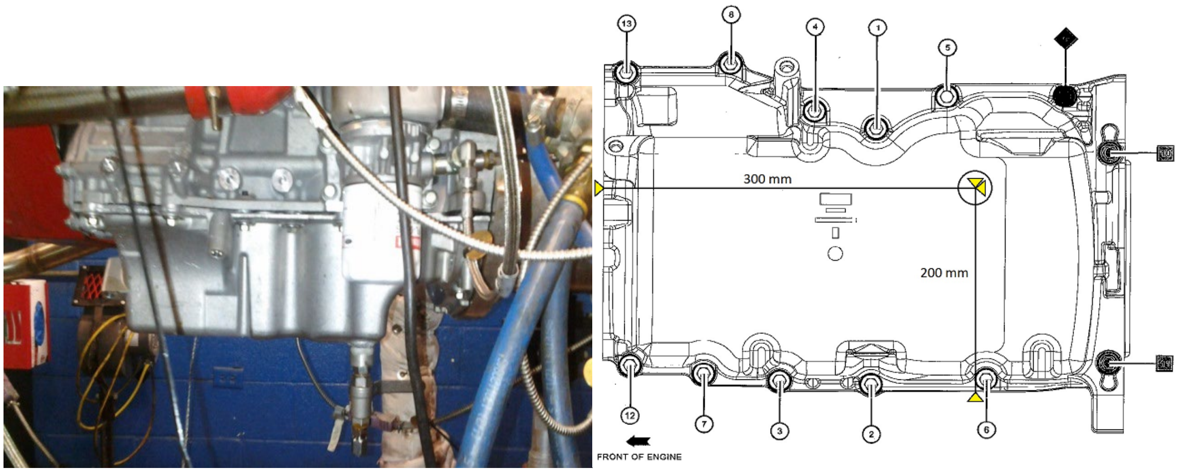


FIG. X2.1A Oil pan additional drain plug location

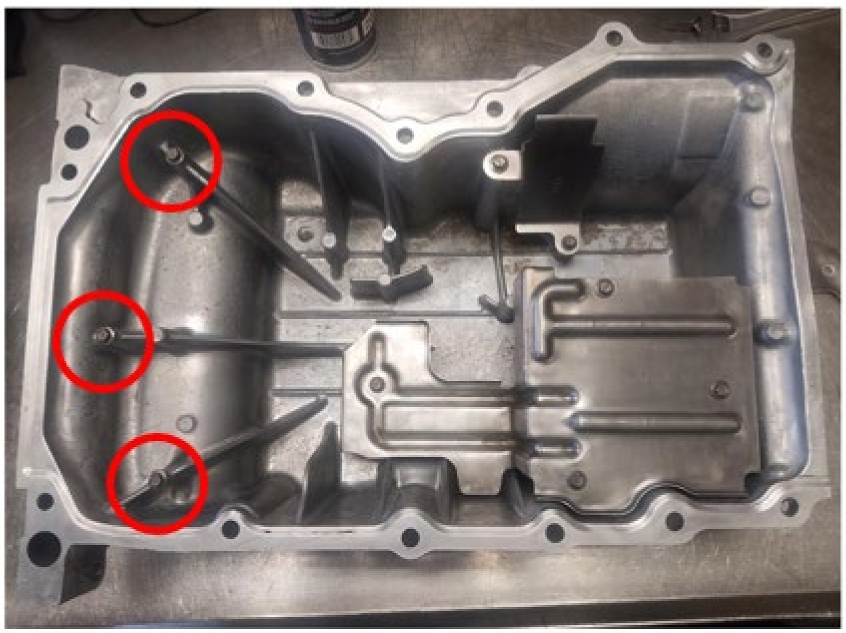
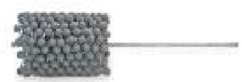


FIG X2.1B Oil pan showing location of three baffles used in the Aging test, and the three screws reinstalled after removal of the “C” shaped baffle (red circles)

<u>Pneumatic Honing Drill (X2.3.2.1)</u>
Brand: Westward
1/2 Reversible Air Drill
Model: 5ZL26G
Speed: 500 r/min
620 kPa (90 psig), max.

FIG. X2.2 Pneumatic Honing Drill



Flexible cylinder hone (see X2.3.2.1).

Flex, Model: GB31232

Bore Diam.: 88.0 mm (3.50 in.)

Abrasive material: Silicon Carbide Grit

FIG. X2.3 Cylinder Hone

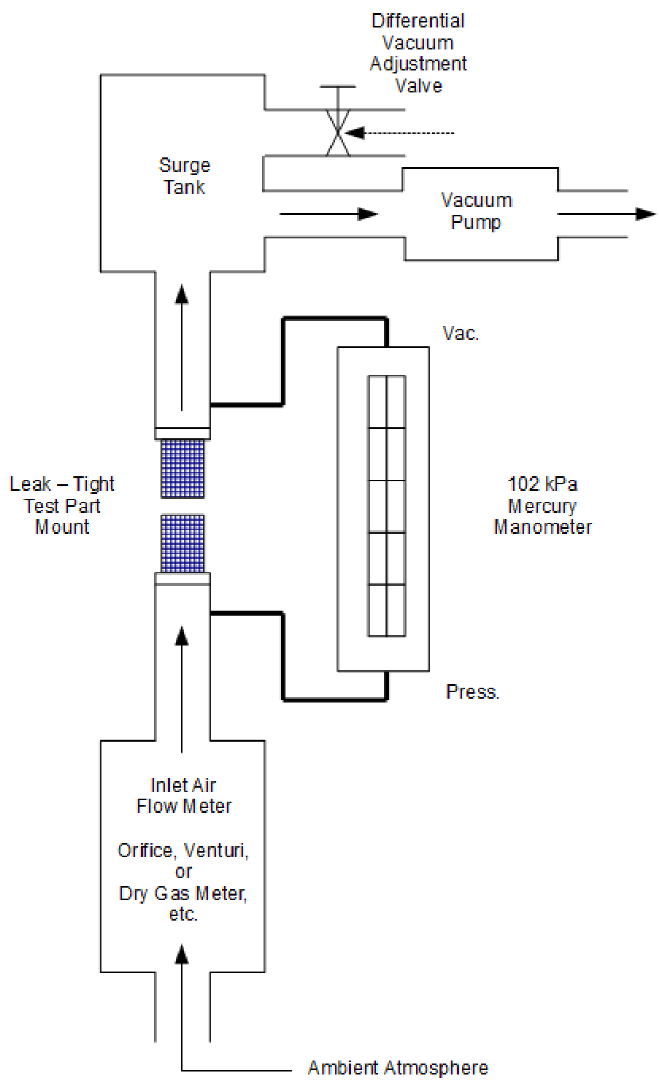


FIG. X2.4 PCV Valve Flow Test Apparatus

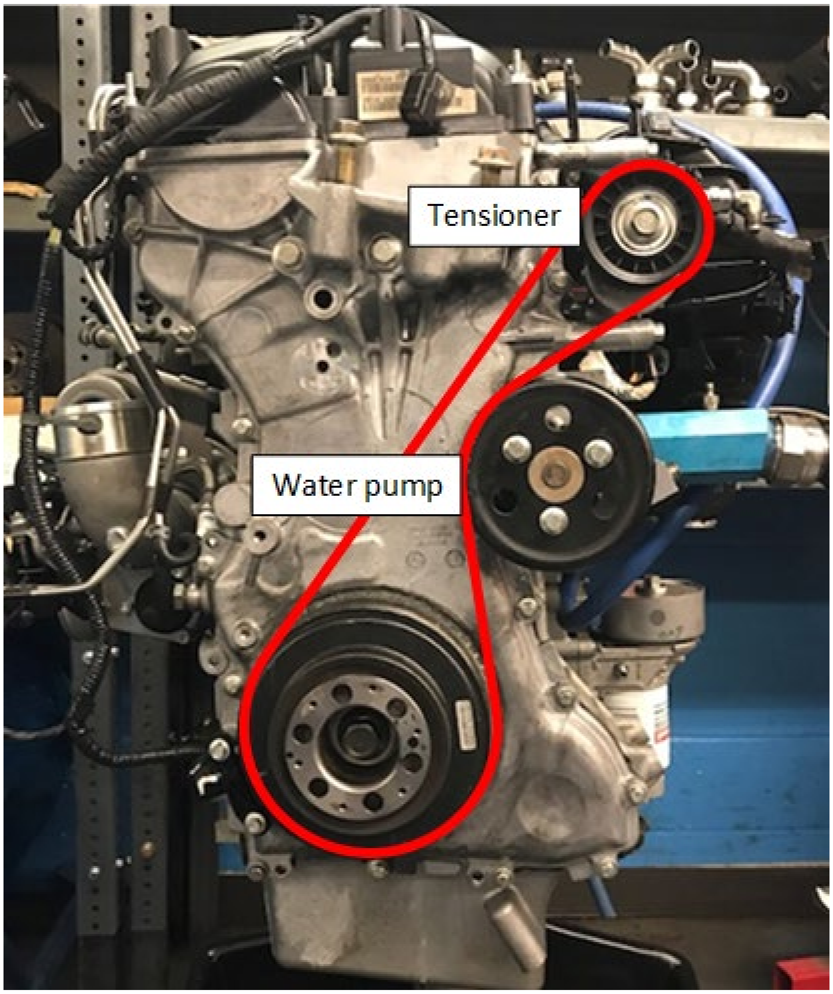


FIG. X2.5 Water-Pump Drive Arrangement

Figs. X2.6 and X2.7 show the piston ring setter and cylinder bore ladder, respectively.

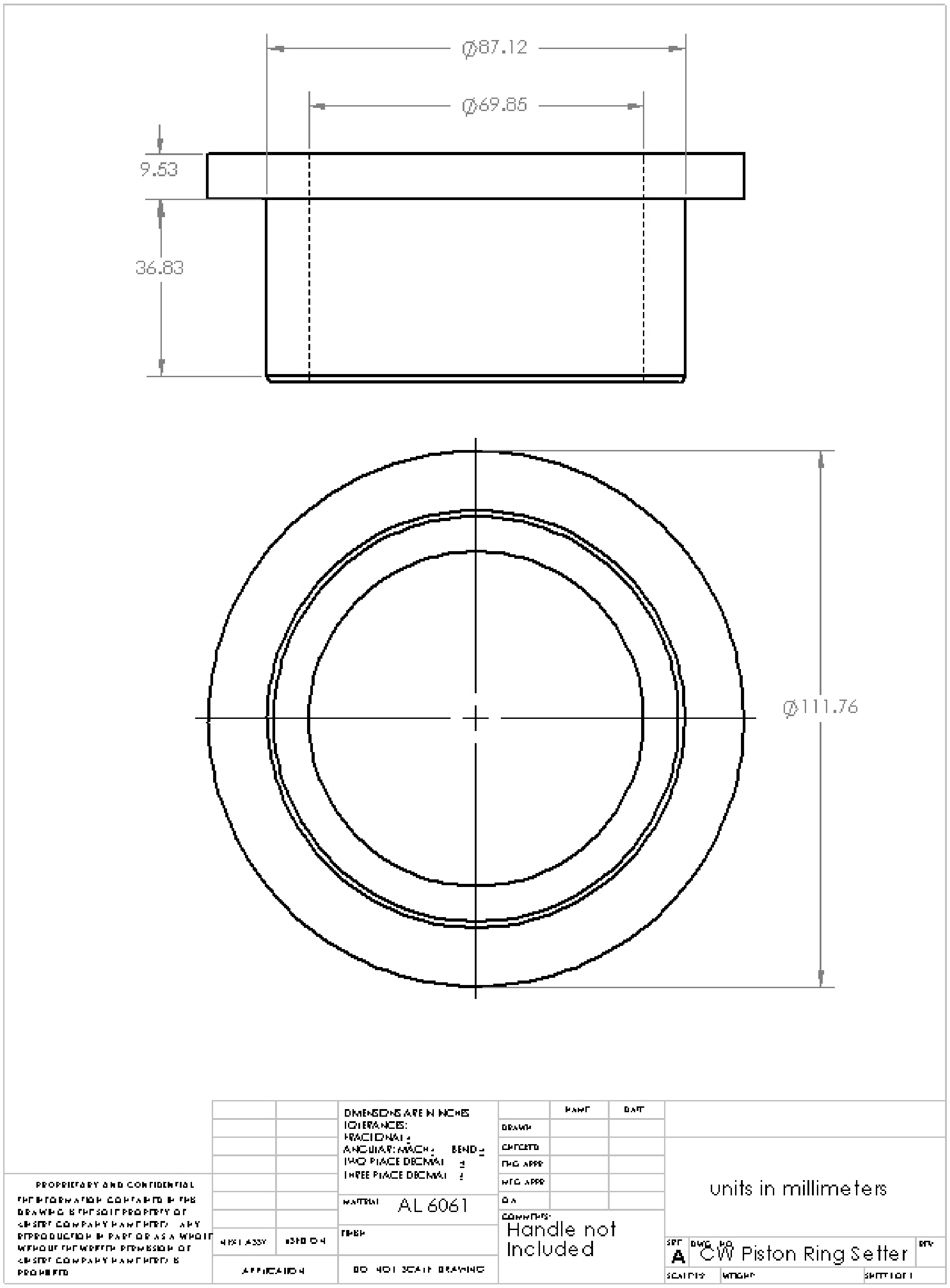


Fig. A7.1 Piston Ring Setter

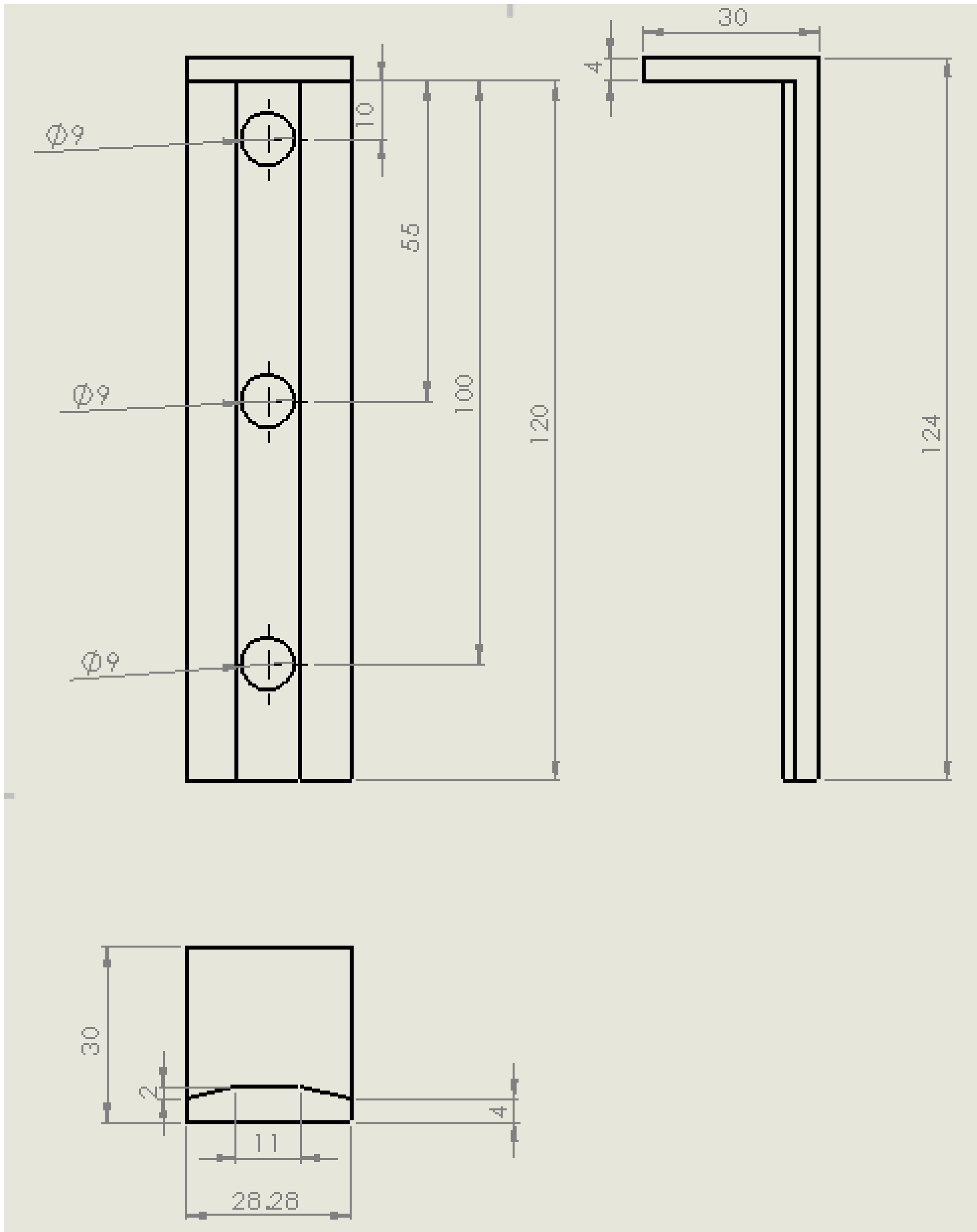


Fig. X2.7 Cylinder Bore Ladder (dimensions are in mm)

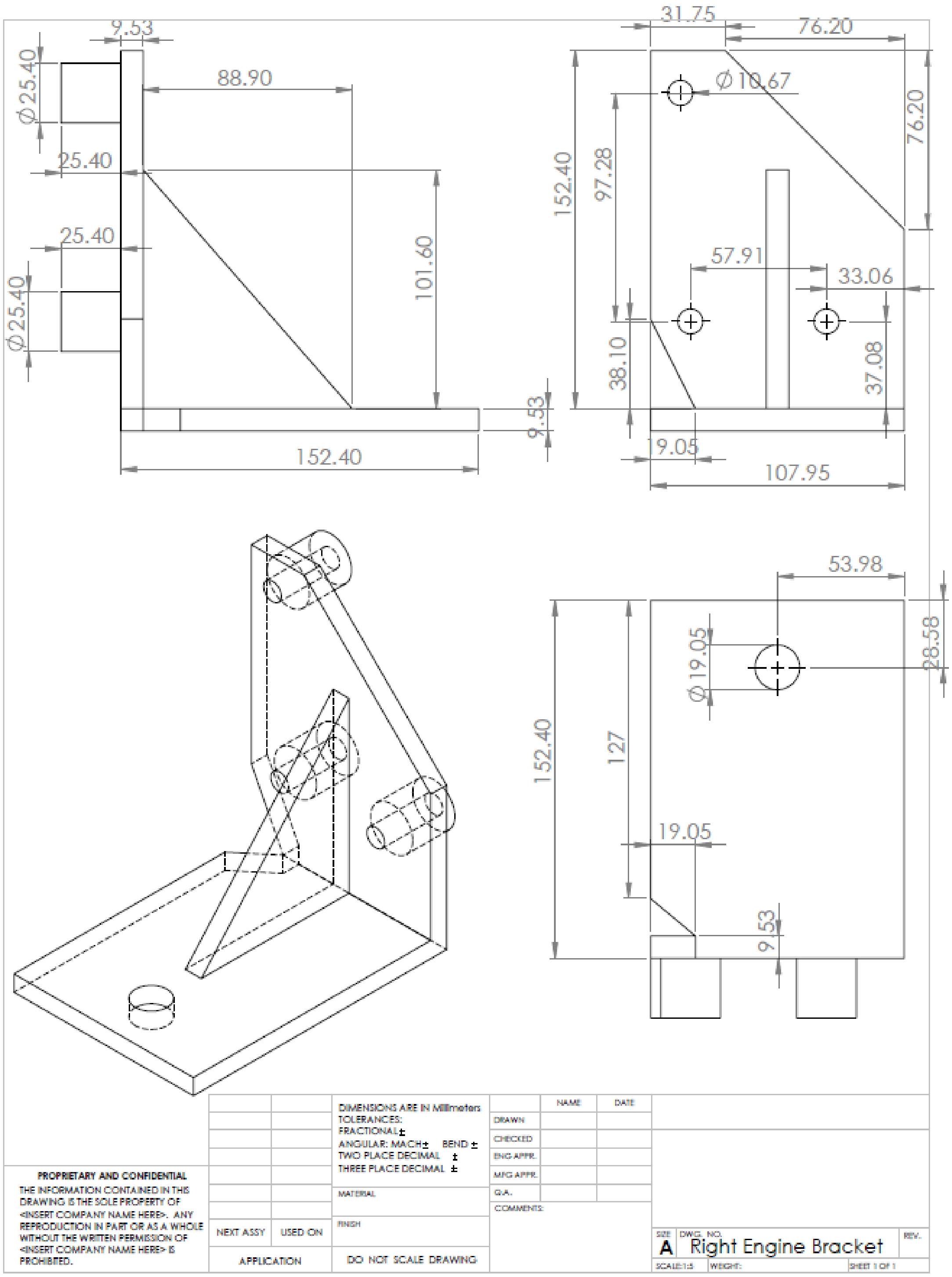


Fig X2.8 Suggested Engine mount Brackets

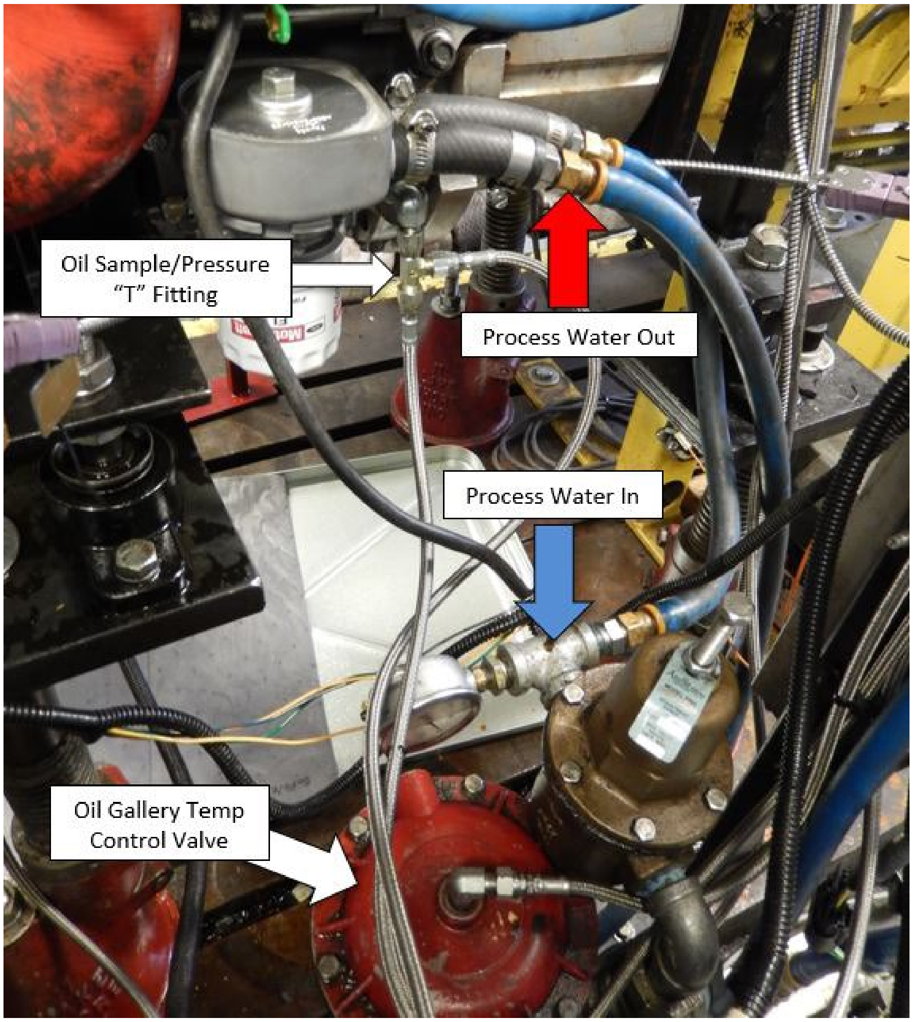


FIG. X2.9 Control System for Oil-Gallery Temperature

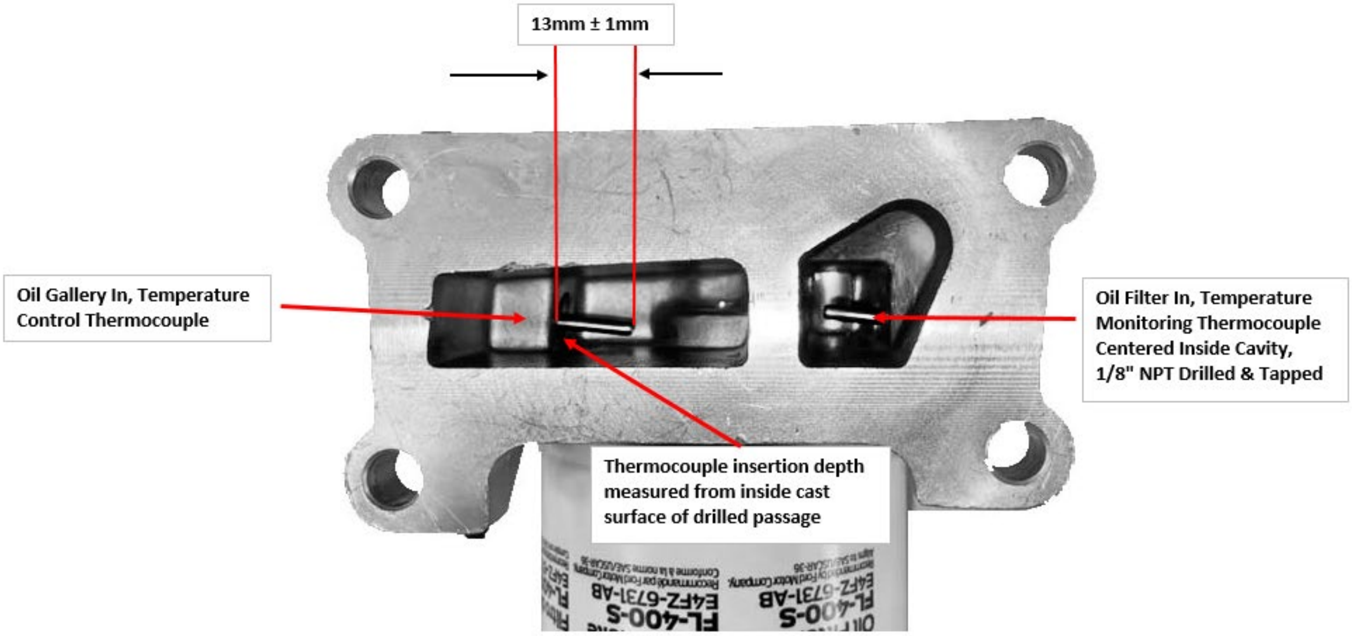


FIG. X2.10 Oil Gallery In "Control Thermocouple" Oil Filter Adaptor Rear View

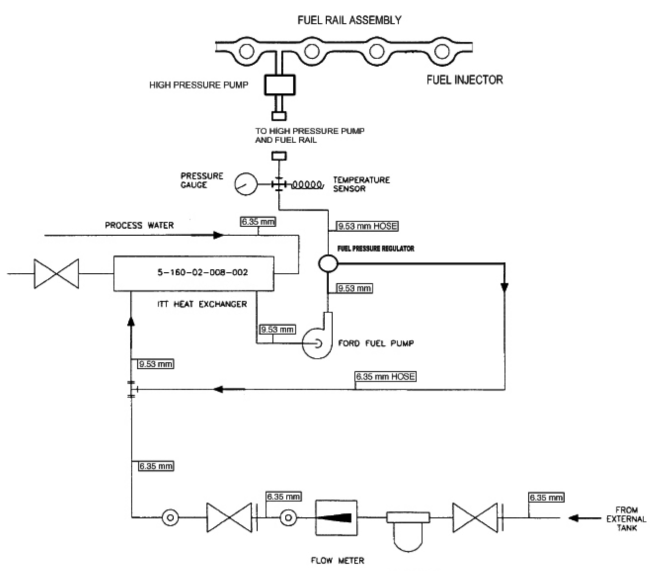


FIG. X2.11 Fuel System Schematic

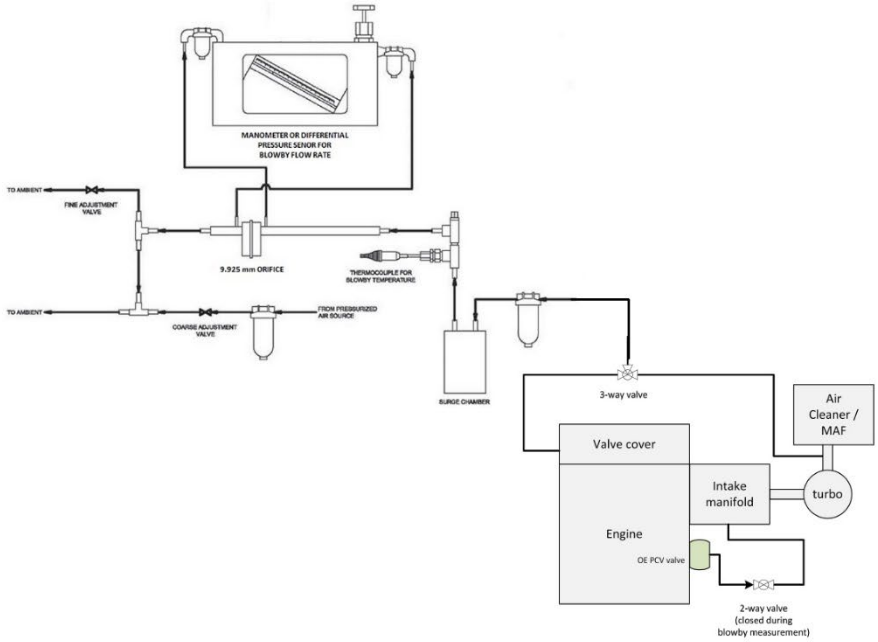


Fig X2.12 Sharp Edged Orifice Blowby Cart Setup for Measuring Blowby Flowrate

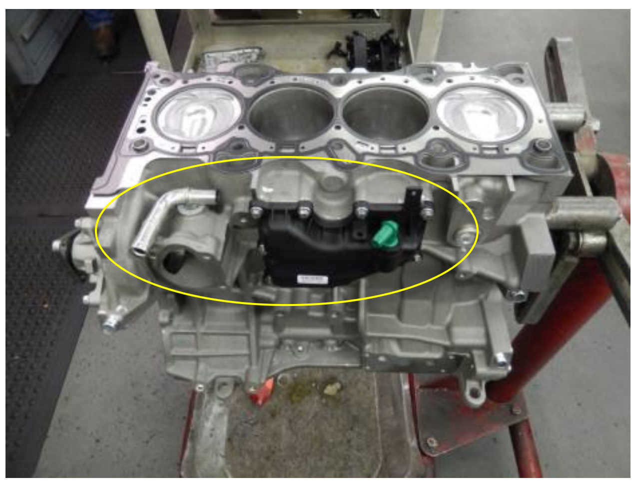


FIG. X2.13 Cylinder Block Heater Hose Tube and Oil Separator

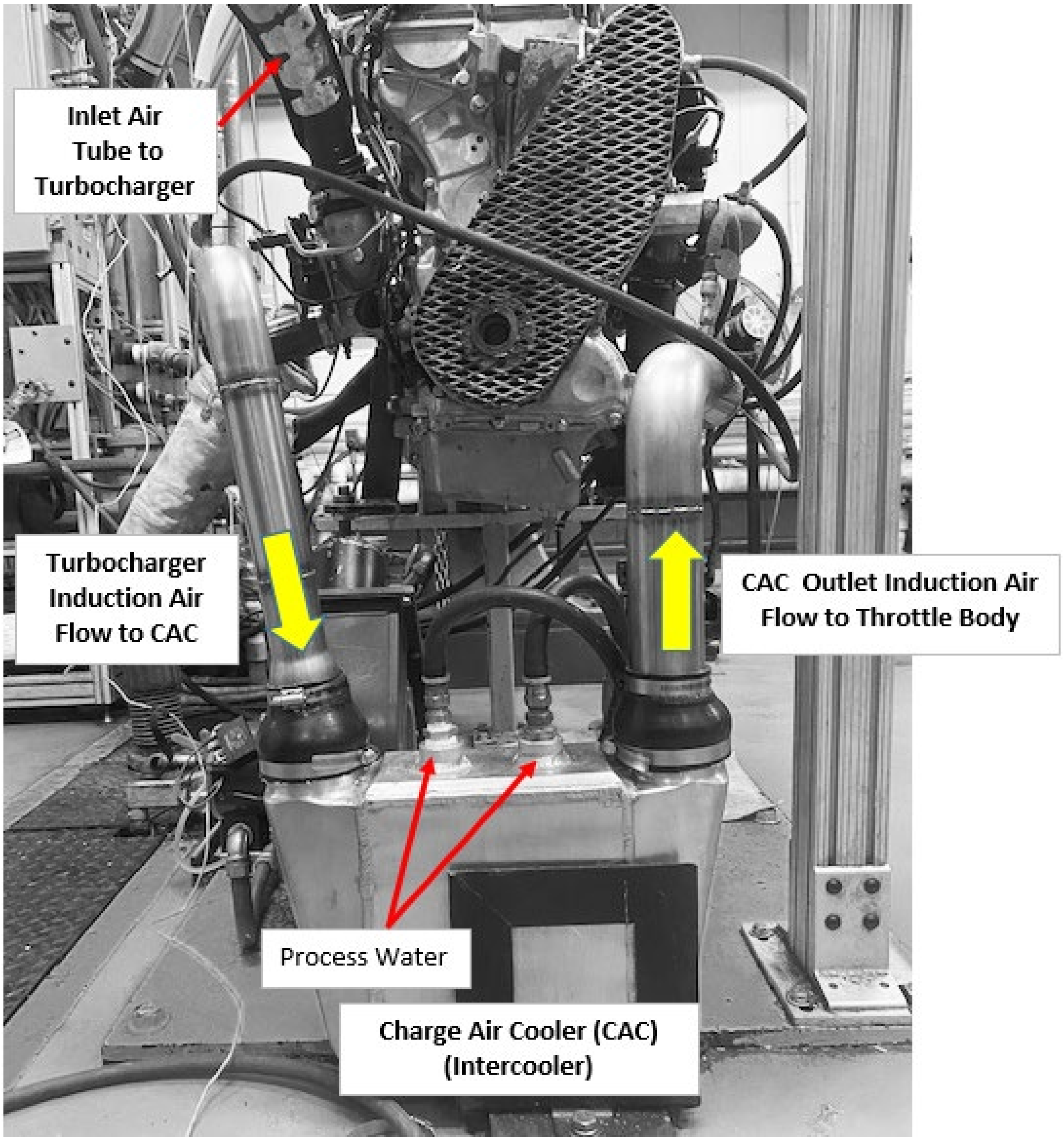


FIG. X2.14 Typical Charge Air Cooler (Intercooler) Installation

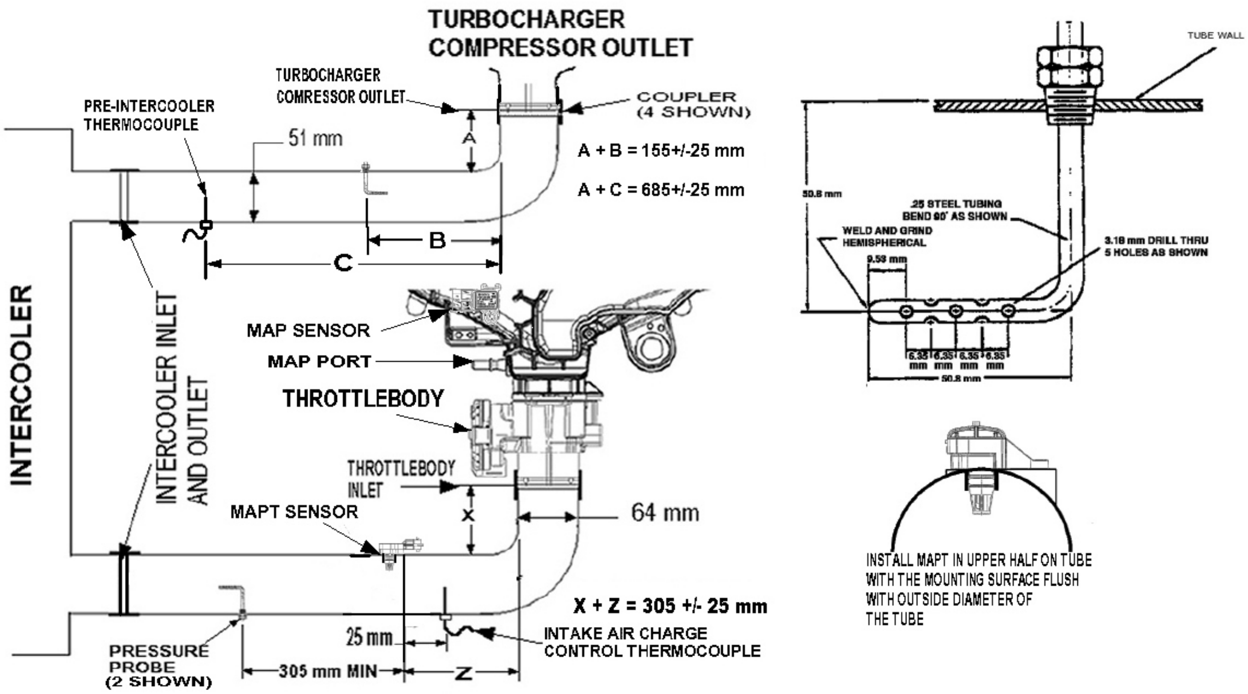
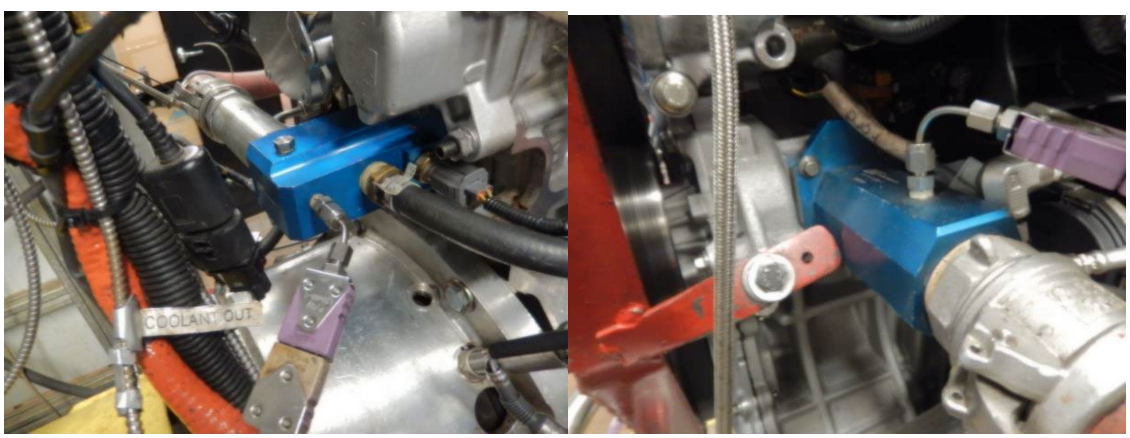
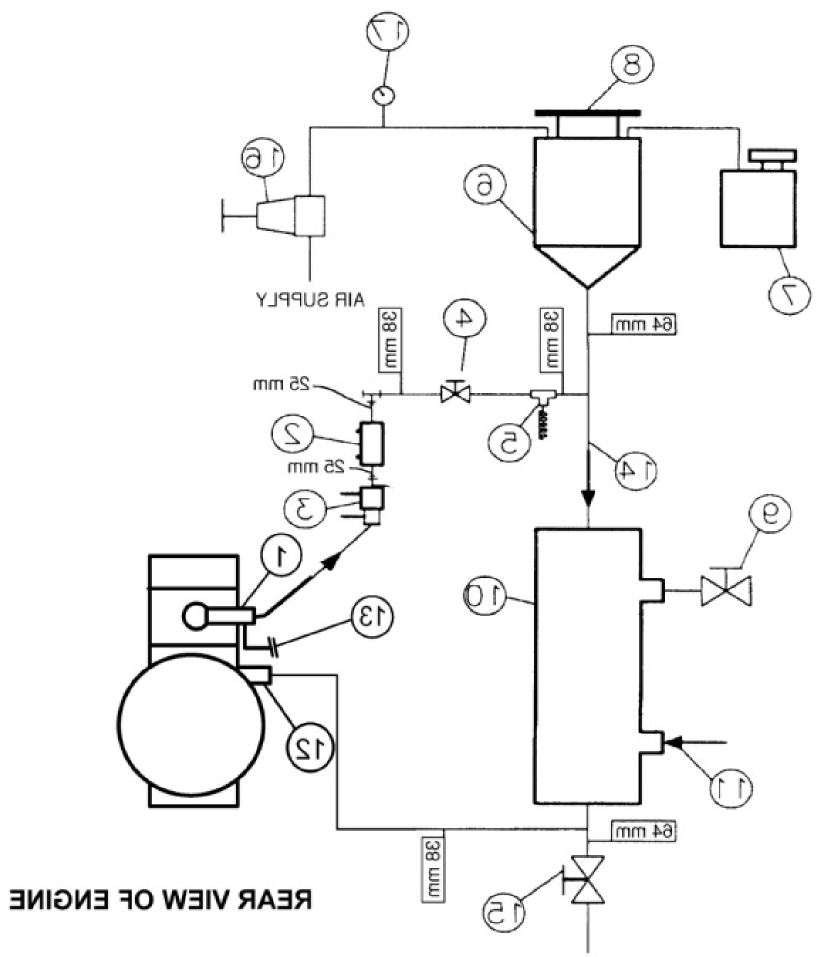


FIG. X2.15: Intercooler Tubing Measurements and Instrumentation



Coolant out Coolant in

FIG. X2.16 Coolant-in and -out connections and thermocouple locations


AIR SUPPLY
38 mm
38 mm
64 mm
25 mm
25 mm
64 mm
38 mm
REAR VIEW OF ENGINE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

The following numbers identify components of the engine cooling system (observe temperature sensor locations in thermostat housing and at water pump inlet):

(1) Thermostat housing, coolant out with temperature sensor (OHTVH-009-1)

(2) Sight glass

(3) Flowmeter

(4) Flow control valve

(5) Optional temperature sensor

(6) Fabricated coolant reservoir

(7) Constant full expansion tank

(8) Pressure radiator cap (MOTORCRAFT RS40 P/N D2YY-8100-A)

(9) Process water control valve (regulated by temperature controller with three remote set points)

(10) Heat exchanger (ITT Standard P/N 5-030-06-048-001 TYP)

(11) Process water supply (shell side)

(12) Water pump inlet with temperature sensor (OHTVH-008-1)

(13) Turbocharger coolant return

(14) Engine coolant (tube side)

(15) Coolant system drain valve

(16) Coolant pressure regulator

(17) Coolant pressure gauge

FIG. X2.17 Typical Engine Cooling System Schematic

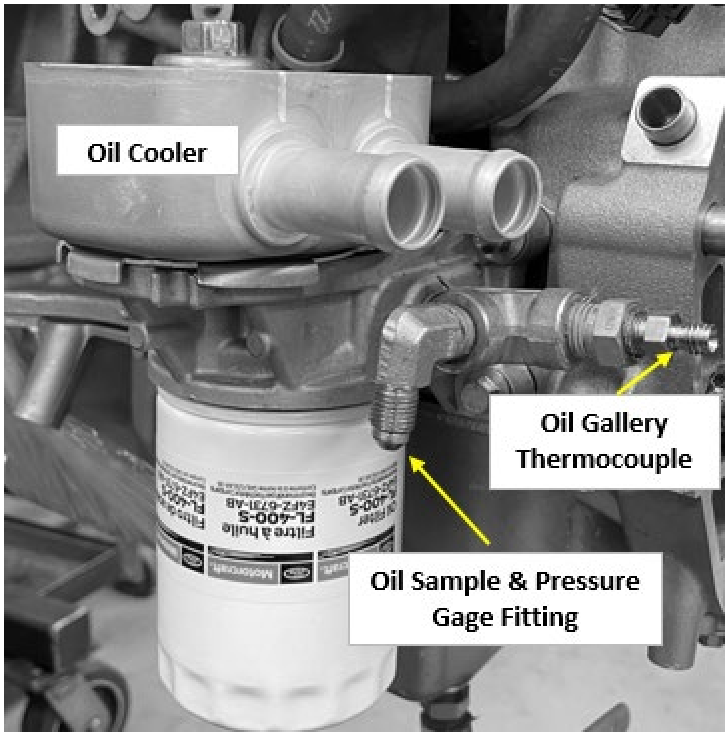


FIG. X2.18 Oil Cooler and Filter Adaptor Showing Temperature and Pressure Measurement Locations

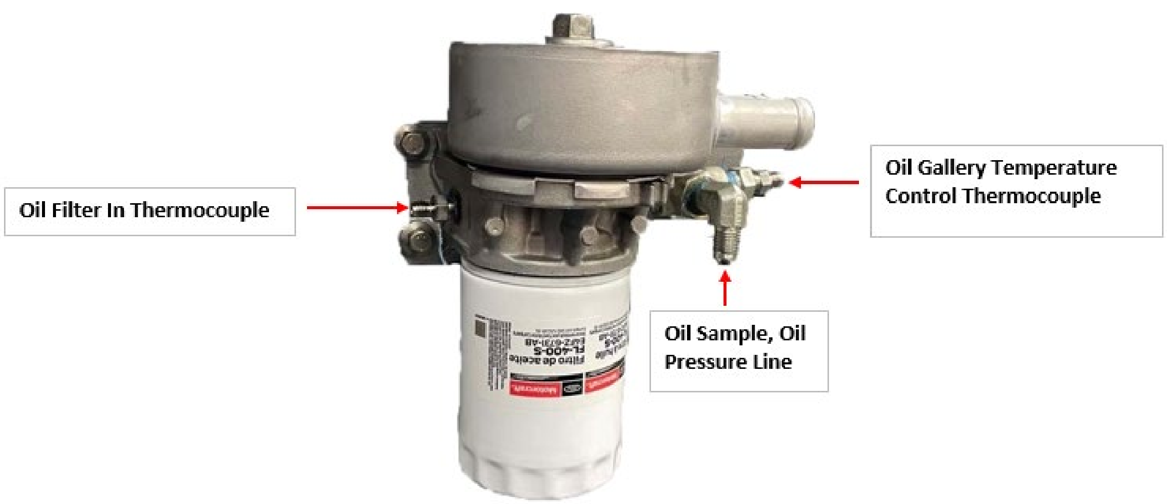


FIG. X2.19 Oil Filter, Cooler, Adaptor Assembly, Thermocouple and Sample Fittings

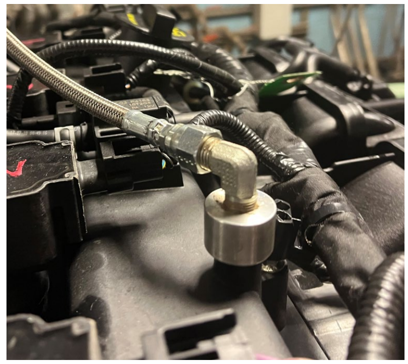


FIG. X2.20 Crankcase Pressure Connection at Dipstick Tube

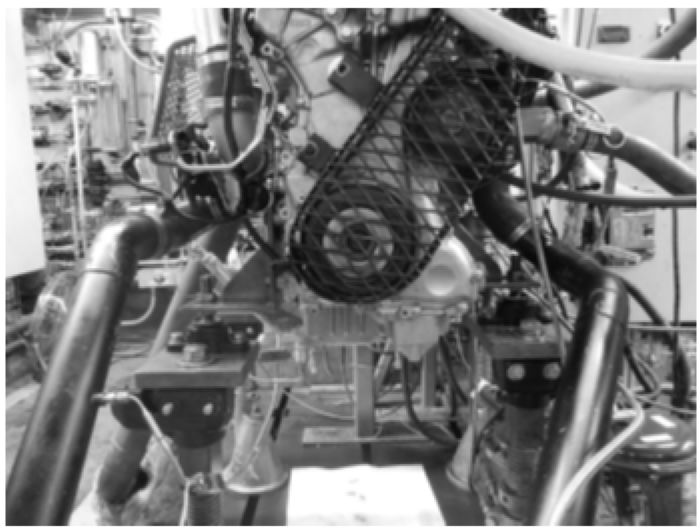


FIG. X2.20 Motor Mounts, Front

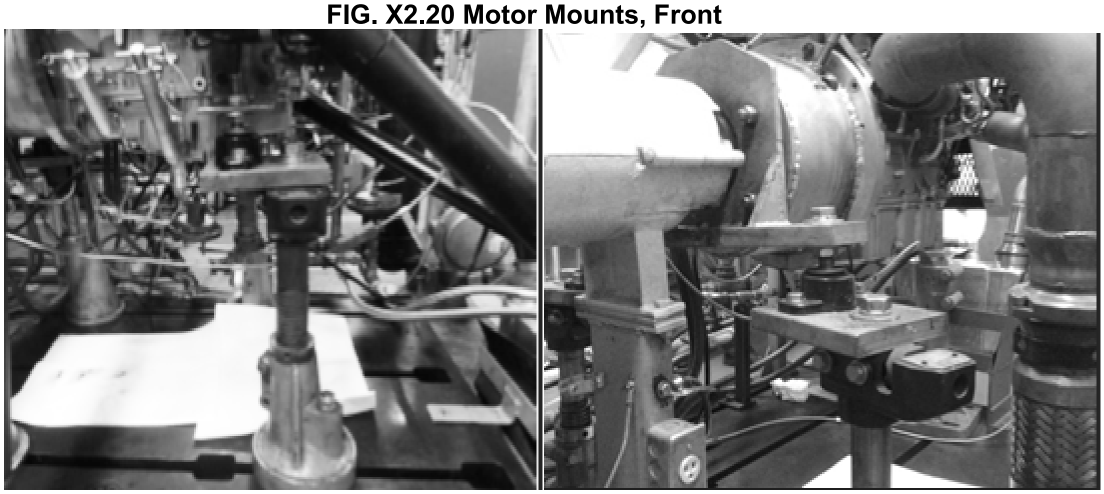


FIG. X2.21 Motor Mounts, Rear

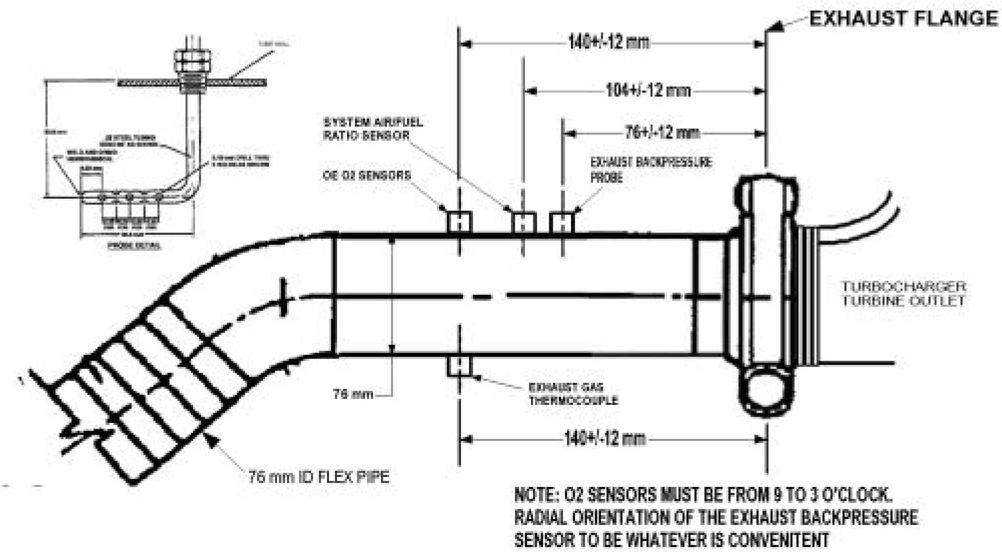


Fig X2.22 Exhaust Measurements and Instrumentation

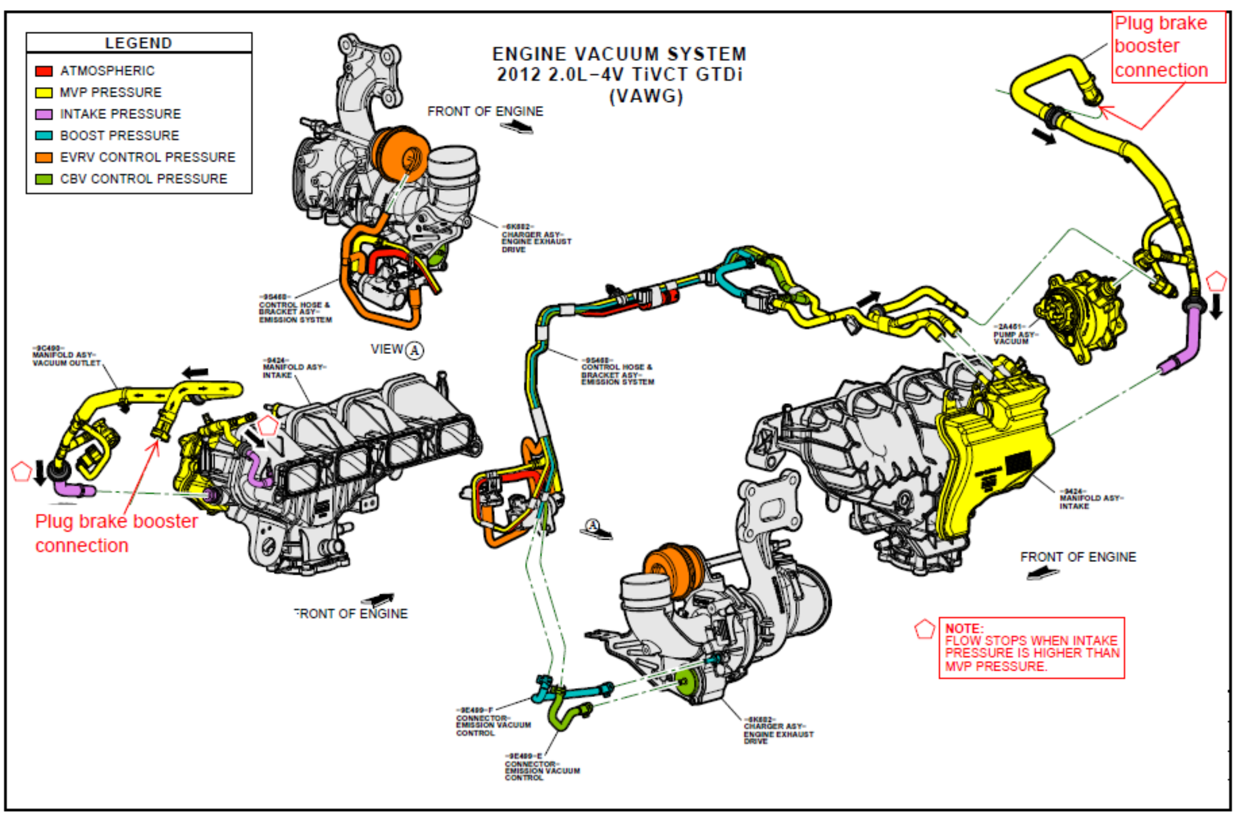


Fig. X2.23 Vacuum System

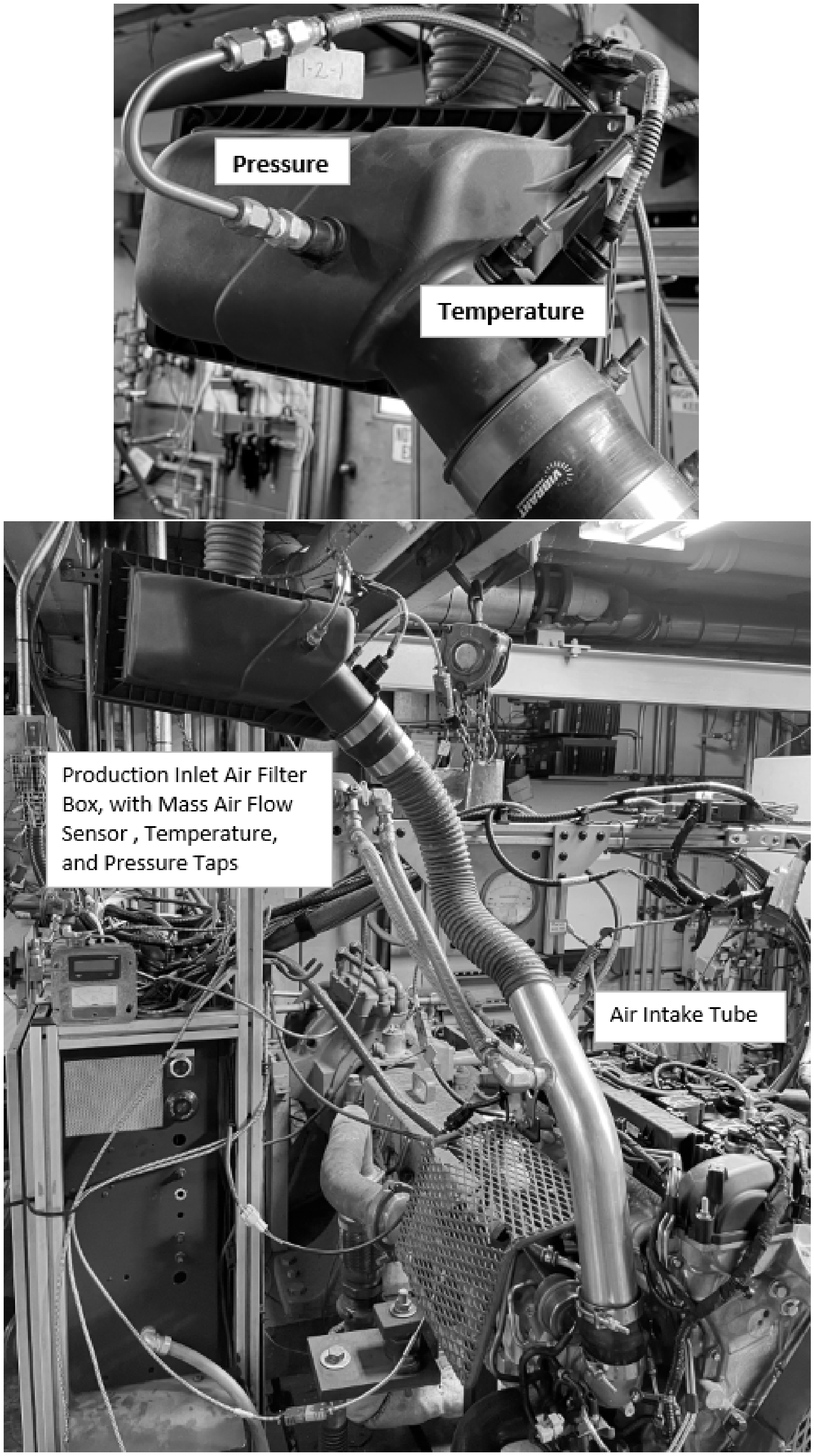


Fig. X2.24 Typical System for Air Intake

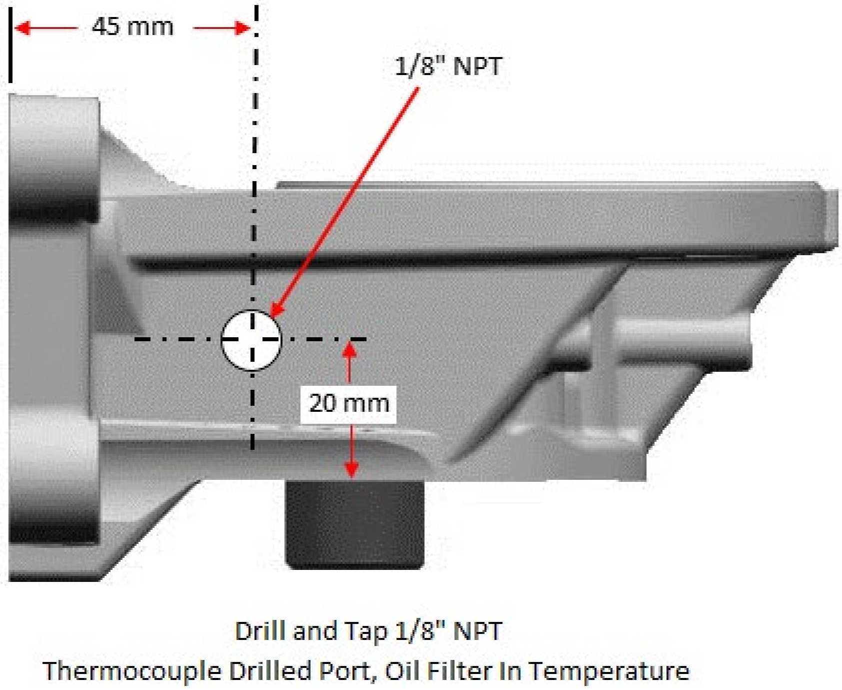


FIG. X2.25 Location of Oil Filter In Thermocouple Fitting

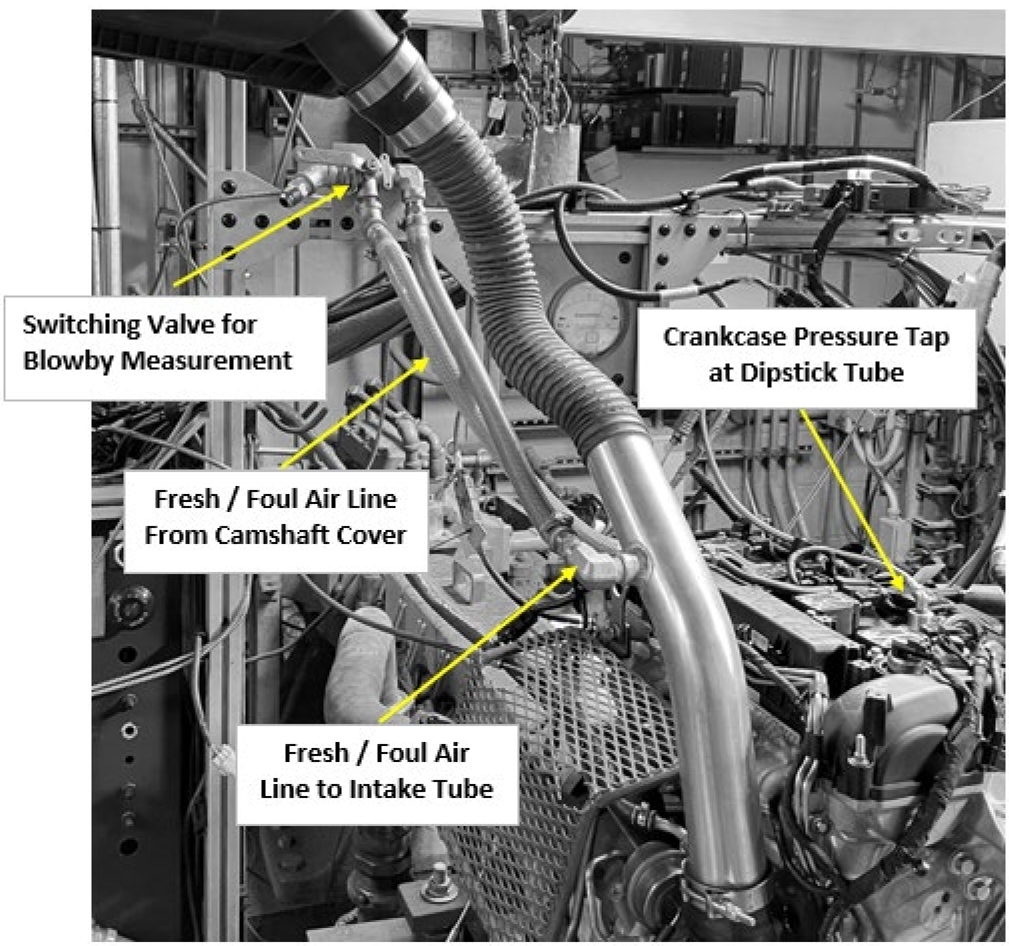


FIG. X2.26 Crankcase Ventilation System Setup

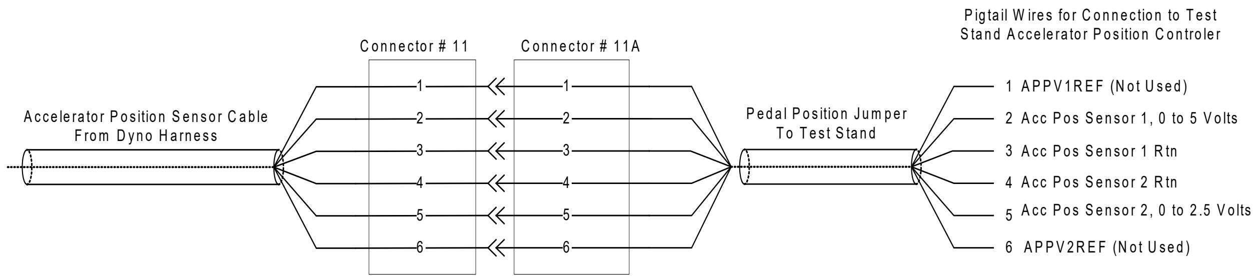


FIG. X2.27 Pedal Wiring

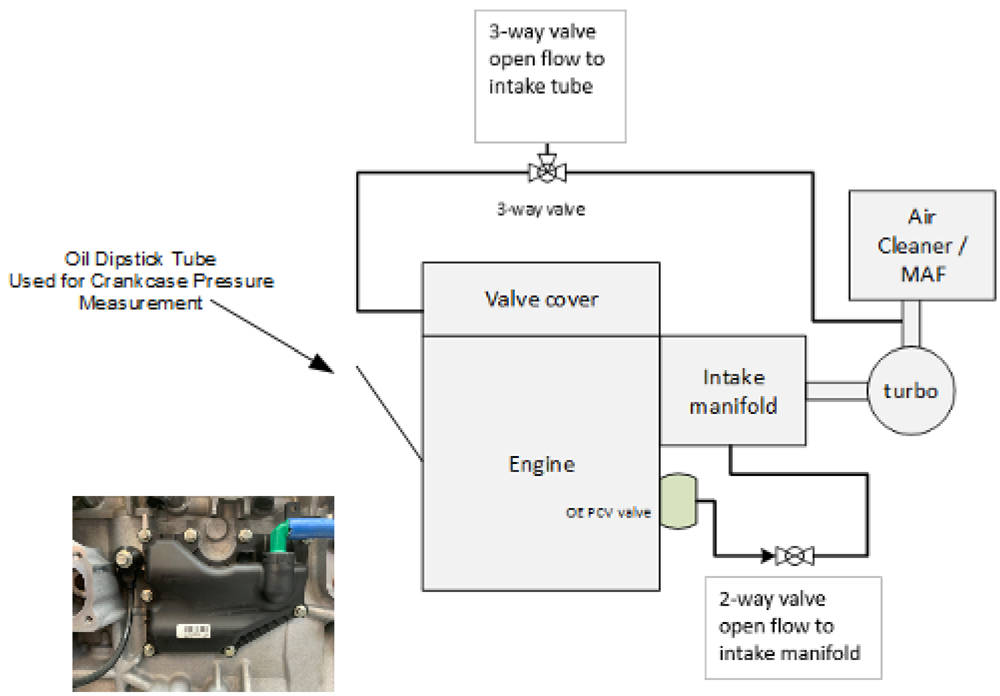


FIG. X2.28 On-Test Crankcase Ventilation System Schematic

Fig. X2.29 Vacuum method of oil retrieval canister

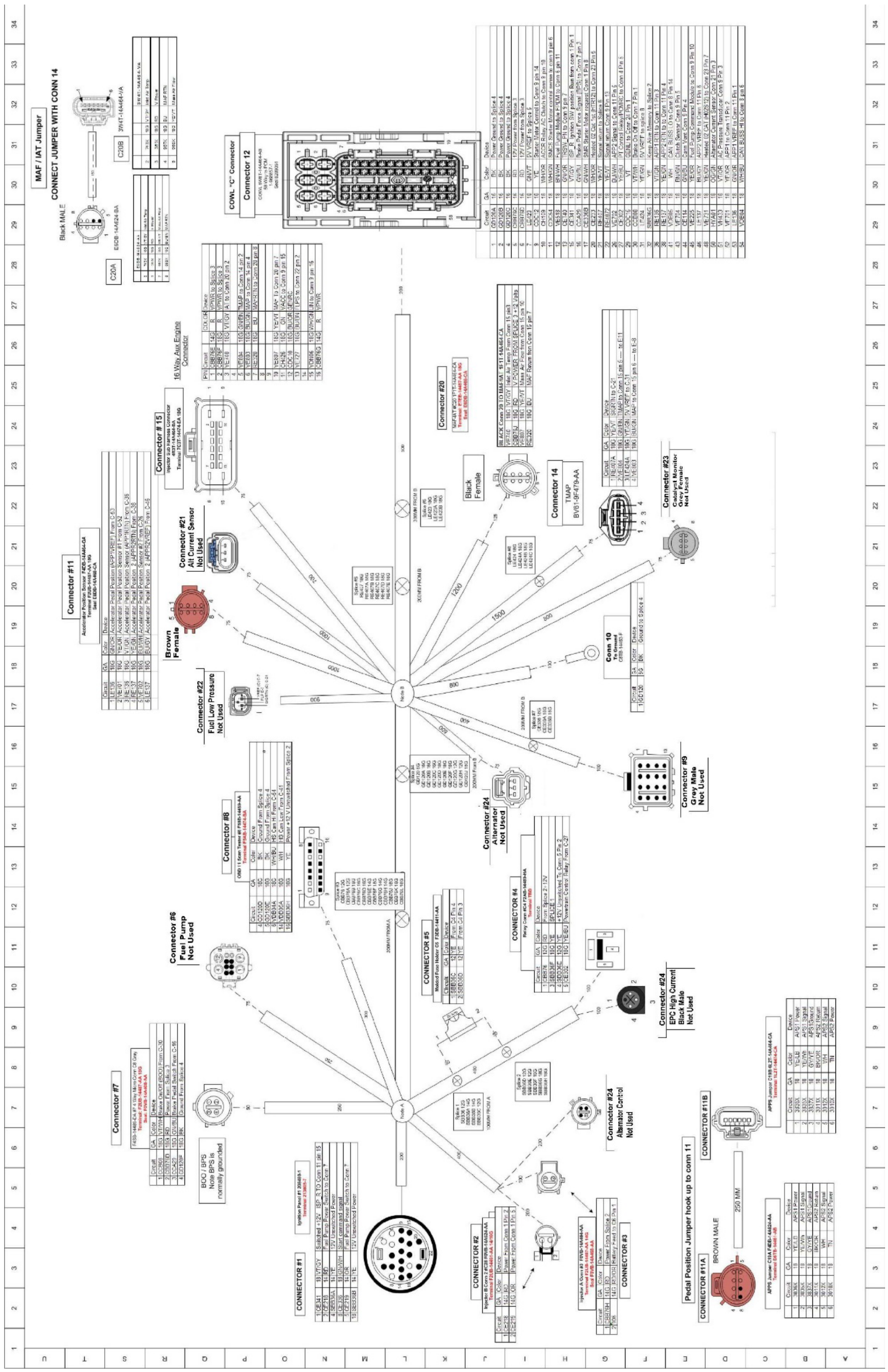
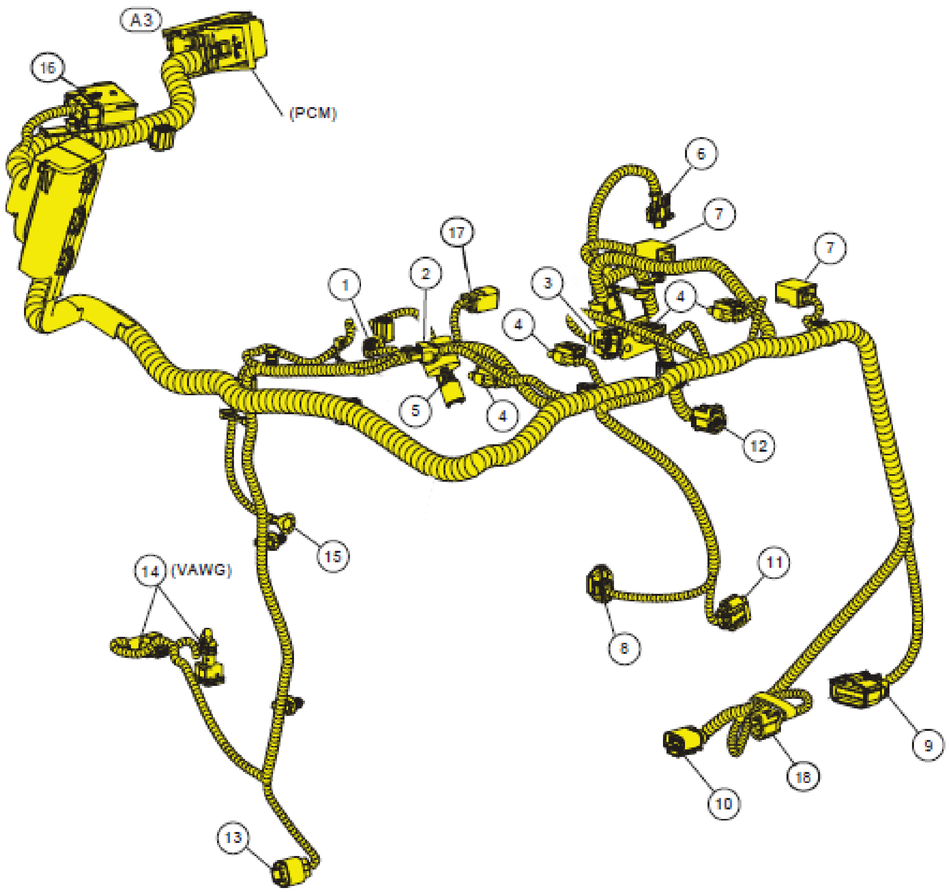


FIG. X2.30 Stand Wiring Harness

WIRING ASY ENGINE



1. TO CAMSHAFT VARIABLE TIMING HOUSING & VALVE ASY (EXHAUST)
2. TO CAMSHAFT VARIABLE TIMING HOUSING & VALVE ASY (INTAKE)
3. TO EMISSIONS SYSTEM CONTROL HOSE & BRACKET ASY / AIR VALVE
4. TO IGNITION COIL & BOOT ASY (4) PLACES
5. TO CYLINDER HEAD TEMP SENSOR ASY
6. TO HIGH PRESSURE FUEL PUMP ASY (SEE SHEET 73)
7. TO CAMSHAFT POSITION TRANSDUCER ASY (2) PLACES
8. TO FUEL PRESSURE SENSOR ASY
9. TO FUEL INJECTOR AND KNOCK SENSOR JUMPER
10. TO AIR INTAKE CHARGE THROTTLE BODY & MOTOR ASY
11. TO MAP SENSOR
12. TO ENGINE COOLANT TEMP SENSOR ASY
13. TO CRANKSHAFT TIMING SENSOR ASY
14. TO TURBOCHARGER ENGINE EXHAUST DRIVE (VAWG)
15. GROUND EYELET
16. ATTACH TO DYNO HARNESS CONNECTOR #15
17. NOT USED
18. NOT USED

X2.31 Engine Wiring Harness