ASTM Sequence IVA

Test Procedure
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ASTM SEQUENCE IVA VALVETRAIN WEAR TEST PROCEDURE

1. Scope

1.1
This test method measures the ability of crankcase oils for spark-ignition engines to prevent camshaft and rocker arm follower wear encountered during stop and go driving conditions and extended engine idling. The primary results include camshaft lobe wear (7-point) and cam lobe nose wear. Secondary results include assessment of wear metal concentration and fuel dilution in the used engine oil, as well as oil consumption.

1.2
This procedure may involve hazardous materials, operations, and equipment. This procedure does not claim to address all of the safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1
``JASO M 328-95 Valve Train Wear Test Procedure for Evaluating Automobile Gasoline Engine Oils'', Japanese Automobile Standards Organization, rev 1995-03-30.

2.2
Hanada, Murakami, et.al, ``Development of a Valve Train Wear Test Procedure for Gasoline Engine Oil'', SAE 940794, Society of Automotive Engineers, 1994.

2.3
McGeehan, J.A., Yamaguchi, E.S., ``Gasoline-Engine Camshaft Wear: The Culprit is Blow-By, SAE 892112, Society of Automotive Engineers, 1989.

2.4
``NISSAN 1994 Service Manual'', Publication No. SM4E-0D21U0, Printed in JAPAN, Nissan Motor Co., Ltd.

2.5
``CEC-L-38-A-94 Peugeot TU-3M/KDX ValveTrain Scuffing Wear Test'', Coordinating European Council, version no. 2.

2.6
``Data Acquisition Guidelines -Instrumentation Accuracy and Calibration,'' ASTM Research Report.

2.7
``DACA II - Data Aquisition and Control Automation'', ASTM Task Force Research Report.

2.8
``Instrumentation and Techniques for Exhaust Gas Emissions Measurement,'' SAE J254 , Society of Automotive Engineers 1971.

2.9
Kabel, R.H., and Voss, L.R., ``A Multiple Square Edge Orifice Meter for Measuring Automotive Engine Blowby Rates,'' General Motors Engineering Journal, Third Quarter 1964, p. 37.

2.10
``Standard Recommended Practice for Indicating Which Places of Figures are to be Considered Significant In Specifying Limited Values,'' ASTM E29 - 67 (Reapproved 1980), ASTM 1980.

2.11
Temperature Measurement - Thermocouples, ANSI Publication MC96.1, ANSI, 1975.

2.12
Temperature Measurement -Resistance Temperature Detectors, ANSI Publication

2.13
``Lubricant Test Monitoring System (LTMS)'', ASTM Test Monitoring Center technical memorandum 94-200 with revisions, ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh PA 15206-4489, telephone (412) 365-1000.

2.14 Updates to Test Procedure
Changes and updates to this procedure are maintained via information letters. Copies of information letters may be obtained from the ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh PA 15206-4489, telephone (412) 365-1000.

2.15
ASME B46.1-1995 Standard for Surface Texture (Surface Roughness, Waviness, and Lay), ASME Headquarters, 345 E. 47th Street, New York, NY 10017.

2.16
M.E Hanna, et.al., "The KA24E Engine Test for ILSAC GF-3, Part 1: Engine Design, Operating Conditions and Wear Mechanisms", SAE Paper No. 982625, Society of Automotive Engineers, 1998.

2.17
C.E. Eldredge-LaMarca, et.al., "The KA24E Engine Test for ILSAC GF-3, Part 2: Valve Train Wear Response to Formulation Variables", SAE Paper No. 982626, Society of Automotive Engineers, 1998.

2.18
B.P. Williamson & J.C. Bell, "The Effects of Engine Oil Rheology on the Oil Film Thickness and Wear Between a Cam and Rocker Follower", SAE Paper No. 962031, Society of Automotive Engineers, 1996.

2.19
T. Fujitsu, S. Doki, B. McCourt, "Investigation of Seasonal Effects on Valve Train Wear Measured with the Nissan KA24E Engine Test", SAE Paper No. xxxxx, Society of Automotive Engineers, 1998.

3. Terminology

3.1 valvetrain
The mechanical engine subsystem comprised of the camshaft, the rocker arms, hydraulic lash adjusters, the poppet valves, and valvesprings.

3.2 reference oils
Specially blended lubricants with known performance of valvetrain wear for the Sequence IVA test method.

3.3 break-in
Initial engine operation to reach stabilization of the engine performance after new parts are installed in the engine.

3.4 flushing
The installation of a fresh charge of lubricant and oil filter for the purpose of running the engine to reduce and eliminate remnants of the previous oil charge. No engine disassembly is requird. Engine running duration is relatively short. Flushing may be carried out in an iterated process to ensure a more thorough process of reducing previous oil remnants.

3.5 cam nose wear
The maximum linear deviation of a worn nose profile from the unworn profile. The nose is the high lift point on the particular cam lobe.

3.6 cam lobe wear
For a particular cam lobe - the sum of the wear determined at the following locations (nose is zero location): 1) 14 cam degrees before the nose, 2) 10 degrees before the nose, 3) 4 degrees before the nose, 4) at the nose, 5) 4 degrees after the nose, 6) 10 degrees after the nose, 7) 14 degrees after the nose.
The average cam lobe wear is an equal weighted average of the individual cam lobe wear of the twelve (12) cam lobes.

3.6 profile
A graph representing the outline of a section normal to its surface.

3.7 assessment length
The length of surface over which measurements are made.

3.8 reference line
After test, the reference line is a deduced, leveled, straight line drawn on the profilometer graph, from the front unworn average edge of a cam lobe to the rear unworn average edge of that cam lobe. In the absence of one unworn edge, the reference line can be extrapolated using the pre-test profilometer trace.

3.9 PR_{ymax}
In the phase-correct filtered waviness profile mode (defined by ASME B46.1 as the Gaussian filter), the maximum excursion of the worn surface as graphically measured normal to the reference line.

3.10 scuffing
Localized metal surface damage caused by mild galling, scoring, or welding between sliding surfaces. Evidence of abrasion (heavy scratching) may also be caused by the scuffing damage as weld asperities break, creating further surface degradation.

3.11 burnishing
An alteration of the original manufactured surface to a more polished condition caused by rubbing.

3.12 scratching
The formation of fine groove(s) in the direction of sliding as caused by the plowing action of a sharp particle moving along that surface.

3.13 pitting
Small, irregular cavities in the metal surface resulting from the breaking out of surface metal. This may be caused by mechanical action and/or corrosion.

3.14 air-to-fuel ratio (AFR)
The ratio of the mass of air to the mass of fuel as delivered to the cylinders. In the context of this procedure, it is measured by an exhaust gas analyzer that computes a theoretical AFR based upon the reaction products of combustion.

3.15 blowby
The portion of combustion by-products and unburned air and fuel that leaks into the crankcase during engine operation.

3.16 carbon deposit
A solid residue of combustion that has visible thickness. In the context of this test procedure, this deposit is found on the piston crowns and the combustion chambers of the cylinder head.

3.17 `golden stand'
The `golden stand' is a term that signifies the standard acceptable configuration of the test apparatus that was used for the ASTM KA24E test development program. All other industry test stands are expected to be clones of the `golden stand', or of proven equivalence.

3.18 quality index
The statistical measure (percent) of the actual error in the process with respect to operational test targets. Please refer to the reference listed in xxxxx for the specific equation used to calculate the quality index.

3.19 calibration check
A comparison of the test stand indicated measurement to a traceable standard. If the difference noted is within the desired accuracy of the Sequence IVA test method, then adjustment of the test stand measurement system is left to the discretion of the laboratory.

4. Summary of Test Method

4.1 Test Numbering Scheme

The test number must follow the format listed below.

AAAAA-BBBB-CCCCC

``AAAAA'' represents the stand number. ``BBBB'' represents the number of tests since the last calibration test on that stand. ``CCCCC'' represents the sequential laboratory number for that test type.
As an example, 6-10-175 represents the 175th Sequence IVA test conducted by the laboratory and the tenth test since the last calibration test. All tests within the laboratory must be consecutively numbered. Stand calibration tests are numbered beginning with zero for the "BBBB" field.
For purposes of test numbering, the "BBBB" field number sequence is not advanced for any test of 50 hours length or less - instead, an alphabetical suffix is added for a restarted test.

4.2 Engine

This procedure utilizes a fired 1994 model Nissan KA24E 2.389 liter, in-line four cylinder, 4-cycle, water cooled, port fuel injected gasoline engine. Nominal oil sump volume is 3.5 liters. The cylinder block is constructed of cast iron, while the cylinder head is aluminum. The engine features a single overhead camshaft with sliding follower rocker arms, with two intake valves and one exhaust valve per cylinder, and hydraulic lash adjusters. The camshaft is NOT phosphate coated or lubrited. The rocker arm contact pad material is powdered metal. The engine compression ratio is 8.6 to 1. The engine is rated at 198 Nm torque @ 4400 rpm. The ignition timing and multi-port fuel injection system is electronically controlled (ECM). The engine is fueled with a specially blended, non-detergent unleaded reference gasoline (Specified Fuels and Chemicals KA24E - green dyed). The production rocker arm cover is replaced with a specially manufactured aluminum jacketed rocker cover. The Nissan production crankcase ventilation system is modified to control the mass flow rate of fresh air supplied to the rocker cover. Exhaust Gas Recirculation (EGR) is made non-operable.

4.3 Test Stand

The test engine (devoid of alternator, cooling fan, waterpump, clutch and transmission) must be coupled to an eddy-current dynamometer for precise control of engine speed and torque. The combined inertia of the driveline and dynamometer is specified to ensure reproducible transient rampings of engine speed and torque. Intake air, provided to the engine air filter housing, must be controlled for temperature, pressure, and humidity. The engine is mounted similar to its vehicle orientation (tilted up 5.5 degrees in front; sideways 10 degrees up on intake manifold side; bottom of oil sump horizontal). Modifications are required for the engine ECM wiring harness, sensors, and actuators. Test stand plumbing must comply with the general diagrams listed in the appendix. The engine is installed on a test stand equipped with computer control of engine speed, torque, various temperatures, pressures, flows, and other parameters outlined in the test procedure.

4.4 Operating Summary

After engine break-in or after the completion of a previous Sequence IVA test, a new test camshaft and rocker arms are installed. Fresh test oil is charged to the engine and two flushes are conducted. After both flushes have been completed, the used oil is drained, and fresh test oil and filter is weighed and installed. The test is then conducted for a total of 100 hours, with no scheduled shutdowns. There are two operating conditions, stage I and stage II. Fifty minutes of stage I and ten minutes of stage II comprise one test cycle. The test length is 100 cycles. A summary of the operating conditions is listed below:

Test Parameter	Stage I	Stage II
Duration, min	50	10
Engine Speed, rpm	800	1500
Torque, N-m	25	25
Cyl. Head Oil Gallery Temp, degC	49	59
Coolant Out Temperature, degC	50	55
Coolant Flow, L/min	30	30
Exhaust Absolute Pressure, kPa	103.5	103.5
Air Flow to RAC, SLPM	10.0	10.0
Blowby, L/min	Approx. 6 - 10	
Intake Air Humidity, g/kg	11.5	11.5

Note that engine torque is maintained at 25.0 Nm in both operating stages. Air-to-fuel ratio is maintained at stochiometric conditions using the production exhaust gas sensor feedback to the engine ECM.

Stage I represents an engine idling condition whereby hydrodynamic lubrication is lessened for the cam lobe to rocker arm interface. A small amount of dynamometer torque is applied to provide smoother engine speed control, to compensate for the load of the auxiliary components that were removed, and to generate a small amount of internal engine heat.

Stage II provides additional engine operation that simulates commuter type service. This low-to-moderate operating condition is conducive to increased levels of fuel dilution, NOx, and blowby exposure to the crankcase oil. Cam lobe wear is influenced by the higher levels of NOx and other constituents of crankcase gas that are present during stage II.

4.5 Engine Modifications

The engine-driven waterpump is disabled and replaced with an electric motor-driven external waterpump. The engine-driven radiator fan blade is removed. The alternator is removed. The clutch and transmission assembly is not utilized, as the engine is coupled directly to a dynamometer driveline. The exhaust gas recirculation (EGR) valve is made inoperable. Other items that are disabled or fixed are the swirl control actuator, the fast idle system, the idle speed control valve, vehicle speed sensor, and water jacket temperature sensor.
A Nissan production oil cooler is installed between the engine block and the oil filter housing.
The production rocker arm cover is replaced with a specially manufactured aluminum jacketed rocker cover.
The Nissan production crankcase ventilation system is modified to control the mass flow rate of fresh air supplied to the valvetrain underneath the rocker

cover
Provisions are made for installing additional exhaust gas sensors, temperature measurement thermocouples, and pressure taps.

4.6 Analyses Conducted

After test, the camshaft lobes are measured using a surface profilometer. From these graphical profile measurements, the maximum wear at each location (7-points) on the cam lobe is determined. The wear points on each cam lobe is summed to establish the overall individual cam lobe wear. The overall wear from the twelve cam lobes are averaged for the final, primary test result. After the completion of the test, the oil consumption is determined by the weight of used oil vs. the fresh oil charged to the engine (including oil filter). The end of test used oil is analyzed for fuel dilution, kinematic viscosity, and wear metals.
A one liter sample of the final drain must be retained for 90 days. The camshaft and rocker arms must be retained for six months.

5. Significance and End Use

5.1 Test Method

This test method simulates stop and go driving, similar to taxi or commuter service. Extended vehicle operation during engine idling is prone to camshaft and rocker arm pad wear when hydrodynamic lubrication is lessened. Fuel dilution of the crankcase oil can reduce the viscosity of the lubricant and aggravate wear. Exposure of the valvetrain to blowby gasses containing NOx and other constituents, also promotes cam lobe wear.

5.1.1 End Use

Evaluating average cam lobe wear (7-point) for lubricants claiming API-SL and/or ILSAC GF-3 performance. Evaluating cam nose wear for JASO M328-95 specification.

5.1.2 Correlation with Field Performance

Limited field correlation data can be found in the ASTM Sequence IVA Research Report RR-D02.1218. Good correlation has been established between the Sequence IVA and the Sequence VE camshaft wear.

5.1.3 Test Precision

Currently, the test precision is estimated to be 9.47 µm for average cam lobe wear (7-point).

5.2 Test Validity

5.2.1 Procedural Compliance

The test results are not considered significant unless the test is completed in compliance with all requirements of this test method. Deviations from the parameter limits presented in the appendix must be judged according to the guidelines detailed in this procedure. Operational data is evaluated with the calculation of a "Quality Index" (QI) that has been defined by the Sequence IVA Surveillance Panel. For controlled operational parameters, the QI is normally above zero. Negative values of QI require engineering investigation and review for assessing test validity. Good engineering judgment must be applied when assessing any anomalies to ensure validity of the test results.

5.2.2 Test Stand Calibration

A test is not considered valid unless it is conducted on a test stand that has been calibrated through evaluation of a reference oil. Laboratories and test stands are calibrated using a control charting protocol "Lubricant Test Monitoring System" (LTMS). The LTMS establishes the precision and severity bias for industry, for laboratories, and for test stands. A severity adjustment system is applied at the laboratory level to correct for severity bias. The LTMS equation constants are established by the Sequence IVA Surveillance Panel. The LTMS is administered by the ASTM Test Monitoring Center.

5.3 Oil Performance Criteria

This valvetrain wear test is suitable for evaluating oils for overhead camshaft equipped with sliding followers. It may, or may not, relate to wear of roller followers or wear of non-overhead camshaft assemblies.
The ASTM will establish pass/fail limits with respect to average cam lobe wear.
Excessive fuel dilution of the crankcase oil (over 7.0%) may render the test result not-interpretable.
Pass/fail limits have not been established for the chemical analysis of the used oil related to kinematic viscosity or wear metal concentration.

6. Apparatus

Apparatus which exhibits proven equivalent performance to the 'golden stand' is allowed except where specifically noted. Coordination with the ASTM Sequence IVA Surveillance Panel is a prerequisite to the use of any "equivalent apparatus". However, the intent is to permit reasonable adaptation of existing laboratory facilities and equipment. Photographs are provided in the appendix to suggest appropriate design details and depict some of the required apparatus.

6.1 Laboratory Environment

6.1.1 Engine Build-up and Measurement Area

The ambient atmosphere of the engine build-up and measurement areas must be reasonably free of contaminants and maintained at a uniform temperature. The specific humidity should be maintained at a uniform level to prevent the accumulation of rust on engine parts. Uniform temperatures are necessary to ensure repeatable dimensional measurements. Since a sensitive surface profilometer instrument is used to measure the wear of the cam lobes, the profilometer must be placed on a baseplate that is free of external vibrations.

6.1.2 Engine Operating Area

The laboratory ambient atmosphere must be reasonably free of contaminants and general wind currents, especially if and when the valvetrain parts are installed while the engine remains in the operating area. The temperature and humidity level of the operating area are not specified.

6.1.4 Parts Cleaning Area

The ambient atmosphere of the parts cleaning area is not specified. **Warning** - Adequate ventilation must be provided in areas where solvents and cleansers are used.

6.2 External Engine Modifications

The Nissan KA24E engine is modified for the valvetrain wear test. Exhaust gas recirculation is made non-operable. The swirl control actuator is disabled. The fast idle system is also disabled. The auxiliary air control (AAC) valve is disabled. The engine coolant temperature sensor is replaced by a fixed resistor. The engine waterpump is modified to incorporate an external electric-driven waterpump. The waterpump fan blade and cooling radiator is not utilized. The alternator is removed. A Nissan production oil cooler (water-to-oil heat exchanger) is installed at the oil filter housing. The engine wiring harness is extensively modified. The Nissan production rocker cover is replaced with a specially manufactured aluminum jacketed rocker cover. Engine coolant is routed through this jacket. A fitting is installed in the front engine cover to allow a portion of the crankcase ventilation air to bypass the rocker cover. Fittings are installed for various temperature and pressure measurements as required by the Sequence IVA test method.

6.2.1 Non-Operable EGR

The Exhaust Gas Recirculation (EGR) valve is not supplied by Nissan and is not utilized. Instead, a 3 mm thickness block-off (blind) plate, part number 14712-V6200, is supplied to cover the EGR port. The hose from the exhaust manifold to the EGR is removed. The EGR supply port in the rear of the exhaust manifold is plugged with a pipe fitting.

6.2.2 Swirl Control Actuator

The swirl control actuator is disabled by removing the harness connector and vacuum line. The source of the vacuum line must be plugged.

6.2.3 Fast Idle Disabling

To disable the fast idle system, the fast idle cam on the throttle body is simply removed. See figure xxxxx.

6.2.4 Engine Coolant Temperature Sensor

The variable input of the coolant temperature sensor to the ECM is substituted with a fixed resistance of 300 ohms at the wiring harness of the ECM.

6.2.5 Dummy Engine Waterpump

The engine waterpump (Nissan part no. 21010-40F25) is modified to serve as a dummy housing on the engine, since an electric motor-driven, external waterpump is utilized for the KA24E test.

a) Support two surfaces, 180 degrees apart, of the underside (non-machined surface) of the 77 mm diameter steel hub. Leave the shaft, body, and impeller free to be pressed out of the supported hub.

b) Using a press punch rod with the approximate diameter of 14 mm, press the shaft out of the hub.

c) Locate the copper wire clip in the slot on the side of the aluminum alloy pump body. Remove the U-shaped wire clip by pulling perpendicular to the longitudinal axis of the waterpump shaft.

d) Support the flat, machined face o fthe aluminum alloy pump body on two sides, 180 degrees apart, leaving the impeller, bearings, seal, and shaft free to be pressed out of the aluminum alloy pump body.

e) Again using press punch rod with the approximate diameter of 14 mm, press the shaft, impeller, double-bearing, and seal assembly out of the aluminum alloy pump body. Press in the direction of the internal cavity.

f) Clean and prepare the aluminum alloy pump body for contamination free welding.

g) Fabricate a water pump bore plug (Appendix B, drawing no. 7826-1712) starting at the neck of the aluminum alloy pump body towards the internal cavity. In some instances, due to manufacturing tolerances, the pump body may need to be heated to approximately 200 degC and the fabricated bore plug cooled to approximately 0 degC. This will allow easy installation of the bore plug.

h) Preheat the aluminum alloy pump body (with plug installed) to approximately 200 degC.

i) Using an argon/tungsten-inert gas (TIG) welder with the approximate settings of: AC, high frequency, pedal/rheostat-operated 220 amps, and 4043 aluminum 3 mm filler rod, weld the base perimeter of the plug to the internal cavity of the aluminum pump body.

j) Allow to cool, then perform final cleaning before installation on engine.

6.2.6 Coolant Bypass Hose

The coolant bypass hose at the intake manifold is disconnected. The connection ends are plugged to prevent bypass flow. See figure xxxx. The thermostat is removed.

6.2.7 Oil Cooler

A Nissan production water-to-oil heat exchanger (part no. 21305-03E00) is inserted between the engine oil filter adapter block and the oil filter, using gasket part number 15239-53F00. See figure xxxx for installation details. The water outlet is plumbed to the cooler fitting that is oriented to the same axis as the oil filter. The cooler is oriented for both water fittings to face the rear of the engine. Flexible hoses (16 mm diameter) of approximately 0.5 m length are used to connect process water to the oil cooler.

Oil temperature is controlled by metering the flow of the process water outlet. A control system valve with Cv of 0.32 has been found to produce satisfactory control.

The Nissan oil cooler, part number 21305-03E00KT, must be replaced any time the short block assembly is replaced. Normally, this allows twelve (12) tests to be conducted using the same oil cooler. It is recommended that any hoses to the oil cooler be replaced whenever a new oil cooler is installed.

6.2.8 Ignition Power Supply

A 15 amp direct-current power supply is used to provide 13.4 to 14.2 volts DC to the ECM which powers the engine ignition system (a Lambda Electronics Corporation Model No. LFS-43-15 has been found to be suitable).
For the starter motor circuit, a separate power source should be provided. An

automotive battery equipped with a low-amperage battery charger is sufficient.

6.2.9 ECM Wiring Harness Modifications

Remove all connectors and wires except for the following wires which are required:

Connector Description	Connector Number(s)
Camshaft Position Sensor	30M
Power Transistor	44M
Distributor	46M
Ignition Coil	47M, 97M
Oxygen Sensor	59M
Mass Air Flow Sensor	63M
Engine Coolant Temp Sensor	65M (Install 300 ohm resistor)
Throttle Position Sensor	66M
Injectors 1 thru 4	72M, 73M, 74M, 75M
Intake Air Temp Sensor	18M
Body Ground	275M
Engine Ground	60M, 61M
Fuel Pump Relay	5M
ECCS Relay	6M
Resistor and Condenser	40M
Check Connector	208M
Joint Connector A	259M
ECM (ECCS Control Module)	262M
Fuel Pump	2C
Joint Connector C	212M (jumper hardwired)
Connector	260M (jumper hardwired)
EGR Temperature sensor	17M (retain, do not connect)
EGRC - solenoid valve	88M (retain, do not connect)
IACV-AAC Valve and IACV-FICD Solenoid Valve	64M (retain, do not connect)
Ground Connector	(retain, do not connect)
Check Engine Light	add and utilize
30 amp fuse holder	add and utilize
Ground	add and utilize
Keep-Alive wire	add and utilize
Ignition wire	add and utilize
Ground wire	add and utilize

See modified wiring diagram in Appendix B.
The fuel pump relay connector (5M) is modified to provide a nominal 13V to the fuel pump only when the ignition power switch is turned on. See figure xxxx for wiring details.
The ECCS relay (part no. 25230-C9980) uses the 6M connector. It should be connected to the battery through a fusible link.
The wiring harness grounds can be conveniently attached to the front engine lifting bracket.

6.2.10 Jacketed Rocker Cover

A specially manufactured aluminum jacketed rocker (part no. TEI-NIVAWCR-020) must replace the production KA24E rocker cover. Engine "coolant-in" is supplied to jacket at the front rocker cover fitting, and exits the rear fitting of the rocker cover. A Badger Meter 2-way Research valve, ½" I.D., Trim C, limits the flow exiting the rocker cover. See Appendix XXXX for the Sequence IVA Cooling System Schematic.

6.2.11 Fresh Air Bypass to Front Engine Cover

Humidity-controlled, fresh air is supplied to the crankcase system. The total amount of fresh air supplied is driven by the flow requirement of the PCV valve. Ten (10) standard liters per minute of fresh air is routed to the valvetrain through the rocker cover. The remainder of the fresh air is externally routed to the crankcase front engine cover. See figure xxxx for the location of fitting that is plumbed to the front engine cover.

6.3 Test Stand and Laboratory Equipment

This engine-dynamometer test is designed for operation using computer control instrumentation and computer data acquisition. An intake air system must be provided for the precise control of engine intake air humidity, temperature, and cleanliness.

6.3.1 Computer Data Acquisition System

It is required that the test stand log operational data with a computer data acquisition system that utilizes the sensor configurations that are detailed in this procedure.

6.3.1.1 Frequency of Logged Steady-State Data
Stage I steady-state (last 45 minutes of stage) operational conditions are to be logged every two minutes or more frequently.
Stage II steady-state (last 5 minutes of stage) operational conditions are to be logged every 30 seconds or more frequently.

6.3.1.2 Frequency of Logged Transient Data
Transient time is defined as the first five minutes following operational stage changes. It is required that cycle 5 transient data be computer logged and plotted. The critical parameters (engine speed, torque, oil cylinder head temperature, and coolant out temperature) shall be logged once per second or higher frequency. If cycle 5 transients are beyond the procedural limits defined in 12.2.6, corrective action should be documented and confirmed with the next available transition plot.

6.3.1.2 System Time Response for Logged Data
Controlled operational parameters are not permitted to exceed the following system time response for measurement. The system time response includes the total system of sensor, transducer, analog signal attenuation, and computer digital filtering. It is desirable that single-pole type filters be utilized for attenuation. For temperature sensors, it is preferable to use grounded thermocouples, although ungrounded thermocouples may be used, provided they meet the time responses defined in the chart below:

Measurement Type	**Maximum Time Response (one time constant)**
Temperatures	2.5 seconds
Pressures	1.6 seconds
Coolant Flow	2.5 seconds
Torque	2.0 seconds
Speed	1.8 seconds

6.3.1 Test Stand Configuration

The engine must be mounted on the test stand similar to its vehicle orientation (tilted up 5.5 degrees in front; sideways 10 degrees up on intake manifold side; bottom of oil sump horizontal). This orientation is important to the return flow of oil in the cylinder head, and ensures reproducible oil levels.
The engine flywheel is directly coupled to an eddy-current dynamometer through a driveshaft. The design of the driveshaft should minimize vibration at the test operating conditions. The dynamometer system must have an inertia of 0.75 ± 0.15 kg-m^2 to ensure satisfactory control of engine speed at 800 rpm, stable air-to-fuel ratio control, and enable reproducible transient control of engine speed and torque during stage changes. Hydraulic type dynamometers are not allowed, as they exhibit residual loads at low speed operation.
The engine cannot be used to drive any external engine accessory.
It is recommended that the area above and to the left of the rocker arm cover be left unobstructed to allow for easier on-site replacement of valvetrain wear parts while the engine rests on the test stand.

6.3.2 Dynamometer Speed and Load Control System

To improve reproducibility among laboratories with respect to transient control of engine speed and torque, the driveline system inertia, excluding engine, must be 0.75 ± 0.15 kg-m^2.

The strategy selected for evaluating the lubricant in a repeatable manner is to control the engine power by:

* Measuring and controlling engine speed and dynamometer torque.
* Controlling exhaust absolute pressure by exhaust pipe throttling.
* Controlling the supply of intake air temperature; humidity; and pressure differential above barometer pressure.

The dynamometer speed and load control systems must be capable of maintaining the steady state operating set points within the performance envelope (i.e. quality index established by the industry matrix testing program).

Two types of full closed-loop speed and load control systems have been successfully utilized. One typical closed-loop system maintains speed by varying dynamometer excitation and maintains torque by varying the engine throttle. This arrangement may provide satisfactory steady-state control. Another closed-loop speed and load control system maintains torque by varying dynamometer excitation and controls speed using the engine throttle. This arrangement may provide satisfactory transient control during stage changes.

6.3.3 Intake-air Supply System

The supply system must be capable of delivering a minimum of 600 l/m (2000 l/m preferred) of conditioned and filtered air to the Sequence IVA test engine during the 100h test, while maintaining the intake-air parameters detailed in the appendix. Usually, a humidifying chamber controls the specific humidity and provides a positive air pressure to an intake air supply duct. A general schematic of the intake air system for the Sequence IVA test is found in Appendix B.

6.3.3.1 Induction Air Humidity
The intake air specific humidity may be measured in the main system duct or at

the test stand. If using a main system duct dew point temperature reading to calculate the specific humidity, then the dew point must be verified periodically at the test stand. The duct surface temperature must be maintained above the dew point temperature at all points downstream of the humidity measurement point to prevent condensation and loss of humidity level.

6.3.3.2 Intake Air Filtering
The production Nissan intake air cleaner assembly (part no. 16500-86G50KT), with filter, must be used at the engine. A snorkel adapter, functionally equivalent to that shown in Appendix B, is used to connect the controlled air duct to the air cleaner. The top of the air cleaner assembly is modified for the installation of the intake temperature sensor, and for the intake pressure sensor line. Refer to section 6.3.10.8, and 6.3.3.5.

6.3.3.3 Intake Air Flow
This measurement is not required for the Sequence IVA test.

6.3.3.4 Intake Air Temperature
For final control of the engine inlet air temperature, an electric air heater strip is installed within the air supply duct. The design of the duct material and heater elements should not generate corrosion debris that could be ingested by the engine. To provide sufficient duct flow for adequate air temperature control, it is recommended that excess air be dumped just prior to the air cleaner snorkel. An air dump area of approximately 6 cm^2 will provide sufficient flow without stagnation. If additional air flow is required to stabilize air temperature, it is permissible to install a nominal 1 cm bleed hole in the air filter housing. The inlet temperature sensor is installed in the air cleaner, centered at the inlet to the air cleaner (see Figure xxx). If vibration of the temperature sensor is a problem, a support brace can be attached to the air cleaner assembly mounting stud and wing-nut.

6.3.3.5 Intake Air Supply Pressure
For controlling the engine inlet air gage pressure, a disc type valve is installed in the controlled air system supply duct. The sensing tube for inlet air pressure is located in the topside of the air cleaner assembly (approximately 5 cm left and 8 cm front of the right rear corner of the assembly). This location senses the pressure before entering the air cleaner element.

6.3.4 Fuel Supply System

The Sequence IVA method requires approximately 200 liters of unleaded Specified Fuels and Chemicals KA24E gasoline per test (100 cycles). Sufficient supply of fuel should be ensured at the start of test to conduct the test without a shutdown.
The Nissan production port fuel injection system is utilized, including fuel pump (part no. 17011-R2200), fuel injector rail, and fuel pressure regulator. Recirculated fuel within the system is cooled using a non-production heat exchanger to maintain fuel temperature ranging from 15 to 30 degrees C. Fuel consumed is measured using a mass flowmeter (MicroMotion model D-6 is suitable). A Nissan fuel filter assembly, part number 16400-72L00KT, (or equivalent) must be installed upsteam of the Nissan fuel pump. Proper filtration of the fuel is essential to maintain precise air-fuel ratio control during the test.

6.3.4.1 Fuel Temperature
Fuel temperature is measured through one of the ports in a cross-fitting located in the line between the Nissan fuel pump and the Nissan fuel rail. The fuel temperature is maintained between 15 degC and 30 degC.

6.3.4.2 Fuel Pressure

The fuel pressure is measured through one of the ports in a cross-fitting located in the line between the Nissan fuel pump and the inlet of the Nissan fuel rail.

6.3.4.3 Fuel Flow
A mass fuel flow meter for the measurement of fuel consumption rate is installed in the fuel supply system, prior to the fuel recirculating loop. A MicroMotion model D-6 fuel flow meter has been found to be suitable.

6.3.5 Exhaust System

The production cast iron exhaust manifold, without insulation, is utilized for the test. The rear of the manifold (EGR supply) is plugged with a pipe fitting. No EGR is utilized for the Sequence IVA test. The production exhaust gas oxygen sensor (one-wire EGO) is utilized and installed in the original location in the exhaust manifold. An industrial cooling blower with a nominal air flow rating within 10,000 L/m to 14,000 L/m is mounted to blow air vertically over the cast iron exhaust manifold and the manifold exhaust gas oxygen (EGO) sensor. This cooling air is essential to the proper operation of the EGO. Care must be taken to ensure that this cooling air is not directed to the engine oil pan or rocker arm cover. A deflector shield will be necessary to prevent air currents at the oil pan.
The front length (minimum 0.5 m) of the production exhaust pipe, including tube collector with shield, leading from the manifold must be used. Following that, the exhaust is routed from the test cell using accepted laboratory practice. An exhaust pressure control valve must be installed at any point after the production exhaust pipe to enable the exhaust to be controlled to an absolute pressure. The use of a catalytic converter, or exhaust attenuator, or pipe cooling is optional, providing these devices are after the front length of the production exhaust pipe and specified absolute pressure can be maintained.

The unused production fitting on the exhaust pipe is removed and a plate welded over the opening (see figure xxxx). Because the Sequence IVA test method is continuously operated at low engine speeds and torque, the water vapor in the exhaust gas tends to condense in the exhaust piping. A low point drain in the exhaust piping should be installed to remove accumulated water before the start of each test. Depending on the exhaust piping arrangement, it may be necessary to remove water periodically throughout the 100-hour test if exhaust pressure fluctuations are observed.

6.3.5.1 AFR (UEGO) Sensor
A Universal Exhaust Gas Oxygen (UEGO) sensor is installed in the production exhaust pipe to monitor the air-to-fuel ratio. For this, a port is made approximately 3 cm downstream of the collector. The UEGO is oriented to the front side of the exhaust pipe using the appropriate weld fitting. It is not necessary to direct cooling air over the UEGO sensor.

6.3.5.2 Exhaust Gas Temperature
Exhaust gas temperature is measured using a 6-mm diameter thermocouple installed in a welded fitting attached to the exhaust pipe at a location 5 cm downstream from the end of the collector. The sensor tip must be inserted to the center of the exhaust pipe. See figure xxxx.

6.3.5.3 Exhaust Absolute Pressure
The exhaust pressure sensor tube is attached to a welded fitting installed on the exhaust pipe at a location 5-cm downstream from the end of the tube collector. This fitting is oriented circumferentially 60 to 90 degrees from the exhaust temperature sensor.

6.3.5.4 Exhaust Sample Probe

It is optional to install an exhaust sampling probe for emission analyses (percent O_2, CO_2, CO, HC). If used, the exhaust sampling probe is located 10 cm downstream from the end of the collector on the exhaust pipe. The probe must extend into the center of the exhaust pipe, with the tip of the probe cut to a 45 degree angle (longest portion facing upstream).

6.3.6 Air-to-Fuel Ratio Control

The air-to-fuel ratio is controlled at a stochiometric mixture (14.4 ± 0.3) by the Nissan ECM, using feedback from the production exhaust gas oxygen sensor installed in the exhaust manifold.

6.3.6.1 AFR Measurement
To monitor the reliability of the AFR control, an AFR analyzer using a separate wide range sensing element (Universal Exhaust Gas Oxygen sensor) computes the AFR. Either a Horiba model MEXA 110 lambda analyzer, or the ETAS Lambda Meter LA3 is recommended. It is configured to read directly the units of air-to-fuel ratio.

For the Specified Fuels KA24E fuel utilized for the Sequence IVA test, the Mexa 110 AFR analyzer must be programmed with the following information:

Hydrogen to Carbon ratio of the fuel	(H/C) = 1.800
	O/C = 0.000
	Zero = 10.00
	Span = 10.00

Stochiometric air-to-fuel ratio for Specified Fuels KA24E fuel is 14.4 to 1.

The Mexa 110 analyzer must be inputted with sensor calibration documentation received with the sensor.
It is recommended that a periodic verification of the calibration can be performed by exposing the sensor to a 4.0% O_2, N_2 balance certified gas. See the manufacturer's calibration procedures.

6.3.7 Ignition System

The ignition system is not modified for the Sequence IVA test method.

6.3.7.1 Monitoring Ignition Timing
An automotive timing light (strobe) is used to visually check the ignition timing.

6.3.8 Engine Coolant System & Jacketed Rocker Cover

A schematic diagram of the external coolant system is show in figure xxxx. A 50% deionized water and antifreeze solution, using an extended life ethylene-glycol based engine coolant, is required. Texaco Havoline Tex-Cool has been found to meet this requirement. The plumbing should be configured such that the total coolant system capacity, including engine and normal reservoir capacity, is 25 to 30 liters. The system pressure is regulated by a 100 kPa radiator-type pressure cap onto the reservoir tank. Coolant is plumbed to enter the engine at the thermostat housing (thermostat is removed). Coolant exits the engine at the front of the intake manifold.
A portion of the engine coolant is also circulated through the specially manufactured jacketed rocker cover, part no. TEI-NIVAWCR-020.

6.3.8.1 External Coolant Pump
An electric motor-driven centrifugal bronze body pump with a nominal minimum

rating of 150 liter/m at 100 kPa head pressure proves satisfactory. The actual flow range during the Sequence IVA test (including break-in) is 20 to 70 liters per minute.

6.3.8.2 Coolant Heater

A nominal 8 kW electric heater, or equivalent external heating source, must be utilized in the coolant system. This allows engine coolant soak temperatures to be maintained while the engine is not running. Because the ECM coolant temperature sensing system is non-operable, smooth running of the engine upon startup depends on maintaining the coolant soak temperature.

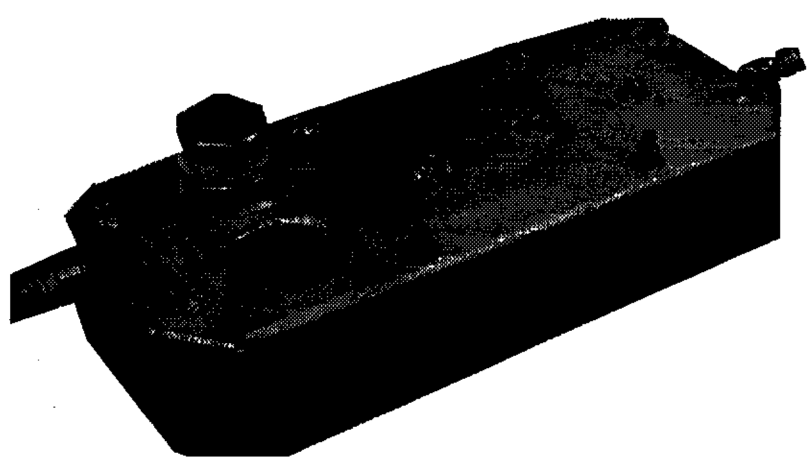
6.3.8.3 Coolant Heat Exchanger

A conventional shell-and-tube heat exchanger is used for cooling. The engine coolant is flowed through the tube side, while process water is used on the shell side. A nominal 150 mm diameter by 1200 mm long exchanger has been found to be suitable. If the heat exchanger is positioned vertically, the coolant inlet should be at the top of the exchanger. A high point bleed must be plumbed to remove system air during initial circulation of coolant. A sight-glass is installed in the coolant line upstream of the external coolant pump. A low point drain should be plumbed to allow complete coolant removal if needed.

6.3.8.4 Coolant Control
For control of the coolant out temperature, an automatic control valve is installed in the process water outlet of the heat exchanger. A control valve with a Cv rating of 1.25 has been found to be suitable for the recommended heat exchanger size. See section xxxxx for details of coolant temperature sensor.

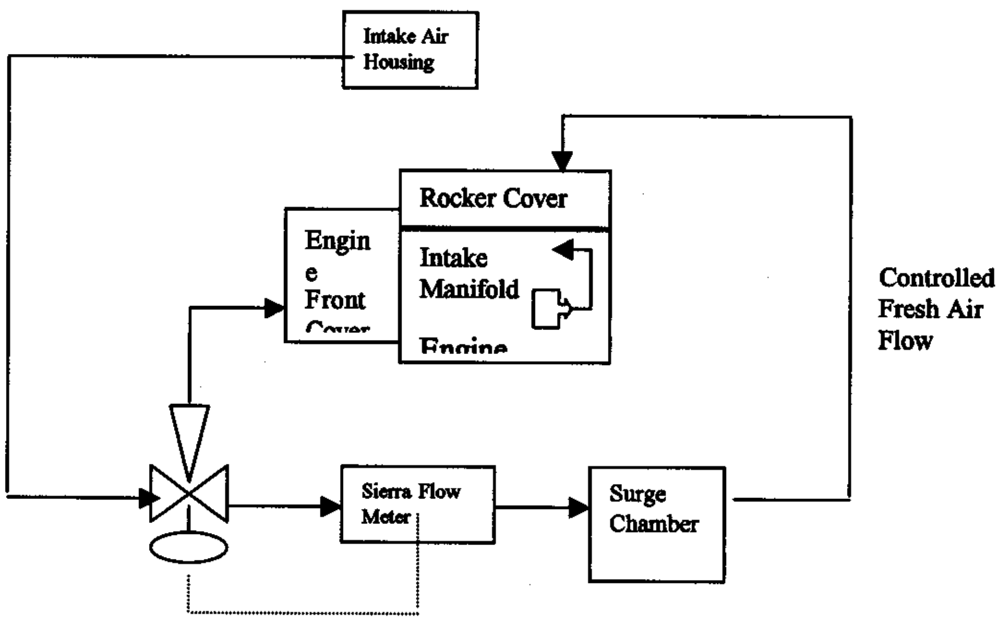
6.3.8.5 Coolant Flow Control
Coolant flow is measured using a volumetric flow sensor installed in the coolant line between the heat exchanger and the coolant inlet to the engine. A Barco venturi metering element, part no. 705, has been found to be suitable. Flow is controlled by an automatic flow control valve on the discharge side of the external pump. A control valve with a Cv rating of 16 has been found to be suitable.

6.3.8.6 Jacketed Rocker Cover Coolant System
A portion of total coolant system flow is routed through the jacketed rocker cover. A tee fitting is installed at the exit of the coolant heat exchanger, to allow the coolant flow to split into two circuits (main circuit to the engine thermostat housing & secondary circuit to the jacketed rocker cover). The secondary circuit enters the front of the jacketed cover and exits the rear of the cover. Near the front of the rocker cover, an automatic air bleed vent should be installed. The secondary circuit flow rate is limited at the exit by the installation of a 2-way control valve, ½" nominal internal diameter size, with a flow coefficient rating (C_v) of 1.25. It should be configured for "fail-safe" open position. The secondary flow joins the primary flow at the suction of the coolant system circulating pump. Refer to the schematic of the cooling system located in the Appendix xxxx.

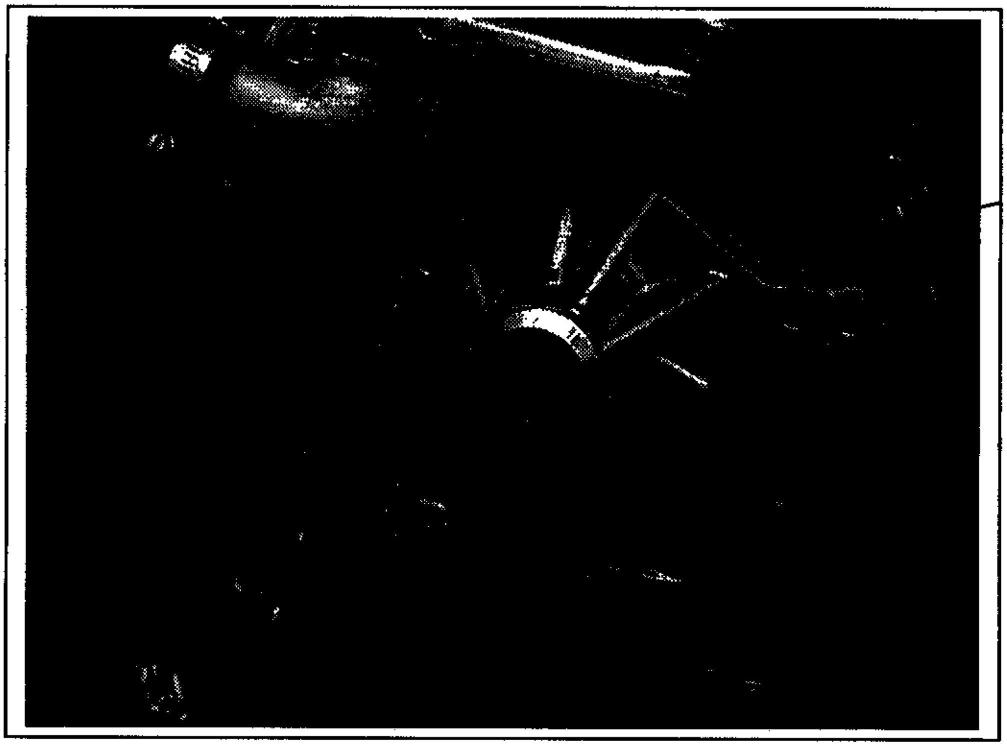


6.3.9 Crankcase Ventilation System

The Nissan production routing of the crankcase gasses is altered to ensure that a certain mass flow rate of fresh air is supplied to the valvetrain underneath the jacketed rocker cover. Humidity-conditioned air is taken from the bottom, left-rear of the air cleaner housing, and is routed to the rear right-side of the rocker arm cover and to the engine front cover. The crankcase off-gas is drawn from the engine at the production breather/oil separator. From the breather, the crankcase gas flows through the Positive Crankcase Ventilation (PCV) valve (part no. 11810-86G00) to the bottom plenum of the intake manifold. See Appendix XXXX for a drawing of the ventilation system plumbing.



A mass flow meter is used to measure the 10.0 SLPM fresh air flow to the rocker cover. This meter, corrected to standard conditions, must have an accuracy of +/- 0.25 SLPM @ 10 SLPM. Full scale of the meter must be a minimum of 20 SLPM. Time response of the measurement must be less than or equal to 1.0 second. One model that meets these specifications is Sierra Mass Flow Meter, model 730-N2-1E0PV1V4 (air; 20 SLPM).
Prior to the meter is a 3-way con-rol valve. This valve should have a nominal size of 1.25 cm, with a flow coefficient rating of 2.5 C_v. It should be configured such that loss of control power routes all air to the rocker cover. A Badger Meter ½" Research valve with Trim "A" meets these requirements.
A surge is utilized at the exit of the flowmeter. It should have a nominal capacity of 20 liters.
The plumbing from the 3-way valve to the engine front cover is a nominal diameter of 1.0 cm. The plumbing from the 3-way valve, through the flow meter and surge chamber, and on to the rear of the rocker cover, is a nominal diameter of 1.6 cm.



1.0 cm.
dia.
fitting
installed
in front
of the

6.3.9.1 Diversion for Blowby Measurement
To facilitate the periodic measurement of engine blowby, a 3-way valve must be installed in the hose between the engine PCV and the intake manifold vacuum source. A longer hose is also used to connect the rocker cover to the air cleaner housing. During blowby measurement, the 3-way valve and hoses are positioned to route blowby from the rocker cover (bypassing the air cleaner), through the blowby meter, through the 3-way valve, then to the intake manifold vacuum source. Crankcase pressure is monitored at the dipstick tube. During blowby measurement, the blowby measurement apparatus is adjusted for zero crankcase pressure.

6.3.10 Temperature Measurement

Temperature measurement equipment and locations for the required temperatures are specified below. Alternative temperature measurement equipment must be approved by the Test Monitoring Center. The accuracy and resolution of the temperature measurement sensors and the complete temperature measurement system must follow the guidelines detailed in Reference Document xxxx.

6.3.10.1 Thermocouples
All thermocouples except the intake air thermocouple must be premium sheathed types with premium wire. The intake air and ambient air thermocouples may be an open-tip type. Grounded thermocouples may provide a more accurate reading, in-situ, when immersion depths are limited. The use of grounded thermouples requires the incorporation of signal conditioning modules for providing electrically isolated inputs to digital computer systems.
Thermocouples of 3.2 or 6.4 mm diameter are to be used in specific locations. The 3.2 mm thermocouples are specified at locations which require short immersion depths to prevent undesirable temperature gradients. For exhaust gas temperature, the 6.4 mm diameter thermocouple is recommended. Thermocouples, wires, and extension wires should be matched to perform in accordance with the ``special'' limits of error as defined by ANSI in publication MC96.1-1975. Either type J (Iron-Constantan) or type T (Copper-Constantan) or type K (Chromel-Alumel) thermocouples are acceptable, type J is preferred (see Reference Document 2.11).

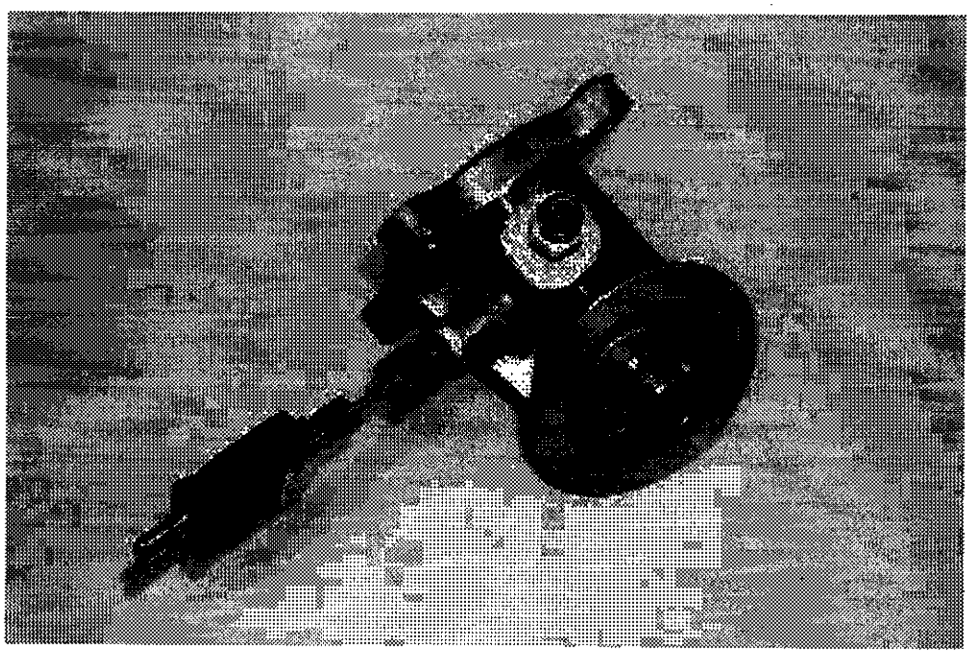
6.3.10.2 Resistance Thermometer Detectors
Resistance Thermometer Detectors (RTDs) are NOT acceptable alternatives to thermocouples, due to inherent signal attenuation characteristics that are different from sheathed, grounded thermocouples.

6.3.10.3 Engine Coolant Inlet
The engine coolant inlet temperature sensor is installed at the inlet pipe, 200 mm from the end of the thermostat housing nipple. Sensor tip should be located at the center of the pipe inner diameter.

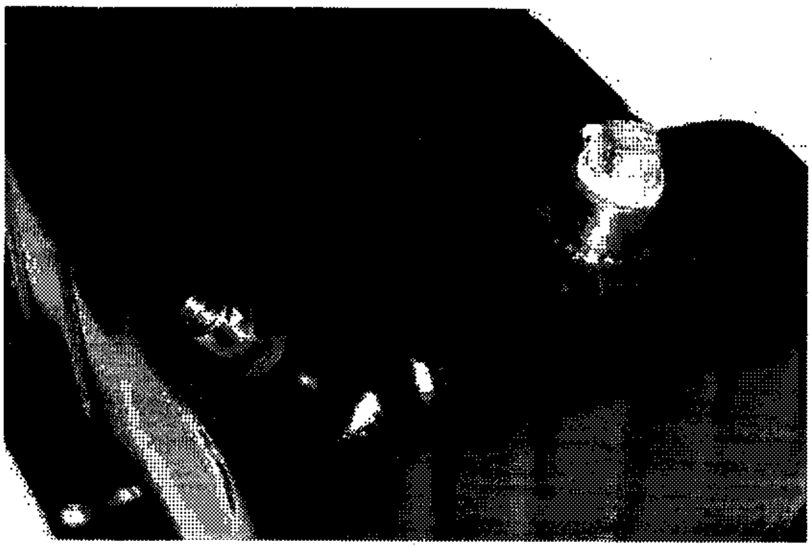
6.3.10.4 Engine Coolant Outlet
The engine coolant outlet temperature sensor is installed at the coolant water outlet passage at the front end of the intake manifold. This existing port is located at the top of the manifold, 5 cm from the intake gasket surface. The sensor tip should be located at the center of flow. The recommended thermocouple diameter is 3.2 mm. This temperature is the coolant control point.

6.3.10.5 Engine Oil Gallery Temperature

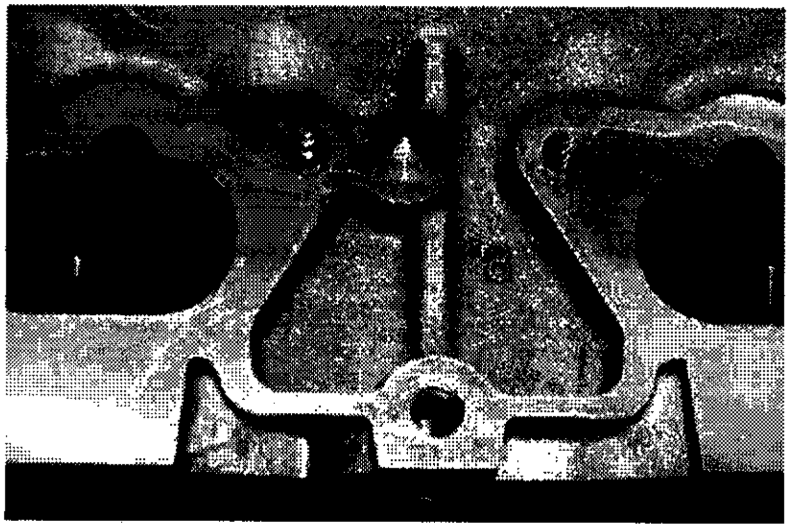
The oil gallery temperature is used for monitoring the oil temperature. A thermocouple fitting is precisely welded to the oil filter block (see figure xxxx). A 3.2 mm diameter thermocouple, or equivalent, is recommended. The sensor tip should be positioned in the center of the oil passageway. This temperature is monitored only. It is not used for oil temperature control.



6.3.10.6 Engine Oil Sump Temperature
The engine oil sump temperature is sensed by modifying the drain plug location of the oil pan for a thermocouple fitting. The sensor tip must be inserted 50 mm inside the interior surface of the oil pan. This sensor is used as the oil temperature control point.



6.3.10.7 Cylinder Head Oil Temperature
The cylinder head oil gallery is fed by a vertical passage, centered front-to-rear, which can be accessed from the intake side of the head. This access port is drilled in a bossed area of the head, and is located 10 mm upward from the deck surface of the head. The access port is drilled and tapped to accept an 1/8" close pipe nipple. An 1/8" pipe tee is connected to the nipple. The straight-through tee connection is utilized for the temperature sensor. The sensing tip is inserted into the center of the oil gallery passage.
The right angle tee connection is oriented downward and utilized for the measurement of cylinder head gallery pressure (see paragraph xxxxx).



6.3.10.8 Rocker Cover Gas Temperature
The rocker cover gas temperature sensor is inserted through the rear cylinder head rubber gasket (half-moon rubber plug). Drill a 2 mm diameter hole in the rear rubber plug; 4 mm down from the top, flat surface; centered horizontally. Press fit a 3.2 mm diameter closed tip type J thermocouple, 4 cm length, into the drilled hole so that the tip of the sensor is 12 mm from the inside surface of the rubber plug.

6.3.10.9 Intake-air
The inlet temperature sensor is installed in the air cleaner, centered at the inlet to the air cleaner (see Figure xxx). If vibration of the temperature sensor is a problem, a support brace can be attached to the air cleaner assembly mounting stud and wingnut.

6.3.10.10 Exhaust Temperature
Exhaust gas temperature is measured using a 6 mm diameter thermocouple installed in a welded fitting attached to the exhaust pipe at a location 5 cm downstream from the end of the collector. The sensor tip must be inserted to the center of the exhaust pipe.
See figure xxxx.

6.3.10.11 Fuel Temperature
Fuel temperature is measured through one of the ports in a cross-fitting located in the line between the Nissan fuel pump and the inlet of the Nissan fuel rail. The fuel temperature at this location is maintained between 15 degC and 30 degC.

6.3.10.12 Dynamometer Load Cell Temperature
If the dynamometer torque is measured using a strain-gage transducer attached to the moment arm, it is recommended that the environment surrounding the transducer be maintained at a constant temperature. Strain-gage transducers are very sensitive to temperature changes. A temperature sensor located near the transducer can be used to monitor ambient variations.

6.3.11 Pressure Measurement Equipment

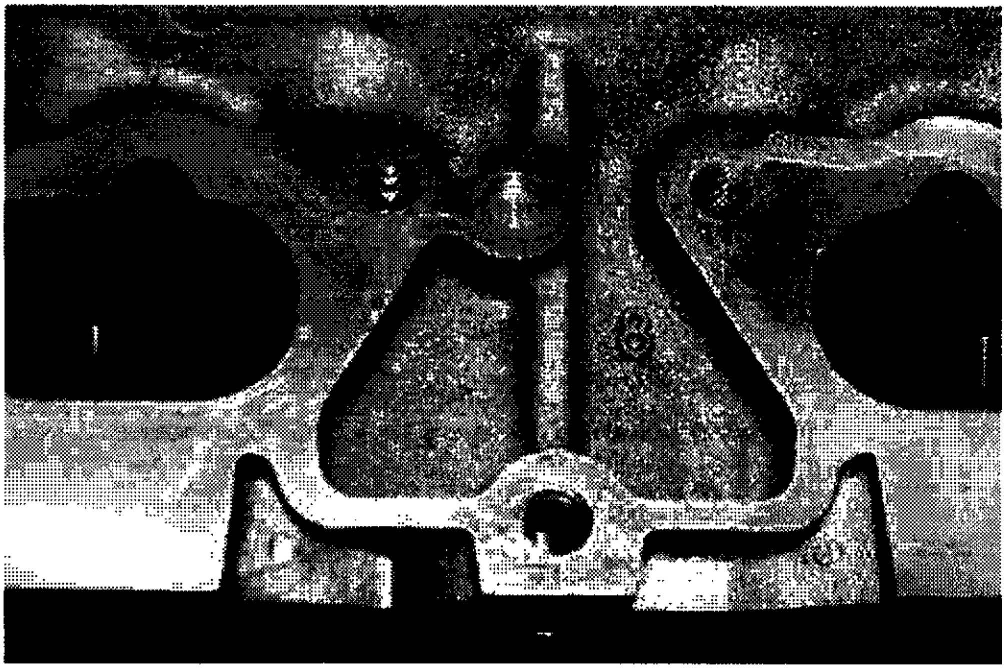
Pressure measurement for each of the seven required parameters is detailed below. Specific measurement equipment is not specified. This allows reasonable opportunity for adaptation of existing test stand instrumentation. The accuracy and resolution of the pressure measurement sensors and the complete pressure measurement system must follow the guidelines detailed in Reference Document 2.6.

6.3.11.1 Allowance for Pressure Head Deviations
Tubing between the pressure tap locations and the final pressure sensors should incorporate condensate traps, as dictated by good engineering practice. This is particularly important in applications where low air pressures are transmitted via lines which pass through low-lying trenches between the test stand and the instrument console.
If the pressure transducer is located at a different elevation than the measurement location, the pressure head must be accounted for.
Oil pressure sensor / tubing lines should be designed to minimize the trapped oil volume in the tubing lines.

6.3.11.2 Intake Manifold Vacuum
The intake manifold vacuum is measured on the throttle body, at an existing port located just below the throttle plate. See figure xxxxx.

6.3.11.3 Engine Oil Pressure
The engine oil pressure is sensed at the production location on the oil filter block. See figure xxxx for a drawing of the oil filter block. The sensing line is routed to a cross fitting, allowing ports to a pressure transducer, an analog pressure gauge, and to an oil sampling valve.

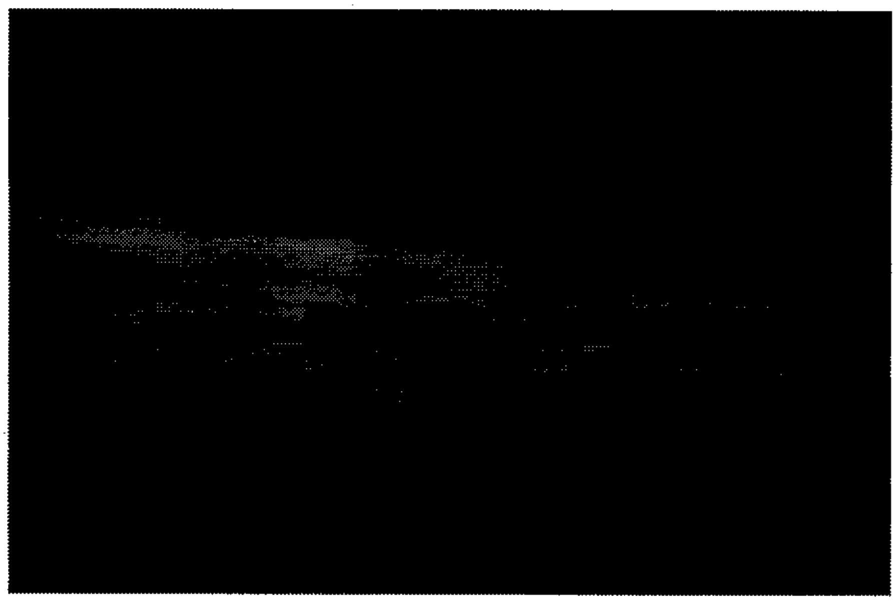
6.3.11.4 Cylinder Head Oil Gallery Pressure
The cylinder head oil gallery is fed by a vertical passage, centered front-to-rear, which can be accessed from the intake side of the head. This access port is drilled in a bossed area of the head, that is located 10 mm upward from the deck surface of the head. The access port is drilled and tapped to accept an 1/8" close pipe nipple. An 1/8" pipe tee is connected to the nipple. The right angle tee connection is oriented downward and utilized for the measurement of cylinder head gallery pressure. The straight-through tee connection is utilized for the temperature sensor (see paragraph xxxxx).



6.3.11.5 Fuel Pressure
The fuel pressure is measured through one of the ports in a cross-fitting located in the line between the Nissan fuel pump and the inlet of the Nissan fuel rail.

6.3.11.6 Intake-air Pressure
For controlling the engine inlet air gage pressure, a disc type valve is installed in the controlled air system supply duct. The sensing tube for inlet air pressure is located in the topside of the air cleaner assembly (approximately 5 cm left and 8 cm front of the right rear corner of the assembly). This location senses the pressure before entering the air cleaner element.

6.3.11.7 Crankcase Pressure
The crankcase pressure sensing line is attached to a fitting welded to the dipstick tube. This fitting is located approximately 8 cm from the top of the dipstick tube. See figure xxxxx.
The sensor must be capable of measuring positive and negative pressure. If a manometer is utilized, a liquid trap must be installed to prevent manometer fluid from entering the crankcase.



6.3.11.8 Exhaust Absolute Pressure
The exhaust pressure sensor tube is attached to a welded fitting installed on the exhaust pipe at a location 5 cm downstream from the end of the tube collector. This fitting is oriented circumferentially 60 to 90 degrees from the exhaust temperature sensor.
A condensate trap should be installed between the probe and sensor to accumulate water present in the exhaust gas.

6.3.12 Flow Rate Measurement Equipment

Flow rate measurement is required for engine coolant, fuel, and blowby. The accuracy and resolution of the flow rate measurement sensors and the complete flow rate measurement system must follow the guidelines detailed in Reference Document 2.6.

6.3.12.1 Engine Coolant Flow Rate
The engine coolant flow rate is determined by measuring the differential pressure drop across a venturi flowmeter. A Barco #705 has been determined to be suitable. A differential pressure transducer can be calibrated to provide an output (l/m). Precautions must be taken 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.

6.3.12.2 Fuel Consumption Rate
The fuel consumption rate is determined using a mass flowmeter installed in the makeup fuel line. The output of the flowmeter should allow real-time measurement of fuel rate (kg/h) and totat fuel consumed (kg). A MicroMotion Model D-6 has been shown to be satisfactory.

6.3.12.3 Blowby Flow Rate Measurement System
The apparatus shown in appendix B is required for measurement of the blowby flow rate. The measurement system routes the blowby through an external, sharp-edge orifice and into the engine intake manifold via an auxiliary (``dummy'') PCV valve. Crankcase gage pressure is maintained at 0.0 - 0.025kPa during operation of the system to minimize the potential for crankcase leakage.

The blowby flow rate is determined by measuring the differential pressure drop across the sharp-edge orifice. An inclined manometer or differential pressure sensor is required for measurement of the orifice differential pressure. The crankcase pressure sensor must have a range of 0-1 kPa and must be adequately damped to indicate a zero gage pressure.

The sharp-edge orifice is specifically designed for blowby flow rate measurement and must be fabricated in strict compliance with the specifications available from the ASTM Test Monitoring Center. The assembly contains five orifices. The 3.175 mm orifice is generally satisfactory for the range (5 to 12 L/m) of blowby flow rate encountered. Details concerning fabrication of the flow rate measurement orifice and blowby flow rate measurement can be found in Reference Document xxxxx.

6.3.13 Process Cooling Water

The engine jacket coolant heat exchanger, the oil cooler, and the eddy-current dynamometer are provided process cooling water to maintain proper operating temperatures.

6.3.13.1 Dynamometer Cooling System.
The eddy current electric dynamometer is water cooled. Provisions should be made for automatic test shutdown in the event the dynamometer cooling water is shutoff.

6.4 Test Engine Hardware

This section specifies the hardware required to build the test engine.

A new engine short block assembly is utilized for 12 tests, and the kit cylinder head assembly is new for the first test and the seventh (7th) test on that shortblock. The engine break-in procedure is conducted prior to the first test and the 7th test on that shortblock.
The new engine is a longblock, as received. The camshaft and rocker arms that are in the new engine are utilized for break-in purposes only. The new cylinder head is removed and modified for the cylinder head oil gallery temperature and pressure measurement port, and for valve spring force calibration. The head is cleaned and reassembled using the break-in camshaft and rocker arms. The break-in procedure is described in section 12.1.3. After the break-in, the break-in camshaft and rocker arms are replaced with the new, official Sequence IVA test camshaft and rocker arms that are the critical parts of the Sequence IVA test kit.

6.4.1 Nissan Supplied Component Kits

The official test parts and engines for the Sequence IVA test are obtained through Nissan Motor Corporation, U.S.A. See appendix xxxx for ordering information.

6.4.1.1 Test Engine Long-block
The test engine long-block assembly (also called bare engine assembly) is ordered as part number A0102-76P01. It includes the final assembly of the block, pistons, rods, crankshaft, oil pan, front cover, cylinder head, rocker arm cover, etc. The camshaft and rocker arms, supplied with part number A0102-76P01, can be used during engine break-in only, but they are NOT official test parts. The short-block from part number A0102-76P01 is utilized for twelve (12) tests. The original cylinder head from part number A0102-76P01 is utilized for tests one through six of the twelve conducted on the short-block.

6.4.1.2 Stand Set-Up kit
There are three (3) component kit part numbers that comprise the 'stand set-up kit'. These part numbers are A0001-76P25, A1001-40F25, and B4010-40F26. These (3) component kits include such items as crankshaft pulleys, flywheel, intake and exhaust manifolds, air cleaner, fuel injection system, EGR block-off plate, ignition distributor, wiring, starter motor, fuel pump, exhaust pipe, oil cooler, etc.
One of each of these (3) part numbers are needed to configure one Sequence IVA test installation. See appendix xxxxx for the item part numbers that are included in these component kits.

6.4.1.3 Test Kit
For every official Sequence IVA test conducted, one test kit (part number 13000-40F85) is required. This kit includes a camshaft, two rocker shafts, twelve rocker arms, three oil filters, and four spark plugs. The camshaft and rocker arms supplied in the test kit are considered critical test parts for the Sequence IVA. Critical test parts cannot be substituted with any other dealer, or aftermarket supplied hardware. If new, critical parts are inspected by the test laboratory and subsequently rejected for test use, then the unused critical parts should be returned to the Nissan Motor Corporation, U.S.A. with a documented explanation(s) for the parts rejection.

6.4.1.4 Cylinder Head Replacement Kit
Every engine short-block is used for twelve (12) tests. The original cylinder head that included in part number A0102-76P01 is utilized for tests one through six on that short-block. After the sixth test, a new replacement cylinder head is installed for tests 7 through 12 on that short-block. The replacement bare cylinder head is NMC part number A1040-40F11. To assemble and install this head, one gasket and seal kit part number 11042-40F27 is required. New calibrated valve springs, intake and exhaust valves, etc. are required to be installed with the replacement head. See appendix xxxx for a detailed listing.
When the replacement head is installed onto the engine, the original camshaft and rocker arms that were supplied with part number A0102-76P01 are used for conducting another "break-in" prior to test number seven (7).

6.4.2 Procurement of Critical Parts

Critical Engine Parts for the conduct of the Sequence IVA test are defined as the test camshaft and rocker arms. These parts can only be obtained by annual orders placed through the Nissan Motor Corporation, U.S.A., P.O. Box 191, Gardena, California 90248-0191. Dealer, service, or aftermarket camshafts and rocker arms are NOT acceptable for use in the Sequence IVA test procedure.

6.4.3 Required New Engine Parts

The Sequence IVA test procedure is a flush-and-run type test. For each test, the camshaft and rocker arms are replaced. All parts in test kit number 13000-40F85 must be utilized.

6.4.4 Reusable Engine Parts

The Sequence IVA test is designed to replace the engine short-block and oil cooler every twelve (12) tests, and the cylinder head every sixth test. If the engine demonstrates deterioration (excessive blowby or oil consumption or fuel dilution; poor compression; low oil pressure; clearances beyond service limits; stripped fasteners; etc.) prior to this expected life, the engine should be replaced and break-in and acceptable calibration test(s) conducted prior to official candidate oil testing. However, no more than twelve tests may be conducted on a short-block or the oil cooler, and no more than six tests allowed on a cylinder head.

The PCV valve, fuel filters, rocker cover gaskets, and air filter element should be replaced after six tests (when new engine or new cylinder head is installed). The ignition distributor is usually replaced when a new engine is installed.

Spark plugs are replaced for each test, just prior to the oil flush (see section 10.9.2). The spark plug (Nissan part no. 22401-30R15, NGK ZFR5E-11) are gapped at 0.99 mm (0.039").

The jacketed rocker arm cover, oil pan, oil cooler, flywheel, intake and exhaust manifolds, throttle body, modified dummy waterpump, spark plug wires, fuel injection system components, engine sensors, etc. can be reused as long as they continue to function properly.

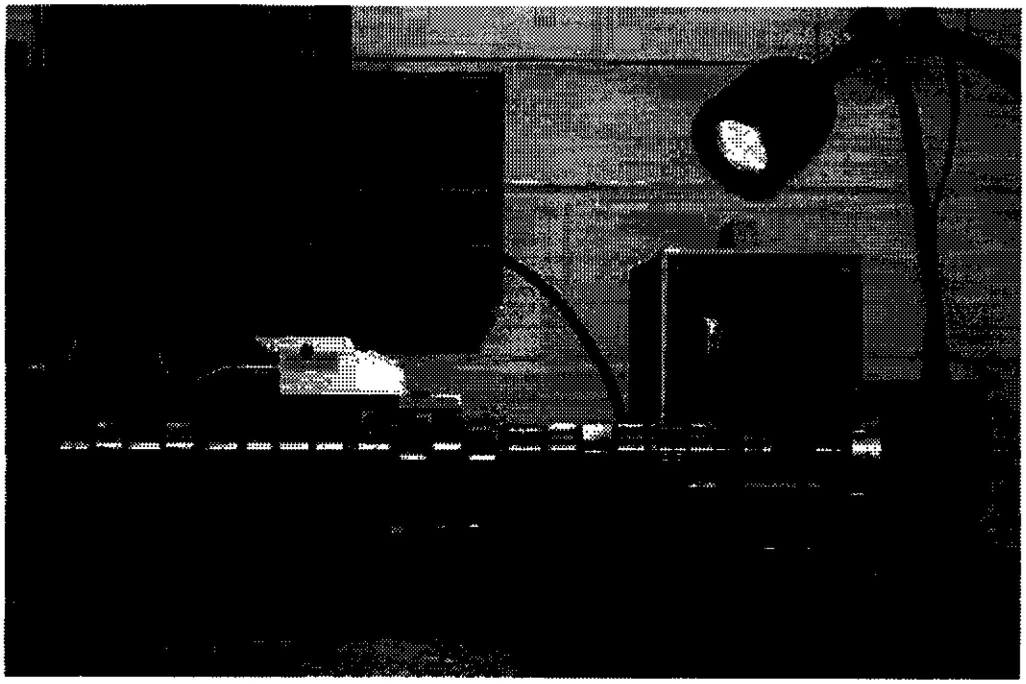
6.5 Special Measurement and Assembly Equipment

This section describes the special apparatus and equipment required for engine measurement and assembly. Items routinely used in the laboratory and workshop are not included. The special engine tools are listed in section xxxxx.

6.5.1 Camshaft Lobe Measurement Equipment

The camshaft lobes are traced with a surface texture profilometer system. A surface measurement profilometer with real time digital display and graphical output capability is required. The vertical scale graphical resolution must be capable of one micrometer per graph division. The profilometer must be capable of traversing at least 100 mm, with a straightness accuracy equal to or less than 1 μm per 100 mm of traversed length. The profilometer pickup must be used without a skid. A diamond tip stylus must be conical or spherical in shape, with a nominal radius of 5 μm. The nominal tracing (traversing) speed is 0.5 mm/s. Although a computer interface may be utilized, it is not required.

One computer-driven profilometer that can be utilized is the Precision Devices Instrument - MicroAnalyzer 2000 system. It should be equipped with custom V-blocks, part numbers PDI 4230-FA, for holding the workpiece (the camshaft on its journals). The PDS-30 {2853-FA} skidless diamond stylus should be used, which features a 0.005 mm stylus radius, and a 6.5 mm stylus height. A trace across the lobe is taken from front-to-rear of the lobe, at a traversing speed of 0.500 mm/s. The data from the trace is viewed in the profile mode, allowing an analysis of the texture and waviness of the trace. The instrument software should be configured for a 2-point line texture leveling at the unworn edges of the cam lobe. This is the reference line from which wear measurements are made. The waviness of the profile is displayed, using the Gaussian smoothing filter, set at 0.25 mm cutoff length, with the filter width NOT removed at the ends of the texture. The lobe wear measurement is based upon the vertical dimension between the horizontally positioned, 2-point leveling line (reference line) and the lowest point in the waviness profile.



6.5.2 Unassembled Valve Spring Calibration Device

This device is used to screen inner and outer valve springs before assembly in the cylinder head. The individual spring loading is measured at various compressed heights according to the Nissan Service Manual (page EM-68). The tester must have an accuracy of 2% and a resolution of 5 N.

6.5.3 Compression Gage

The cranking compression of the individual cylinders of the engine is measured once prior to test, near the end of the double-flush process. Any standard automotive compression gage can be used. Since this is a primitive measurement to detect a serious engine malfunction, the calibration requirements of this device is not specified in this procedure.

6.5.4 Special Nissan 2.4 liter Engine Service Tools

Special tools are necessary to perform the items listed below. Special tools are also available for other service items.

Item	Tool Number

6.6 Miscellaneous Apparatus Related to Engine Operation

6.6.1 Timing Light

An inductive pickup timing light is required to measure ignition-timing.

6.6.2 Volumetric Graduates

The primary measurement of the specified quantity of test oil is by volume. It is NOT permissable to use weight, converted to a calculated volume. A 1000 ml graduate and 500 ml graduate are recommended for volumetric determinations. All volumetric graduates must have an accuracy of 2% of full scale. The resolution of the large graduate must be 100 ml, and the resolution of the small graduate must be 25 ml.

7. Reagents and Materials

The test oil sample required to perform the 100-hour Sequence IVA Valve Train Wear test is 13 L. A sample volume of 15 L is typically supplied to account for inadvertent losses during the test.

7.1 Coolant for Engine and RAC

The coolant must be demineralized (less than 0.29g/kg) or distilled water mixed with an extended-life ethylene glycol antifreeze/coolant at a 50% volume ratio. Texaco Havoline Dex-Cool antifreeze/coolant has been found to be a satisfactory product.

7.2 Fuel

The required fuel is Specified Fuels KA24E reference unleaded gasoline. It is dyed green to thwart unintentional contamination with other test fuels. Approximately 200 liters of fuel are required for each test (100 cycles). This fuel has a hydrogen-to-carbon ratio of 1.80 to one. See appendix xxxxx for procurement of this fuel.

7.2.1 Fuel Approval Requirements

Fuel is approved by the Sequence IVA Surveillance Panel chairman and the Test Monitoring Center. Acceptance of fuel batches is based upon the physical and chemical specifications given in appendix xxxx. No engine validation tests are normally required for fuel batch acceptance.

7.2.1.1 Authorization

The Test Monitoring Center will issue a memorandum for the authorization of use of a new fuel batch of Specified Fuels KA24E.

7.2.2 Fuel Analysis

Good laboratory practices should be used to monitor the test fuel. Each fuel shipment should be analyzed upon receipt to determine the value of each parameter listed below. The results should be compared to the original values supplied by the fuel supplier, Specified Fuels and Chemicals, for the particular fuel batch. The results should be within the tolerances shown in parentheses beside each parameter. This provides a method to determine if the fuel batch is contaminated or has aged prematurely. If any result falls outside the tolerances listed below, the laboratory should contact the fuel supplier for resolution of the problem.

7.2.2.1 Fuel Deterioration
In addition, the fuel should be analyzed periodically to ensure the fuel has not deteriorated excessively or been contaminated in storage.

Existent Gum, ASTM D381
Oxidation Stability, ASTM
RVP, ASTM D323
API Gravity @ 60 degF, ASTM D287

7.2.3 Fuel Shipment and Storage

The fuel should be shipped in containers with the minimum allowable venting as dictated by all safety and environmental regulations, especially when shipment times are anticipated to be longer than one week. The fuel should be stored in accordance with all applicable safety and environmental regulations.
If the "run" tank has more than one batch of fuel, document the most recent batch in the test report. Do not "top-off" the "run" tank with the new fuel batch unless tank is less than 10% "full".

7.3 Lubricating Oils

7.3.1 Break-in Lubricating Oil

As detailed in section 12.1.3, an engine break-in procedure is immediately conducted following the replacement of new, major engine components (i.e. engine shortblock and/or cylinder head). This engine oil utilized for the break-in procedure is ASTM 926-2 and can be procurred through the ASTM Test Monitoring Center for these purposes. Approximately 3.5 liters of ASTM 926-2 is needed for each break-in procedure.

7.3.2 Lubricant for Hydraulic Lash Adjusters

The hydraulic lash adjusters in the rocker arms can ingest air during shipping and handling. Prior to installing the rocker arms in the KA24E engine, the lash adjusters must be primed with an SAE 20 API "SA" grade oil. Place the rocker arms on their side, for a minimum of one hour, in a container filled with the "SA" grade oil to allow trapped air to bleed out (see Nissan service manual). Alternatively, if a vacuum chamber is utilized, the minimum soak time can be reduced from one hour to five (5) minutes. Immediately install the rocker arms in the engine after the rocker arms are removed from the oil-filled container. Do not allow the rocker arms to lay on their side after air has been bled.

7.3.3 Short-block Assembly Lubricant

For inspection and/or rebuild of the engine shortblock, use SAE 20 API "SA" grade oil as the assembly lubricant.

7.4 Miscellaneous Materials

7.4.1 Solvents and Cleansers

The various solvents and cleansers used in the test are listed below. No other solvents or other types of cleansers can be substituted. **Warning** - Adequate safety provisions are required with the use of all solvents and cleansers.

Solvents and Cleansers
Aliphatic Naphtha - Stoddard Solvent or equivalent
Ethyl Acetate
Pentane
Cylinder Block and RAC Cleaning Detergent - tri-sodium phosphate detergent

7.4.2 Sealing Compounds

A silicone based gasketing compound is used during engine assembly (e.g. oil pan). Only the Nissan branded part number 999MP-A7007 silicone gasket maker can be used.

8. Hazards

8.1 Specific Hazards

Personnel are exposed to various hazards in the operating environment which are listed below. Technical precautions concerning procedures that may produce erroneous results or cause injury to personnel or damage to equipment or both are noted in the appropriate sections.

Specific Hazards

Electrical Shock

Exhaust Gas Analyzer Venting - Noxious gases are present in the exhaust gas analysis system, and these gases must be vented in a safe manner. Abnormal failure modes and normal operating modes must be considered in the design of the venting system.

Gasoline

Handling of New and Used Crankcase Oils

High-Speed Rotating Equipment

High-Temperature Surfaces

Noise

Solvents and Cleansers

9. Oil Blend Sampling Requirements

9.1 Sample Selection and Inspection

The candidate sample must be uncontaminated and representative of the lubricant formulation being evaluated. If the test is registered using the Chemical Manufacturers Association protocols, the formulation number assigned to the oil container must match the registration form.

9.2 Candidate Oil Sample Quantity

A minimum of 13 l of new oil are required to complete the Sequence IVA test, including the oil flushes. A 15 l sample of new oil is normally provided to allow for inadvertent losses.

9.3 Reference Oil Sample Quantity

A 15 l sample of reference oil is provided by the Test Monitoring Center for each stand calibration test.

10. Preparation of Apparatus

This section details the recurring preparations that are necessary during the operation of the test. This section is written under the assumption that the engine test stand facilities and other hardware described in Sec. 6 are in place.

10.1 Test Stand Preparations

10.1.1 Instrumentation Calibration

Calibrate all sensors and indicators before or during the test as required by the particular types of instrumentation utilized. Sec. 11 provides details on all calibration requirements.

10.1.2 Oil Cooler Cleaning

Cleaning of the oil cooler is not normally required. If it is needed to clean the oil cooler, use clean aliphatic naphtha followed by forced-air drying.

10.1.3 Mass Air Flow Sensor Cleaning

Should we????

10.1.4 Air Cleaner Filter

The air cleaner filter element should be replaced every six tests, or more frequently if intake air pressure is insufficient.

10.1.5 Draining Exhaust Piping

Prior to the start of each test, the low point of the exhaust piping is drained to eliminate water accumulation. It may also be necessary to drain water during a test if exhaust pressure control becomes unstable.

10.1.6 External Hose Replacement

Inspect all external hoses used on the test stand and replace any hoses that have become unserviceable. Check for internal wall separations that could cause flow restrictions. Oil cooler coolant hoses should be inspected/replaced when oil cooler is normally replaced (every 12 tests).

10.1.7 Stand Ancillary Equipment

Service the dynamometer and driveline components, if needed. The dynamometer torque measurement must be accurate (i.e. no unaccounted forces from hoses; load cell temperature gradients; trunnion bearing hysteresis; etc.).

10.2 General Engine Assembly Preparations and Instructions

The assembly instructions shown below are a guide to detail all functions that must be completed. Different laboratories and engine assemblers may complete the functions in slightly different sequences. Functions that must be performed in a specific manner or at a specific time in the assembly process are noted. Any assembly instructions not detailed below should be completed according to the instructions in the 1994 Nissan Service Manual. The following bolt torque specifications are to be used:

Cylinder head bolts	82 degrees beyond 29 N-m
Camshaft Sprocket bolt	137 N-m
Intake Manifold bolts	19 N-m
Camshaft cap bolts	39 N-m
Exhaust Manifold bolts	22 N-m
Rocker Cover bolts	9 N-m

10.4 Cylinder Head Preparations

All new Sequence IVA cylinder heads must be modified, cleaned, assembled, and calibrated before using the cylinder head for testing purposes. A cylinder head can be used for up to six (6) tests.

10.4.1 Cylinder Head Modification

The cylinder head oil gallery is fed by a vertical passage, centered front-to-rear, which can be accessed from the intake side of the head. This access port is drilled in a bossed area of the head, that is located 10 mm upward from the deck surface of the head. The access port is drilled and tapped to accept an 1/8" close pipe nipple

10.4.2 Cylinder Head Cleaning

After the modification detailed in section 10.4.1 has been completed, the cylinder head is throroughly cleaned using aliphatic naphtha spray. The valve guide bores and oil passages should be cleaned using a nylon bristle brush in conjunction with the aliphatic naphtha spray. Then rinse the head with a clear water spray. Dry with forced-air.

10.4.3 Camshaft Journal Clearance

Only the vertical measurements are used to determine the overall cam journal to bearing clearance (front and rear). This clearance cannot exceed 0.120 mm. If it does exceed 0.120 mm clearance, the cylinder head and/or camshaft will need to be replaced.

10.4.3.1 Camshaft Bearing Bore Measurements
Without camshaft, install cam bearing caps with rocker shafts and tighten the lubricated cap bolts to 39 N-m.

When the cylinder head is new, perform a comprehensive set of measurements of the five (5) cam bearing bores to ensure that the bores are sized to specification, and that the bores are round and not tapered. The front and rear of each cam bore is measured in three (3) directions - vertical, and two measurements at 45 degrees from vertical. This results in six (6) measurements for each cam bore. The standard inner diameter specification is 33.000 to 33.025 mm. Run-out and/or taper should not exceed 0.025 mm.

After the first test on a cylinder head, only the vertical dimension of the front and rear of each cam bore is required to determine the cam journal to bearing bore clearance before subsequent tests.

10.4.3.2 Camshaft Journal Measurements
Measure the front and rear outer diameters of each of the five (5) camshaft journals. The standard outer diameter is 32.935 to 32.955 mm. These measurements are used to calculate cam journal to bearing bore clearance.

10.4.3.3 Camshaft End Play
With the camshaft installed in the cylinder head, measure the camshaft end play with a dial indicator. If the end play is beyond 0.07 to 0.20 mm, do not use that cylinder head/camshaft combination.

10.4.4 Cylinder Head Assembly

Assemble the cylinder head using the instruction in the Nissan KA24E service manual. It is permissible to lap the valve faces to their respective valve seats to ensure a proper seal. Since the cylinder head is new when it is assembled, the valves, valve guides, and valve seats should not need to be replaced or machined. API "SA" SAE grade 20 lubricant should be used to lubricate the valve stems and valve guides upon assembly.

10.4.5 Initial Valve Spring Screening

Measure and record the valve spring free length and out-of-square dimensions. The springs should be within the specifications shown below. If the springs are within the specifications for free length and out-of-square dimensions, measure the load on the unassembled valve spring calibration device. The valve spring parameters should be within the specifications shown below. However, because the final valve spring load is determined with the valve springs installed in the cylinder head, springs slightly outside the load specification noted above may be within the load specification when installed in the cylinder head, provided shims are used.

Valve Spring Specifications

	Intake	Exhaust
Free Height		
outer	57.44 mm	53.21 mm
inner	53.34 mm	47.95 mm
Pressure		
outer	604.1 N @ 37.6 mm	640.4 N @ 34.1 mm
inner	284.4 N @ 32.6 mm	328.5 N @ 29.1 mm
Out-of-Square		
outer	2.5 mm	2.3 mm
inner	2.3 mm	2.1 mm

10.4.6 Installed Valve Spring Calibration

Lubricate each valve seal and valve stem with API "SA" oil. Install the valve seal over the end of the valve stem with a plastic installation cap in place. Carefully seat the seals fully on the guides. Install pre-screened valve springs and retainers. When installing the valve springs and retainers, do not compress the springs excessively. Excessive spring compression can damage the valve seals.

10.4.6.1 Assembled Height

10.4.6.2 Assembled Force Calibration

Measure the record the assembled valve spring loading with the valve spring force measurement apparatus described in Appendix xxxx. The procedure detailed below includes measuring each installed valve spring at two (2) deflection points.

a) Check the calibration of the apparatus load cell for accuracy.

b) Install the cylinder head holding fixtures (drawing 0751-1700) for the Nissan KA24E cylinder head.

c) Position the Nissan KA24E cylinder head in the holding fixture with intake valve springs accessible.

d) Install the rocker cover gasket rail extension bracket on the Nissan KA24E cylinder head.

e) Starting with the intake valve spring no. 1 (far right), position the air cylinder and load cell on valve tip to allow compressing of the valve spring.

f) Position the dial indicator with the plunger on rocker cover gasket rail extension bracket.

g) With no air pressure to the cylinder, the dial indicator should read between 2.5mm and 5.00mm deflection preload against the rocker cover gasket rail extension bracket. This will allow determination of positive or negative displacement of the valve.

h) Adjust the dial indicator face to position the needle at the zero (0) mark with no air pressure to the air cylinder.

i) Adjust the air regulator to provide enough air pressure to the air cylinder for compression of the valve spring to occur. If a valve spring has already been measured, then the air regulator should already be adjusted.

j) Actuate and discharge the air cylinder in a rapid and consistent manner, several times, to compress the valve spring and assure proper movement of the valvetrain components.

k) Actuate the air cylinder and adjust the air regulator to decrease the air pressure to allow the valve to close to the fully seated position.

l) Adjust the air regulator to gradually apply force to achieve exactly 1.27mm valve opening. Record the indicated load (N) at 1.27mm.

m) Continue to adjust the air regulator to gradually apply force to achieve exactly 9.86mm valve opening. Record the indicated load (N) at 9.86mm.

n) Discharge the air cylinder without adjusting the air regulator, and allow the intake valve to close to the fully-seated position. Position the air cylinder / load cell to check the remaining seven intake valve springs. Conduct steps e) through m) above for each remaining intake valve spring.

o) Position the Nissan KA24E cylinder head in the holding fixture with the exhaust valves accessible.

p) Install the rocker cover gasket rail extension bracket on the cylinder head, and position the air cylinder / load cell to check the four (4) exhaust valve springs. Conduct steps e) through m) for each exhaust valve spring.

q) The intake valve spring specification is:

889 ± 35 N @ 9.86mm

438 ± 35 N @ 1.27mm

The exhaust valve spring specification is:

969 ± 35 N @ 9.86mm

447 ± 35 N @ 12.7mm

r) Replace any springs that are too strong. Shims may be used to adjust springs to a higher installed force. Recheck spring calibration and record indicated load of any replaced or shimmed springs.

10.5 Short Block Preparations

None are normally required.

10.6 Short Block Assembly

For inspection and/or rebuild of the engine shortblock, use SAE 20 API "SA" grade oil as the assembly lubricant.

10.7 Final Engine Assembly

The engine shortblock assembly can be utilized as received from Nissan. Alternatively, the engine shortblock can be disassembled, inspected, and reassembled according to the Nissan Service Manual. For the Sequence IVA test, the piston ring end gaps are maintained to factory specifications. Ring end gaps are NOT increased to elevate engine blowby. Corrected blowby rate is normally observed to be 6.0 to 10.0 liters per minute during the Stage I operating condition.

10.7.1 Cylinder Head Installation

The assembled, new cylinder head is included in the KA24E parts kit. The valve seats and valve faces are already machined to Nissan production specifications. Lapping of valve seat and valve faces is permissable if laboratory inspection reveals the need. Before the assembled cylinder head can be installed, it must undergo the following:

a) be stamped with a laboratory specific identification code
b) modified for measurement access to the cylinder head oil gallery (see section 6.3.10.7).
c) measured for cam bearing bore diameter (specification 33.000 - 33.025mm).
d) cleaned with aliphatic naptha and forced-air dried
e) reassembled according to the Nissan Service Manual. Use SAE 20 API "SA" grade oil to lubricate valve guides and valve stems. Install new valve seals.

f) as-installed valve spring force is measured and adjusted to KA24E test specifications (see section 10.4.6.2).

The modified and measured cylinder head is installed on the shortblock using a new cylinder head gasket that is included in the Nissan parts kit. The head bolts are torqued in proper sequence and in five (5) stages according to the Nissan Service Manual. An angle-meter torque wrench is required to properly torque the cylinder head bolts.

10.7.2 Camshaft Installation

After the cylinder head has been modified, cleaned, assembled and calibrated per section 10.4 of this procedure, the measured test camshaft can be installed. Clean the camshaft with aliphatic naphtha and force-air dry. Coat the lobes and journals with clean TEST OIL only. Do NOT use ASTM 926-2 to lubricate the test camshaft.

Install the test camshaft, camshaft journal caps and dummy rocker shafts, and torque to 39 N-m (28 ft-lbs). Install the camshaft sprocket and snug the sprocket bolt (do not torque to specification yet).

Measure and record the camshaft end-play and the camshaft sprocket run-out according to page EM-65 of the Nissan Service Manual.

Temporarily remove the test camshaft, camshaft sprocket, camshaft journal caps and dummy rocker shafts.

Pre-fill the cavities of the cylinder head under the camshaft with new test oil.

Oil the camshaft and journal bores with new test oil and install the test camshaft.

Install the camshaft journal caps in their proper positions.

Install the rocker shaft assemblies and loosely screw the bolts. Do not yet tighten the bolts yet.

Install the camshaft sprocket and timing chain, aligning the punch-mark with the glaring link. Torque the camshaft bolt to 135 N-m (100 ft-lbs) using the appropriate cam sprocket holding tool.

Center each individual rocker arm on its respective cam lobe as best as possible and then snug the ten (10) rocker shaft bolts and torque to 39 N-m (28 ft-lbs) using the torque sequence on page EM-70 of the Nissan Service Manual.

Pour new test oil over the rocker arms, rocker shafts and camshaft once all is installed. Excess oil will drain through the open oil pan drain-plug.

10.8 Engine Installation on Test Stand

10.9 Replacement of ValveTrain Wear Parts

The Sequence IVA valvetrain wear test is a flush-and-run type procedure, except that valvetrain test parts are replaced for each test. The procedure below must be used when these parts are replaced.

10.9.1 Removal of ValveTrain Wear Parts

1) Disconnect wiring or hoses that hinder access to the rocker cover.

2) Remove the crankshaft pulley guard.

3) Remove the blowby fresh air line and the spark plug wire loom from the rocker cover.

4) Remove the rocker cover.

5) Remove all four (4) spark plugs.

6) Rotate engine by hand to set piston no. 1 at TDC on its compression stroke (align timing indicator with 0° □yellow□ mark on crankshaft pulley). The dowel pin on camshaft front should be at the 12:00 position and the punch-mark on the camshaft sprocket should be aligned with the glaring link on the timing chain. Note that this may require rotating the engine several times until the mark and glaring link line up.

7) Remove the front hoist bracket from the cylinder head. It can hang from the ground straps that are attached to it.

8) Remove the □half-moon□ rubber plug from the front of the cylinder head.

9) Install the timing chain wooden wedge tool between timing chain at the tensioner using a large screwdriver to set it in place.

10) Remove the camshaft bolt and sprocket using a 24mm impact deep socket.

11) Remove the ten (10) rocker shaft bolts according to page EM-64 of the Nissan Service Manual.

12) Carefully remove the rocker shafts and rocker arms. Avoid touching the rocker arm pads. At this time the rocker arms should remain assembled on the rocker shafts.

13) Remove the five (5) camshaft journal caps. Caps should be numbered for their location.

14) Carefully remove the test camshaft without damaging the lobes. Avoid touching the camshaft lobes.

15) Using a suction device, remove the used test oil that is trapped in the cavities of the cylinder head under the camshaft. Do not add this oil to the drained test oil. It can be discarded.

16) Bring the end-of-test test parts, including the assembled rocker shaft assemblies to the engine disassembly area. Before disassembling the used rocker shaft assemblies, verify that the rocker arms have been properly labeled. If not, do so at this time. See the **Additional Notes** section in sectin xxxxx for information on

positioning and labeling the rocker arms.

17) Once it has been verified that the rocker arms have been properly labeled for position, then the rocker shaft assemblies can be disassembled.

18) Remove the retainer clips from the used rocker shafts. These will be reused.

19) Clean the end-of-test test camshaft and rocker arms with aliphatic naptha solvent and pentane if necessary, then forced-air dry. Have the cleaned camshaft delivered to metrology and the cleaned rocker arms taken to the rating area or placed in a desiccator.

10.9.2 Installing New Valvetrain Test Parts

1) Obtain the new test parts, including the pre-measured test camshaft. See the **Parts List** in section xxxx for a listing of all new parts with their corresponding part numbers to be used for each turn-around.

2) Number the new rocker arms E1 - E4 and I1 - I8. See the **Additional Notes** in section xxxxx for information on positioning and labeling the rocker arms.

3) Clean the new camshaft, rocker shafts and rocker arms, as well as the used retainer clips, camshaft journal caps, camshaft sprocket, rocker cover and all bolts with aliphatic naptha solvent and forced-air dry.

4) Perform and record camshaft bearing journal diameter measurements.

5) Perform a bleed down of the rocker arms with built in hydraulic lash adjustors. Place the rocker arms in a container or vacuum chamber, fully submerging them in SAE 20 API "SA" grade oil. If a vacuum chamber is utilized, the minimum soak time can be reduced from one hour to five (5) minutes. Once the rocker arms are bled of air, they cannot be placed on their sides - they must be oriented in their natural engine position.

6) Assemble the new rocker arms and used retainer clips on the new rocker shafts according to page EM-69 and EM-70 of the Nissan Service Manual.

7) Install and torque to 39 N-m (28 ft-lbs) the five (5) camshaft journal caps and bare rocker shafts (use the designated dummy rocker shafts).

8) Perform and record camshaft bearing bore diameter measurements.

9) Remove the camshaft journal caps and dummy rocker shafts.

10) Install the test camshaft, camshaft journal caps and dummy rocker shafts, and torque to 39 N-m (28 ft-lbs). Install the camshaft sprocket and snug the sprocket bolt (do not torque to specification yet).

11) Measure and record the camshaft end-play and the camshaft sprocket run-out according to page EM-65 of the Nissan Service Manual.

12) Remove the test camshaft, camshaft sprocket, camshaft journal caps and dummy rocker shafts.

13) Pre-fill the cavities of the cylinder head under the camshaft with new

test oil.

14) Oil the camshaft and journal bores with new test oil and install the test camshaft.

15) Install the camshaft journal caps in their proper positions.

16) Install the rocker shaft assemblies and loosely screw the bolts. Do not yet tighten the bolts yet.

17) Install the camshaft sprocket and timing chain, aligning the punch-mark with the glaring link. Torque the camshaft bolt to 135 N-m (100 ft-lbs) using the appropriate cam sprocket holding tool.

18) Center each individual rocker arm on its respective cam lobe as best as possible and then snug the ten (10) rocker shaft bolts and torque to 39 N-m (28 ft-lbs) using the torque sequence on page EM-70 of the Nissan Service Manual.

19) Pour new test oil over the rocker arms, rocker shafts and camshaft once all is installed. Excess oil will drain through the open oil pan drain-plug.

20) Inspect the □half-moon□ rubber plugs found on the front and rear of the cylinder head. Replace them if necessary.

21) Install the □half-moon□ rubber plug on the front of the cylinder head. Apply the proper amount of the Nissan silicone gasket maker to the bottom of the plug. Do the same for the □half-moon□ rubber plug found on the rear of the cylinder head.

22) Inspect the rocker cover gasket and replace if necessary.

23) Install the rocker cover and torque in sequence to 8 N-m (70 in-lbs) according to page EM-72 of the Nissan Service Manual.

24) Re-install the blowby fresh air line on to the rocker cover and tighten the clamp.

25) Install spark plug wire loom and reconnect any other wiring or hoses.

26) Install the front hoist bracket and torque the nuts to 20 N-m (15 ft-lbs).

27) Install new spark plugs (Nissan part no. 22401-30R15, NGK ZFR5E-11). Gap the plugs to 0.99 mm (0.039") and torque them to 14 N-m (10 ft-lbs).

28) Install the front pulley guard.

11. Test Stand Calibration and Maintenance

The calibration status of the test laboratory and engine test stands is verified with reference oils which are supplied by the Test Monitoring Center. Stand calibration tests are normally conducted periodically to verify that proper severity level and precision is being achieved. A pre-requisite to the conduct of reference oil calibration tests is the proper processing of computer acquired operational data, ensuring accuracy of measurements, and test stand preventative maintenance.

11.1 Computer Data Acquisition

It is required that the test stand log operational data with a computer data acquisition system that utilizes the sensor configurations that are detailed in this procedure.

11.1.1 Frequency of Logged Steady-State Data

Stage I steady-state (last 45 minutes of stage) operational conditions are to be logged every two minutes or more frequently.
Stage II steady-state (last 5 minutes of stage) operational conditions are to be logged every 30 seconds or more frequently.

11.1.2 Frequency of Logged Transient Data

Transient time is defined as the first five 5) minutes following operational stage changes.
It is required that cycle 5 transient data be computer logged and plotted. The critical parameters (engine speed, torque, oil gallery temperature, coolant out temperature) be logged once per second or higher frequency. If cycle 5 transients are beyond the procedural limits defined in 12.2.6, corrective action should be documented and confirmed with the next available transition plot.

11.1.3 Signal Conditioning

Controlled operational parameters are not permitted to exceed the following system time response for measurement. The system time response includes the total system of sensor, transducer, analog signal attenuation, and computer digital filtering. It is desirable that single-pole type filters be utilized for attenuation. For temperature sensors, grounded thermocouples are preferred, although ungrounded thermocouples are acceptable for use.

Measurement Type	**Maximum Time Response (one time constant)**
Temperatures	2.5 seconds
Pressures	1.6 seconds
Coolant Flow	2.5 seconds
Torque	2.0 seconds
Speed	1.8 seconds

11.1.3.1 Isolated Inputs
If grounded, sheathed thermocouples are used in the Sequence IVA test, signal conditioning modules are needed to provide isolated inputs to the digital computer.

11.2 Instrumentation Calibration

In general, a thorough re-calibration adjustment of all instrumentation and transducers, including computer channels, must be performed whenever the KA24E engine is replaced (normally after twelve tests have been completed), or not to exceed 180 days since the previous re-calibration.

A calibration check must be performed for critical parameters after the sixth test following a recalibration adjustment. These critical parameters are:

Oil Gallery temperature
Coolant Out temperature
Intake Air temperature
Dynamometer torque

Instrumentation calibration checks may also be required more frequently, where noted below. It is also recommended to perform additional calibration checks whenever operational data indicates an abnormality.

The standards, that are used for instrumentation calibration, must be traceable to the National Standards Bureau for that country. Where possible, the accuracy of the standard should be at least four (4) times better than the required accuracy of the test stand instrumentation.

11.2.1 Engine Load Measurement System (Torque)

The final readout of engine load must be scaled in torque (Nm).

The load measurement and readout system must be calibrated with deadweights. Calibration can be affected by coolant flow through the dynamometer, reaction forces due to coolant plumbing, brinnelled trunnion bearings of the dynamometer, and by temperature excursions of the dynamometer electronic load transducer.

The required accuracy of the torque measurement is ± 0.2 Nm.

11.2.2 Coolant Flow Measurement Systems

The venturi flowmeter must be checked for calibration using a 50% water/glycol fluid controlled at 50 degrees C. The flowmeter should be calibrated as installed in the system at the test stand. Alternatively, the flowmeters may be detached from the test stand and calibrated, providing the adjacent upstream and downstream plumbing is left intact during the calibration process. The flowmeters must be calibrated with a turbine flowmeter or by a total volume per unit time method.

The required accuracy of the coolant flow measurement is ± 0.3 l/m.

11.2.3 Fuel Consumption Measurement Calibration

Mass flowmeter or gravimetric systems must be checked for calibration whenever the KA24E engine is replaced (normally after twelve tests have been completed), or not to exceed 180 days since the previous re-calibration. The required accuracy of the fuel flow measurement is ± 0.05 kg/hr.

11.2.4 UEGO Sensor Calibration

The Air-to-Fuel ratio meter is recalibrated per the instrument manufacturers recommended procedure whenever the universal (or wide-range) exhaust gas oxygen sensor is replaced.

11.2.5 Temperature Measurement Calibration

The engine oil-gallery, engine coolant-out, and intake-air temperature measurement sensors must be checked for calibration after six (6) tests. All other temperature sensors must be checked at least after twelve (12) tests.

The temperature measurement system must indicate within ± 0.5 degrees C of the laboratory calibration standard. The calibration standard must be traceable to national standards.

11.2.6 Pressure Measurement Calibration

All pressure measurement systems must be checked for calibration whenever the Sequence IVA engine is replaced (normally after twelve tests have been completed), or not to exceed 180 days since the previous re-calibration.

The required accuracy of the exhaust pressure measurement is ± 1.0 kPa.

11.2.7 Humidity of Induction Air Calibration

11.2.7.1
Calibrate the primary laboratory measurement system at each stand on a semi-annual basis using a hygrometer with a minimum dew point accuracy of ±0.55 degC @ 16 degC. Locate the sample tap on the air supply line to the engine, between the main duct and 1 meter upsteam of the intake air cleaner. The calibration consists of a series of paired humidity measurements comparing the laboratory system with the calibration hygrometer. The comparison period lasts from twenty minutes to two hours with measurements taken at one-to-six minute intervals, for a total of twenty paired measurements. The measurement interval shall be appropriate for the time constant of the humidity measurement instruments.

11.2.7.2
Verify that the flow rate is within the equipment manufacturer's specification, and that the sample lines are non-hygroscopic. Correct dew point hygrometer measurements to standard conditions (101.12 kPa) using the appropriate equation. Compute the difference between each pair of readings and calculate the mean and standard deviation of the twenty paired readings. The absolute value of the mean difference shall not exceed 1.43 g/kg, and the standard deviation shall not be greater than 0.714 g/kg. If these conditions are not met, investigate the cause, make repairs, and recalibrate. Maintain calibration records for two years.

11.3 Apparatus Calibration and Maintenance

11.3.1 Cam Lobe Profilometer Calibration

Follow the manufacturer's instruction for calibration and verification checks of the profilometer.

11.3.2 Valve Spring Force Measurement Calibration

The valve spring force measurement device must be calibrated at least once every three months. The calibration technique is left to the discretion of the testing laboratory.

11.3.3 Blowby Flow Rate Measurement System Maintenance

Clean the blowby measurement apparatus at least weekly. Exercise particular care when cleaning the orifice meter assembly. Clean the 3-way valve by soaking the valve in solvent. Inspect the port passages and remove any carbonaceous deposits by scraping. If the valve is disassembled for cleaning, make sure the core is properly seated upon reassembly. **Caution** - Internal leakage within the 3-way valve may cause some of the blowby gas to pass directly to the intake manifold from the test PCV valve and result in erroneous blowby flow rate measurements.

11.4 Test Stand Maintenance

11.4.1 Periodic Cleaning of Coolant System Plumbing

Every 12 tests, it is recommended that the engine coolant system plumbing be internally cleaned by a chemical flushing method. Use any commercial radiator cleaner/flush chemical that is safe for vehicle use. After using the cleaner according to its instructions, flush the test stand coolant plumbing with fresh water, until clear.

If a flush cart is used, stronger chemicals can be used provided the engine coolant pumps are bypassed and the instrument transducers are not included in the flush.

11.4.2 Replacement of Nissan Oil Cooler

The Nissan oil cooler, part number 21305-03E00KT, must be replaced any time the short block assembly is replaced. Normally, this allows twelve (12) tests to be conducted using the same oil cooler. It is recommended that any hoses to the oil cooler be replaced whenever a new oil cooler is installed.

12. Test Procedure

Whenever a new engine and/or cylinder head is installed, a break-in procedure must be conducted according to section 12.1.3 before running official 100 hour tests. Once the break-in has been completed, the official test valvetrain parts are installed according to the procedures detailed in section 10.9 and 12.2.1. Then a double oil-flush procedure is conducted according to procedures detailed in section 12.2.2. Once the double oil-flush has been performed, the 100 hour test can be conducted according to procedures detailed in section 12.2.3.

12.1 Pre-test Procedure

12.1.1 Engine Coolant System Flushing

Whenever the engine shortblock is replaced (normally every 12 tests), the coolant system (including heat exchanger) should be cleaned before conducting the engine break-in. Since an external electric-driven coolant circulating pump is used, the engine should be in place but does not have to be running during the flush-cleaning process. It is recommended that sensitive components of the coolant flowmeter be excluded from the flushing chemicals. Also, the calibration of the coolant flowmeter should be checked after the coolant system flush has been completed.

12.1.1.1
Prepare the coolant system cleanser solution by adding oxalic acid at the ratio of 23 g/l of water and adding Petro Dispersant 425 at the ratio of 1 g/l of water for the coolant flush charge. Circulate this cleaning solution for 30 minutes at a target temperature of 50 degC using the electric heating element for the coolant system.

12.1.1.2
Following the 30 minute cleaning process, turn off the electric heater for the coolant system. Open the coolant system drain valves and add fresh water until the drains are clear and the pH of the incoming and outgoing fresh water is unchanged. Fully drain the system.

12.1.1.3
Fill coolant system with a pre-mixed coolant consisting of 50/50 volume percent mixture of the specified extended-life ethylene-glycol anti-freeze and deionized, demineralized, or distilled water. Operate the coolant pump to bleed air from the coolant system.
This coolant charge can be utilized for twelve tests, or until the engine shortblock is replaced.

12.1.2 Engine Pre-lubrication

Since the oil pump drive is directly connected to the engine crankshaft, it is not practical to pressure lubricate the engine prior to startup. However, it is very important to build oil pressure quickly by pre-filling the oil filter with 325 ml of the appropriate lubricant. It is also important to bleed air from the rocker arm lash adjusters before these components are installed in the engine. This is done by immersing the rocker arms in a container of SAE 20 API "SA" grade oil while laying on their side. After soaking, the rocker arms should be kept straight up until they are installed to prevent air from entering the lash adjusters.

12.1.3 Engine Break-in Procedure

The break-in procedure is conducted, prior to lubricant evaluation testing, when a new engine shortblock, new long-block, or new cylinder head is installed on the test stand.
The break-in allows an opportunity to set the ignition-timing, purge air from the coolant system, check for leaks in the various systems, and monitor engine performance and test stand instrumentation.

Follow the prescribed break-in conditions (**Table xxxx**). The engine short block assembly will be utilized for 12 tests and the cylinder head assembly will be utilized for 6 tests. Therefore, a new engine break-in will only need to be performed once every 6 tests. The necessary steps to conduct the break-in are included below.

1) Install the new Sequence IVA engine assembly with break-in test parts (camshaft, rocker arms, rocker shafts, etc. that come with pre-assembled cylinder head) onto the test stand.

2) Remove the oil drain plug and pre-fill the cavities of the cylinder head under thecamshaft with break-in oil (ASTM 926-2 REO). Replace the oil drain plug once completed.

3) Install the rocker cover.

4) Charge the coolant system with a 50/50 mixture of deionized water and Texaco Havoline DEX-COOL Extended Life Coolant (Product Code 7994). The coolant system capacity is 25 liters (6.6 gallons).

5) Connect the stand to a fuel tank containing the Howell VG test fuel.

6) Measure by volume, 3.5L of break-in oil (ASTM 926-2 REO).

7) Install a new Nissan oil filter (p/n 15208-55Y00) onto the engine. Perform the following steps to help the oil pressure build quicker during initial start-up. Do not install a dry oil filter on a Nissan KA24E engine.

    A) Obtain a new break-in oil filter and remove it from its packaging.

    B) Measure out 325ml (11 ounces) of oil from the new break-in oil charge.

    C) Holding the oil filter upright, pre-fill the filter with the 325ml (11 ounces) of new break-in oil.

    D) Tilt the filter and slowly rotate it a full 360° several times to let the oil absorb into the entire fiber filter element.

    E) Install the filter onto the engine. By letting the oil absorb into the entire filter element no oil should spill out when tilting the filter to install it.

8) Fill the engine with the remainder of the 3.5L break-in oil charge.

9) Circulate and preheat the engine coolant to 50°C and then warm soak the engine for 10 minutes before initial start-up.

10) Start the engine and crack the throttle opened 5-10% to raise the engine speed, not to exceed 1500 rpm, to help the oil pressure build quicker. Once oil pressure has started to build control engine speed to 800 rpm,

control torque to 10 N-m and ramp oil temperature to 50°C.

11) Once the engine has achieved 800 rpm, using a timing light, set the ignition timing to 10° BTDC.

12) Start the break-in sequence and run through all eight (8) steps. Total running time is 95 minutes.

13) At completion of the break-in sequence perform a compression check on all 4 cylinders.

14) Once the compression check has been completed drain the engine oil for 30 minutes and remove the used oil filter.

15) Remove the rocker cover.

16) Using a suction device, remove the used break-in oil that is trapped in the cavities of the cylinder head under the camshaft.

17) Examine the used engine oil for unusual amounts of metal particles.

18) Remove the break-in test parts (camshaft, rocker arms, rocker shafts).

19) Check the engine assembly for anything unusual after break-in has been completed.

20) If everything checks out to be acceptable then the engine is ready for test work.

12.2 Engine Operating Procedure

The ASTM Sequence IVA Valve Train Wear test is a double-flush and run test. Conduct the oil flush and test operations as follows.

12.2.1 Preparation of Test

1) Obtain the test oil and remove a 237ml (8 ounce) sample of new test oil for chemical analyses of the 0 hour test oil. Use an 8 ounce plastic Nalgene container.

2) Install the test parts (camshaft, rocker arms, rocker shafts) according to procedure.

3) Remove the oil drain plug and pre-fill the cavities of the cylinder head under the camshaft with new test oil. Replace the oil drain plug once completed.

4) Re-install the rocker cover. Inspect and replace rocker cover gasket if necessary.

5) Connect the stand to a fuel tank containing the Specified Fuels KA24E test fuel.

12.2.2 Double Oil Flush

6) Measure by volume, 3.5L of new test oil.

7) Install a new Nissan oil filter (p/n 15208-55Y00) onto the engine. Perform the following steps to help the oil pressure build quicker during initial start-up. Do not install a dry oil filter on a Nissan KA24E engine.

   A) Obtain a new flush oil filter and remove it from its packaging.

   B) Measure out 325ml (11 ounces) of oil from the new flush oil charge.

   C) Holding the oil filter upright, pre-fill the filter with the 325ml (11 ounces) of new flush oil.

   D) Tilt the filter and slowly rotate it a full 360° several times to let the oil absorb into the entire fiber filter element.

   E) Install the filter onto the engine. By letting the oil absorb into the entire filter element no oil should spill out when tilting the filter to install it.

8) Fill the engine with the remainder of the 3.5L flush oil charge.

9) Circulate and preheat the engine coolant to 50°C and then warm soak the engine for 10 minutes before initial start-up.

10) Start the engine and crack the throttle opened 5-10% to raise the engine speed, not to exceed 1500 rpm, to help the oil pressure build quicker. Once oil pressure has started to build control engine speed to 800 rpm, control torque to 10 N-m and ramp oil temperature to 50°C.

11) Once the oil temperature has reached 50°C run "Flush 1" according to the prescribed flush conditions (**Table xxxx**). Flush 1 is a 20 minute flush operating the engine at 800 rpm and 10 N-m of torque.

12) Check ignition timing with timing light during "Flush 1" to verify it to be set at 10° BTDC. Correct if not set at 10° BTDC.

13) Shutdown the engine at the end of the 20 minute flush. Proceed to drain the engine oil and remove the used oil filter.

14) Once the "Flush 1" oil is drained, measure by volume, 3.5L of new test oil.

15) Install a new Nissan oil filter (p/n 15208-55Y00) onto the engine. Perform the following steps to help the oil pressure build quicker during initial start-up. Do not install a dry oil filter on a Nissan Sequence IVA engine.

   A) Obtain a new flush oil filter and remove it from its packaging.

   B) Measure out 325ml (11 ounces) of oil from the new flush oil charge.

   C) Holding the oil filter upright, pre-fill the filter with the 325ml (11 ounces) of new flush oil.

   D) Tilt the filter and slowly rotate it a full 360° several times to let the oil absorb into the entire fiber filter element.

E) Install the filter onto the engine. By letting the oil absorb into the entire filter element no oil should spill out when tilting the filter to install it.

16) Fill the engine with the remainder of the 3.5L flush oil charge.

17) Start the engine and crack the throttle opened 5-10%, to raise the engine speed, not to exceed 1500 rpm, to help the oil pressure build quicker. Once oil pressure has started to build control engine speed to 1500 rpm, control torque to 10 N-m and ramp oil temperature to 60°C.

18) Once the oil temperature has reached 60°C run "Flush 2" according to the prescribed flush conditions (**Table xxx**). Flush 2 is a 20 minute flush operating the engine at 1500 rpm and 10 N-m of torque.

19) Shutdown the engine at the end of the 20 minute flush. Before draining the engine oil perform a compression check on all 4 cylinders and record the data on the sheet provided. If the compression on any cylinder is below 900 kPa or is lower than 20% from the median value for that engine, then investigate the cause before proceeding with a test.

20) Once the compression check has been completed, drain the engine oil and remove the used oil filter. Drain the used oil for 30 minutes.

12.2.3 Test

21) Once both 20 minute flushes and the 30 minute oil drain have been completed, obtain the tare weight of a container to measure the test oil charge.

22) Measure by volume, 3.00L of new test oil.

23) Weigh and record the 3.00L oil sample before charging the engine.

24) Obtain a new test oil filter (p/n 15208-H8903), weigh it dry and record.

25) Install the weighed, new oil filter onto the engine. Perform the following steps to help the oil pressure build quicker during initial start-up. Do not install a dry oil filter on a Nissan KA24E engine.

    A) Measure out 325ml (11 ounces) of oil from the new test oil charge.

    B) Holding the oil filter upright, pre-fill the filter with the 325ml (11 ounces) of new test oil.

    C) Tilt the filter and slowly rotate it a full 360° several times to let the oil absorb into the entire fiber filter element.

    D) Install the filter onto the engine. By letting the oil absorb into the entire filter element no oil should spill out when tilting the filter to install it.

26) Fill the engine with the remainder of the 3.00L test oil charge.

27) Circulate and preheat the engine coolant to 50°C and then warm soak the engine for 10 minutes before initial start-up.

28) Start the engine and crack the throttle opened 5-10%, to raise the engine speed, not to exceed 1500 rpm, to help the oil pressure build quicker. Once oil pressure has started to build control engine speed to 800 rpm, control torque to 25 N-m and ramp oil temperature to 50°C.

29) Once the oil temperature has reached 50°C initiate the 100 hour test. Follow the prescribed test conditions (**Table xxxx**).

30) While engine is running check for any coolant or oil leaks. The engine will run for the entire 100 cycles (100 hours) without any scheduled shutdowns, but unscheduled shutdowns for repair may be permitted.

31) Drain condensation traps once every eight (8) hours.

12.2.4 Unscheduled Engine Shutdown Procedure

The procedure detailed below must be followed each time an unscheduled engine shutdown is performed.
Document the duration of the shutdown, reason it was necessary, and what action was performed. This downtime is not considered part of the test time requirement.

12.2.4.1 Emergency Shutdown
Usually the emergency at hand precludes an organized shutdown. But try to prevent the test lubricant from overheating or excessive fuel dilution. Avoid excessive cranking of the engine if it will not start. Excessive cranking could affect camshaft lobe wear.

12.2.4.2 Restart After Unscheduled Shutdown
Pre-heat the coolant to 50 degC. Start engine and bring speed up to 1500 rpm and 25 N-m torque. Stabilize for five (5) minutes. Then use five (5) minute ramp to intended stage of test. This ensures each startup will take ten (10) minutes before the test is resumed.

12.2.5 Cyclic Schedule, General Description

See appendix A or the following table of the steady-state operating test conditions (specification targets).

PARAMETER	UNITS	STAGE I	STAGE II
Duration	Minutes	50	10
Engine Speed	Rpm	800	1500
Engine Torque	N-m	25	25
Coolant Flow	L/m	30	30
Coolant Out Temperature	deg C	50	55
Cyl.Hd.Oil Gallery Temp.	deg C	49	59
Fresh Air to RAC	SLPM	10.0	10.0
Intake Air Temperature	deg C	32	32
Intake Air Pressure	Kpa	0.050	0.050
Intake Air Humidity	g/kg	11.5	11.5
Exhaust Pressure	kPa-absolute	103.5	103.5
Ignition Timing	deg BTDC	10	Not specified

12.2.6 Transient Ramping of Parameters

Ramping of engine speed, temperatures, and torque fluctuations between stages can influence wear severity. Therefore, ramping rates are very important.

12.2.6.1 Oil Temperature Transitions
After stage I, the cylinder head oil gallery temperature is increased linearly from a nominal 49 degC to the stage II oil gallery temperature target of 59 degC. The transitory time is defined as the first five (5) minutes of stage II, following the end of stage I. At 1 minute into the ramp, the cylinder head oil gallery temperature should range from 51 to 53 degC. At 2 minutes into the ramp, the cylinder head oil gallery temperature should range from 54 to 56 degC. At 3 minutes into the ramp, the cylinder head oil gallery temperature should be at or above 57.0 degC. By the end of the 5 minute ramp, the cylinder head oil gallery temperature should be stabilized at 59 $\pm$ 1.5 degC.

After stage II, the cylinder head oil gallery temperature is decreased linearly from a nominal 59 degC to the stage I cylinder head oil gallery temperature target of 49 degC. The transitory time is defined as the first five (5) minutes of stage I, following the end of stage II. At 1 minute into the ramp, the cylinder head oil gallery temperature should range from 55 to 57 degC. At 2 minutes into the ramp, the cylinder head oil gallery temperature should range from 52 to 54 degC. At 3 minutes into the ramp, the cylinder head oil gallery temperature should be at or below 51.0 degC. By the end of the 5 minute ramp, the cylinder head oil gallery temperature should be stabilized at 49 $\pm$ 1.5 degC.

12.2.6.2 Coolant Temperature Transitions
After stage I, the coolant out temperature is increased linearly from a nominal 50 degC to the stage II coolant out temperature target of 55 degC. The transitory time is defined as the first five (5) minutes of stage II, following the end of stage I. At 1 minute into the ramp, the coolant out temperature should range from 51 to 52 degC. At 3 minutes into the ramp, the coolant out temperature should be at or above 54 degC with minimal overshoot. By the end of the 5 minute ramp, the coolant out temperature should be stabilized at 55 $\pm$ 1.5 degC.

After stage II, the coolant out temperature is decreased linearly from a nominal 55 degC to the stage I coolant out temperature target of 50 degC. The transitory time is defined as the first five (5) minutes of stage I, following the end of stage II. At 1 minute into the ramp, the coolant out temperature should range from 53 to 54 degC. At 3 minutes into the ramp, the coolant out temperature should be at or below 51 degC with minimal undershoot. By the end of the 5 minute ramp, the coolant out temperature should be stabilized at 50 $\pm$ 1.5 degC.

12.2.6.3 Engine Speed Transitions
After stage I, the engine speed is increased linearly with minimal overshoot from a nominal 800 rpm to the stage II engine speed target of 1500 rpm. Speed must not be allowed to exceed 1600 rpm during the transition. The transitory time is defined as the first five (5) minutes of stage II, following the end of stage I. At 30 seconds into the ramp, the engine speed should range from 1150 to 1250 rpm. At 60 seconds into the ramp, the engine speed should range from 1400 to 1500 rpm. By the end of the 5 minute ramp, the engine speed should be stabilized at 1500 $\pm$ 20 rpm.

After stage II, the engine speed is decreased linearly with minimal undershoot from a nominal 1500 rpm to the stage I engine speed target of 800 rpm. Speed must not be allowed to drop below 750 rpm during the transition. The transitory time is defined as the first five (5) minutes of stage I, following the end of stage II. At 30 seconds into the ramp, the engine speed should range from 1100 to 1200 rpm. At 60 seconds into the ramp, the engine speed should range from 800 to 900 rpm. By the end of the 5 minute ramp, the engine speed should be stabilized at 800 ± 20 rpm.

12.2.6.4 Torque Steadiness During Transitions
The torque target of 25 N-m is unchanged during the transition from stage 1 to stage II, and from stage II to stage I. During the five (5) minute transitions for speed and temperature changes, the torque must be controlled within 23 to 27 N-m. By the end of the five minute transition, the torque should be stabilized at 25 ± 1.5 N-m.

12.2.7 Unscheduled Down Time

12.3 Periodic Measurements and Functions

12.3.1 Data Monitoring

12.3.2 Blowby Flow Rate Measurement

Measure and record the blowby flow rate during the middle of Stage I of cycle 5 and of cycle 100. The engine must be stable and operating at normal Stage I operating conditions. The procedure for measuring blowby flow rate is detailed below. The blowby orifice size normally used is 3.175 mm diameter for the normal blowby flow range of 5 to 12 liters/minute.
Using the apparatus schematic detailed in Appendix B:

(a) Open the flow valve (bleeder valve) completely.
(b) Connect the blowby apparatus flow line to the 3-way valve located between the engine PCV and intake vacuum port.
(c) Disconnect the hose at the air cleaner that is routed from the rocker cover. Then, connect it to the inlet plumbing of the blowby apparatus orifice meter.
(d) Position the 3-way valve to divert intake manifold vacuum from the engine PVC to the exhaust plumbing of the blowby apparatus meter.
(e) Connect the blowby apparatus pressure sensor to the dipstick tube.
(f) Adjust the flow valve (bleeder valve) to maintain crankcase pressure at 0 - 25 Pa.
(g) Record the differential pressure across the blowby meter orifice, record the blowby gas temperature, and the barometric pressure.
(h) After measurement is completed, return the engine to normal operating configuration. First, the dipstick tube pressure port; second, reconnect the hose from the rocker cover to the air cleaner; third, reposition the 3-way valve so intake vacuum is ported to the engine PCV; fourth, disconnect blowby apparatus hose from the closed port of the 3-way valve.
(i) Calculate the blowby flow rate and correct the value to standard conditions (38 degC, 100.3 kPa) using the calibration data for that orifice.

12.3.3 Ignition Timing Measurement

Measure and record the ignition timing during stage I every fifth cycle. The specification is 10 ± 1 degree at Stage I. Adjust if needed.

If the timing is checked during Stage II, a typical reading of 24 ± 2 degrees indicates proper advance as determined by the engine controller.

12.3.4 AFR Measurement

The air-to-fuel ratio is monitored continuously using the output of a wide-range exhaust gas oxygen sensor.

12.3.5 Oil Additions and Used Oil Sampling

No oil additions are allowed during the 100 hour test. New oil makeup is not allowed if oil leaks should occur.

It is required to take a 10 mL oil sample of the new oil, used oil at 25 hours, used oil at 50 hours, and used oil at 75 hours. Remove used oil samples during the transient portion of stage II (near end of cycle 25; 50; 75). It is also required to take a 100 mL sample of drain oil at the end of test (100 hours).

After the oil consumption has been calculated at the end of 100 hours, remove a 100ml sample of used test oil for chemical analyses of the 100 hour test oil.

12.3.6 General Maintenance

12.3.6.1 Spark Plug Replacement

Replace the spark plugs (Nissan part no. 22401-30R15, NGK ZFR5E-11) before the oil flushing procedure is conducted (see section 10.9.2).

12.3.6.2 PCV Valve Replacement

Replace the PCV valve after six (6) tests, whenever the engine or cylinder head is replaced. The PCV valve part no. is 11810-86G00.

12.4 Special Maintenance Procedures

12.5 Diagnostic Data Review

This section outlines significant characteristics of specific engine operating parameters. The parameters may directly influence the test or may be used to indicate normalcy of other parameters.

12.5.1 Intake Manifold Pressure

Intake manifold pressure is affected by several factors, including barometric pressure, engine load, air-fuel ratio, ignition timing, and engine wear. As a result it is not a specifically controlled parameter but is used to monitor the condition of the engine.

12.5.2 Fuel Consumption Rate

The fuel consumption rate during a given stage should remain relatively constant throughout the test. Like intake manifold pressure, fuel consumption rate is not a specifically controlled parameter but is used as a diagnostics tool. In addition, fuel consumption rate and intake manifold pressure relate to similar operating parameters. **Caution** - High fuel consumption rate can promote excessive cylinder bore, camshaft, and rocker arm wear.

12.5.3 Spark Knock

Spark knock does not normally occur in the Sequence IVA test. The octane rating of the fuel, ignition timing, engine speed and load, and operating temperatures do not promote spark knock. Spark knock indicates abnormal combustion is occurring and can cause extensive engine damage. If spark knock is noted, corrective action should be taken immediately. Errors in the measurement and control of engine load, ignition timing, operating temperatures, and air- fuel ratio may result in spark knock.

12.5.4 Crankcase Pressure

Crankcase pressure is a function of blowby flow rate and PCV valve flow. High crankcase pressure is usually caused by high blowby flow rate or a significant loss of PCV valve flow. Incorrect 3-way valve plumbing or port plugging also promotes high crankcase pressure. High crankcase pressure can also cause oil leaks (gasket or seal failure). Low or negative crankcase pressure may be caused by low blowby flow rate or a restriction of vent air to the PCV valve.

12.5.5 Oil Pressure

The oil pressure is a function of oil viscosity, operating temperature, and engine bearing clearances. The oil pressure is normally higher in Stage II than Stage I. The oil pressure should remain consistent throughout the test, unless the oil exhibits a significant increase in viscosity.

12.5.5.1 Abnormal Oil Pressures
An excessive oil pressure fluctuation may indicate large bearing clearance. An excessive oil pressure differential between the engine gallery and head gallery indicates the presence of a gallery restriction at the head gasket or an increased oil flow rate to the cam bearing pedestals.

12.5.6 Coolant Temperature Differential

The coolant temperature differential is primarily a function of the coolant flow rate and is normally stable throughout the test. Large variations in the differential may be caused by coolant flow rate or temperature measurement errors. Coolant flow rate measurement errors can be caused by foreign objects in or near the flowmeter.

12.6 End of Test Procedures

Shutdown the engine at the end of cycle 100.

12.6.1 Oil Consumption Determination

A = Empty Container Weight, dry @ test start (g)
B = Initial Oil Charge & Container Weight (g)
C = Initial OIl Charge (g)
D = New Oil Filter Weight, dry @ test start (g)
E = Empty Container Weight, dry @ test end (g)
F = Drain Oil and Container Weight "E" (g)
G = Drain Oil @ end of test (g)
H = Used Oil Filter Weight, with absorbed oil, @ end of test (g)
I = Oil Remaining in Filter, (g)
J = Oil Consumption per test (g)

Oil Consumption for the 100 hour test "J" is:

$$J = \{(B-A)-[(F-E)+(H-D)]\} = C-(G+I)$$

where $C = B-A$
$G = F-E$
$I = H-D$

12.6.1.1 Oil Drain
Drain the engine test oil and remove the used test oil filter. Catch any oil that drains out of the oil filter while removing it. Add this oil to the drained test oil. Drain the used test oil for 30 minutes. The engine must maintain a warm condition during the 30 minute drain, therefore continue to circulate the coolant and maintain a 50°C coolant temperature.
Remove the rocker cover.
Using a suction device, remove the used test oil that is trapped in the cavities of the cylinder head under the camshaft. Do not add this oil to the drained test oil. It can be discarded.

12.6.1.2 Measurement of Oil Drained
Once the 30 minute drain has been completed and the oil from the oil filter has been added, weigh the drained test oil and weigh the used test oil filter. Use the equation provided in section 12.6.1 to calculate oil consumption.

12.6.1.3 Used Oil Sample
After the oil consumption has been calculated, remove a 237ml (8 ounce) sample of used test oil for chemical analyses of the 100 hour test oil. Use an 8 ounce plastic Nalgene container.
After oil consumption has been calculated and the 237ml (8 ounce) sample has been obtained for chemical analyses, the remaining used test oil should be put into a 4 liter container and stored.

12.6.2 Test Parts Removal

Remove the test parts (camshaft, rocker arms, rocker shafts) for wear measurement and rating according to the procedures outlined in section 10.9.1.

13. Determination of Test Results

Utilize the measurement forms in the appendix.

13.1 Engine Wear Measurements

13.1.1 Camshaft Lobe Wear

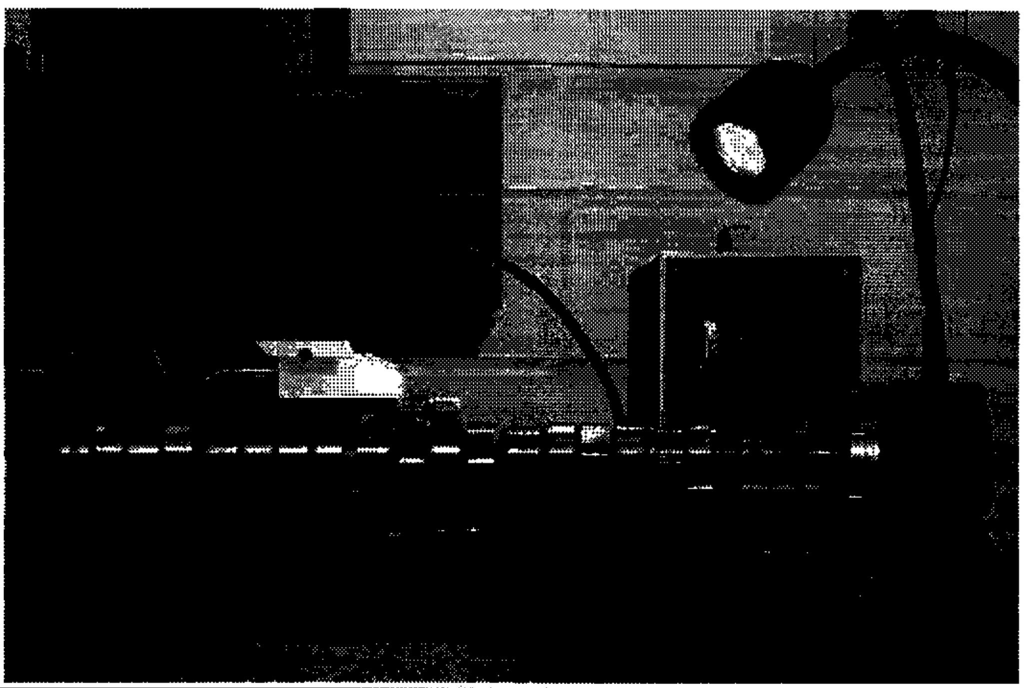
A surface roughness meter (profilometer) is used to measure the change in profiles across the worn cam lobe. Normally, each lobe will have an unworn edge at the front of the lobe, and at the rear of the lobe. These unworn edges are used to define a 2-point reference line, from which a maximum depth of wear is measured. For each lobe, seven (7) profilometer traces are made, scribing from front to rear of the lobe. The seven (7) locations on each lobe are: at the nose which is zero (0) cam lobe degrees; □ 4 degrees; □ 10 degrees; □ 14 degrees). The nose is found by reading the highest profilometer position (to within 0.5 micron) on the unworn cam lobe surface. A 360 degree wheel of a minimum of 25 cm diameter is affixed to the front of the camshaft. Resolution of the degree wheel is 1 degree or better. Once the nose of the lobe is found, the degree wheel "zero" reference mark is determined.

When viewed from the front of the engine, the camshaft normally rotates clockwise. This is the same sign convention that is used for profilometer measurements. When viewing the front of the camshaft, the "plus" direction is before top center of the cam nose. The "minus" direction is after the top center of the cam nose.

The maximum deviation (PR_{ymax}) of the worn nose profile (phase-correct filtered waviness profile) from a deduced unworn profile (reference line) is the wear value for that cam lobe location. Individual measurements of wear are recorded to a resolution of one-half of one micrometer in the range of 0-30 □m wear, or better; and to a resolution of one micrometer in a wear range greater than 30 □m wear, or better. For an individual lobe, the lobe wear is a mathematical summation of the (PR_{ymax}) values for the seven (7) defined locations on each lobe.

The lobe wear values for the twelve lobes of the camshaft are averaged (equal weighting) to determine the single test result (reported to a tenth of a micrometer).

One computer-driven profilometer that can be utilized is the Precision Devices Instrument - MicroAnalyzer 2000 system. It should be equipped with custom V-blocks, part numbers PDI 4230-FA, for holding the workpiece (the camshaft on its journals). The PDS-30 (2853-FA) skidless diamond stylus should be used, which features a 0.005 mm stylus radius, and a 6.5 mm stylus height. A trace across the lobe is taken from front-to-rear of the lobe, at a traversing speed of 0.500 mm/s. It will be necessary for the stylus to slightly extend (drop) off the lobe edges to ensure a full trace. The data from the trace is viewed in the profile mode, allowing an analysis of the texture and waviness of the trace. The instrument software should be configured for a 2-point line texture leveling at the average value of the unworn edges of the cam lobe. The waviness of the profile is displayed, using the Gaussian smoothing filter, set at 0.25 mm cutoff length, with the filter set (non-standard setting) to extend to the ends of the texture. Typically, the leveling line coincides with (contacts or is very close to) the highest peak of the waviness profile that exists at each unworn end. To obtain the wear measurement, the waviness evaluation length encompasses the whole lobe width. The "Wt" parameter (waviness total) yields the value of the height from the maximum peak to the lowest valley of the waviness profile. The "Wt" measurement is the wear measurement that is recorded.



Definitions

Profile -
A graph representing the outline of a section normal to its surface.

Assessment Length -
The length of surface over which measurements are made.

Reference Line -
After test, the reference line is a deduced, leveled, straight line drawn on the profilometer graph, from the front unworn average edge of a cam lobe to the rear unworn average edge of that cam lobe. In the absence of one unworn edge, the reference line can be extrapolated using the pre-test profilometer trace.

PR_{ymax} -
In the phase-correct filtered waviness profile mode (defined by ASME B46.1 as the Gaussian filter), the maximum excursion of the worn surface as graphically measured normal to the reference line.

Measurement Equipment

A surface measurement profilometer with real time digital display and graphical output capability. The vertical scale graphical resolution must be capable of one micrometer per graph division. The profilometer must be capable of traversing at least 100mm, with a straightness accuracy equal to or less than 1 μm per 100 mm of traversed length. A right angle pickup is utilized without a skid. The diamond tip stylus must be conical or spherical in shape, with a nominal radius of 2μm - 5μm.

The profilometer must be housed in an environment that meets the profilometer manufacturers recommendations. This area must be maintained clean, temperature controlled, and the worktable for the profilometer must be stable and free from external vibration sources.

Procedure

1. Pre-test Check for Camshaft Defects and Straightness

1.1. The pre-test camshaft lobes and bearing journals are visually inspected for rust, scratches, gouges, chipped areas, and other surface defects. Reject camshafts that are judged unsuitable for test.

1.2 The pre-test camshaft is checked for straightness. With the camshaft supported by Vee-blocks at journals #1 and #5, measure the camshaft runout at the center journal. Reject the camshaft if the total indicator reading of the runout exceeds 20μm.

2. The camshaft lobe noses are measured and graphically represented with the profilometer before test (pre-test) and after test (post-test).
The pre-test measurement of profiles are used to reject the camshaft for any lobe nose profile that exhibits taper, concavity, or convexity of more than 10 μm variation from bearing journal profile. Also, the pre-test cam nose profile is used to extrapolate the cam nose reference line on the post-test profile if necessary due to the absence of one of the non-worn edges on the lobe.
The post-test profiles are measured to determine the cam nose wear with

respect to the reference line.

2.1 To measure the profile of the cam lobe noses, configure the profilometer to read in the direct graph mode (profile mode), with NO filtration (i.e. no filter cutoff length). All measurements will be performed in metric units, therefore requiring the use of metric graphing paper (or equivalent printout) for the profilometer recorder. Use a right angle skidless pickup with a diamond stylus having a nominal radius of 2μm - 5μm.

2.1.1. Camshaft lobes will profiled with the profilometer head tracing the lobe from rear of lobe to front of lobe. The graphic output of this trace will read from left to right on the graph paper.

2.1.2 Clean the camshaft with aliphatic naptha and force-air dry. Then rest the camshaft on the profilometer worktable using two Vee-blocks at bearing journals #2 and #4. The Vee-blocks must be installed in the worktable tee-slots to ensure a consistent horizontal placement of the camshaft axis to the profilometer traversing unit.

2.1.3. Position the lobe to be measured with its nose facing upward, under the stylus.

2.1.4. Carefully lower the stylus onto the lobe surface and rotate the camshaft each direction by hand to locate the high point on the lobe using the real-time digital readout. This is the lobe nose and is the axial location where the profilometer trace will be taken.

2.1.5. Adjust the profilometer traverse unit to be exactly vertically parallel to the camshaft centerline (within 1□m average deviation per distance traveled). This process is done by raising the stylus from the cam lobe, moving the stylus to a corresponding cam journal surface. The cam journal surface can be assumed to be exactly parallel to the camshaft centerline.

a) Run a trace (minimum assessment length of 6mm) across the journal surface, using a 5X horizontal magnification and 2000X vertical magnification.

b) Review the graphic output of this trace. If indicated taper exceeds an average of 1 □m over the assessment length, then adjust the profilometer head or worktable until successive measurements indicate parallel vertical alignment. Once aligned, do not rotate the camshaft until after the corresponding cam lobe nose measurement has been done.

2.1.6. Once the camshaft has been aligned properly, raise the stylus from the journal surface to the lobe nose to be measured. For a pre-test trace, carefully drop the stylus on the lobe surface as close to the rear lobe edge as possible. For a post-test trace, carefully place the stylus just off the rear lobe edge so when the trace is started it will run up onto the lobe surface.

2.1.7 Run a surface profile trace across the entire lobe surface only once, and let the stylus run off of the front edge of the lobe. Use the following
magnifications.

Horizontal Magnification	Pre and post test		20X
Vertical Magnification	Pre-test		2000X = 1µm/DIV.
Vertical Magnification	Post-test	(Wear<30µm)	2000X = 1µm/DIV.
Vertical Magnification	Post-test	(Wear=30-60µm)	1000X = 2µm/DIV.
Vertical Magnification	Post-test	(Wear=60-100µm)	500X = 4µm/DIV.
Vertical Magnification	Post-test	(Wear>100µm)	200X = 10µm/DIV.

2.1.8 After each lobe nose is measured, it is permissable to relocate the camshaft and V-blocks to allow the stylus arm to reach the next lobe to be measured. However, any time the camshaft is rotated or moved it will be necessary to perform a parallel vertical realignment using the appropriate journal surface.

2.1.9. Repeat Steps 2.1.3 to 2.1.8 for all twelve lobe noses of the Nissan KA24E camshaft. See the attached table for a sequential listing of the order that lobe noses are to be measured and the corresponding journal for alignment of the profilometer traversing unit to camshaft centerline.

3. After test, the graphs of the profilometer traces of the cam lobe noses must be analyzed to determine the PR_{ymax} for each nose. Since the cam lobe is wider than the rocker arm pad, usually there is a narrow non-worn edge at the rear of the cam lobe and another at the front of the cam lobe. If these distinct non-worn edges can be discerned, the reference line can be drawn on the graph. The nose wear is the maximum excursion (deepest valley) of the worn surface on the cam nose, as graphically measured normal to the reference line. In the absence of one of the discrete non-worn lobe edges, the pre-test profile is used to extrapolate the reference line. Caution: the vertical scale for the pre-test profiles may be different from the post-test profiles.

3.1 The maximum deviation (PR_{ymax}) of the worn nose profile from a deduced unworn nose profile (reference line) is the wear value for that cam lobe. Individual nose wear is recorded to a resolution of one-half of one micrometer in the range of 0-30 μm wear; and to a resolution of one micrometer in a wear range greater than 30 μm wear. The nose wear values for the twelve lobes of the camshaft are averaged to determine the test result (reported to the tenth of a micrometer).

The following table includes the order in which the camshaft lobes should be measured. The lobe numbers are listed with their corresponding leveling journal. Indication of permissable relocation of the camshaft and V-blocks is also included in this table.

Lobe # 1	Leveling Journal # 1 rear-half
Lobe # 3	Leveling Journal # 2 front-half
Lobe # 2	Leveling Journal # 2 front-half
RELOCATE	CAMSHAFT & V-BLOCKS
Lobe # 4	Leveling Journal # 2 front-half
Lobe # 6	Leveling Journal # 3 front-half
Lobe # 5	Leveling Journal # 3 front-half
RELOCATE	CAMSHAFT & V-BLOCKS
Lobe # 7	Leveling Journal # 3 front-half
Lobe # 9	Leveling Journal # 4 front-half
Lobe # 8	Leveling Journal # 4 front-half
RELOCATE	CAMSHAFT & V-BLOCKS
Lobe # 10	Leveling Journal # 4 front-half
Lobe # 12	Leveling Journal # 5 front-half
Lobe # 11	Leveling Journal # 5 front-half

13.1.2 Rocker Pad Wear

Rocker Pad Wear or distress is not evaluated.

13.2 Oil Analysis

It is required to take a 10 mL oil sample of the new oil, used oil at 25 hours, used oil at 50 hours, and used oil at 75 hours. Remove used oil samples during the transient portion of stage II (near end of cycle 25; 50; 75). It is also required to take a 100 mL sample of drain oil at the end of test (100 hours).

13.2.1 Wear Metals

Measure the used oil samples (25 hrs; 50 hrs; 75 hrs; 100 hrs) for wear metal concentration (parts per million). Iron and copper concentrations are required to be reported. Use ASTM procedure D 5185.

13.2.2 Kinematic Viscosity

Determine and report the kinematic viscosity (at 40 degC) for the new oil sample and the used oil sample at 100 hours. Use ASTM procedure D 445.

13.2.3 Fuel Dilution

Measure the mass percent fuel dilution of the used oil sample at 100 hours. Fuel dilution typically ranges from 3.5% to 7.0%. If the fuel dilution exceeds 7.0%, then the valvetrain wear test results may not be interpretable.

Use the following procedure:

Fuel Dilution, % mass, by gas chromatography (D3525 with the modifications listed below)

(1)
Use C16 in place of C14 for the internal standard. (1 L injector volume)

(2)
All components lighter than C16 are defined as fuel.

(3)
The integrator should establish a horizontal baseline under the output curve.

(4)
Column details - 10 ft by 0.125 in. (305 cm x 3.2 mm) SS; packing material - 5% OV-1 on Chromosorb W HP

(5)
Temperature details - oven temp 60 - 320 degC, 8 degC/min rate of delta T,hold at 320 degrees C for 16 min to elude oil

14.Final Test Report

14.1 Report Format

The various required sections and specific details concerning the format of the report are outlined below. Examples of each section are shown in appendix D. Deviations in the format are generally not permitted.

14.1.1 Standard Report

The standard test report must include the sections listed below. Each section must begin on a new page, and the sections must be inserted in the order listed below. Each page should be numbered with respect to the total number of pages.

1.	Title / Validity Declaration Page	Form 1
2.	Summary of Test Method	Form 3
3.	Results Summary	Form 4
4.	Camshaft Lobe Wear Table	Form 5
5.	Operational Data Summary	Form 6
6.	Used Oil Analysis	Form 7
7.	Engine Build Measurements	Form 8
8.	Special Maintenance Record	Form 9
9.	Cycle 5 Stage II to I transition (oil cyl. head temp)	Form 10
10.	Cycle 5 Stage I to II transition (oil cyl. head temp)	Form 11
11.	Cycle 5 Stage II to I transition (coolant out temp)	Form 12
12.	Cycle 5 Stage I to II transition (coolant out temp)	Form 13
13.	Cycle 5 Stage II to I transition (engine torque)	Form 14
14.	Cycle 5 Stage I to II transition (engine torque)	Form 15
15.	Cycle 5 Stage II to I transition (engine speed)	Form 16
16.	Cycle 5 Stage I to II transition (engine speed)	Form 17

14.2 Photographs

No photographs are required in the final test report. If photographs are desired to depict the rocker pad scuffing/polishing wear (optional), it is suggested that black & white photography be utilized.

14.3 Electronic Data Dictionary

See appendix xxxx for the definition of the electronic data dictionary. This dictionary is to be utilized for electronic transmission of final report data to the end-user, or to the Test Monitoring Center for calibration tests.

15.Precision and Accuracy

15.1 Precision of the Test Method

Repeatability is the measure of variability for the same oil run at the same laboratory using the same approved fuel batch.
Reproducibility is the measure of variability for the same oil run at any laboratory with any approved fuel batch. The test precision is currently stated as 9.47 μm for average cam lobe wear (7-point).

15.2 Assessment of Test Validity

The testing laboratory must use engineering judgment to assess the validity of tests that have deviations from the procedure. The guidelines listed below should be used as a basis for determining test validity.

15.2.1 Quality Index

The "Quality Index" (QI) is an overall statistical measure of the variation from test targets of the steady-state operational controlled parameters. The QI upper and lower control limits, utilized in the QI calculation equation, have been chosen by the Sequence IVA Surveillance Panel. If the QI calculation of a controlled parameter is less than zero, then the laboratory engineer must investigate the reason, assess its impact on test operational validity, and document such finding in the final test report. For calibration tests, it is recommended that the laboratory engineer and the Test Monitoring Center agree on the validity assessment.

The QI calculation upper and lower control limits have been selected by the Sequence IVA Surveillance Panel:

PARAMETER	L	U
Coolant Flow	29.8	30.2
Coolant Out Temperature,	49.88	50.12
Stage I & II	54.88	55.12
Exhaust Backpressure	103.34	103.66
Intake Air Humidity	10.8	12.2
Intake Air Pressure	0.047	0.053
Intake Air Temperature	31.71	32.29
Oil Cylinder Head Temperature,	48.7	49.3
Stage I & II	58.7	59.3
Speed,	793.5	806.5
Stage I & II	1493.5	1506.5
Torque	24.5	25.5
Rocker Cover Air Flow	9.5	10.5

15.2.2 Used Oil Analyses

Iron (Fe) and copper (Cu) content of the used oil samples correspond with the level of wear that occurs during a test. Camshaft and follower wear can be expected for the Sequence IVA test, therefore, iron content may vary widely. If cam nose wear is low, yet iron content is high (over 500 ppm), then overall engine condition may be suspect.
Significant levels of copper (over 200 ppm) may also indicate general

deterioration of the engine, or corrosion of the engine oil cooler. Valvetrain wear test results may not be interpretable if excessive wear of bearings, piston rings, pistons, etc. is proven to have occurred.

15.2.2.1 Interpretation of Fuel Dilution
Fuel dilution indicates the degree the crankcase oil has been diluted with fuel. Excessive fuel dilution may promote increased wear above designed levels. The reproducibility of fuel dilution results tends to be poor. Therefore, fuel dilution levels should only be compared to other results obtained from the same analytical laboratory, using the same fuel batch and analysis equipment and technique. An abnormally high level of fuel dilution (over 7.0%) should be investigated. The test results may not be interpreted, and may be invalid, if it is determined that excessive fuel dilution of the engine oil was caused by an operational or engine-related problem.

15.2.3 Blowby Flow Rate

Normal blowby flow rate ranges from 6.0 to 10.0 liter/min during Stage I steady-state operating conditions. If significantly beyond this range, it is recommended that an investigation should be commenced. The compression of the engine should be compared to previous data. Piston ring gaps should be within the Nissan manual specifications. Excessive piston deposits, ring sticking, or piston/ring/bore wear can contribute to blowby variation.

15.2.4 Intake Manifold Vacuum

If intake manifold vacuum is beyond 60±5 for stage I, or 65±5 kPa for stage II, the engine performance should be checked (e.g. ignition timing; exhaust pressure measurement; misfire; ECM diagnostics; dynamometer load; excessive cam lobe wear; etc.).

15.2.5 Fuel Consumption Rate

To be determined.

15.2.6 Oil Pressure

To be determined

15.2.7 Oil Consumption

To be determined.

PARTS LIST:

QUANTITY	PART NUMBER	DESCRIPTION
1	A3020-40F01	Camshaft
1	13245-40F10	Rocker Shaft - Exhaust
1	13252-40F10	Rocker Shaft - Intake
4	A3257-40F06	Rocker Arm - Intake LH
4	A3257-40F07	Rocker Arm - Intake RH
2	A3257-40F16	Rocker Arm - Exhaust RH
2	A3257-40F17	Rocker Arm - Exhaust LH
4	22401-30R15	Spark Plug
3	15208-H8903	Oil Filter

TOOL LIST:

3/8" Drive Impact Gun
3/8" Drive Speed Handle
3/8" Drive Rachet
3/8" Drive 4" Extension
□" Drive Rachet
Medium Flat Head Screwdriver
Large Flat Head Screwdriver
5/8" Wrench, Combination
5/8" Spark Plug Socket, 3/8" Drive
27mm Deep Socket, □" Drive
24mm Impact Deep Socket, 3/8" Drive
12mm Deep Socket, 3/8" Drive
10mm Deep Socket, 3/8" Drive
Digital Bore Gauge w/ Metric Head
Dial Indicator Set w/ Magnetic Base
Mounting Plate for Dial Indicator
1-2" Digital Micrometer
Spark Plug Gapping Tool
Suction Device (Syringe and Tubing)
Wooden Wedge Tool

ADDITIONAL NOTES:

ROCKER - VALVE LH
A3257 - 40F06
POSITION # I 1, 3, 5, 7

ROCKER - VALVE RH
A3257 - 40F07
POSITION # I 2, 4, 6, 8

ROCKER - VALVE RH
A3257 - 40F16
POSITION # E 1, 3

ROCKER - VALVE LH
A3257 - 40F17
POSITION # E 2, 4

APPENDICES

A. Sequence IVA Operational Charts and Tables

- Break-in schedule and operating conditions
- Oil Flush operating conditions
- Steady-state test specifications
- Typical operational performance

B. Figures and Drawings

- Engine oil system schematic
- Oil filter adapter modification
- Oil pan modification
- Engine coolant system schematic
- Coolant system plumbing
- Fuel system schematic
- Intake air system schematic
- Wiring Harness modifications
- Dummy waterpump modifications
- Exhaust pipe modifications
- Cylinder head modification
- Pedestals for cylinder head calibration
- Engine backplate
- Flywheel adapter
- Crankcase ventilation schematic
- Universal blowby measurement schematic
- Jacketed Rocker Cover
- Fresh Air Supply to Rocker Cover

C. Nissan KA24E 2.4 liter engine specifications

- Engine oil flow schematic
- Nissan manual specifications and clearances
- Engine fastener torque specifications
- Test Kits procurement
- Test Kits parts listing
- Special tools required

D. Product Specification Information

- Fuel specification charts
- Texaco DexCool ethylene glycol coolant specification

E. Test Reports

- Formal report format
- Operator data log sheets
- Engine rebuild worksheets
- Rating work booklet
- Electronic Data Dictionary

Appendix A

A. Sequence IVA Operational Charts and Tables

- Break-in schedule and operating conditions
- Oil Flush operating conditions
- Steady-state test specifications
- Typical operational performance

SEQUENCE IVA VALVETRAIN WEAR TEST

ENGINE BREAK-IN SCHEDULE

Step	Duration Min	Engine Speed rpm	Engine Torque N-m	Coolant Flow L/m	Coolant Out Temp degC	Cyl. Head Oil Gallery Temp. degC	Intake Air Temp degC	Intake Air Pressure kPa	Exhaust Pressure kPa-abs
1	10	800	10	20	50.0	49.0	32	0.050	103.5
2	10	1600	10	30	50.6	51.4	32	0.050	103.5
3	10	2000	40	40	55.2	62.6	32	0.050	103.5
4	10	2400	40	50	56.4	65.3	32	0.050	103.5
5	10	2400	75	50	62.5	80.0	32	0.050	103.5
6	15	2800	75	60	64.7	85.2	32	0.050	103.5
7	15	3200	75	70	66.9	90.5	32	0.050	103.5
8	15	3200	110	70	75.0	110.0	32	0.050	103.5

SEQUENCE IVA

CONDITIONS FOR OIL FLUSH

Parameter	Units	Flush #1	Flush #2
Duration	minutes	20	20
Engine Speed	rpm	800	1500
Engine Torque	N-m	10	10
Coolant Flow	L/m	30	30
Coolant Out Temperature	deg C	50	55
Cylinder Head Oil Gallery Temp.	deg C	49	59
Air to RAC	SLPM	10.0	10.0
Intake Air Temperature	deg C	32	32
Intake Air Pressure	kPa	0.050	0.050
Intake Air Humidity	g/kg	11.5	11.5
Exhaust Pressure	kPa-abs	103.5	103.5

SEQUENCE IVA

OPERATIONAL TARGETS

Parameter	Units	Stage I	Stage II
Duration	minutes	50	10
Engine Speed	rpm	800	1500
Engine Torque	N-m	25	25
Coolant Flow	L/m	30	30
Coolant Out Temperature	deg C	50	55
Cylinder Head Oil Gallery Temp.	deg C	49	59
Air to RAC	SLPM	10.0	10.0
Intake Air Temperature	deg C	32	32
Intake Air Pressure	kPa	0.050	0.050
Intake Air Humidity	g/kg	11.5	11.5
Exhaust Pressure	kPa-abs	103.5	103.5
Ignition Timing	deg BTDC	10	

Nissan KA24E ValveTrain Wear Test

Typical Operational Performance

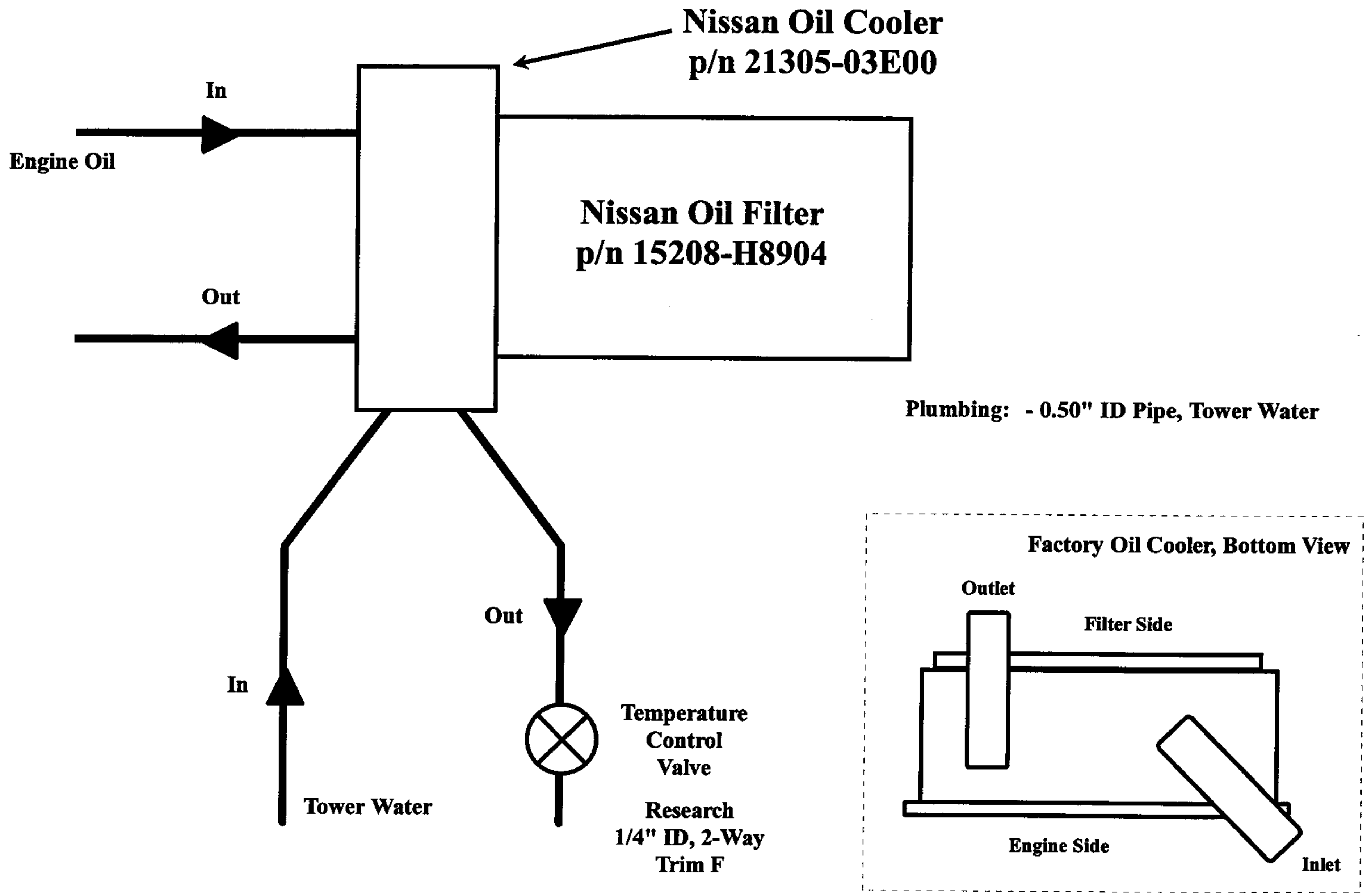
Parameter	Units	Stage I Performance	Stage II Performance
Oil Sump temperature	°C	53.5 ± 3	63.5 ± 3
Oil Gallery temperature	°C	50 ± 3	60 ± 3
Oil Cylinder Head temperature	°C	49 ± 3	59 ± 3
Coolant In temperature	°C	45.5 ± 3	49 ± 3
Coolant Out temperature	°C	50 ± 3	55 ± 3
Intake Air temperature	°C	32 ± 3	32 ± 3
Exhaust Gas temperature	°C	340 ± 50	450 ± 50
Fuel Rail temperature	°C	22.5 ± 10	22.5 ± 10
Oil Gallery pressure	kPa	130 ± 40	260 ± 80
Oil Cyl Head pressure	kPa	40 ± 20	65 ± 30
Fuel pressure	kPa	238 ± 10	234 ± 10
Manifold vacuum	kPa-vac	60 ± 5	65 ± 5
Exhaust pressure	kPa-abs	103.5 ± 1.0	103.5 ± 1.0
Intake Air pressure	kPa	0.05 ± 0.025	0.05 ± 0.025
Crankcase pressure	kPa	-0.3 ± 0.1	-0.3 ± 0.1
Coolant flow	l/m	30 ± 0.5	30 ± 0.5
Air-to-Fuel ratio	none	14.4 ± 0.3	14.4 ± 0.3
Fuel flow	kg/hr	1.3 ± 0.3	2.15 ± 0.3
Engine speed	rpm	800 ± 20	1500 ± 20
Engine torque	N-m	25.0 ± 2.5	25.0 ± 2.5
Humidity	g/kg	11.4 ± 0.7	11.4 ± 0.7
Ignition timing	°BTDC	10 ± 1	24 ± 2

Appendix B

B. Figures and Drawings

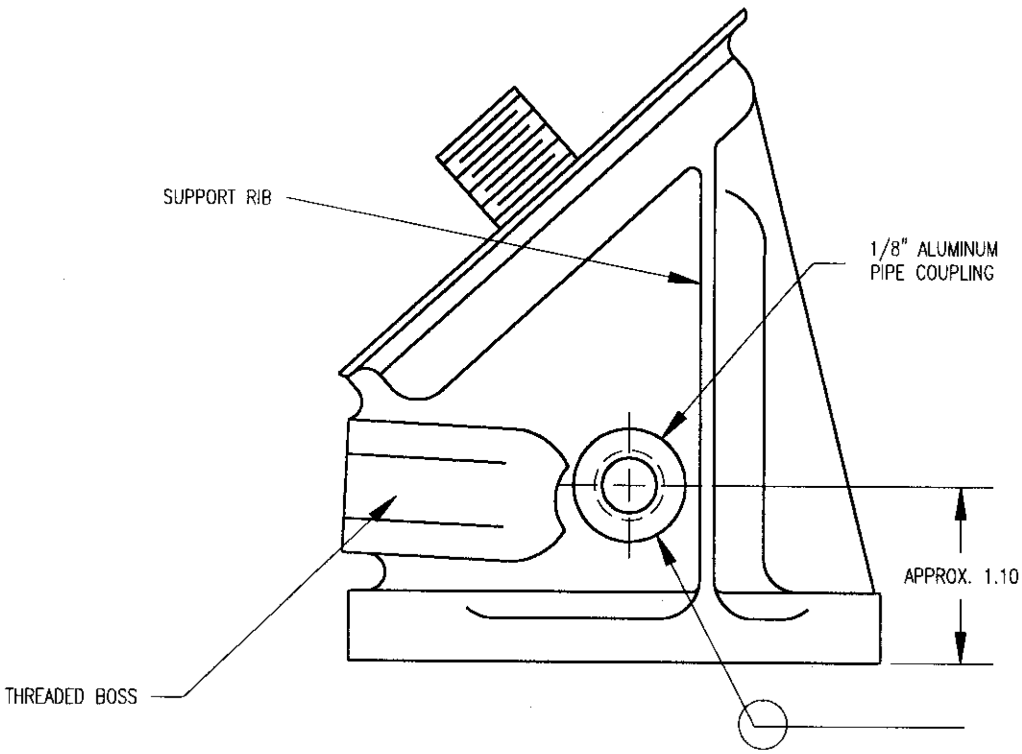
Engine oil system schematic
Oil filter adapter modification
Oil pan modification
Engine coolant system schematic
Coolant system plumbing
Fuel system schematic
Intake air system schematic
Wiring Harness modifications
Dummy waterpump modifications
Exhaust pipe modifications
Cylinder head modification
Pedestals for cylinder head calibration
Engine backplate
Flywheel adapter
Crankcase ventilation schematic
Universal blowby measurement schematic
Modified crankcase ventilation system
Jacketed Rocker Cover
Fresh Air Supply to Rocker Cover

Sequence IVA
Oil Cooling System Schematic



REVISIONS			
REV	DESCRIPTION	DATE	APPROVED

1. GRIND ALUMINUM COUPLING TO FIT CONTOURS OF THE FILTER ADAPTER HOUSING.
2. WELD COUPLING BETWEEN THREADED BOSS AND SUPPORT RIB. (WELD MUST BE LIQUID TIGHT).
3. DRILL THRU WITH A "Q" SIZE DRILL.



2.4L NISSAN OIL FILTER ADAPTER

CONTRACT NO.

DRAWN T. HABY	13MAR97
CHECKED	
ENGR	
FILE FLTRADT	DIR GE

NEXT ASSY	USED ON
APPLICATION	

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO, TEXAS

2.4L NISSAN OIL FILTER ADAPTER MODIFICATIONS

SIZE	CODE IDENT. NO.	DWG NO.	REV.
A	26401	GE-1759	

SCALE NONE | SHEET 1 OF 1

26401 DWG NO. * SH 1

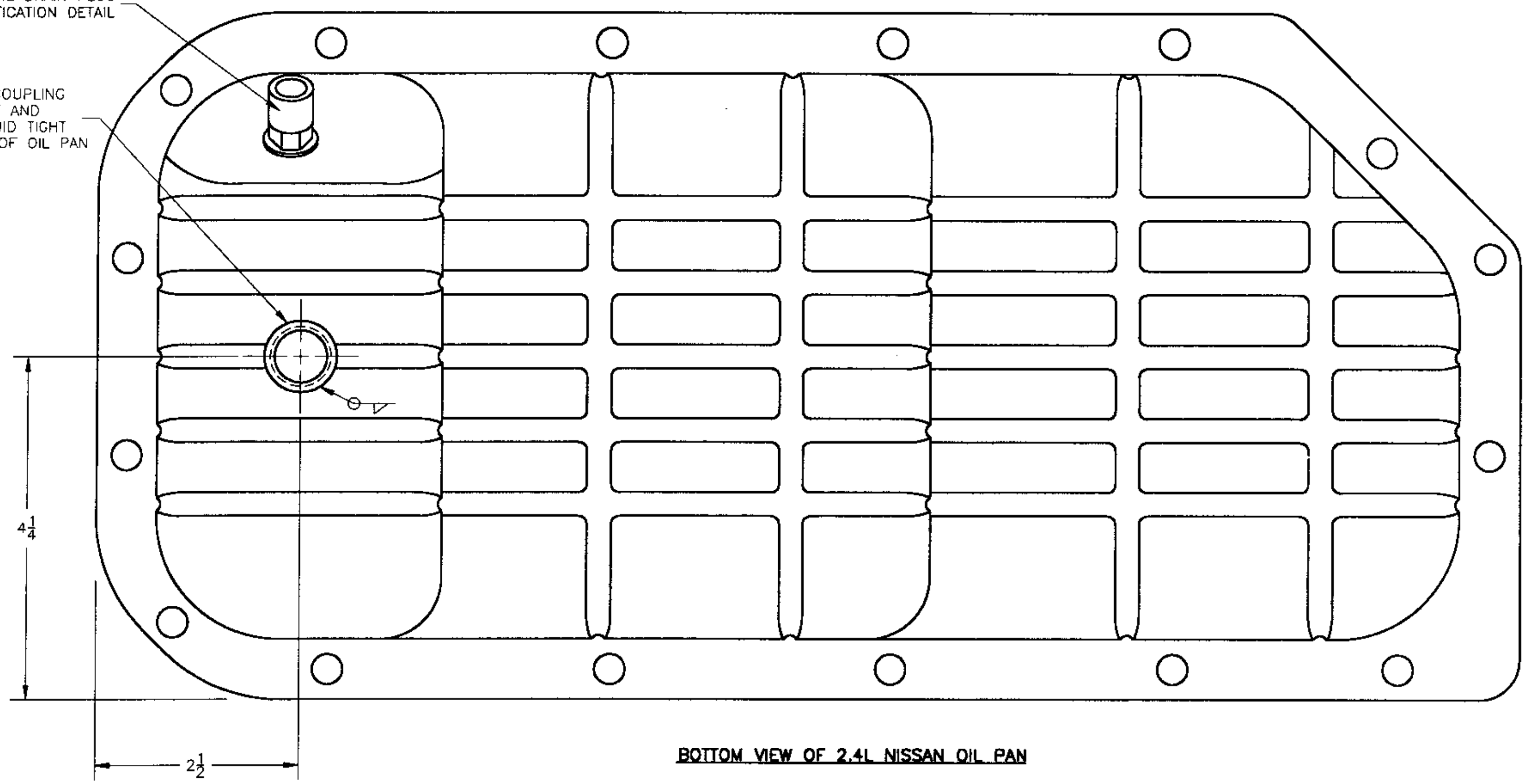
NOTES:

1. UNLESS OTHERWISE SPECIFIED, REMOVE BURRS AND BREAK SHARP EDGES.

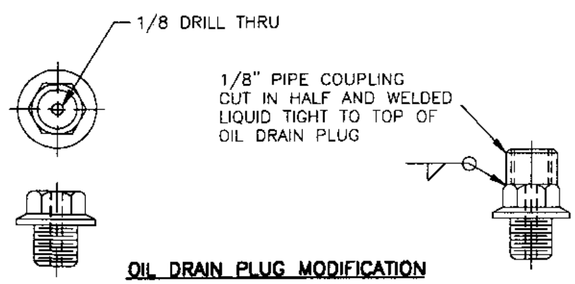
26401	DWG NO. C-GE-1762	SH 1	REV –

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED



BOTTOM VIEW OF 2.4L NISSAN OIL PAN



OIL DRAIN PLUG MODIFICATION

NEXT ASSY	USED ON
APPLICATION	

DO NOT SCALE PRINT

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH

TOLERANCE
UNLESS OTHERWISE SPECIFIED

LOCATIONAL
.XX= ± .02 .XXX= ± .010 ∠ = ± 30'

HOLE DIAMETER

0 THRU .250	.251 THRU .500	.501 AND UP
+ .003 − .002	+ .005 − .003	+ .010 − .005

CONTRACT		
DRN	T. HABY	20MAR97
CHK		
ENGR		
FILE	NISPAN	DIR GE

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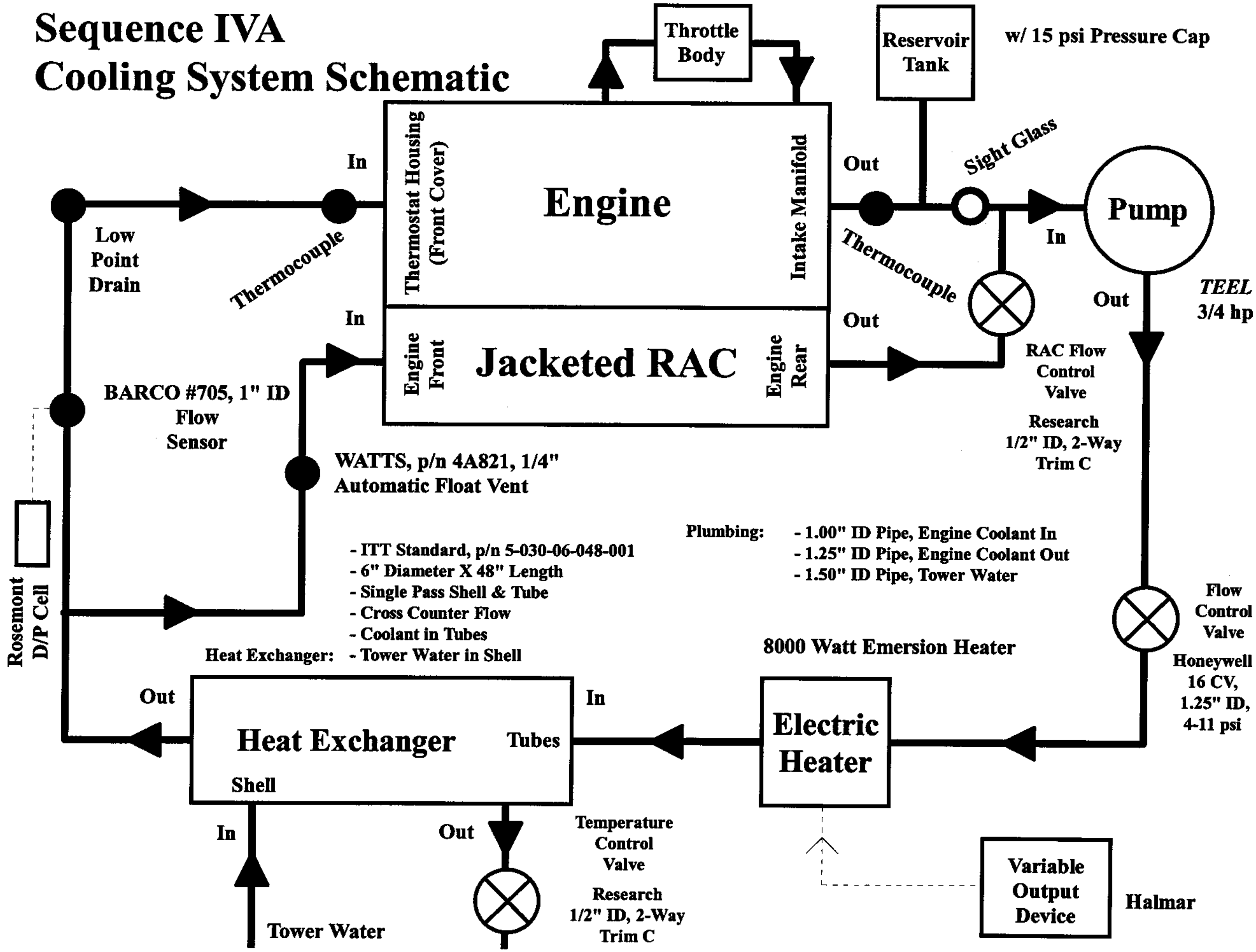
SAN ANTONIO, TEXAS

KA24E 2.4L
NISSAN OIL PAN MODIFICATION

SIZE	CODE IDENT NO.	DRAWING NO.	REV
C	26401	GE-1762	–
SCALE: 1=1		SHEET 1 OF 1	

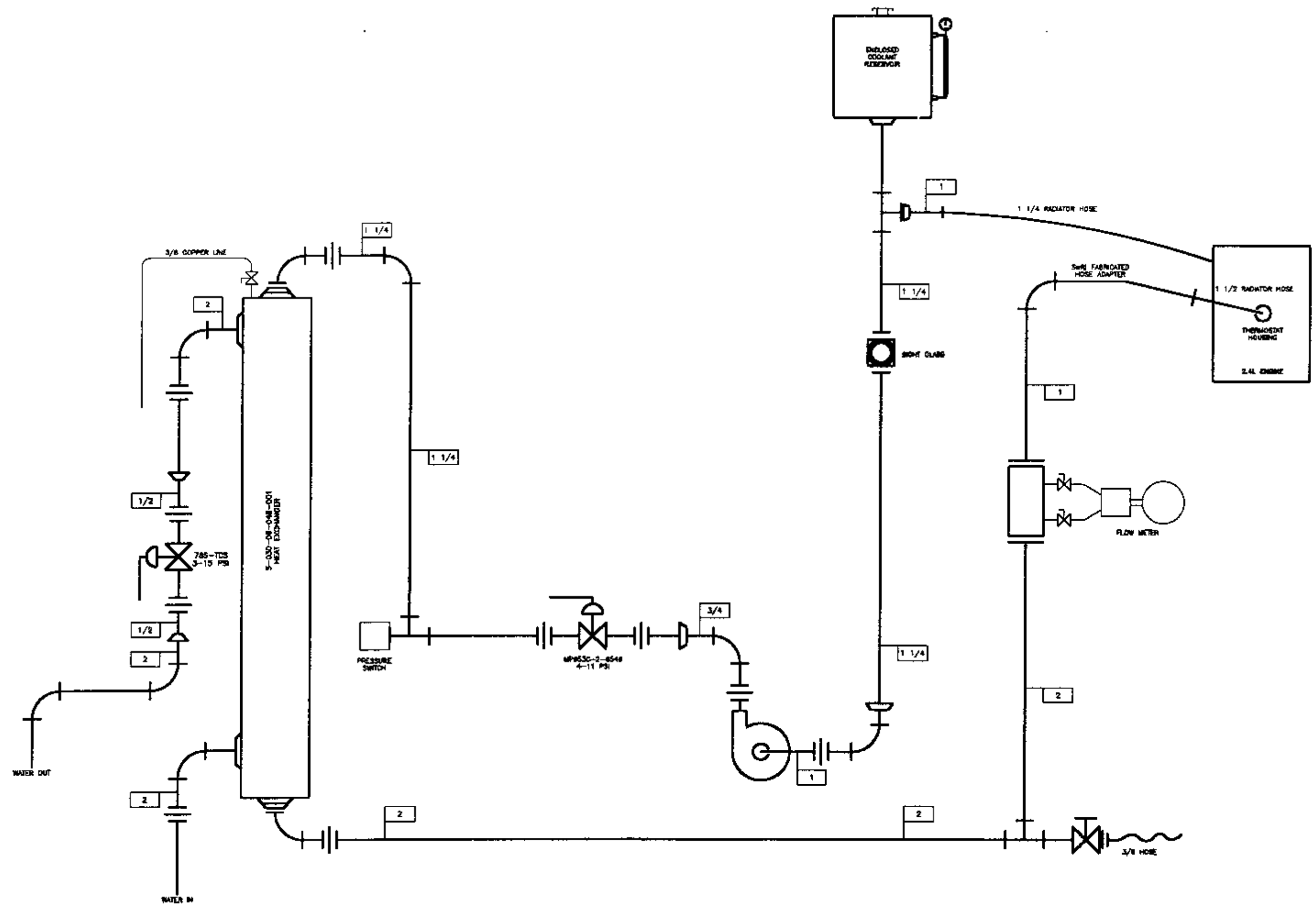
Sequence IVA
Cooling System Schematic



26401	DWG NO. C-GE-1760	SH 1	REV –

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED



NEXT ASSY	USED ON
APPLICATION	

DO NOT SCALE PRINT

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH

TOLERANCE
UNLESS OTHERWISE SPECIFIED

LOCATIONAL
.XX= ± .02 .XXX= ± .010 ∠ = ± 30'

HOLE DIAMETER

0 THRU .250	.251 THRU .500	.501 AND UP
+ .003 − .002	+ .005 − .003	+ .010 − .005

CONTRACT		
DRN	T. HABY	17MAR97
CHK		
ENGR		
FILE	41WATER	DIR GE

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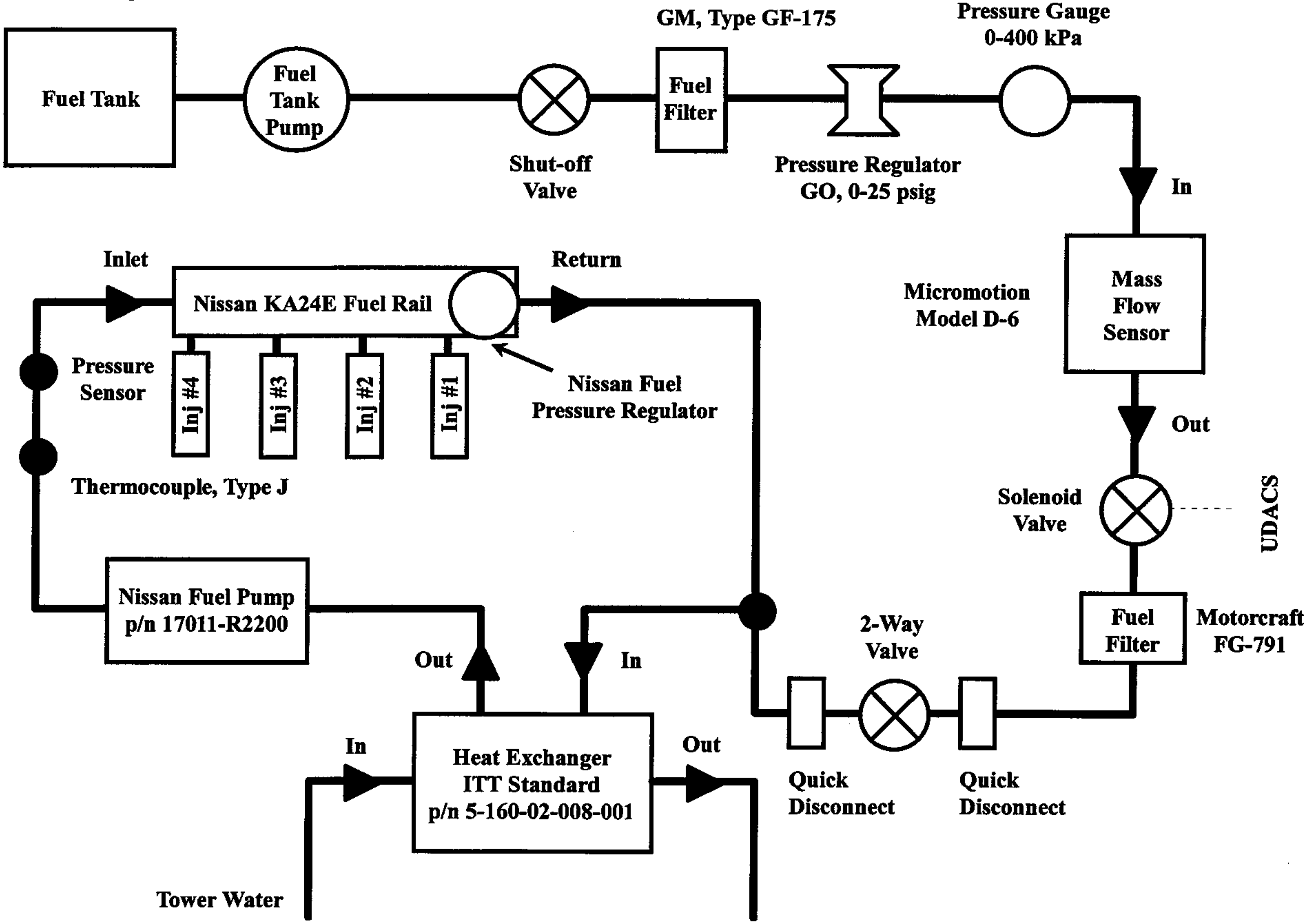
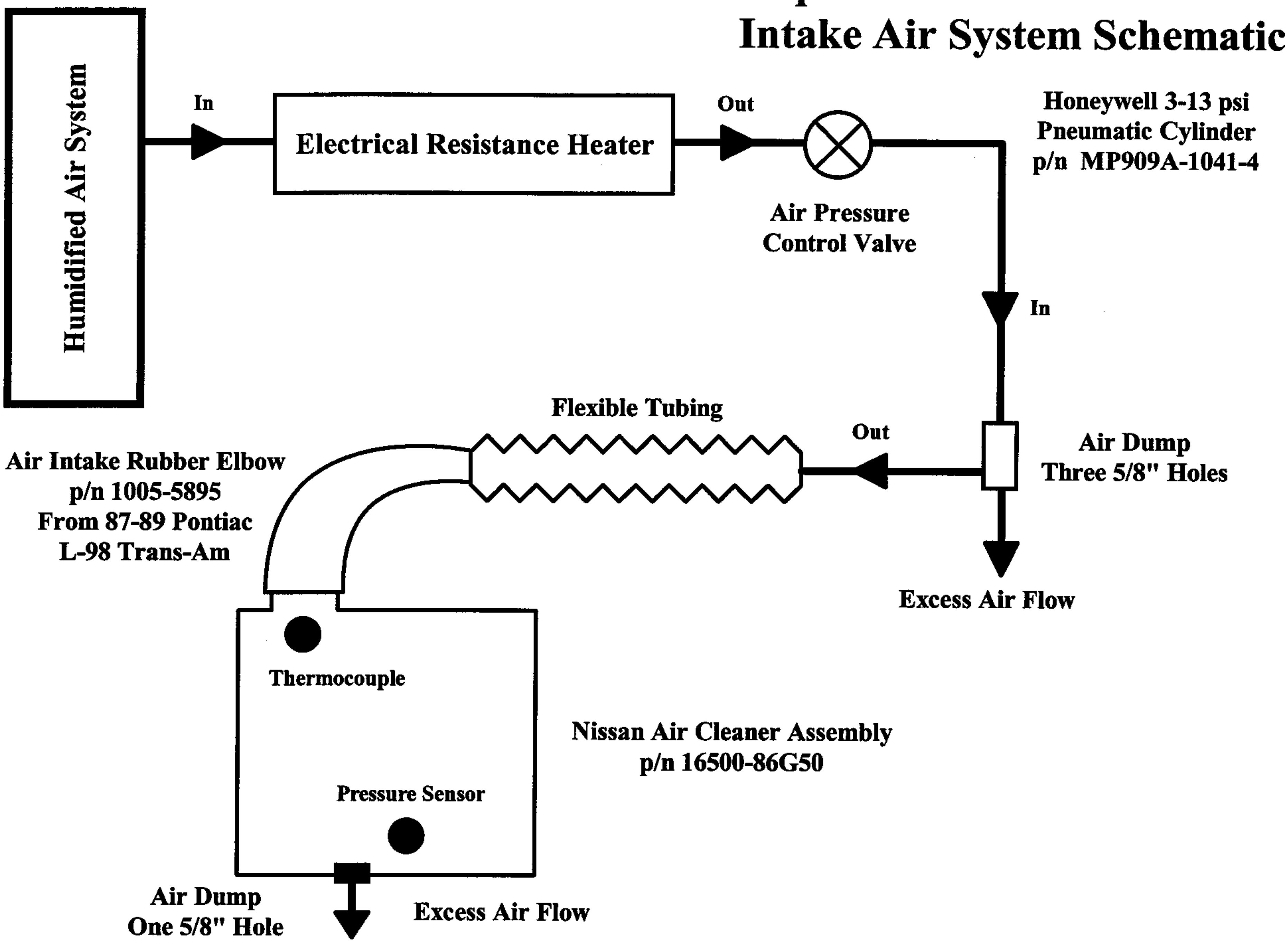
KA24E 2.4L NISSAN COOLANT SPOOL

SIZE	CODE IDENT NO.	DRAWING NO.	REV
C	26401	GE–1760	–
SCALE: NONE		SHEET 1 OF 1	

Sequence IVA
Fuel System Schematic



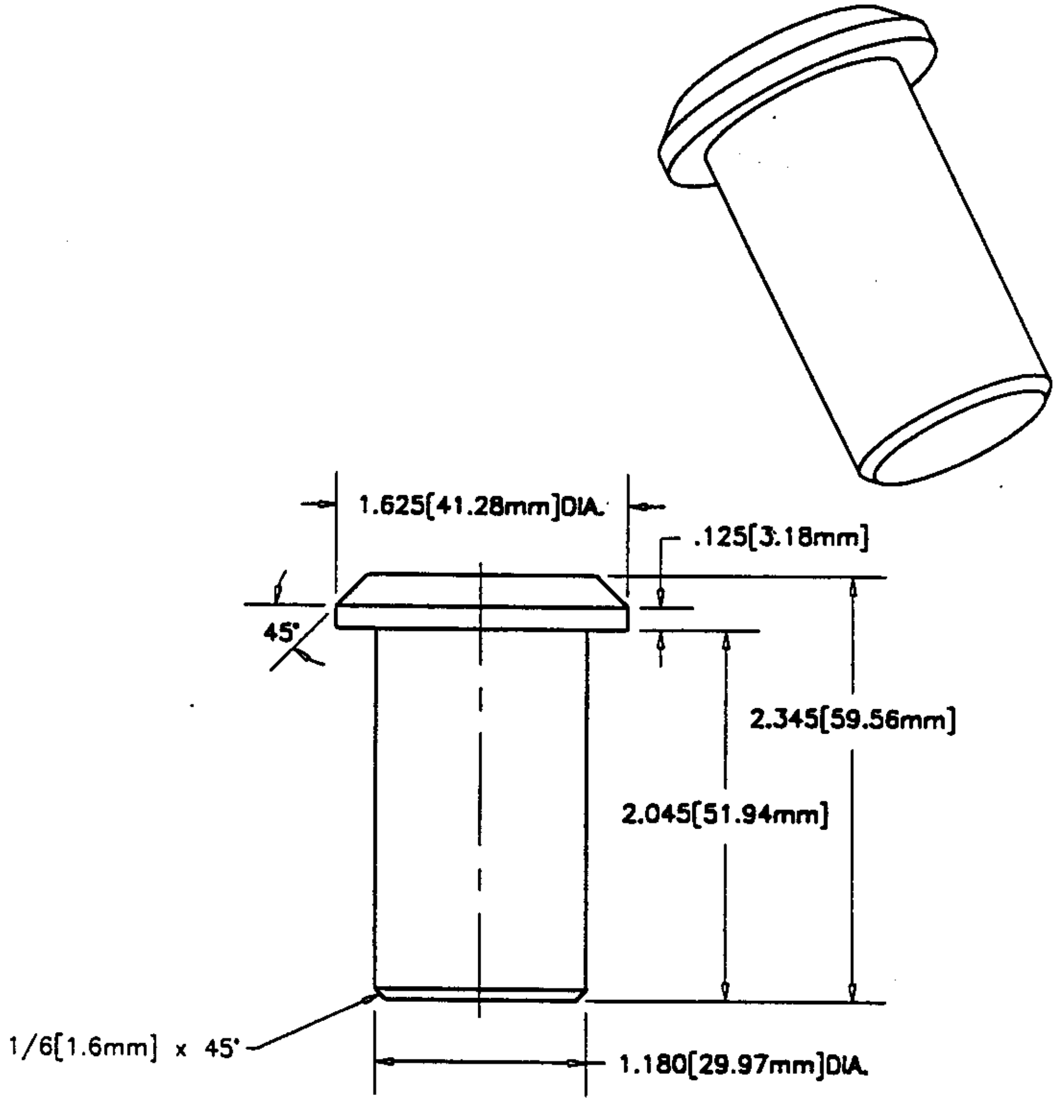
Sequence IVA
Intake Air System Schematic



WIRING HARNESS DRAWING IS BEING PREPARED BY OHT TECHNOLOGIES (DWIGHT BOWDEN). IT WILL BE INCLUDED IN A LATER DRAFT OF THE KA24E TEST PROCEDURE.

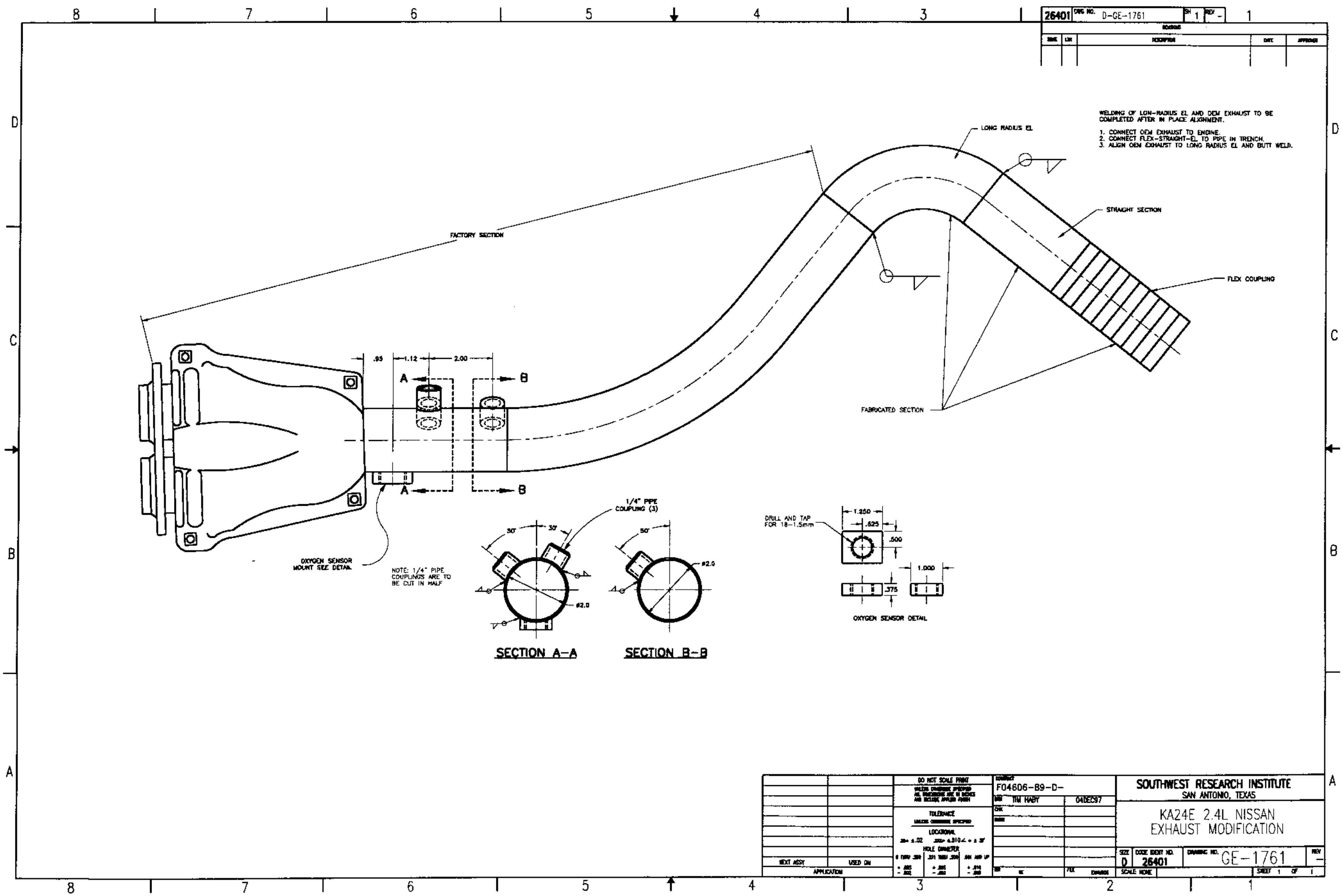
26401 DWG NO A-7826-1712 SH REV

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED



BREAK SHARP CORNERS
DIMENSIONS ARE IN INCHES AND [MILLIMETERS]

CONTRACT NO. 08-7862-301		SOUTHWEST RESEARCH INSTITUTE SAN ANTONIO, TEXAS	
DRAWN T HABY	7JULY96	WATER PUMP BORE PLUG	
CHECKED			
ENGR			
±.005[.127mm] TOLERANCE	NISSAN KA24E VTW USED ON	SIZE A	CODE IDENT. NO. 26401
APPLICATION		DWG NO. 7826-1712	REV.
FILE PUMPPLUG	DIR DIESEL	SCALE 1=1	SHEET 1 OF 1


26401 DWG NO. D-GE-1761 SH 1 REV -
WELDING OF LOW-RADIUS EL AND OEM EXHAUST TO BE COMPLETED AFTER IN PLACE ALIGNMENT.
1. CONNECT OEM EXHAUST TO ENGINE.
2. CONNECT FLEX-STRAIGHT-EL TO PIPE IN TRENCH.
3. ALIGN OEM EXHAUST TO LONG RADIUS EL AND BUTT WELD.
LONG RADIUS EL
STRAIGHT SECTION
FLEX COUPLING
FACTORY SECTION
FABRICATED SECTION
.93
1.12
2.00
A
B
OXYGEN SENSOR MOUNT SEE DETAIL
NOTE: 1/4" PIPE COUPLINGS ARE TO BE CUT IN HALF
1/4" PIPE COUPLING (3)
50°
30°
ø2.0
SECTION A-A
SECTION B-B
DRILL AND TAP FOR 18-1.5mm
1.250
.625
.500
1.000
.375
OXYGEN SENSOR DETAIL
DO NOT SCALE PRINT
TOLERANCE
LOCATIONAL
HOLE DIAMETER
NEXT ASSY
USED ON
APPLICATION
F04606-B9-D-
TIM HABY
04DEC97
SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO, TEXAS
KA24E 2.4L NISSAN
EXHAUST MODIFICATION
SIZE D
CODE IDENT NO. 26401
DRAWING NO. GE-1761
REV -
SCALE NONE
SHEET 1 OF 1

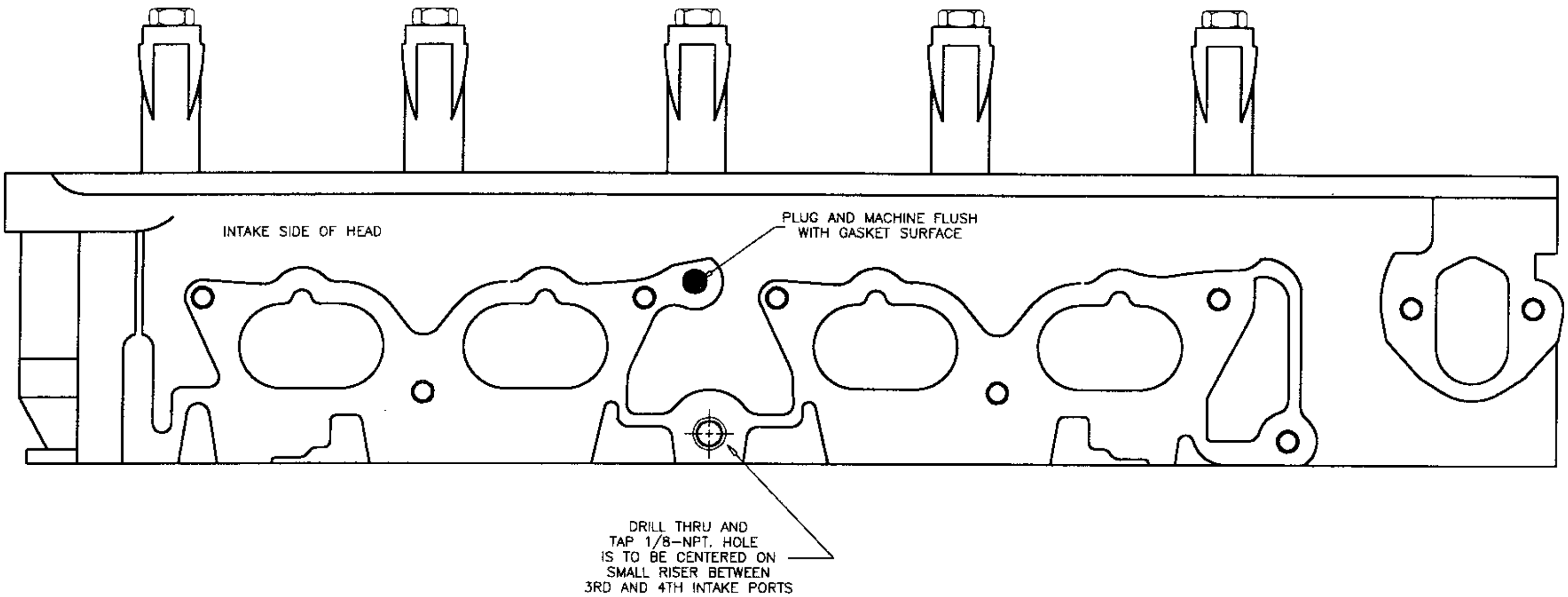
26401	DWG NO. C-GE-1755	SH 1	REV –

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:

1. UNLESS OTHERWISE SPECIFIED, REMOVE BURRS AND BREAK SHARP EDGES.



X	X
NEXT ASSY	USED ON
APPLICATION	

DO NOT SCALE PRINT

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH

TOLERANCE UNLESS OTHERWISE SPECIFIED

LOCATIONAL

.XX= ±.02 .XXX= ±.010 ∠ = ± 30'

HOLE DIAMETER

0 THRU .250	.251 THRU .500	.501 AND UP
+ .003 − .002	+ .005 − .003	+ .010 − .005

CONTRACT		
DRN	T. HABY	95–
CHK		
ENGR		
FILE	NISHEAD	DIR GE

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SAN ANTONIO, TEXAS

KA24E
2.4L NISSAN HEAD MODIFICATION

SIZE	CODE IDENT NO.	DRAWING NO.	REV
C	26401	GE–1755	–
SCALE: NONE		SHEET 1 OF 1	

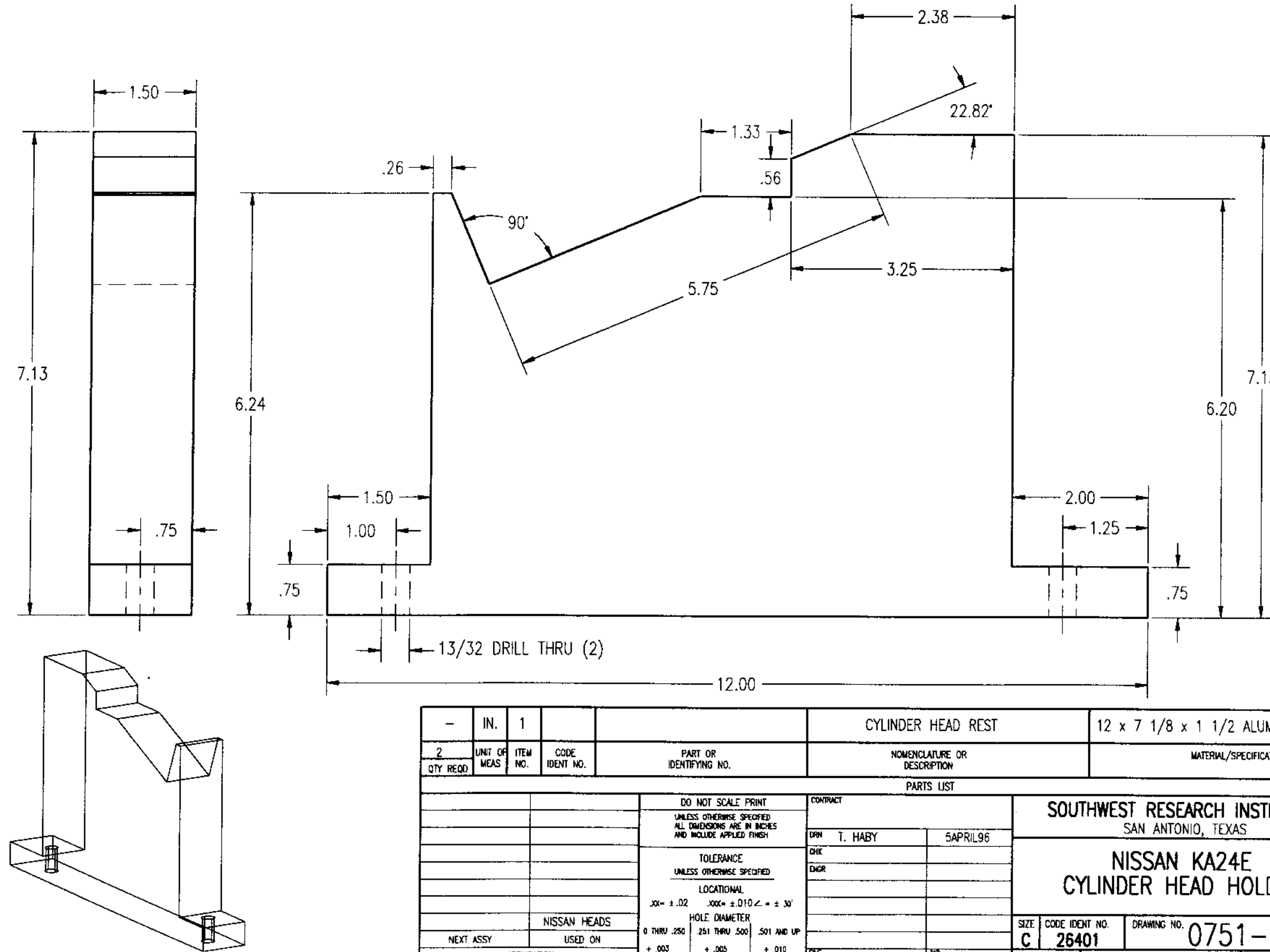
26401	DWG NO. 0751-1700	SH 1	REV –

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:

1. UNLESS OTHERWISE SPECIFIED, REMOVE BURRS AND BREAK SHARP EDGES.



–	IN.	1			CYLINDER HEAD REST	12 x 7 1/8 x 1 1/2 ALUM.
2 QTY REQD	UNIT OF MEAS	ITEM NO.	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION

PARTS LIST

DO NOT SCALE PRINT

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH

TOLERANCE
UNLESS OTHERWISE SPECIFIED

LOCATIONAL
.XX= ±.02 .XXX= ±.010 ∠ = ± 30'

HOLE DIAMETER

0 THRU .250	.251 THRU .500	.501 AND UP
+ .003 - .002	+ .005 - .003	+ .010 - .005

NEXT ASSY	USED ON
	NISSAN HEADS

APPLICATION

CONTRACT
DRN T. HABY 5APRIL96
CHK
ENGR

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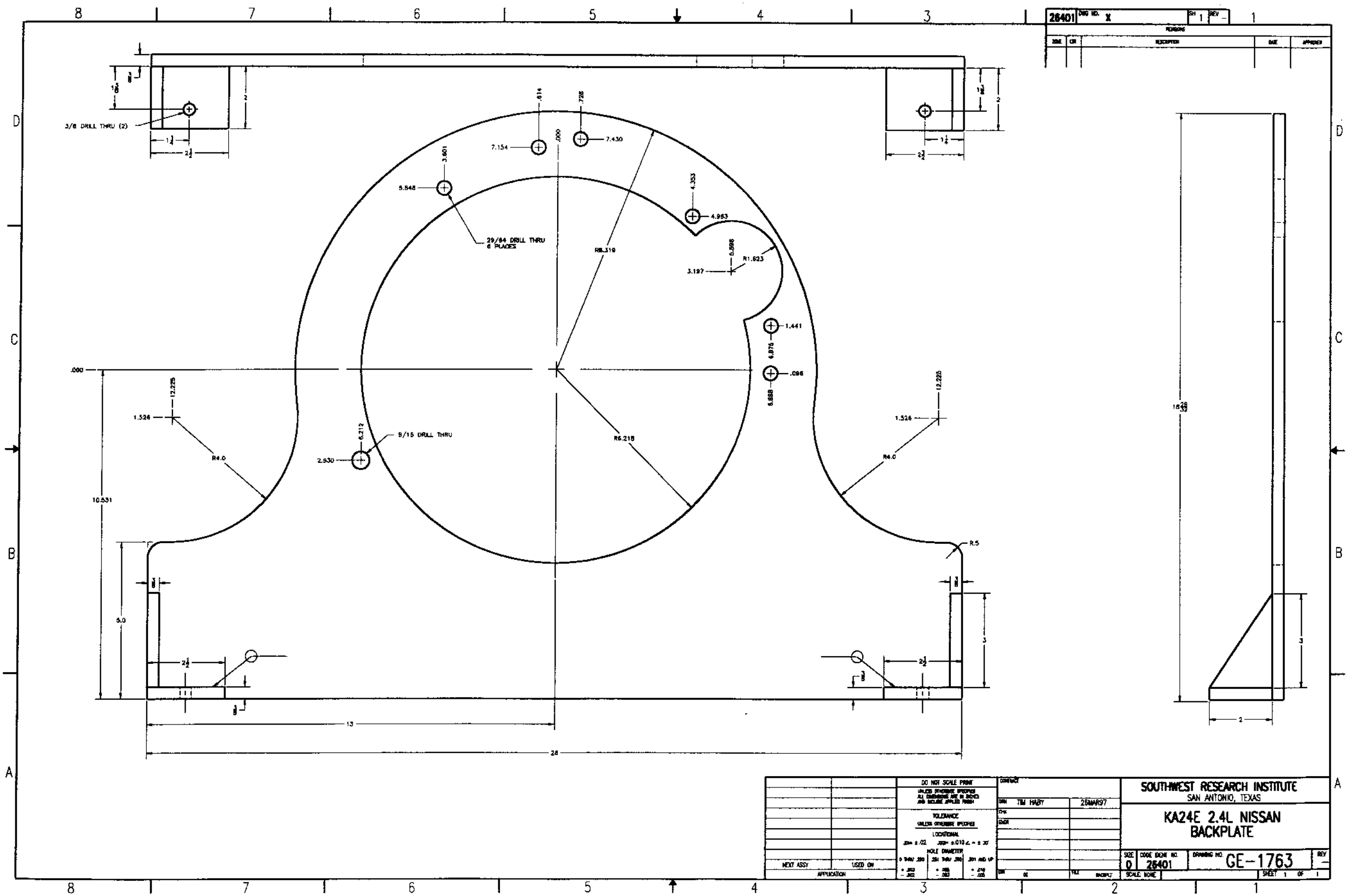
SAN ANTONIO, TEXAS

NISSAN KA24E
CYLINDER HEAD HOLDER

SIZE C | CODE IDENT NO. 26401 | DRAWING NO. 0751-1700 | REV –

FILE HEADREST | DIR DIESEL | SCALE: NONE | SHEET 1 OF 1



3/8 DRILL THRU (2)
29/64 DRILL THRU
6 PLACES
9/16 DRILL THRU
R8.319
R6.218
R1.623
R4.0
R4.0
R.5
13
28
10.531
5.0
DO NOT SCALE PRINT
TOLERANCE
LOCATIONAL
HOLE DIAMETER
NEXT ASSY
USED ON
APPLICATION
DRN TIM HABY 25MAR97
SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO, TEXAS
KA24E 2.4L NISSAN
BACKPLATE
SIZE D
CODE IDENT NO. 26401
DRAWING NO. GE-1763
SCALE NONE
SHEET 1 OF 1

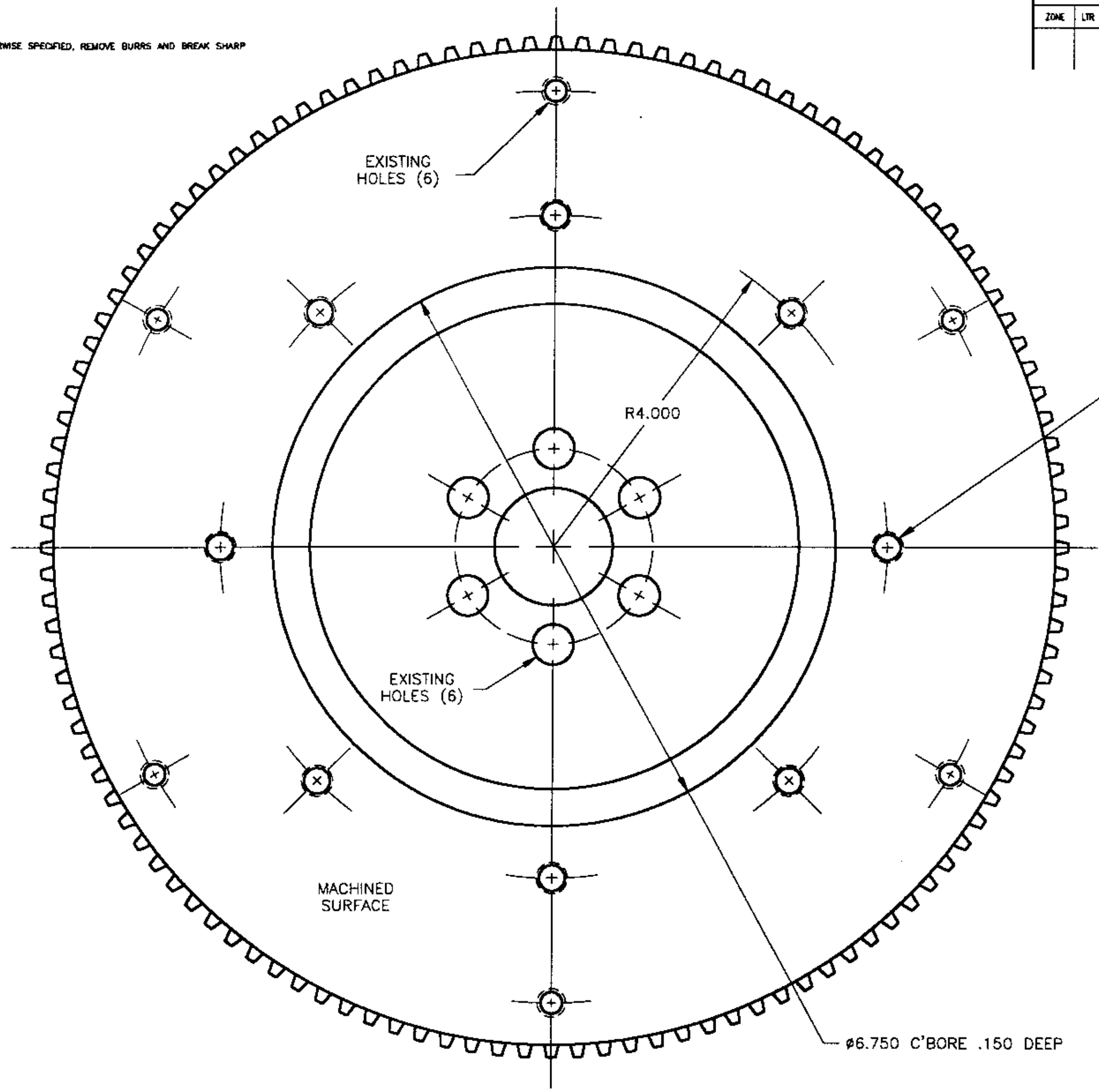
26401	DWG NO. C-GE-1765	SH 1	REV -

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:

1. UNLESS OTHERWISE SPECIFIED, REMOVE BURRS AND BREAK SHARP EDGES.



DO NOT SCALE PRINT

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH

TOLERANCE UNLESS OTHERWISE SPECIFIED

LOCATIONAL .XX= ±.02 .XXX= ±.010 ∠ = ± 30'

HOLE DIAMETER

0 THRU .250	.251 THRU .500	.501 AND UP
+ .003 - .002	+ .005 - .003	+ .010 - .005

NEXT ASSY	USED ON
APPLICATION	

CONTRACT		
DRN	T. HABY	28MAR97
CHK		
ENGR		
FILE	FLYWHEEL	DIR GE

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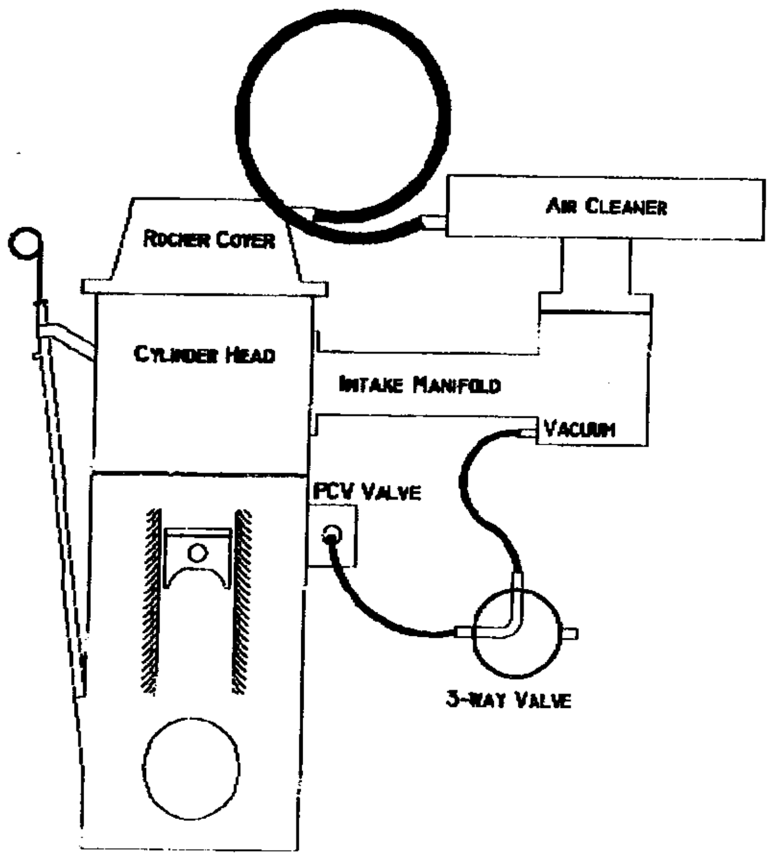
KA24E 2.4L NISSAN FLYWHEEL MODIFICATIONS

SIZE	CODE IDENT NO.	DRAWING NO.	REV
C	26401	GE-1765	-
SCALE: 1=1		SHEET 1 OF 1	

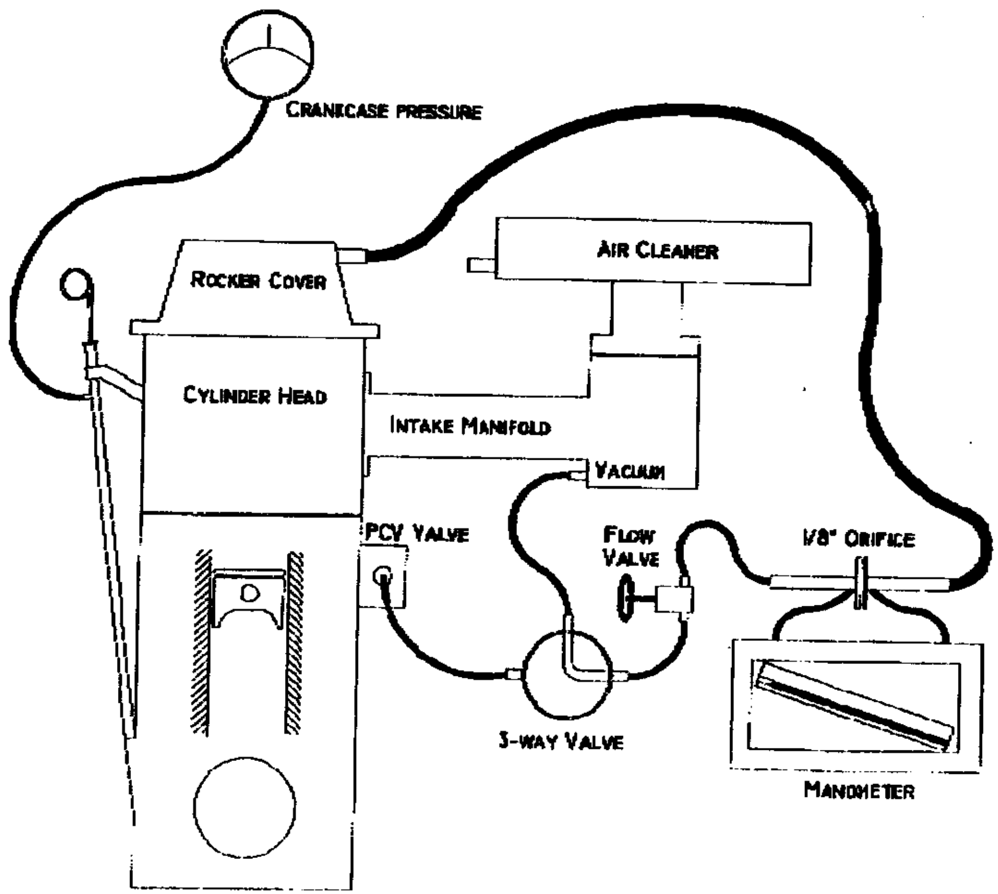
KA24E Blowby Measurement
Equipment Schematic

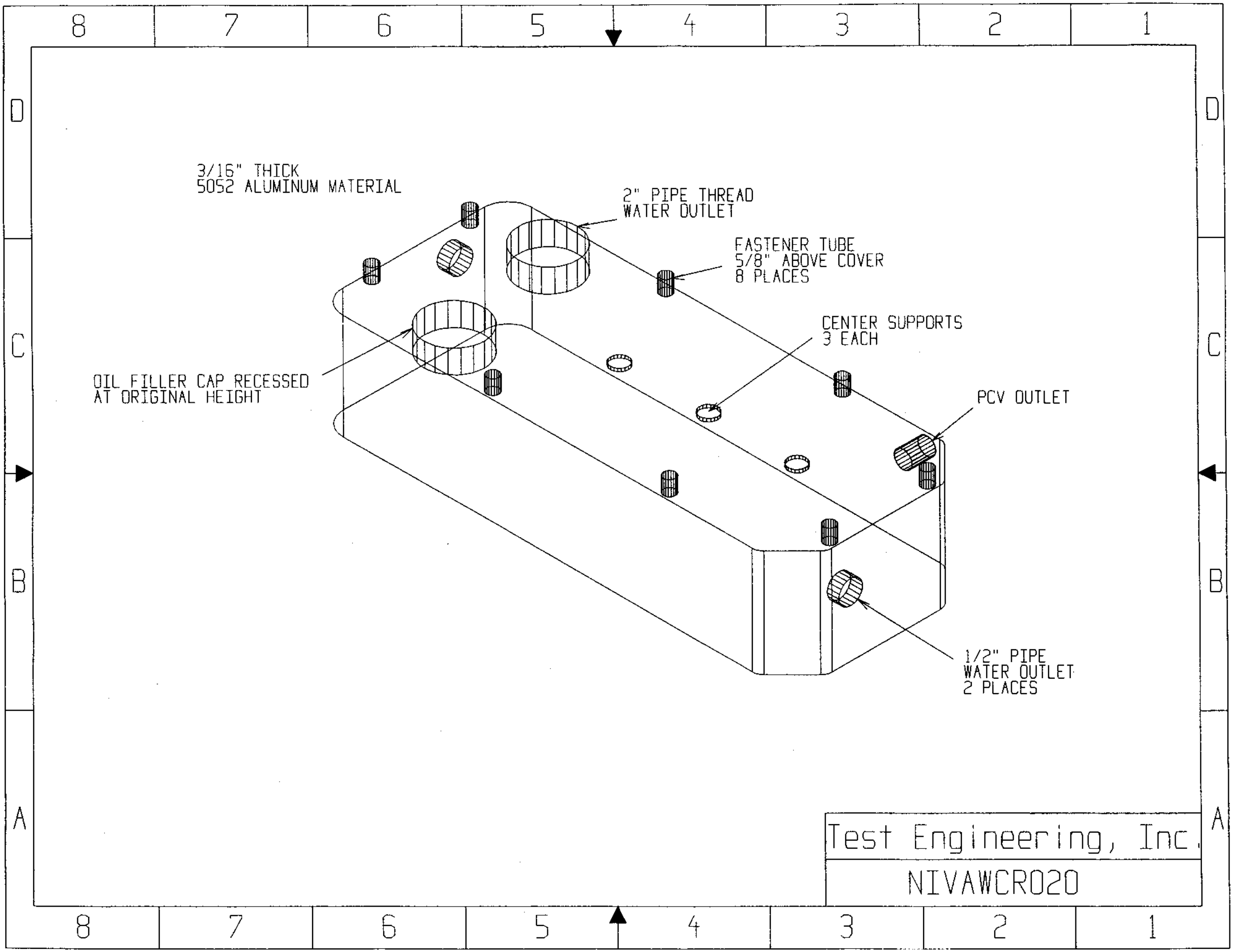
Erwin Mazariegos / Oct 27, 1997

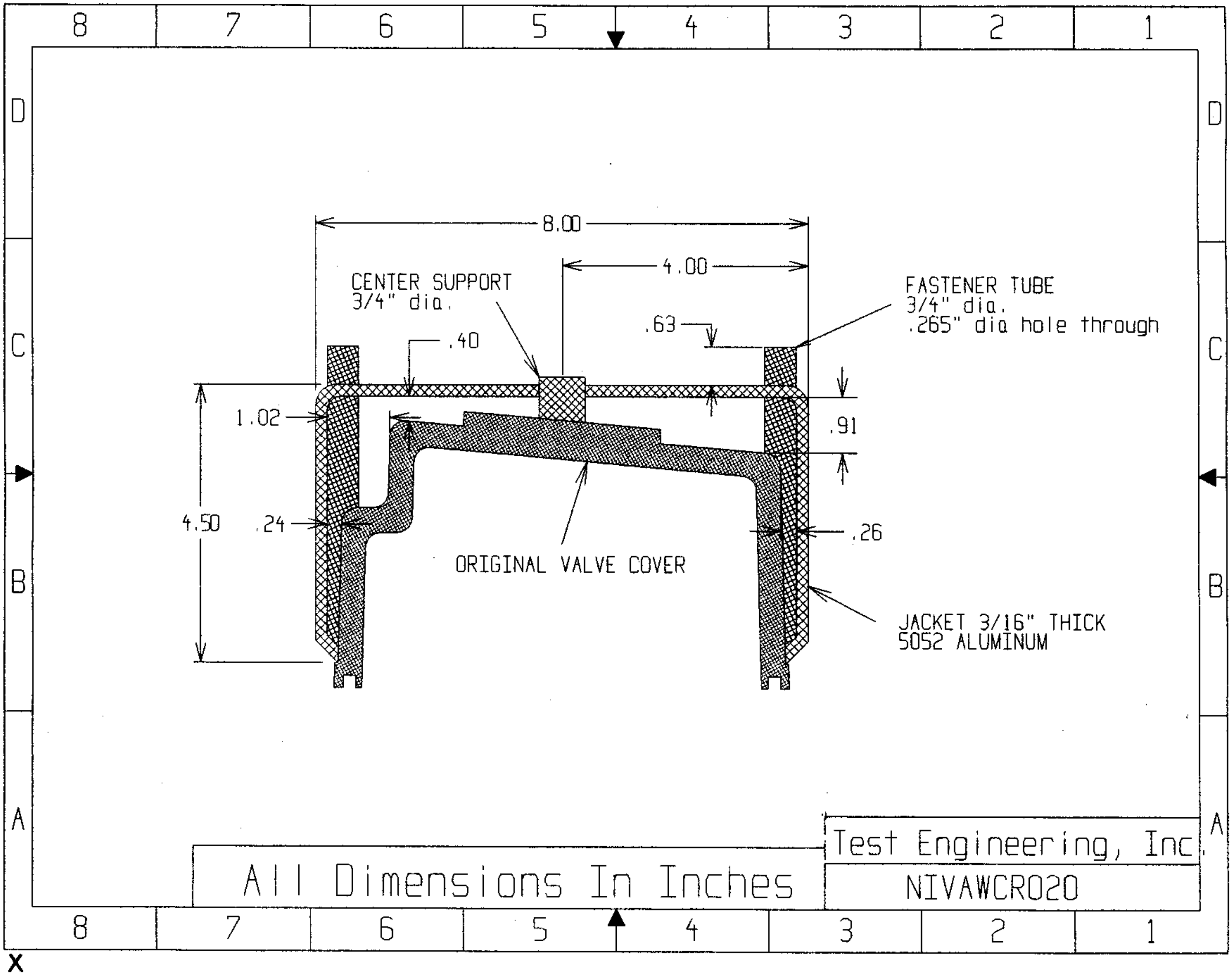
Normal Running Condition



Blowby Measurement

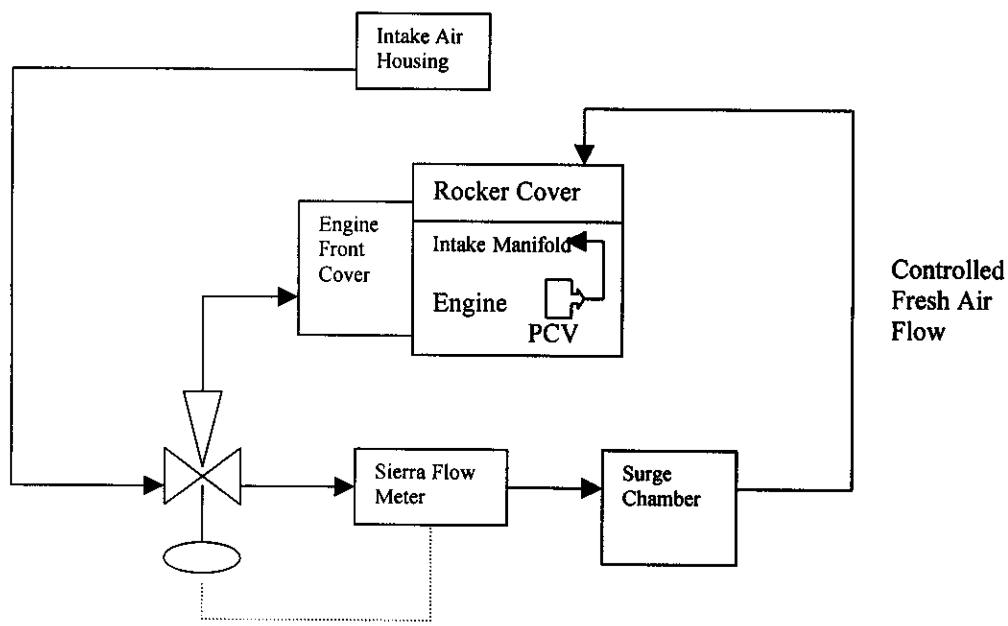



3/16" THICK
5052 ALUMINUM MATERIAL
2" PIPE THREAD
WATER OUTLET
FASTENER TUBE
5/8" ABOVE COVER
8 PLACES
CENTER SUPPORTS
3 EACH
OIL FILLER CAP RECESSED
AT ORIGINAL HEIGHT
PCV OUTLET
1/2" PIPE
WATER OUTLET
2 PLACES
Test Engineering, Inc.
NIVAWCR020


8.00
4.00
CENTER SUPPORT
3/4" dia.
.40
.63
FASTENER TUBE
3/4" dia.
.265" dia hole through
1.02
.91
4.50
.24
.26
ORIGINAL VALVE COVER
JACKET 3/16" THICK
5052 ALUMINUM
All Dimensions In Inches
Test Engineering, Inc.
NIVAWCR020

Notes on the equipment used:

- 3-way Research Valve is made by Badger Meter; ½" diameter; Trim Style "A"; 2.50 Cv flow rating; pneumatic controlled (air-to-close).
- Mass Flow Meter with an accuracy of +/- 0.25 SLPM @ 10 SLPM (std. Conditions 70 degF and 1 atm). Full scale of at least 20 SLPM. Pressure drop negligible (<0.5 in water). Time response less than or equal to 1.0 second. One model that meets these specs is Sierra Mass Flow meter, model 730-N2-1E0PV1V4 (air, 20 SLPM).
- Surge chamber has a volume of approximately 19 liters.
- 3/8" hose is used to connect from 3-way valve to front engine cover.
- 5/8" hose is used to connect from 3-way valve to rocker cover.
- Initial controller settings are:
  - Proportional Band - -75%
  - Integral Reset – 15 repeats/minute
  - Derivative Rate – 0.005



WIRING HARNESS DRAWING TO BE PROVIDED BY OHT TECHNOLOGIES (DWIGHT BOWDEN) IN NEXT DRAFT OF PROCEDURE.

Appendix C

C.   Nissan KA24E 2.4 liter engine specifications

- Engine oil flow schematic
- Nissan manual specifications and clearances
- Engine fastener torque specifications
- Test Kits procurement
- Test Kits parts listing
- Special tools required

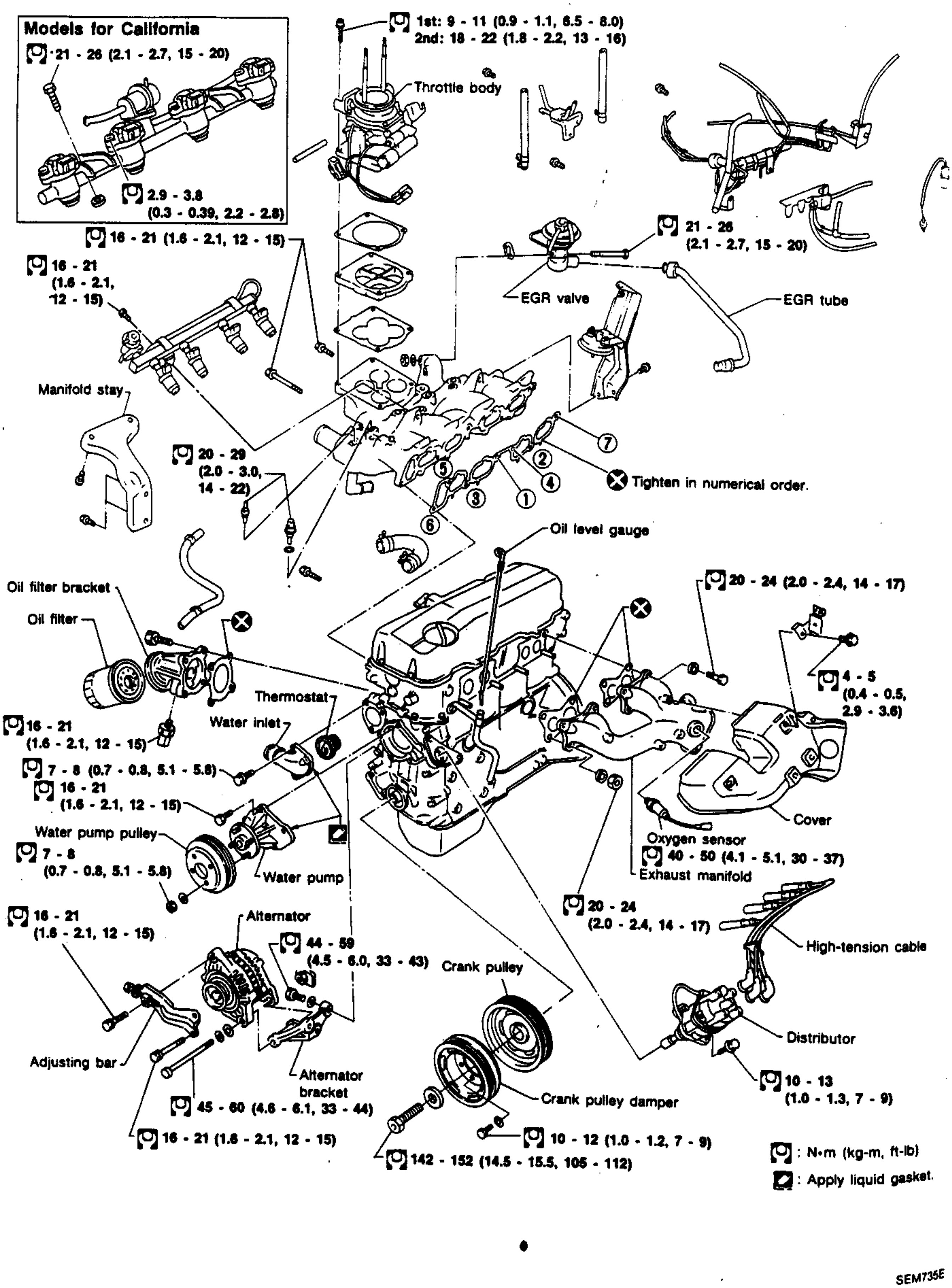
Nissan Test Kits

- Bare Engine Assembly
- Test Kit
- Head Assembly
- Engine Valve Regrind kit
- Distributor Assembly
- Test Stand Kit

NISSAN KA24E
VTW TEST

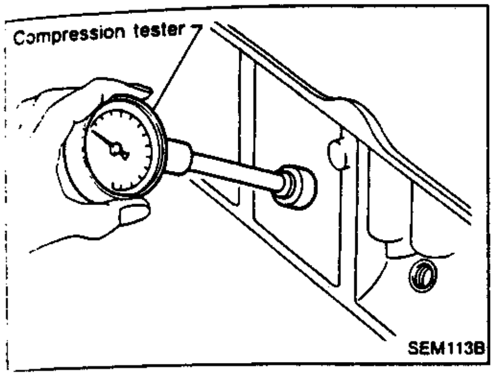
ENGINE MECHANICAL

SECTION EM


Models for California
21 - 26 (2.1 - 2.7, 15 - 20)
2.9 - 3.8 (0.3 - 0.39, 2.2 - 2.8)
1st: 9 - 11 (0.9 - 1.1, 6.5 - 8.0)
2nd: 18 - 22 (1.8 - 2.2, 13 - 16)
Throttle body
16 - 21 (1.6 - 2.1, 12 - 15)
16 - 21 (1.6 - 2.1, 12 - 15)
21 - 26 (2.1 - 2.7, 15 - 20)
EGR valve
EGR tube
Manifold stay
20 - 29 (2.0 - 3.0, 14 - 22)
Tighten in numerical order.
Oil level gauge
Oil filter bracket
Oil filter
20 - 24 (2.0 - 2.4, 14 - 17)
4 - 5 (0.4 - 0.5, 2.9 - 3.6)
Thermostat
Water inlet
16 - 21 (1.6 - 2.1, 12 - 15)
7 - 8 (0.7 - 0.8, 5.1 - 5.8)
16 - 21 (1.6 - 2.1, 12 - 15)
Water pump pulley
7 - 8 (0.7 - 0.8, 5.1 - 5.8)
Water pump
Cover
Oxygen sensor
40 - 50 (4.1 - 5.1, 30 - 37)
Exhaust manifold
20 - 24 (2.0 - 2.4, 14 - 17)
High-tension cable
16 - 21 (1.6 - 2.1, 12 - 15)
Alternator
44 - 59 (4.5 - 6.0, 33 - 43)
Crank pulley
Distributor
Adjusting bar
Alternator bracket
45 - 60 (4.6 - 6.1, 33 - 44)
Crank pulley damper
10 - 13 (1.0 - 1.3, 7 - 9)
16 - 21 (1.6 - 2.1, 12 - 15)
10 - 12 (1.0 - 1.2, 7 - 9)
142 - 152 (14.5 - 15.5, 105 - 112)
: N·m (kg-m, ft-lb)
: Apply liquid gasket.
SEM735E

Measurement of Compression Pressure

1. Warm up engine.
2. Turn ignition switch off.
3. Disconnect fusible link for injectors.
4. Remove all spark plugs.
5. Disconnect distributor center cable.



SEM113B

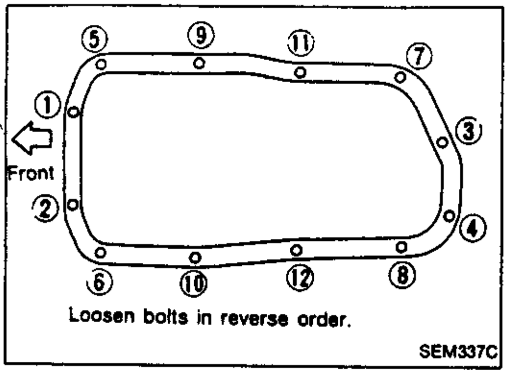
6. Attach a compression tester to No. 1 cylinder.
7. Depress accelerator pedal fully to keep throttle valve wide open.
8. Crank engine and record highest gauge indication.
9. Repeat the measurement on each cylinder as shown above.

- **Always use a fully-charged battery to obtain specified engine speed.**

  Compression pressure:
  kPa (kg/cm², psi)/rpm
  Standard
  1,324 (13.5, 192)/300
  Minimum
  981 (10, 142)/300
  Difference limit between cylinders
  98 (1.0, 14)/300

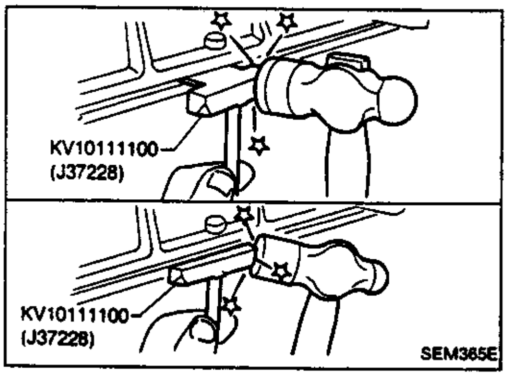
10. If cylinder compression in one or more cylinders is low, pour a small amount of engine oil into cylinders through spark plug holes and retest compression.

- **If adding oil improves cylinder compression, piston rings may be worn or damaged. If so, replace piston rings after checking piston.**
- **If pressure stays low, a valve may be sticking or seating improperly. Inspect and repair valve and valve seat. (Refer to SDS) If valve or valve seat is damaged excessively, replace them.**
- **If compression in any two adjacent cylinders is low and if adding oil does not improve compression, there is leakage past the gasket surface. If so, replace cylinder head gasket.**



Removal

1. Raise vehicle and support it with safety stands.
2. Drain engine oil.
3. Remove front stabilizer bar securing bolts and nuts from side member.
4. Lift engine.
5. Remove oil pan bolts.



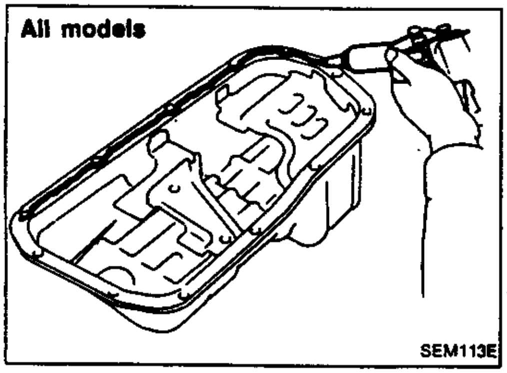
6. Remove oil pan.

(1) Insert Tool between cylinder block and oil pan.

- **Do not drive seal cutter into oil pump or rear oil seal retainer portion, or aluminum mating face will be damaged.**
- **Do not insert screwdriver, or oil pan flange will be deformed.**

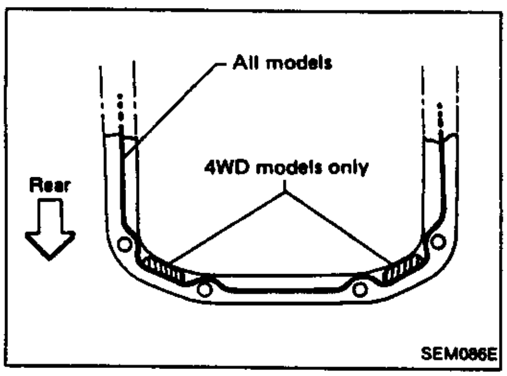
(2) Slide Tool by tapping its side with a hammer, and remove oil pan.

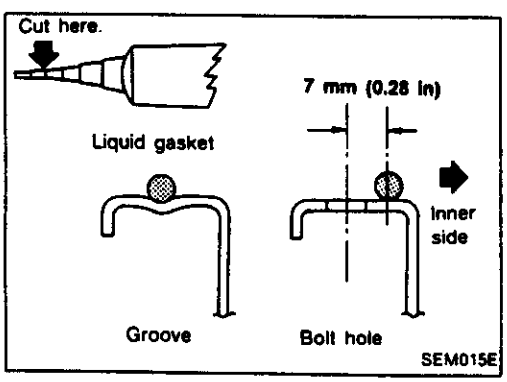
7. Pull out oil pan from front side.



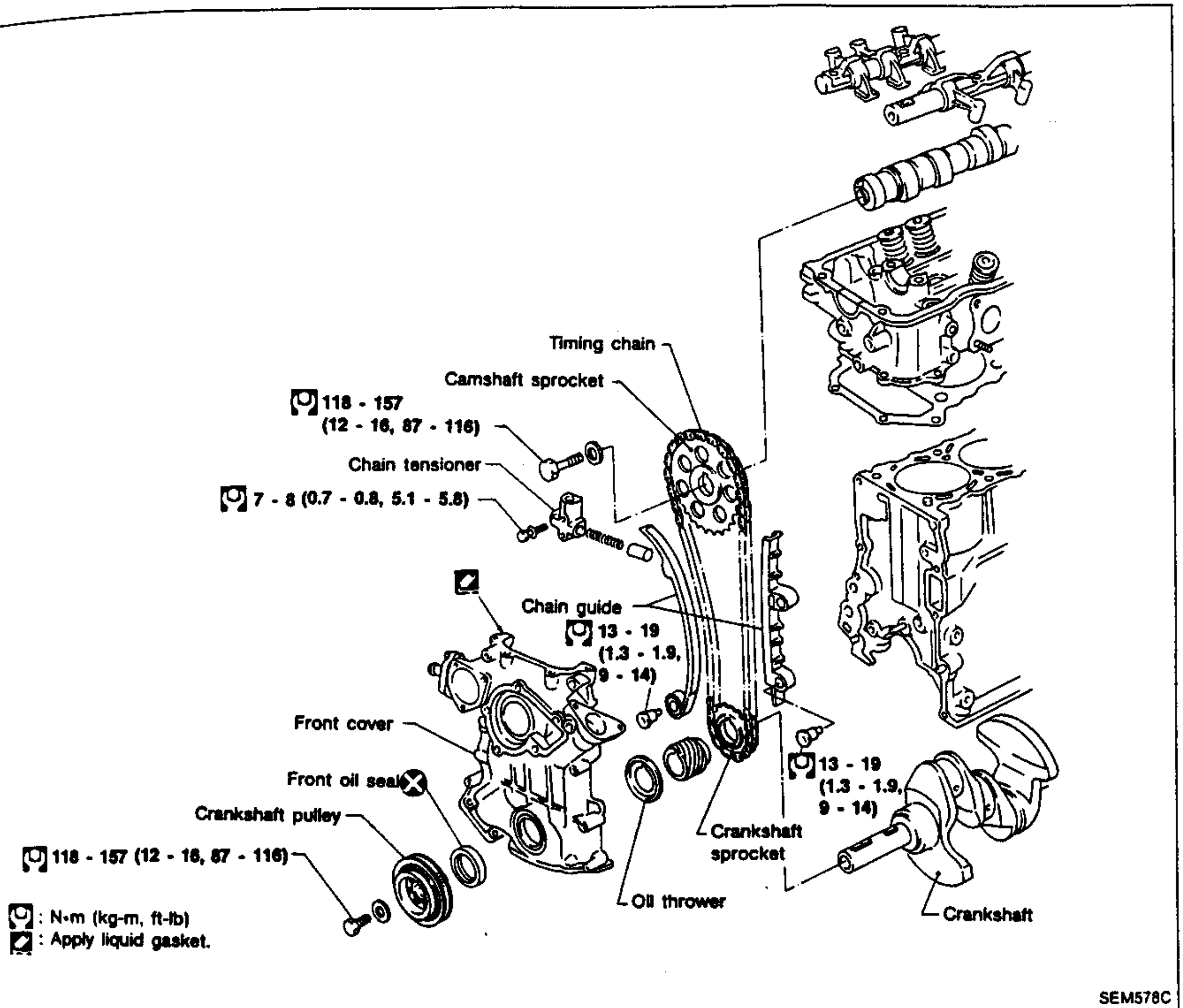
Installation

1. Before installing oil pan, remove all traces of liquid gasket from mating surface using a scraper.
- Also remove traces of liquid gasket from mating surface of cylinder block.
2. Apply a continuous bead of liquid gasket to mating surface of oil pan.
- **Use Genuine Liquid Gasket or equivalent.**





- Be sure liquid gasket is 3.5 to 4.5 mm (0.138 to 0.177 in) wide.
3. Apply liquid gasket to inner sealing surface as shown in figure.
- Attaching should be done within 5 minutes after coating.
4. Install oil pan.
- **Wait at least 30 minutes before refilling engine oil.**

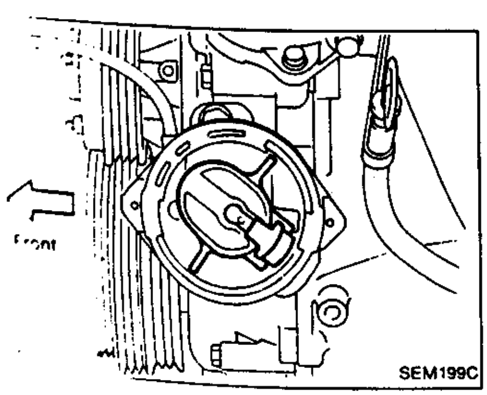


SEM578C

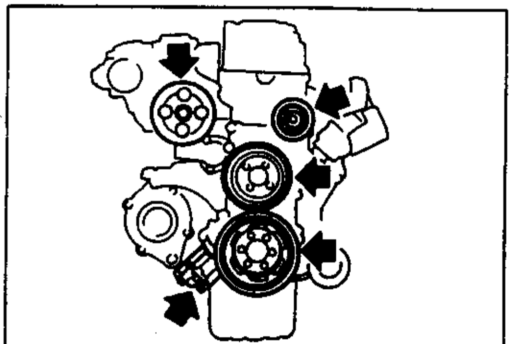
CAUTION:
After removing timing chain, do not turn crankshaft and camshaft separately, or valves will strike piston heads.

Removal

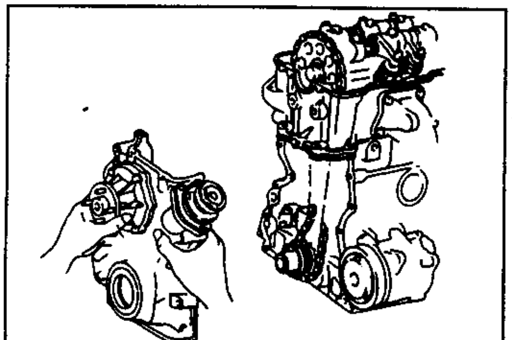
1. Disconnect battery terminal.
2. Drain coolant from radiator.
3. Remove radiator shroud and cooling fan.
4. Remove the following belts.
- Power steering drive belt
- Compressor drive belt
- Alternator drive belt
5. Remove all spark plugs.
6. Set No. 1 piston at TDC on its compression stroke.


SEM199C

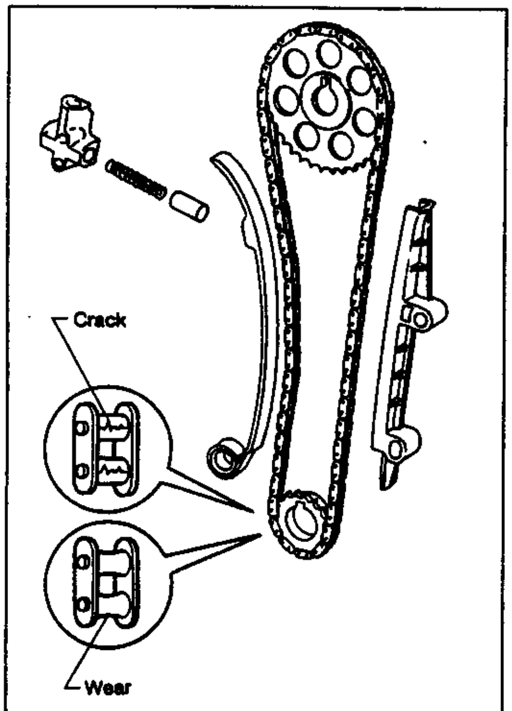
Removal (Cont'd)


SEM200C

7. Remove the following parts.
- Power steering pump, idler pulley and power steering pump brackets
- Compressor idler pulley
- Crankshaft pulley with a suitable puller
- Oil pump with pump drive spindle
- Rocker cover


SEM202C

8. Remove oil pan. (Refer to OIL PAN.)
9. Remove front cover.

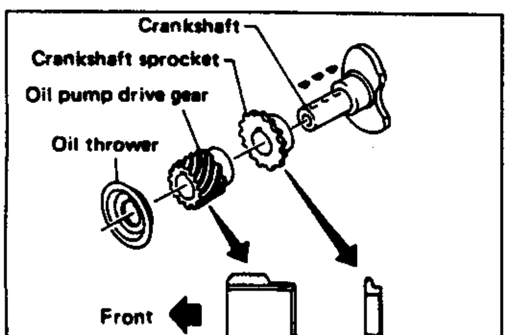


SEM204C

10. Remove the following parts.
- Chain tensioner
- Chain guides
- Timing chain and sprocket
- Oil thrower, oil pump drive gear and crankshaft sprocket

Inspection

Check for cracks and excessive wear at roller links. Replace if necessary.

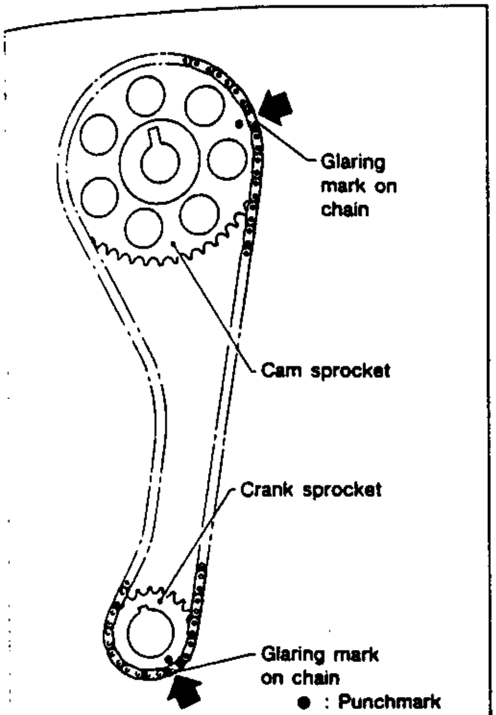


SEM205C

Installation

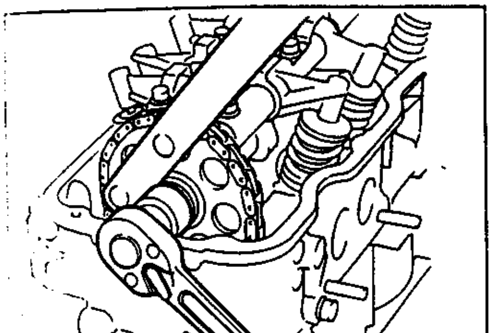
1. Install crankshaft sprocket, oil pump drive gear and oil thrower.
- **Make sure that mating marks of crankshaft sprocket face engine front.**

Installation (Cont'd)

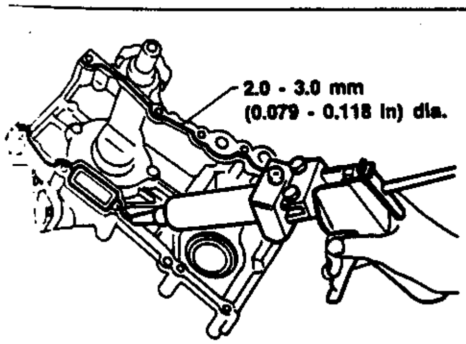


SEM730E

2. Install camshaft sprocket.
3. Confirm that No. 1 piston is set at TDC on its compression stroke.
4. Install timing chain.
- **Set timing chain by aligning its mating marks with those of crankshaft sprocket and camshaft sprocket.**

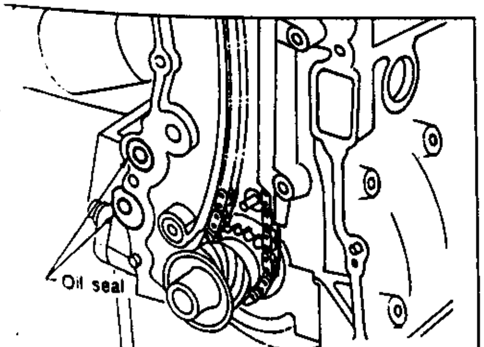

SEM207C

5. Tighten camshaft sprocket bolt.
6. Install chain guide and chain tensioner.



SEM440C

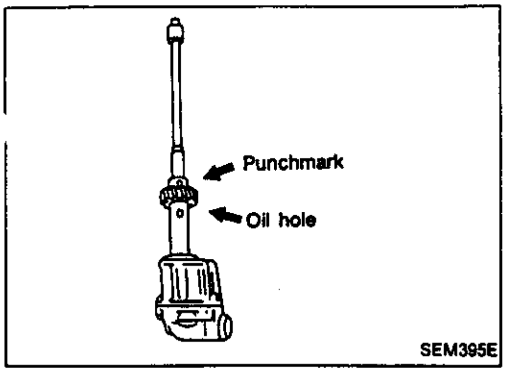
7. Apply liquid gasket to front cover.
8. Apply lithium grease to sealing lip of crankshaft oil seal.



SEM453C

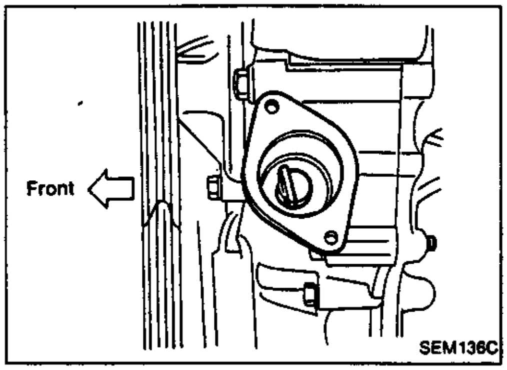
9. Install front cover.
- **Be careful not to damage cylinder head gasket.**
- **Do not forget oil seal.**
10. Install rubber plug. (Refer to "Installation" of CYLINDER HEAD.)
11. Install oil pan. (Refer to OIL PAN.)

Installation (Cont'd)



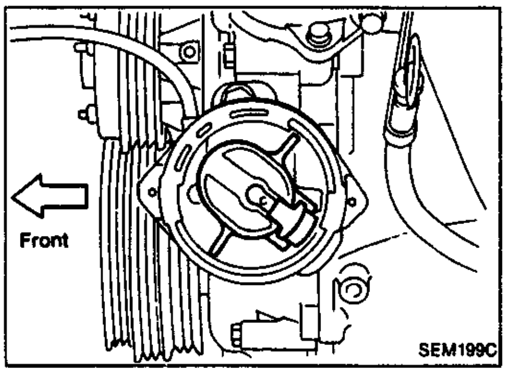
SEM395E

12. Install oil pump and distributor driving spindle with new gasket in front cover.
(1) Assemble oil pump and driving spindle, aligning punchmark on driving spindle with oil hole.



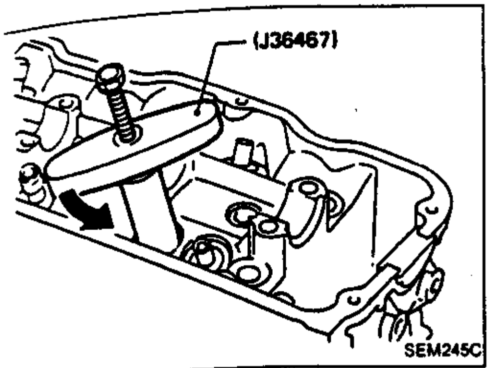
SEM136C

(2) Make sure that driving spindle is set as shown in figure.



SEM199C

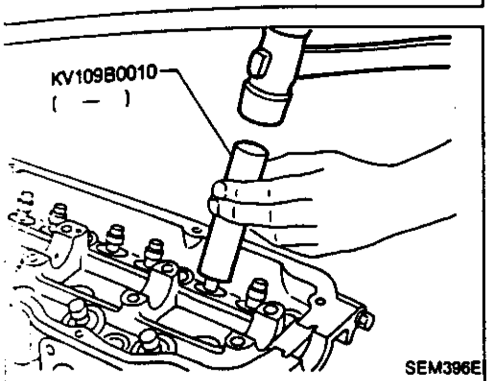
13. Install distributor.
14. Make sure that No. 1 piston is set at TDC and that distributor rotor is set at No. 1 cylinder spark position.



VALVE OIL SEAL

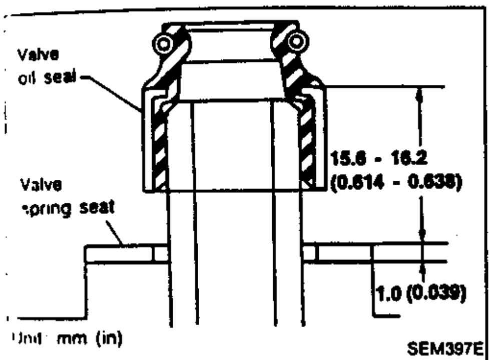
1. Remove rocker cover.
2. Remove rocker shaft assembly.
3. Remove valve spring and valve oil seal with Tool or suitable tool.

Piston concerned should be set at TDC to prevent valve from falling.

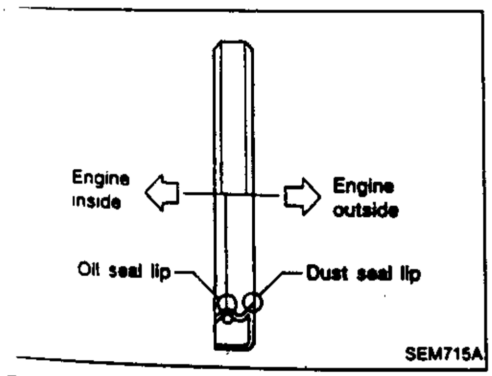


4. Apply engine oil to new valve oil seal and install it with Tool.

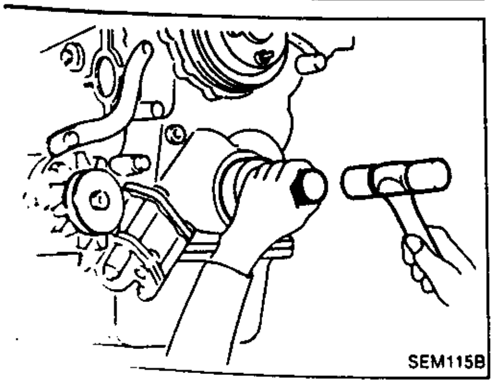
Before installing valve oil seal, install valve spring seat.



OIL SEAL INSTALLING DIRECTION



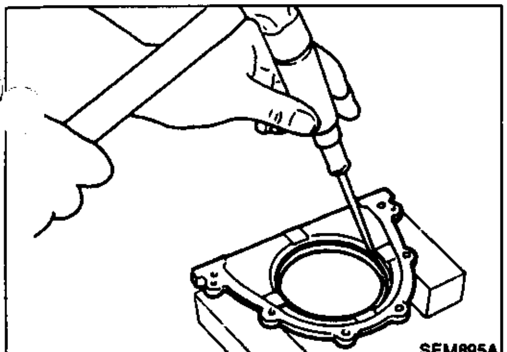
FRONT OIL SEAL



1. Remove radiator shroud and crankshaft pulley.
2. Remove front oil seal.

Be careful not to damage crankshaft.

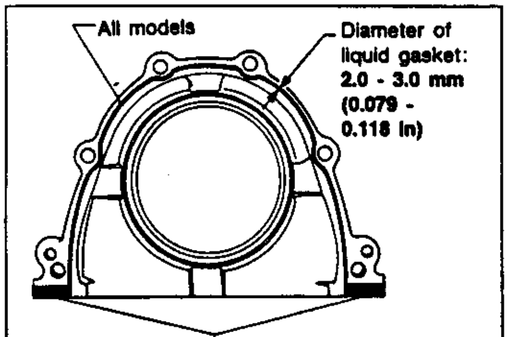
3. Apply engine oil to new oil seal and install it using suitable tool.



SEM895A

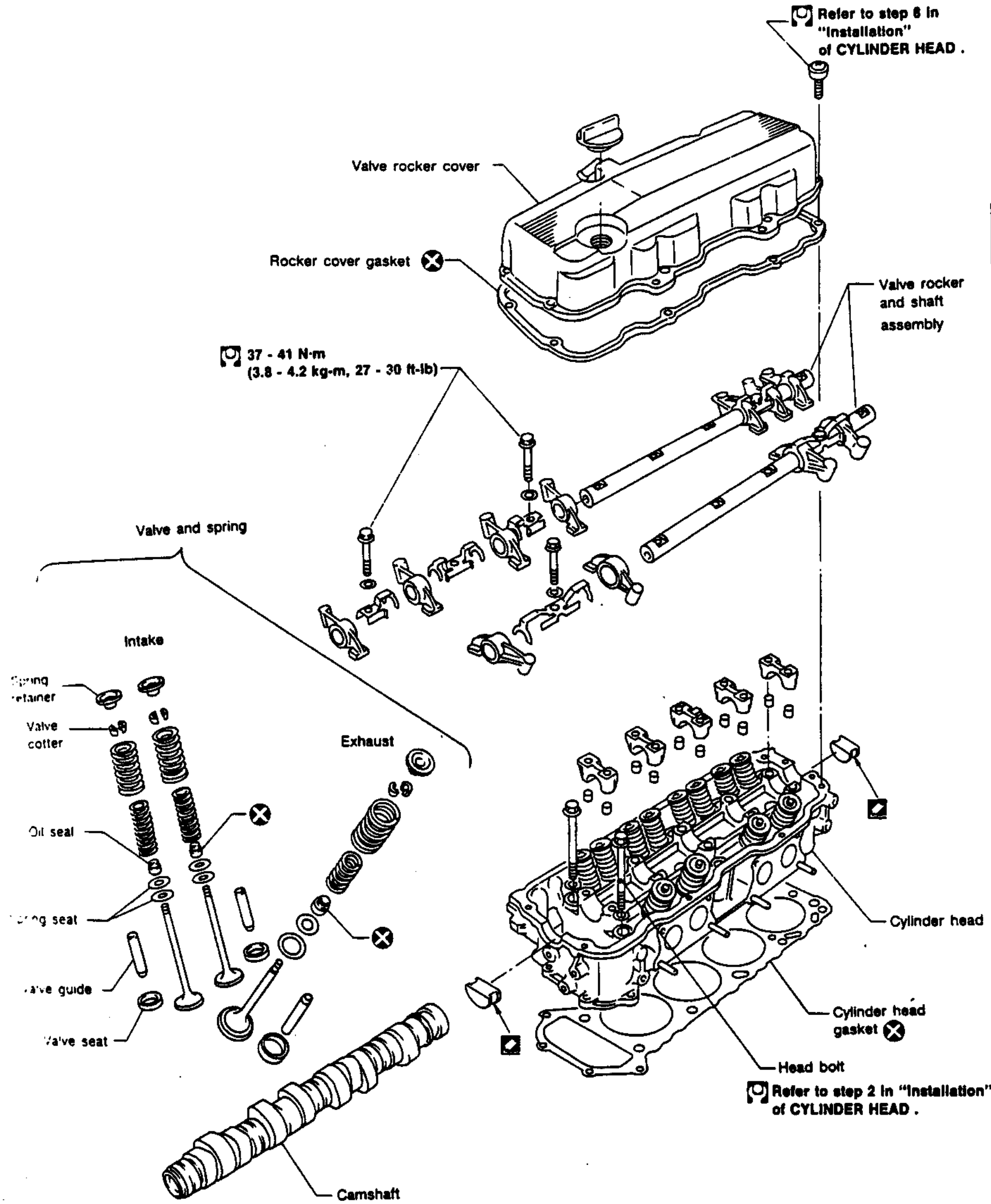
REAR OIL SEAL

1. Remove flywheel or drive plate.
2. Remove rear oil seal retainer.
3. Remove traces of liquid gasket using scraper.
4. Remove rear oil seal from retainer.
5. Apply engine oil to new oil seal and install it using suitable tool.

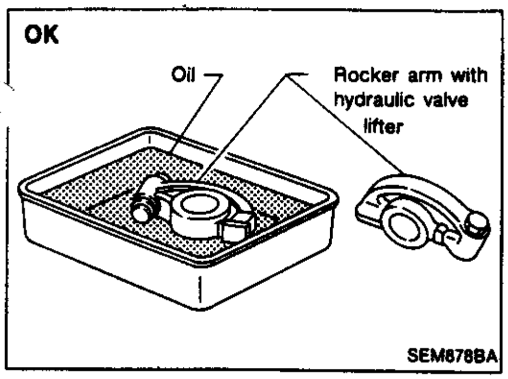


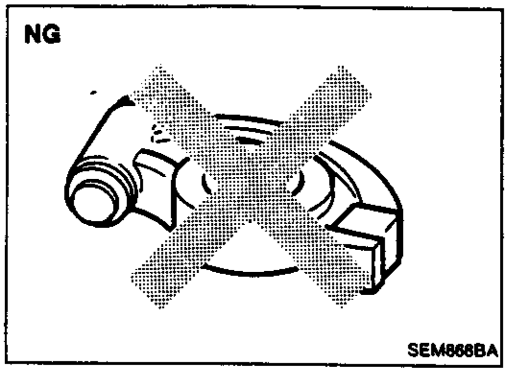
SEM085E

6. Apply liquid gasket to rear oil seal retainer.



Refer to step 6 in "Installation" of CYLINDER HEAD .
Valve rocker cover
Rocker cover gasket
Valve rocker and shaft assembly
37 - 41 N·m (3.8 - 4.2 kg-m, 27 - 30 ft-lb)
Valve and spring
Intake
Spring retainer
Valve cotter
Exhaust
Oil seal
Spring seat
Valve guide
Valve seat
Cylinder head
Cylinder head gasket
Head bolt
Refer to step 2 in "Installation" of CYLINDER HEAD .
Camshaft
SEM552E





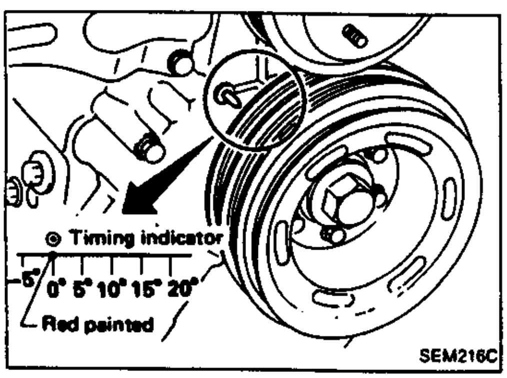
CAUTION:

- **When installing sliding parts such as rocker arms, camshaft and oil seal, be sure to apply new engine oil on their sliding surfaces.**
- **When tightening cylinder head bolts and rocker shaft bolts, apply new engine oil to thread portions and seat surfaces of bolts.**
- **Hydraulic valve lifters are installed in each rocker arm. If hydraulic valve lifter is kept on its side, even when installed in rocker arm, there is a possibility of air entering it. After removal, always set rocker arm straight up, or when laying it on its side, have it soak in new engine oil.**
- **Do not disassemble hydraulic valve lifter.**
- **Attach tags to valve lifters so as not to mix them up.**

Removal

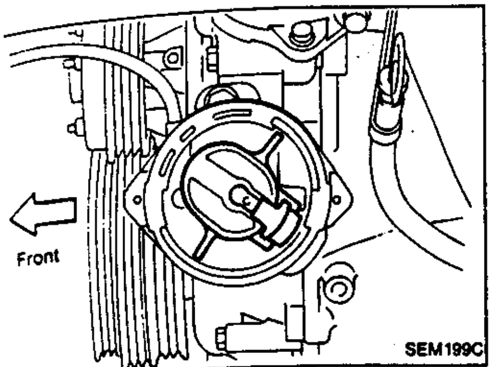
1. Drain coolant from radiator and drain plug of block.
2. Remove the following parts.
- Power steering drive belt
- Power steering pump, idler pulley and power steering brackets
- Vacuum hoses of SCV and pressure control solenoid valve
- Accelerator wire bracket
3. Disconnect EGR tube from exhaust manifold.
4. Remove bolts which hold intake manifold collector to intake manifold.
5. Remove bolts which hold intake manifold to cylinder head while raising collector upwards.
6. Remove rocker cover.

When removing rocker cover, do not hit rocker cover against rocker arm.

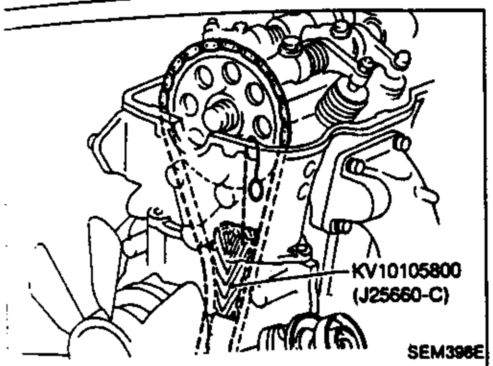


7. Set No. 1 piston at TDC on its compression stroke.

Removal (Cont'd)

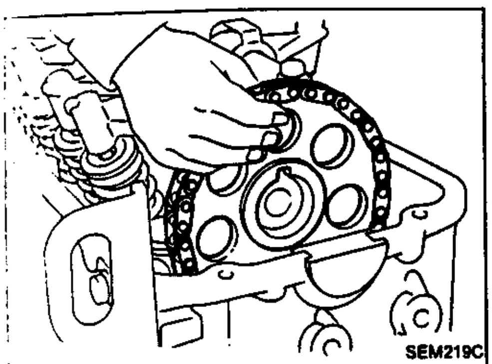


SEM199C

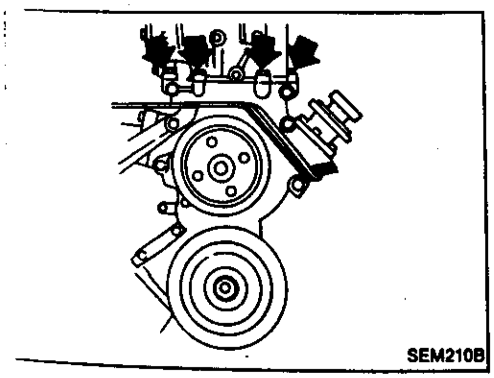


SEM398E

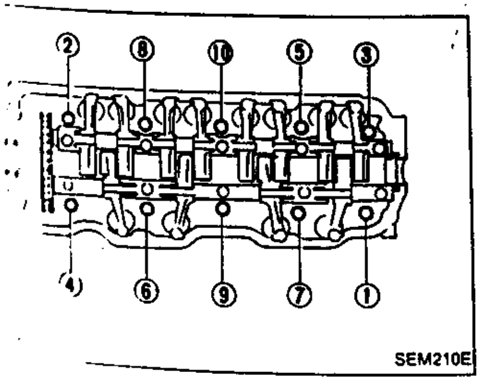
8. Loosen camshaft sprocket bolt.
- Support timing chain by using Tool as shown in figure.


SEM219C

9. Remove camshaft sprocket.


SEM210B

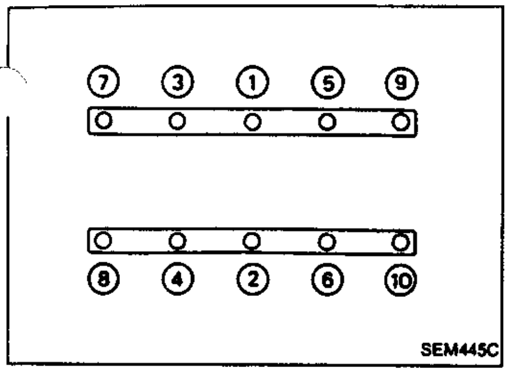
10. Remove front cover tightening bolts to cylinder head.



SEM210E

11. Remove cylinder head.
- **A warped or cracked cylinder head could result from removing in incorrect order.**
- **Cylinder head bolts should be loosened in two or three steps.**

Disassembly



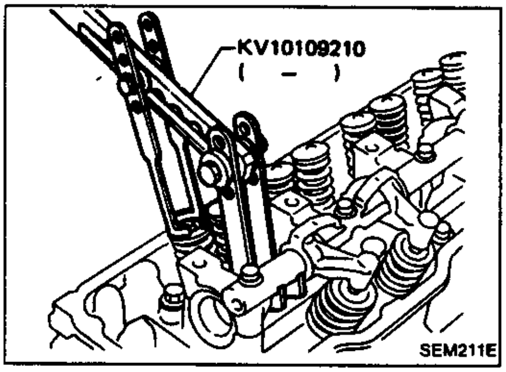
1. Remove rocker shaft assembly.

a. **When loosening bolts, evenly loosen from outside in sequence.**

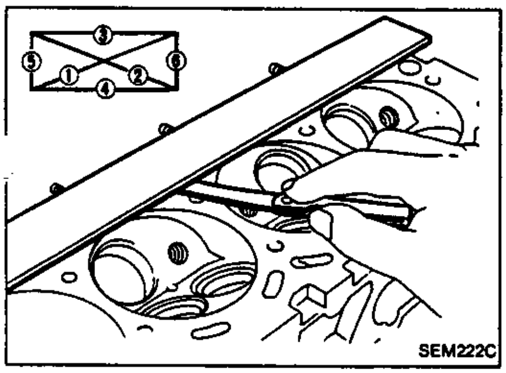
b. **Bolts should be loosened in two or three steps.**

2. Remove camshaft.

- **Before removing camshaft, measure camshaft end play. (Refer to "Inspection".)**



3. Remove valve components with Tool.
4. Remove valve oil seals. (Refer to OIL SEAL REPLACEMENT.)



Inspection

CYLINDER HEAD DISTORTION

Head surface flatness:

Less than 0.1 mm (0.004 in)

If beyond the specified limit, replace it or resurface it.

Resurfacing limit:

The resurfacing limit of cylinder head is determined by the cylinder block resurfacing in an engine.

Amount of cylinder head resurfacing is "A"

Amount of cylinder block resurfacing is "B"

The maximum limit is as follows:

A + B = 0.2 mm (0.008 in)

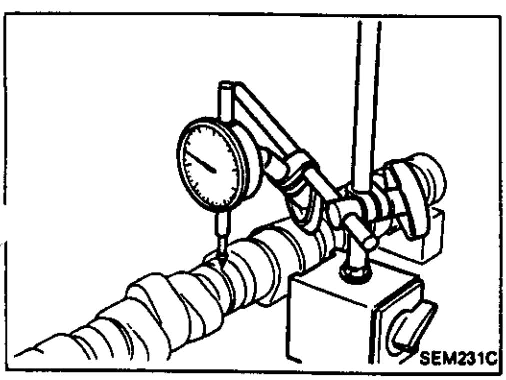
After resurfacing cylinder head, check that camshaft rotates freely by hand. If resistance is felt, cylinder head must be replaced.

Nominal cylinder head height:

98.8 - 99.0 mm (3.890 - 3.898 in)

CAMSHAFT VISUAL CHECK

Check camshaft for scratches, seizure and wear.



CAMSHAFT RUNOUT

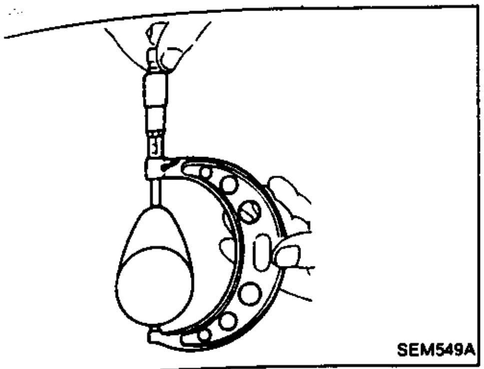
1. Measure camshaft runout at the center journal.

   Runout (Total indicator reading):

   0 - 0.02 mm (0 - 0.0008 in)

2. If it exceeds the limit, replace camshaft.

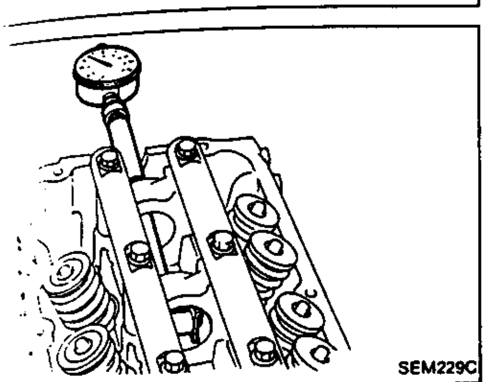
Inspection (Cont'd)



SEM549A

CAMSHAFT CAM HEIGHT

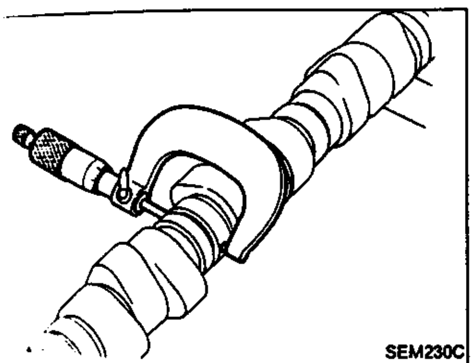
1. Measure camshaft cam height.
   Standard cam height:
   44.839 - 45.029 mm (1.7653 - 1.7728 in)
   Cam wear limit:
   0.2 mm (0.008 in)
2. If wear is beyond the limit, replace camshaft.



SEM229C

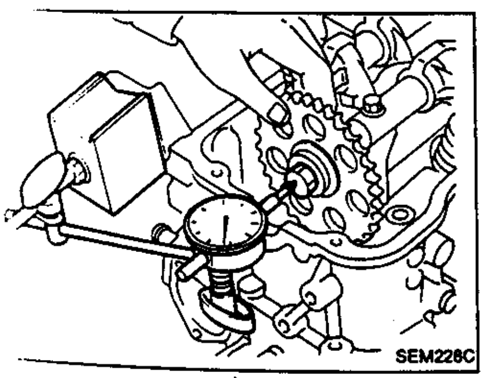
CAMSHAFT JOURNAL CLEARANCE

1. Install camshaft bracket and rocker shaft and tighten bolts to the specified torque.
2. Measure inner diameter of camshaft bearing.
   Standard inner diameter:
   33.000 - 33.025 mm (1.2992 - 1.3002 in)



SEM230C

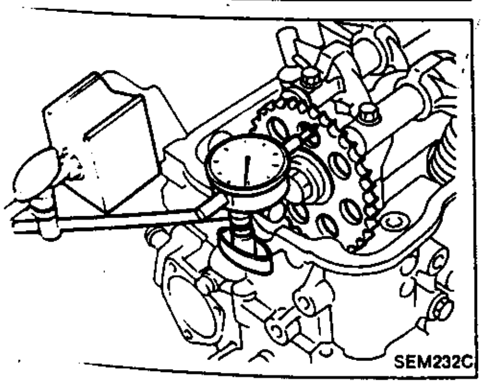
3. Measure outer diameter of camshaft journal.
   Standard outer diameter:
   32.935 - 32.955 mm (1.2967 - 1.2974 in)
4. If clearance exceeds the limit, replace camshaft and/or cylinder head.
   Camshaft journal clearance:
   Standard
   0.045 - 0.090 mm (0.0018 - 0.0035 in)
   Limit
   0.12 mm (0.0047 in)



SEM228C

CAMSHAFT END PLAY

1. Install camshaft in cylinder head.
2. Measure camshaft end play.
   Camshaft end play:
   Standard
   0.07 - 0.15 mm (0.0028 - 0.0059 in)
   Limit
   0.2 mm (0.008 in)



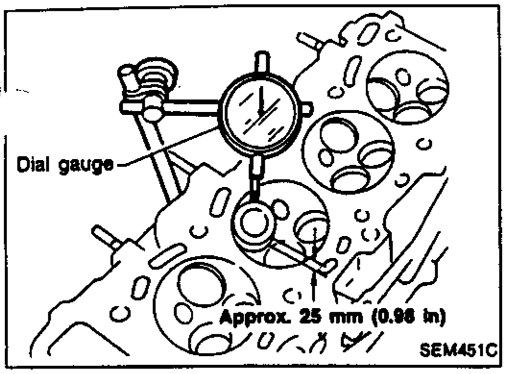
SEM232C

CAMSHAFT SPROCKET RUNOUT

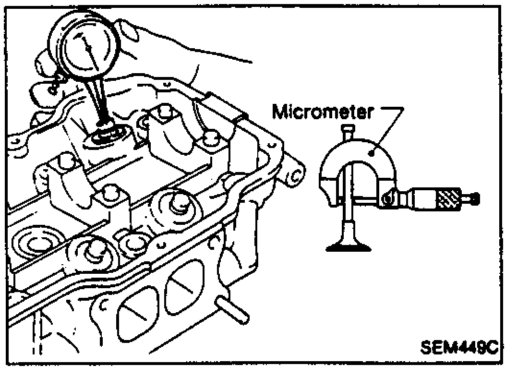
1. Install sprocket on camshaft.
2. Measure camshaft sprocket runout.
   Runout (Total indicator reading):
   Limit 0.12 mm (0.0047 in)
3. If it exceeds the limit, replace camshaft sprocket.

Inspection (Cont'd)

VALVE GUIDE CLEARANCE

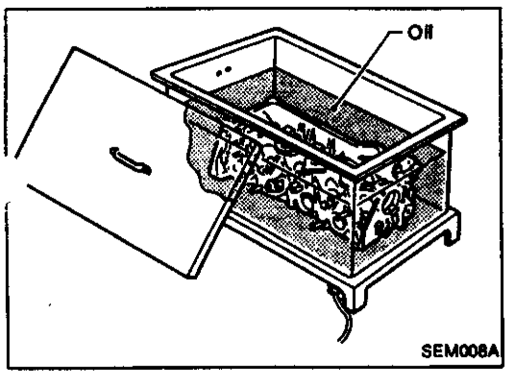


1. Measure valve deflection in a right-angled direction with camshaft. (Valve and valve guide mostly wear in this direction.)
   Valve deflection limit (Dial gauge reading):
   0.15 mm (0.0059 in)

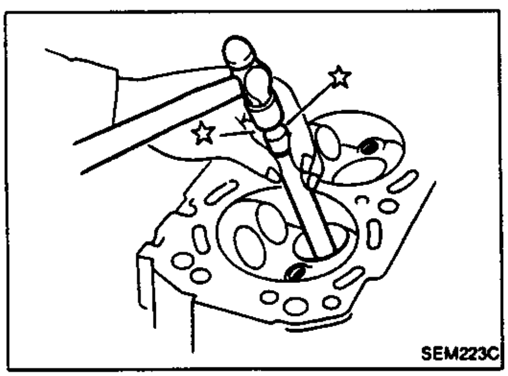


2. If it exceeds the limit, check valve to valve guide clearance.
   a. Measure valve stem diameter and valve guide inner diameter.
   b. Check that clearance is within specification.
   Valve to valve guide clearance:
   Standard 0.020 - 0.053 mm (0.0008 - 0.0021 in) (Intake)
   0.040 - 0.070 mm (0.0016 - 0.0028 in) (Exhaust)
   Limit 0.1 mm (0.004 in)
   c. If it exceeds the limit, replace valve or valve guide.

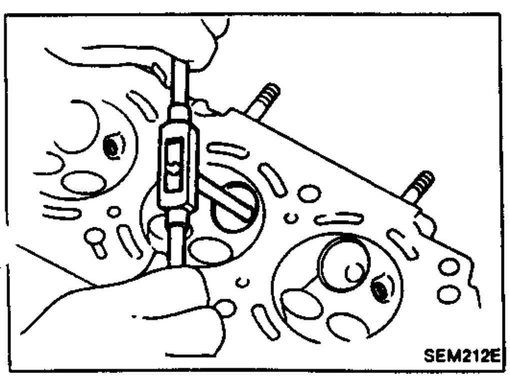
VALVE GUIDE REPLACEMENT



1. To remove valve guide, heat cylinder head to 150 to 160°C (302 to 320°F) by soaking in heated oil.

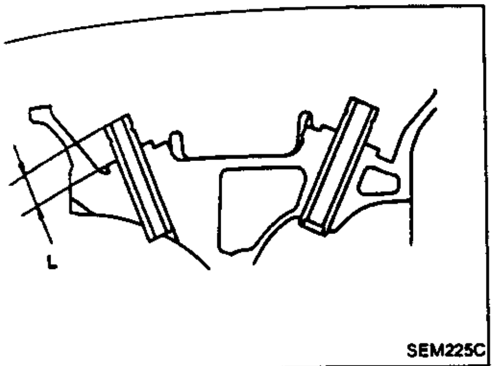


2. Drive out valve guide with a press [under a 20 kN (2 ton, 2.2 US ton, 2.0 Imp ton) pressure] or hammer and suitable tool.



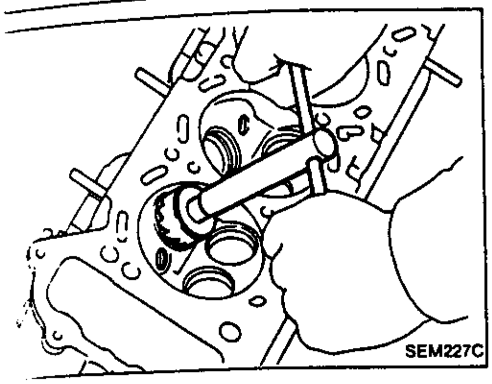
3. Ream cylinder head valve guide hole.
   Valve guide hole diameter
   (for service parts):
   Intake
   11.175 - 11.196 mm (0.4400 - 0.4408 in)
   Exhaust
   12.175 - 12.196 mm (0.4793 - 0.4802 in)

Inspection (Cont'd)



SEM225C

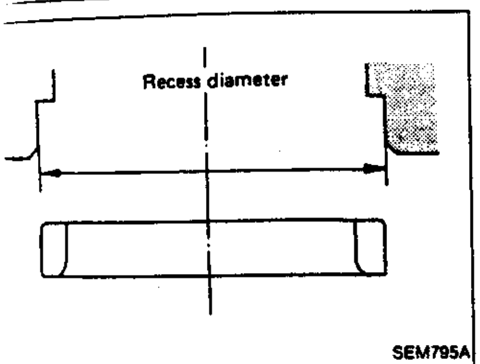
4. Heat cylinder head to 150 to 160°C (302 to 320°F) and press service valve guide onto cylinder head.
   Projection "L":
   14.9 - 15.1 mm (0.587 - 0.594 in)
5. Ream valve guide.
   Finished size:
   Intake
   7.000 - 7.018 mm (0.2756 - 0.2763 in)
   Exhaust
   8.000 - 8.018 mm (0.3150 - 0.3157 in)


SEM227C

VALVE SEATS

Check valve seats for any evidence of pitting at valve contact surface, and reseat or replace if it has worn out excessively.

- **Before repairing valve seats, check valve and valve guide for wear. If they have worn, replace them. Then correct valve seat.**
- **Cut with both hands to uniform the cutting surface.**

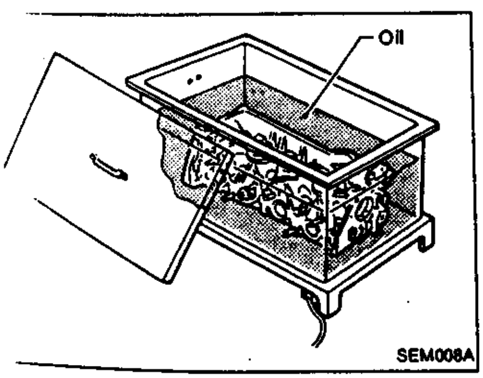


SEM795A

REPLACING VALVE SEAT FOR SERVICE PARTS

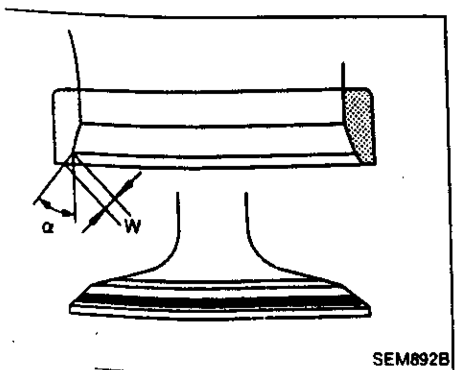
1. Bore out old seat until it collapses. The machine depth stop should be set so that boring cannot continue beyond the bottom face of the seat recess in cylinder head.
2. Ream cylinder head recess.
   Reaming bore for service valve seat
   Oversize [0.5 mm (0.020 in)]:
   Intake 36.500 - 36.516 mm (1.4370 - 1.4376 in)
   Exhaust 42.500 - 42.516 mm (1.6732 - 1.6739 in)

Reaming should be done to the concentric circles to valve guide center so that valve seat will have the correct fit.



SEM008A

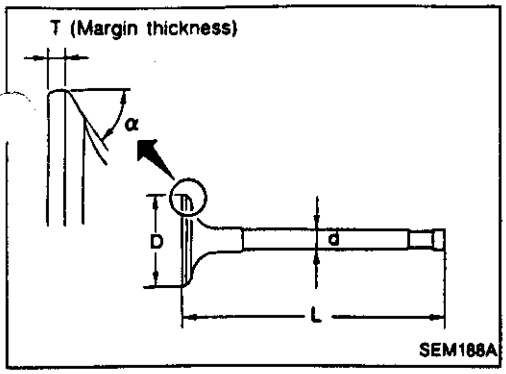
3. Heat cylinder head to 150 to 160°C (302 to 320°F) by soaking in heated oil.



SEM892B

4. Cut or grind valve seat using suitable tool at the specified dimensions as shown in SDS.
5. After cutting, lap valve seat with abrasive compound.
6. Check valve seating condition.
   Seat face angle "α":
   45 deg.
   Contacting width "W":
   Intake
   1.6 - 1.7 mm (0.063 - 0.067 in)
   Exhaust
   1.7 - 2.1 mm (0.067 - 0.083 in)

Inspection (Cont'd)

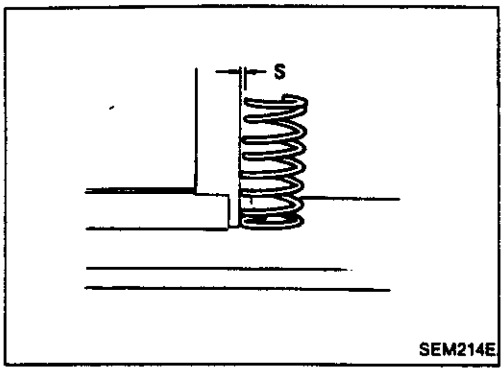


SEM188A

VALVE DIMENSIONS

Check dimensions in each valve. For dimensions, refer to SDS. When valve head has been worn down to 0.5 mm (0.020 in) in margin thickness, replace valve.

Grinding allowance for valve stem tip is 0.2 mm (0.008 in) or less.

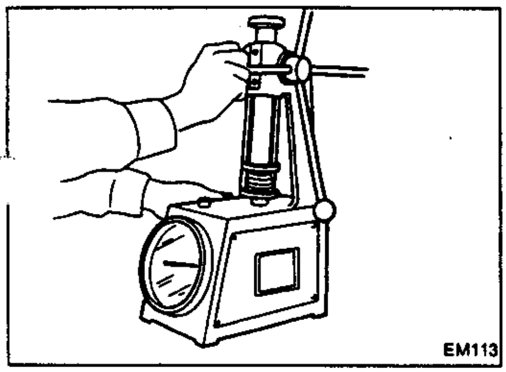


SEM214E

VALVE SPRING

Squareness

1. Measure "S" dimension.
   Out-of-square:
   Outer
   Intake Less than 2.5 mm (0.098 in)
   Exhaust Less than 2.3 mm (0.091 in)
   Inner
   Intake Less than 2.3 mm (0.091 in)
   Exhaust Less than 2.1 mm (0.083 in)
2. If it exceeds the limit, replace spring.

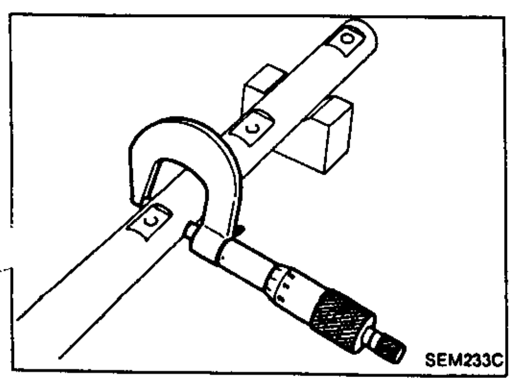

EM113

Pressure

Check valve spring pressure.

Pressure: N (kg, lb) at height mm (in)
Standard
Outer
Intake 604.1 (61.6, 135.8) at 37.6 (1.480)
Exhaust 640.4 (65.3, 144.0) at 34.1 (1.343)
Inner
Intake 284.4 (29.0, 63.9) at 32.6 (1.283)
Exhaust 328.5 (33.5, 73.9) at 29.1 (1.146)
Limit
Outer
Intake 567.8 (57.9, 127.7) at 37.6 (1.480)
Exhaust 620.8 (63.3, 139.6) at 34.1 (1.343)
Inner
Intake 266.8 (27.2, 60.0) at 32.6 (1.283)
Exhaust 318.7 (32.5, 71.7) at 29.1 (1.146)

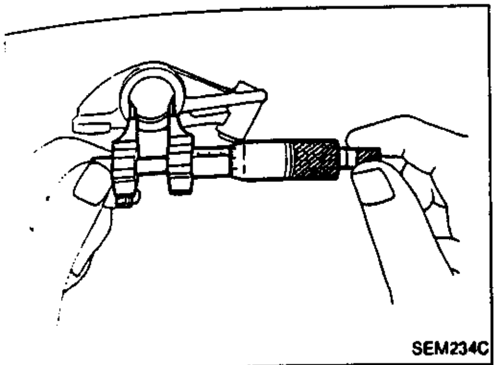
If it exceeds the limit, replace spring.


SEM233C

ROCKER SHAFT AND ROCKER ARM

1. Check rocker shafts for scratches, seizure and wear.
2. Check outer diameter of rocker shaft.
   Diameter:
   21.979 - 22.000 mm (0.8653 - 0.8661 in)

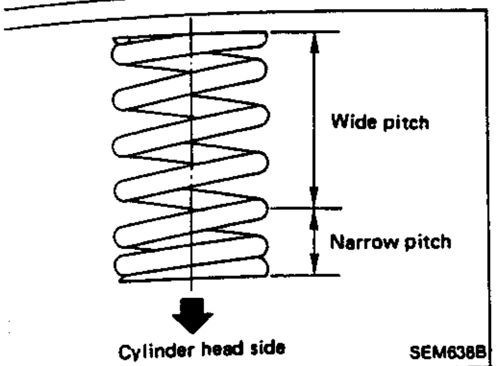
Inspection (Cont'd)



3. Check inner diameter of rocker arm.
   Diameter:
   22.012 - 22.029 mm (0.8666 - 0.8673 in)
   Rocker arm to shaft clearance:
   0.012 - 0.050 mm (0.0005 - 0.0020 in)

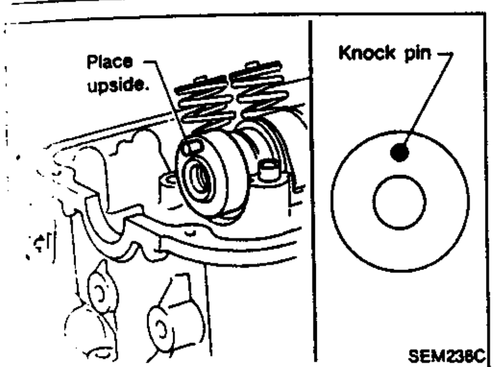
- **Keep rocker arm with hydraulic valve lifter standing to prevent air from entering hydraulic valve lifter when checking.**

Assembly



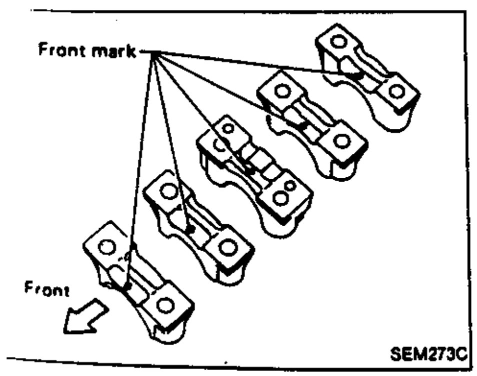
1. Install valve component parts.

- **Always use new valve oil seal. Refer to OIL SEAL REPLACEMENT.**
- **Before installing valve oil seal, install inner valve spring seat.**
- **Install outer valve spring (uneven pitch type) with its narrow pitch side toward cylinder head side.**
- **After installing valve component parts, use plastic hammer to lightly tap valve stem tip to assure a proper fit.**



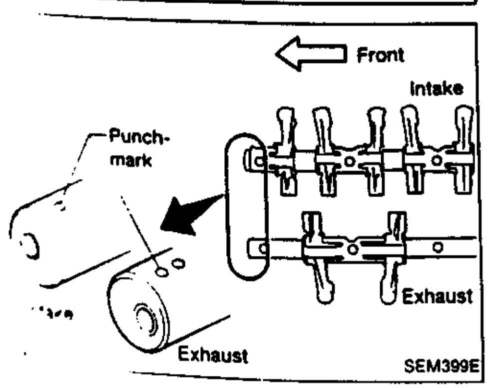
2. Mount camshaft onto cylinder head, placing knock pin at front end to top position.

Apply engine oil to camshaft when mounting onto cylinder head.



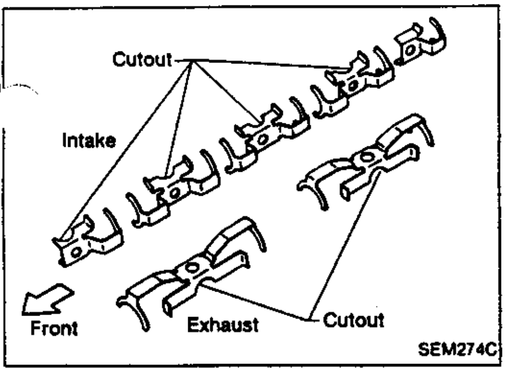
3. Install camshaft brackets.

Front mark is punched on the camshaft bracket.

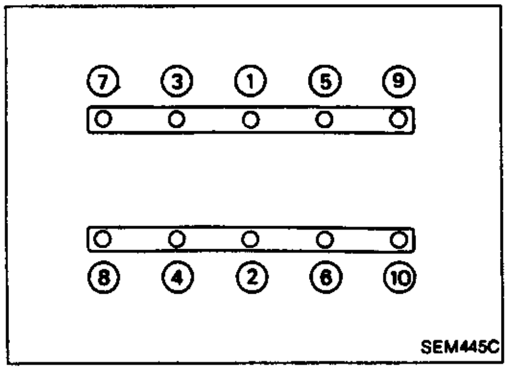


4. Install rocker shaft with rocker arms.

Assembly (Cont'd)

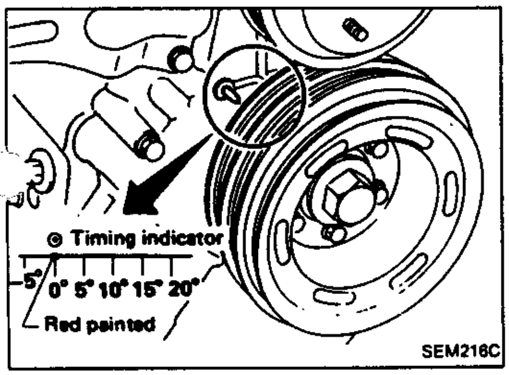


- Install retainer with cutout facing direction shown in figure at left.



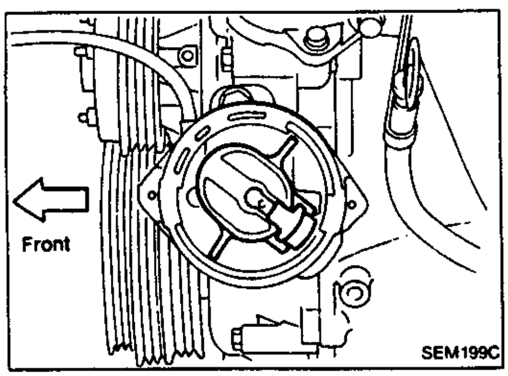
5. Tighten bolts as shown in figure at left.

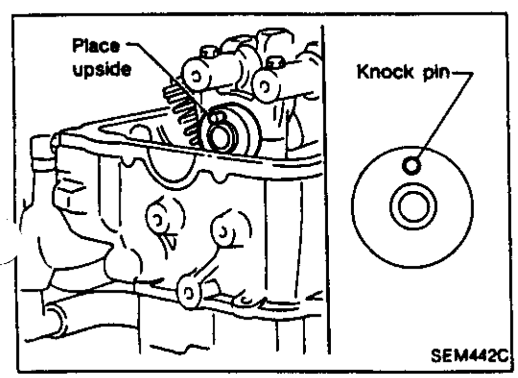
Installation



1. Set No. 1 piston at TDC on its compression stroke as follows:

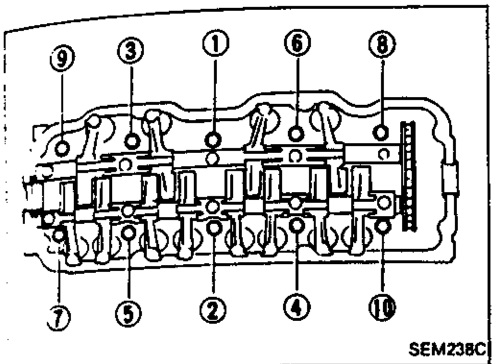
(1) Align mark on crankshaft pulley with "0°" position and confirm that distributor rotor head is set as shown in figure.





(2) Confirm that knock pin on camshaft is set at the top.

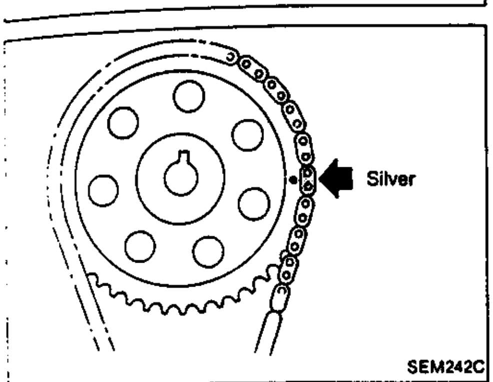
Installation (Cont'd)



SEM238C

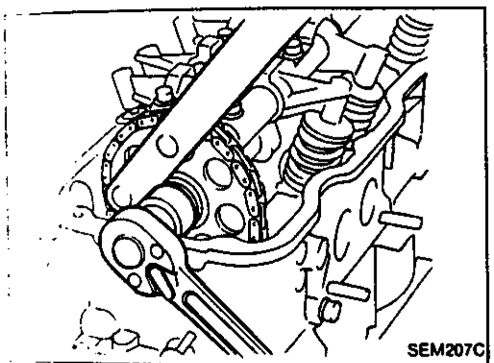
2. Install cylinder head with new gasket and tighten cylinder head bolts in numerical order.
- **Do not rotate crankshaft and camshaft separately, or valves will hit piston heads.**
- **Tightening procedure**

(1) Tighten all bolts to 29 N·m (3.0 kg-m, 22 ft-lb).
(2) Tighten all bolts to 78 N·m (8.0 kg-m, 58 ft-lb).
(3) Loosen all bolts completely.
(4) Tighten all bolts to 29 N·m (3.0 kg-m, 22 ft-lb).
(5) Turn all bolts 80 to 85 degrees clockwise with an angle wrench, or if an angle wrench is not available, tighten all bolts to 74 to 83 N·m (7.5 to 8.5 kg-m, 54 to 61 ft-lb).

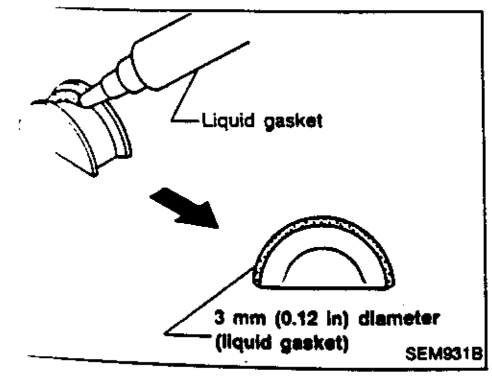


SEM242C

3. Set chain on camshaft sprocket by aligning each mating mark. Then install camshaft sprocket to camshaft.


SEM207C

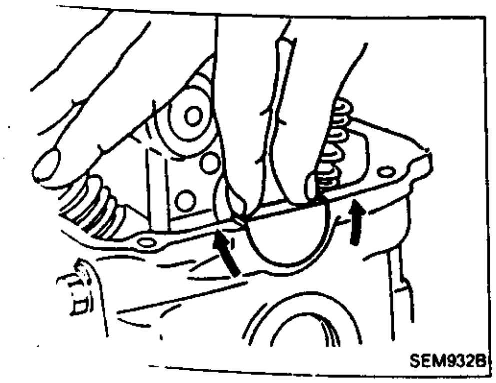
4. Tighten camshaft sprocket bolt.



SEM931B

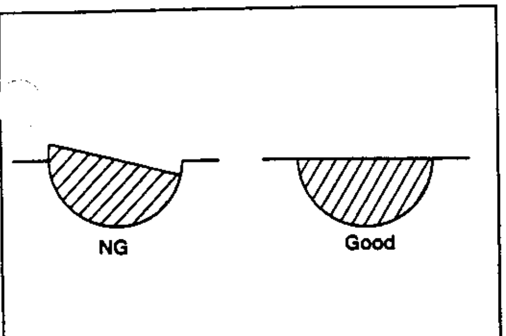
5. Install rubber plugs as follows:

(1) Apply liquid gasket to rubber plugs.
- **Rubber plugs should be replaced with new ones.**
- **Rubber plugs should be installed within 5 minutes of applying liquid gasket.**

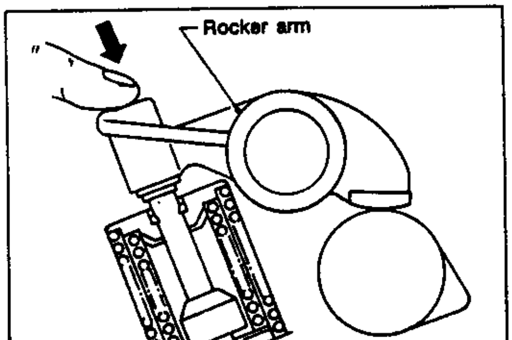

SEM932B

(2) Install rubber plugs, then move them with your fingers to uniformly spread the gasket on cylinder head surface.
- **Rubber plugs should be installed flush with the surface.**
- **Do not start the engine for 30 minutes after installing rocker cover.**
- **Wipe clean excessive liquid gasket from cylinder head top surface.**

Installation (Cont'd)



SEM933BA

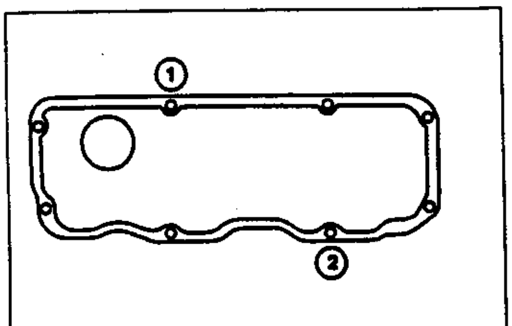


SEM275C

6. Check hydraulic valve lifter.
(1) Push hydraulic valve lifter forcefully with your finger.
- **Be sure to check it with rocker arm in its free position.**

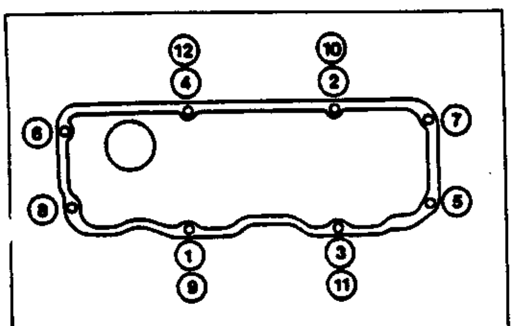
(2) If valve lifter moves more than 1 mm (0.04 in), air may be inside of it.
(3) Bleed air off by running engine at 1,000 rpm under no-load for about 20 minutes.
(4) If hydraulic valve lifters are still noisy, replace them and bleed air off again in the same manner as in step (3).

7. Install rocker cover.
- **Be sure to avoid interference between rocker cover and rocker arm.**



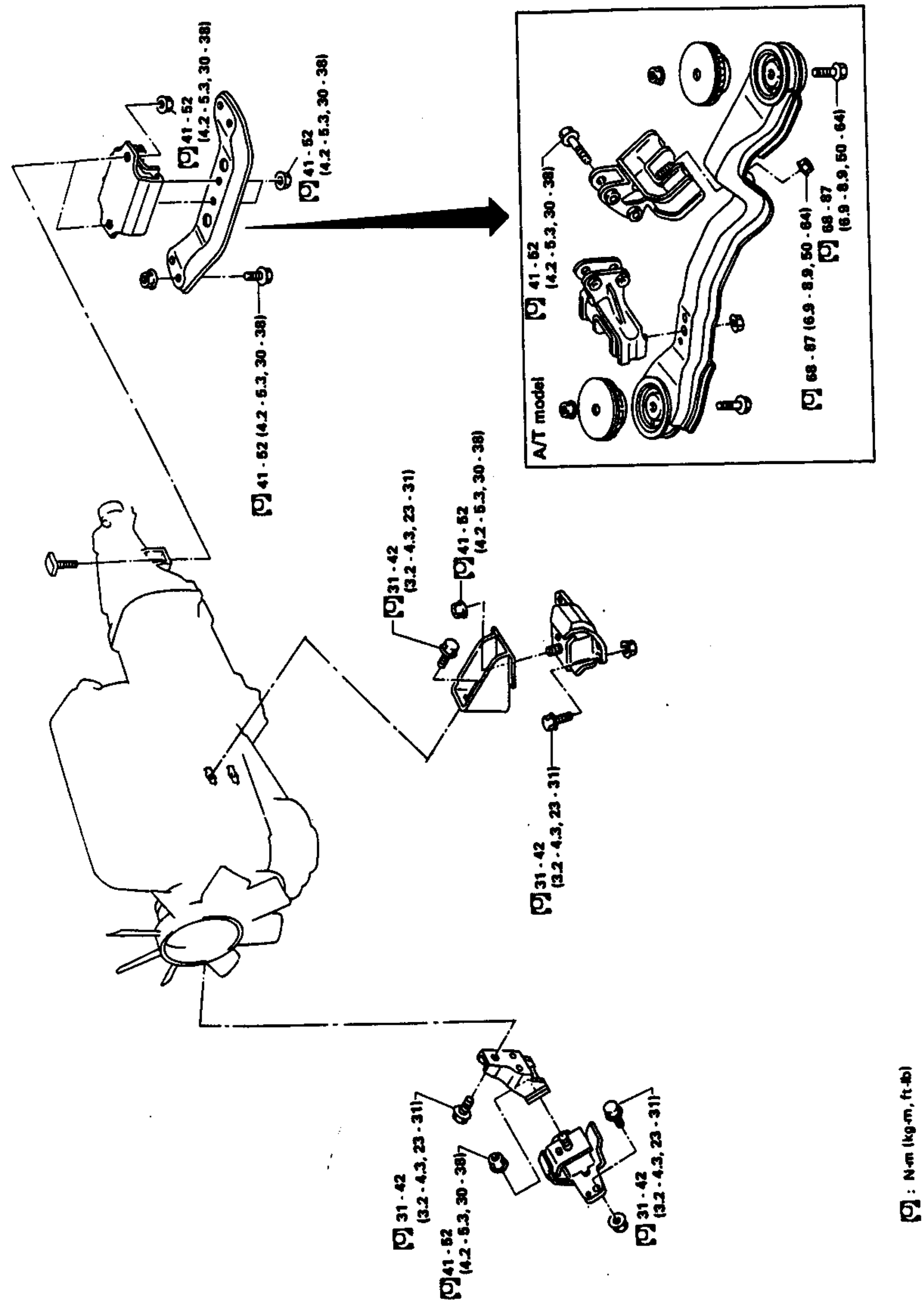
SEM546C

8. Tighten bolts as follows:
(1) Tighten 2 bolts to 3 N·m (0.3 kg-m, 2.2 ft-lb) temporarily in order shown in figure.



SEM547C

(2) Then tighten bolts to 7 to 11 N·m (0.7 to 1.1 kg-m, 5.1 to 8.0 ft-lb) in order shown in figure.
9. Install any parts removed.



SEM938B

GI
MA
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EF & EC
FE
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BR
ST
BF
HA
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IDX

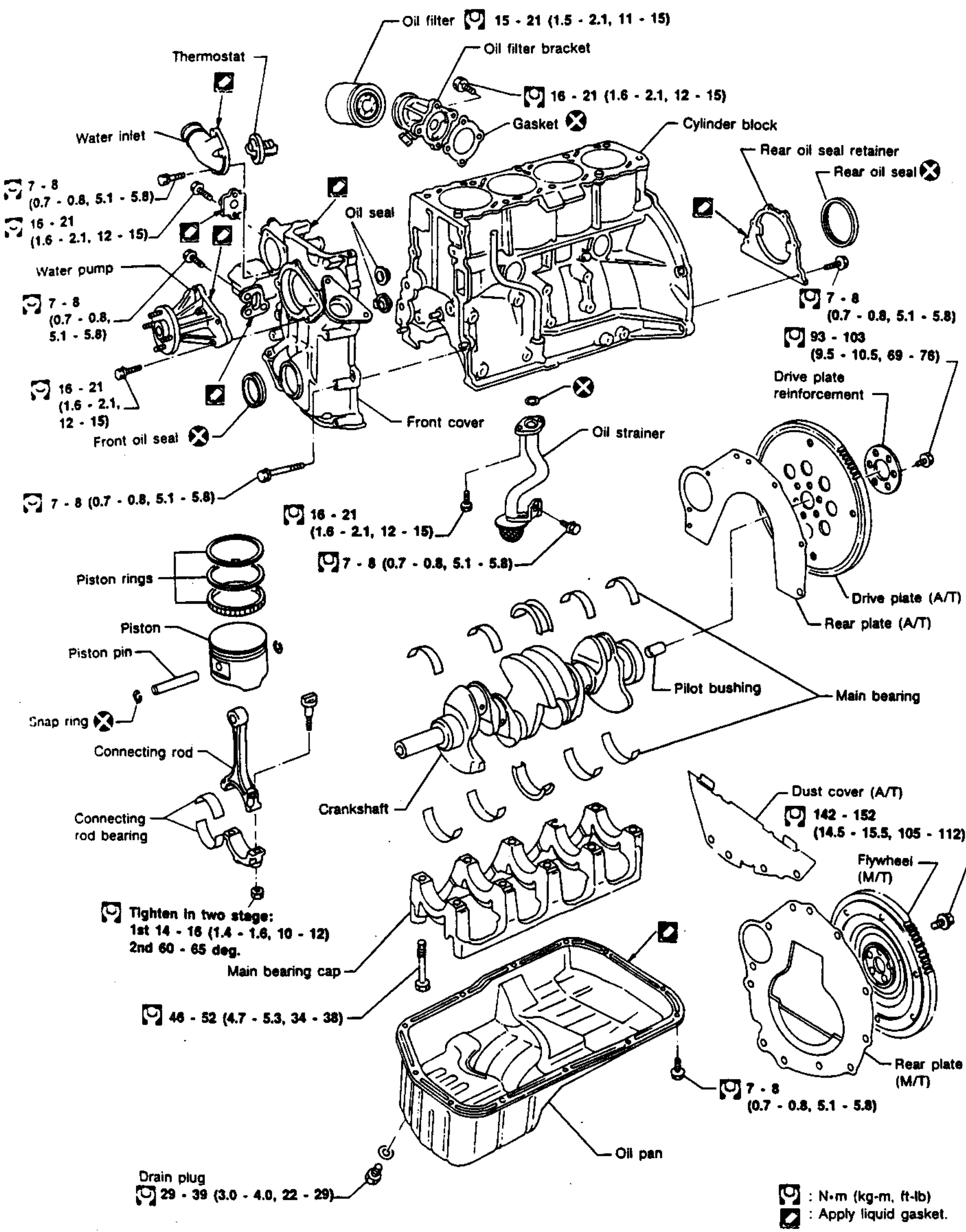
WARNING:

a. **Situate vehicle on a flat and solid surface.**
b. **Place chocks at front and back of rear wheels.**
c. **Do not remove engine until exhaust system has completely cooled off.**
   Otherwise, you may burn yourself and/or fire may break out in fuel line.
d. **For safety during subsequent steps, the tension of wires should be slackened against the engine.**
e. **Before disconnecting fuel hose, release fuel pressure from fuel line.**
   Refer to "Releasing Fuel Pressure" in section EF & EC.
f. **Be sure to hoist engine and transmission in a safe manner.**
g. **For engines not equipped with engine slingers, attach proper slingers and bolts described in PARTS CATALOG.**

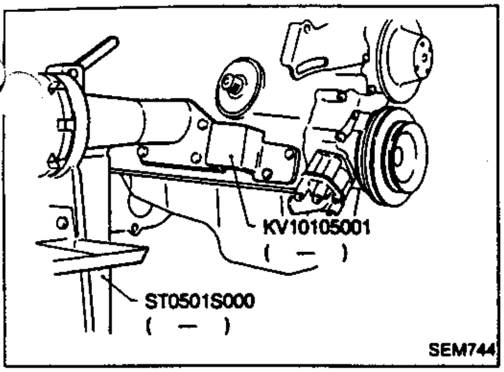
CAUTION:

- **When lifting engine, be careful not to strike adjacent parts, especially accelerator wire casing, brake lines, and brake master cylinder.**
- **In hoisting the engine, always use engine slingers in a safe manner.**

CYLINDER BLOCK



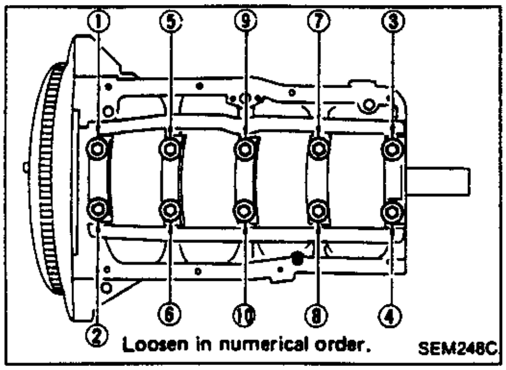
SEM247C



Disassembly

PISTON AND CRANKSHAFT

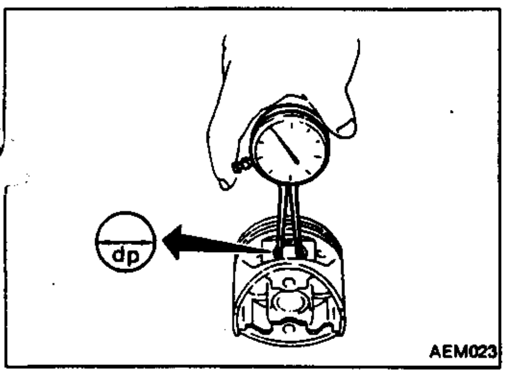
1. Place engine on a work stand.
2. Drain coolant and oil.
3. Remove oil pan.
4. Remove timing chain.
5. Remove water pump.
6. Remove cylinder head.
7. Remove pistons with connecting rod.



8. Remove bearing caps and crankshaft.

- **Before removing bearing caps, measure crankshaft end play.**
- **Bolts should be loosened in two or three steps.**

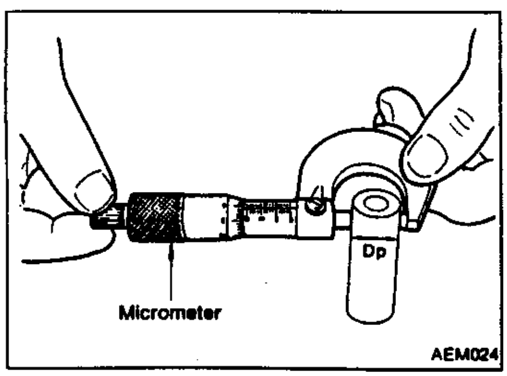
Inspection



PISTON AND PISTON PIN CLEARANCE

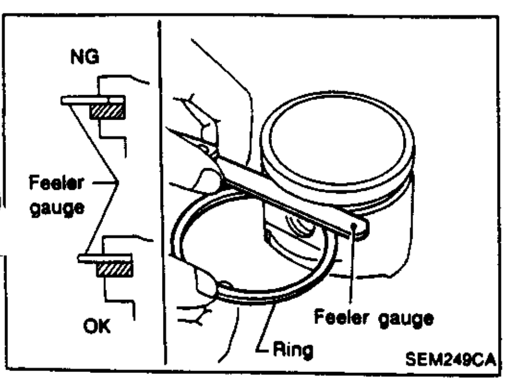
- Confirm the fitting of piston pin into piston pin hole to such an extent that it can be pressed smoothly by finger at room temperature.

1. Measure inner diameter of piston pin hole "dp".
   Standard diameter "dp":
   21.002 - 21.008 mm (0.8268 - 0.8271 in)



2. Measure outer diameter of piston pin "Dp".
   Standard diameter "Dp":
   20.994 - 20.996 mm (0.8265 - 0.8266 in)
3. Calculate interference fit of piston pin to piston.
   dp – Dp = 0.008 - 0.012 mm (0.0003 - 0.0005 in)

If it exceeds the above value, replace piston assembly with pin.



PISTON RING SIDE CLEARANCE

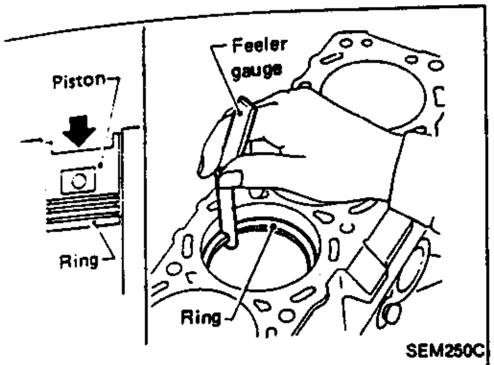
Side clearance:

Top ring	**0.04 - 0.08 mm (0.0016 - 0.0031 in)**
2nd ring	**0.03 - 0.07 mm (0.0012 - 0.0028 in)**
Oil ring	**0.065 - 0.135 mm (0.0026 - 0.0053 in)**

Max. limit of side clearance:
0.1 mm (0.004 in)

If out of specification, replace piston and/or piston ring assembly.

Inspection (Cont'd)



SEM250C

PISTON RING END GAP

End gap:

Top ring

0.28 - 0.52 mm (0.0110 - 0.0205 in)

2nd ring

0.45 - 0.69 mm (0.0177 - 0.0272 in)
(R or T is punched on the ring.)
0.55 - 0.70 mm (0.0217 - 0.0276 in)
(N is punched on the ring.)

Oil ring

0.20 - 0.69 mm (0.0079 - 0.0272 in)

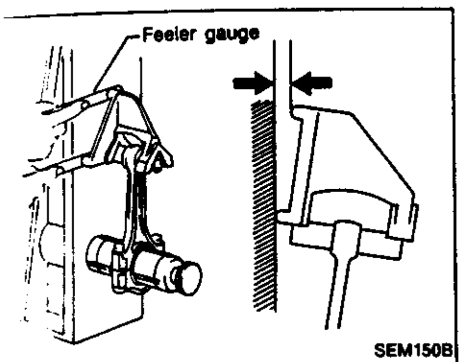
Max. limit of ring gap:

0.5 mm (0.020 in)

If out of specification, replace piston ring. If gap still exceeds the limit even with a new ring, rebore cylinder and use oversized piston and piston rings.

Refer to SDS.

- When replacing the piston, inspect cylinder block surface for scratches or a seizure. If scratches or a seizure is found, hone or replace the cylinder block.



SEM150B

CONNECTING ROD BEND AND TORSION

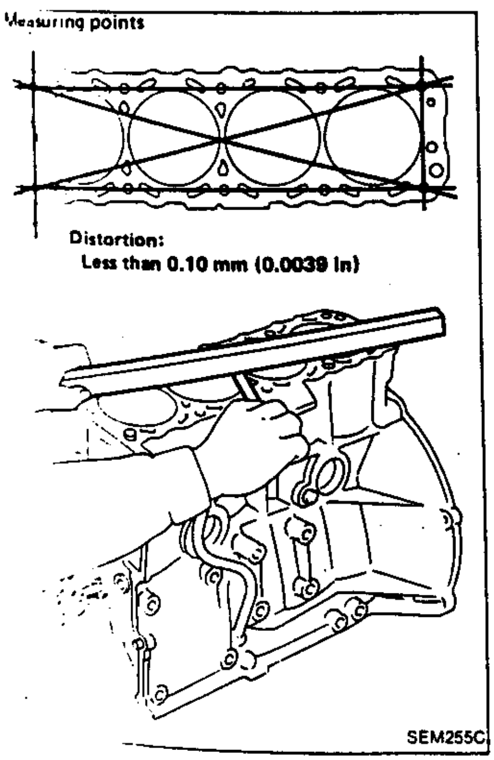
Bend:

Limit 0.15 mm (0.0059 in)
per 100 mm (3.94 in) length

Torsion:

Limit 0.30 mm (0.0118 in)
per 100 mm (3.94 in) length

If it exceeds the limit, replace connecting rod assembly.



SEM255C

CYLINDER BLOCK DISTORTION AND WEAR

1. Clean upper face of cylinder block and measure the distortion.
   Limit:
   0.10 mm (0.0039 in)
2. If out of specification, resurface it.
   The resurfacing limit is determined by cylinder head resurfacing in engine.

Amount of cylinder head resurfacing is "A"
Amount of cylinder block resurfacing is "B"

The maximum limit is as follows:

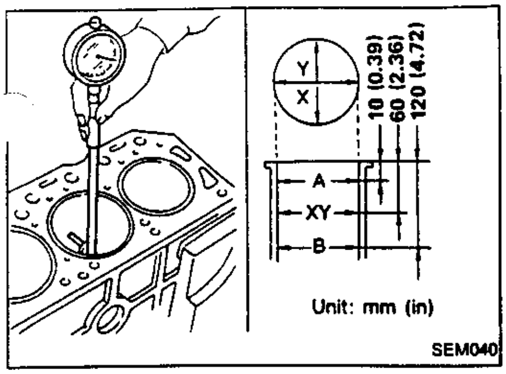
A + B = 0.2 mm (0.008 in)

Nominal cylinder block height from crankshaft center:

246.95 - 247.05 mm (9.7224 - 9.7264 in)

3. If necessary, replace cylinder block.

Inspection (Cont'd)



SEM040

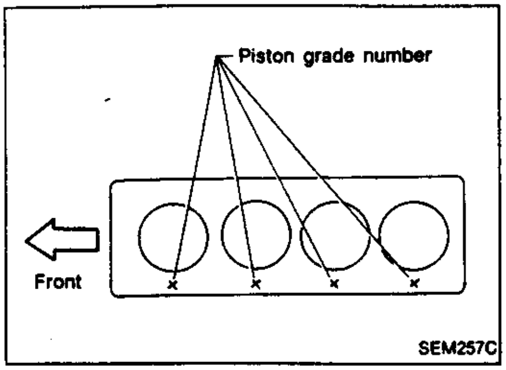
PISTON-TO-BORE CLEARANCE

1. Using a bore gauge, measure cylinder bore for wear, out-of-round and taper.
   Standard inner diameter:
   89.000 - 89.030 mm (3.5039 - 3.5051 in)
   Wear limit: 0.2 mm (0.008 in)

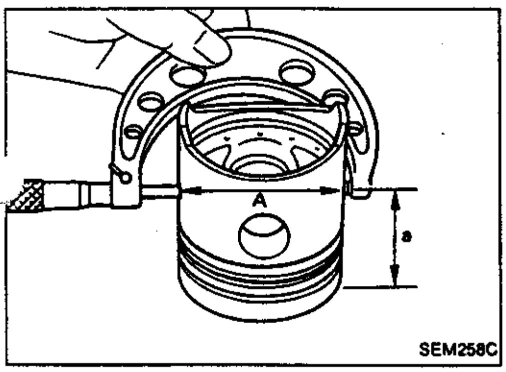
If it exceeds the limit, rebore all cylinders. Replace cylinder block if necessary.
   Out-of-round (X–Y) standard: 0.015 mm (0.0006 in)
   Taper (A–B) standard: 0.015 mm (0.0006 in)

2. Check for scratches and seizure. If seizure is found, hone it.

- **If both cylinder block and piston are replaced with new ones, select piston of the same grade number punched on cylinder block upper surface.**



SEM257C



SEM258C

3. Measure piston skirt diameter.
   Piston diameter "A":
   Refer to SDS.
   Measuring point "a" (Distance from the top):
   52 mm (2.05 in)
4. Check that piston-to-bore clearance is within specification.
   Piston-to-bore clearance "B":
   0.020 - 0.040 mm (0.0008 - 0.0016 in)
5. Determine piston oversize according to amount of cylinder wear.

Oversize pistons are available for service. Refer to SDS.

6. Cylinder bore size is determined by adding piston-to-bore clearance to piston diameter "A".
   Rebored size calculation:
   D = A + B – C
   where,
   D: Bored diameter
   A: Piston diameter as measured
   B: Piston-to-bore clearance
   C: Honing allowance 0.02 mm (0.0008 in)
7. Install main bearing caps, and tighten to the specified torque to prevent distortion of cylinder bores in final assembly.
8. Cut cylinder bores.

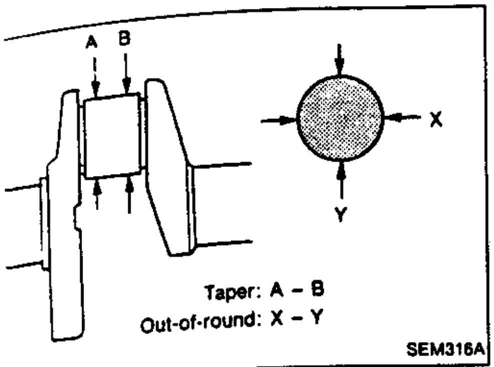
- **When any cylinder needs boring, all other cylinders must also be bored.**
- **Do not cut too much out of cylinder bore at a time. Cut only 0.05 mm (0.0020 in) or so in diameter at a time.**

9. Hone cylinders to obtain specified piston-to-bore clearance.
10. Measure finished cylinder bore for out-of-round and taper.

- **Measurement should be done after cylinder bore cools down.**

Inspection (Cont'd)

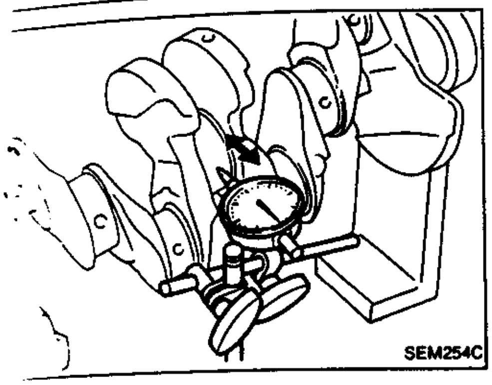
CRANKSHAFT



1. Check crankshaft main and pin journals for score, wear or cracks.
2. With a micrometer, measure journals for taper and out-of-round.

   Out-of-round (X – Y):
   - **Main journal Less than 0.01 mm (0.0004 in)**
   - **Crank pin Less than 0.005 mm (0.0002 in)**

   Taper (A – B):
   - **Main journal Less than 0.01 mm (0.0004 in)**
   - **Crank pin Less than 0.005 mm (0.0002 in)**



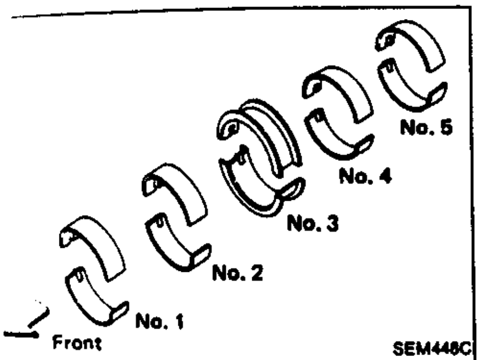
3. Measure crankshaft runout.

   Runout (Total indicator reading):
   Less than 0.10 mm (0.0039 in)

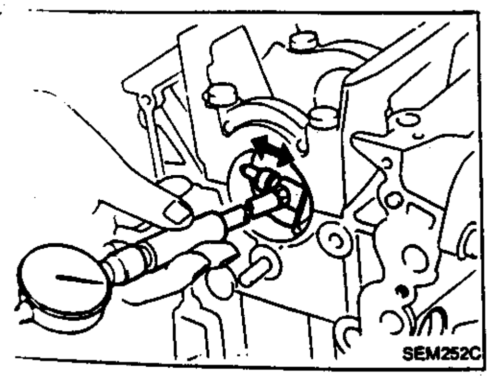
BEARING CLEARANCE

Method A (Using bore gauge and micrometer)

Main bearing



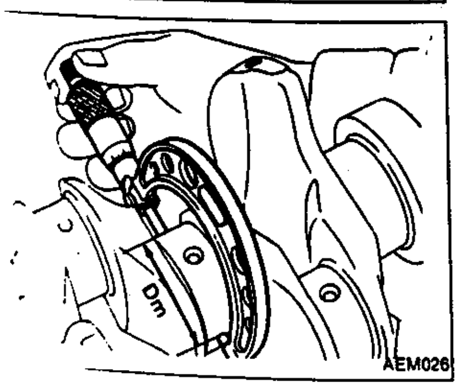
1. Set main bearings in their proper positions on cylinder block and main bearing cap.



2. Install main bearing cap to cylinder block.

Tighten all bolts in correct order in two or three stages. Refer to "Assembly".

3. Measure inner diameter "A" of each main bearing.

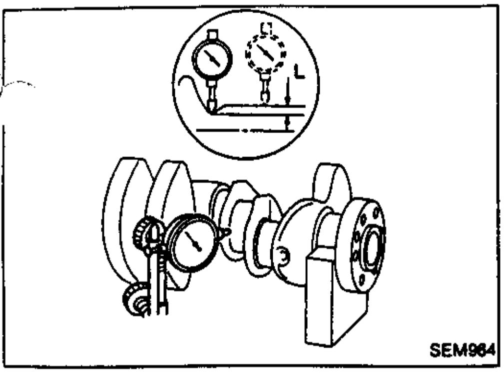


4. Measure outer diameter "Dm" of each crankshaft main journal.
5. Calculate main bearing clearance.

   Main bearing clearance = A – Dm

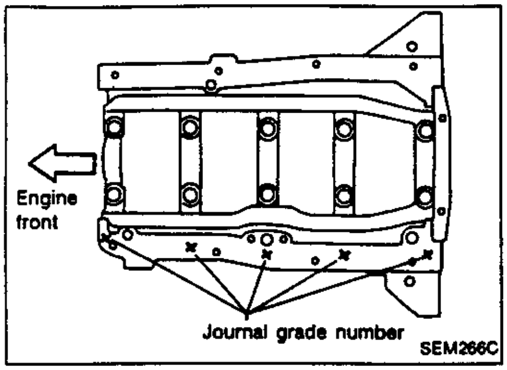
   Standard:
   0.020 - 0.047 mm (0.0008 - 0.0019 in)
   Limit: 0.1 mm (0.004 in)
6. If it exceeds the limit, replace bearing.
7. If clearance cannot be adjusted within the standard of any bearing, grind crankshaft journal and use undersized bearing.

Inspection (Cont'd)



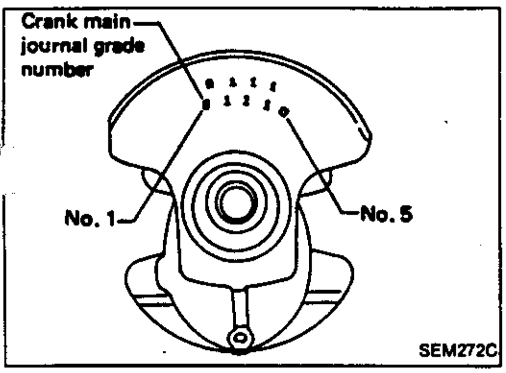
SEM964

a. **When grinding crankshaft journal, confirm that "L" dimension in fillet roll is more than the specified limit.**
   "L": 0.1 mm (0.004 in)
b. **Refer to SDS for grinding crankshaft and available service parts.**



SEM266C

8. If crankshaft is reused, measure main bearing clearance and select thickness of main bearing.
   If crankshaft is replaced with a new one, it is necessary to select thickness of main bearings as follows:
   a. Grade number of each cylinder block main journal is punched on the respective cylinder block. These numbers are punched in either Arabic or Roman numerals.



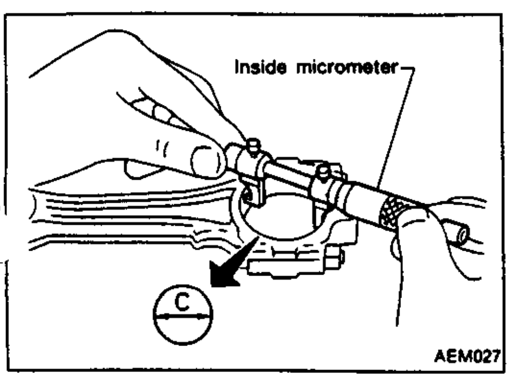
SEM272C

   b. Grade number of each crankshaft main journal is punched on crankshaft. These numbers are punched in either Arabic or Roman numerals.
   c. Select main bearing with suitable thickness according to the following example or table.

   For example:
   Main journal grade number: 1
   Crankshaft journal grade number: 2
   Main bearing grade number = 1 + 2
   = 3 (Yellow)

Main bearing grade number and identification color:

		Main journal grade number		
		"0"	"1"	"2"
Crankshaft journal grade number	"0"	0 (Black)	1 (Brown)	2 (Green)
	"1" or "I"	1 (Brown)	2 (Green)	3 (Yellow)
	"2" or "II"	2 (Green)	3 (Yellow)	4 (Blue)



AEM027

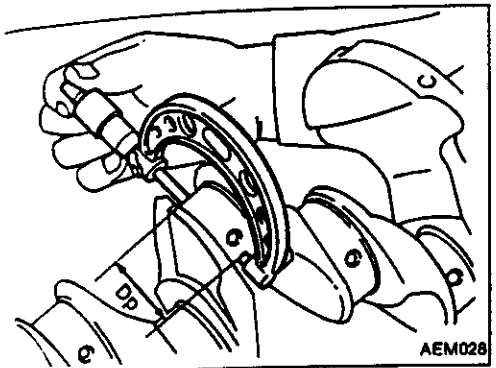
Connecting rod bearing (Big end)

1. Install connecting rod bearing to connecting rod and cap.
2. Install connecting rod cap to connecting rod.

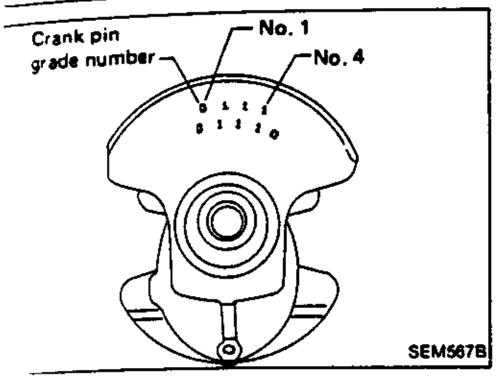
Tighten bolts to the specified torque.

3. Measure inner diameter "C" of each bearing.

Inspection (Cont'd)



4. Measure outer diameter "Dp" of each crankshaft pin journal.
5. Calculate connecting rod bearing clearance.
   Connecting rod bearing clearance = C – Dp
   Standard: 0.010 - 0.035 mm (0.0004 - 0.0014 in)
   Limit: 0.09 mm (0.0035 in)
6. If it exceeds the limit, replace bearing.
7. If clearance cannot be adjusted within the standard of any bearing, grind crankshaft journal and use undersized bearing. Refer to step 7 of "BEARING CLEARANCE — Main bearing".

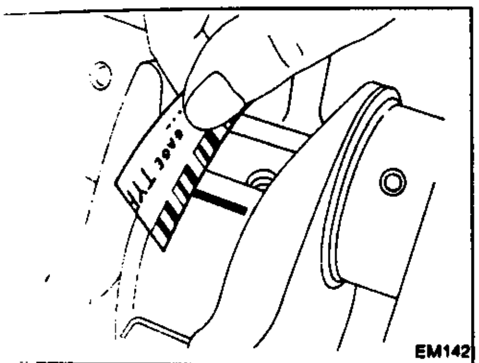


8. If crankshaft is replaced with a new one, select connecting rod bearing according to the following table.

Connecting rod bearing grade number:

These numbers are punched in either Arabic or Roman numerals.

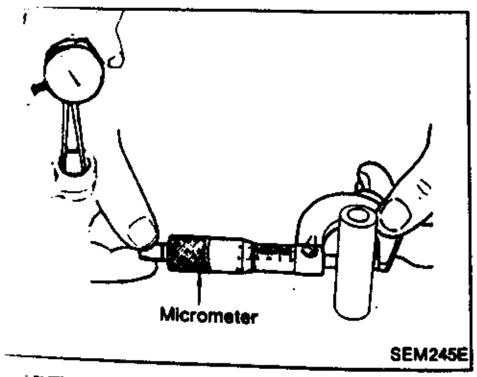
Crank pin grade number	Connecting rod bearing grade number
0	0
1 or I	1
2 or II	2



Method B (Using plastigage)

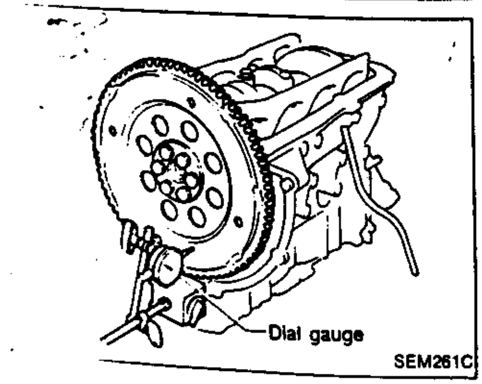
CAUTION:

- **Do not turn crankshaft or connecting rod while plastigage is being inserted.**
- **When bearing clearance exceeds the specified limit, ensure that the proper bearing has been installed. Then if excessive bearing clearance exists, use a thicker main bearing or undersized bearing so that the specified bearing clearance is obtained.**



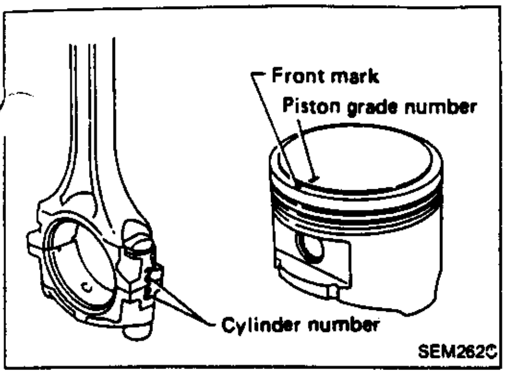
CONNECTING ROD BUSHING CLEARANCE (Small end)

1. Measure inner diameter "C" of bushing.
2. Measure outer diameter "Dp" of piston pin.
3. Calculate connecting rod bearing clearance.
   C – Dp =
   –0.015 to –0.033 mm (–0.0006 to –0.0013 in) (Standard)
   If it exceeds the limit, replace connecting rod assembly and/or piston set with pin.



FLYWHEEL/DRIVE PLATE RUNOUT

Runout (Total indicator reading):
Flywheel (M/T model)
Less than 0.1 mm (0.004 in)
Drive plate (A/T model)
Less than 0.1 mm (0.004 in)

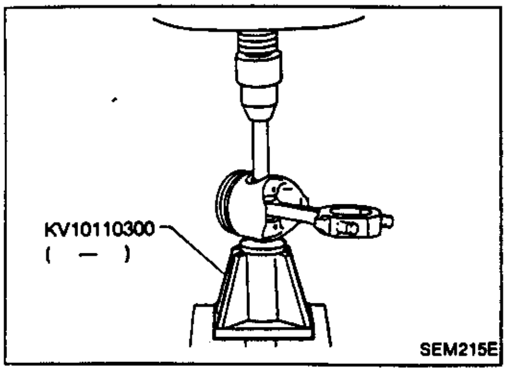


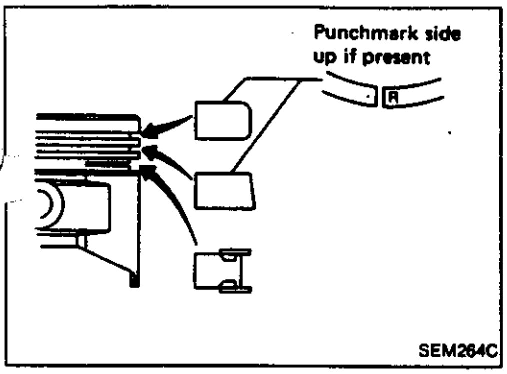
Assembly

PISTON

1. Heat piston to 60 to 70°C (140 to 158°F) and assemble piston, piston pin and connecting rod.

- **Align the direction of piston and connecting rod.**
- **Numbers stamped on connecting rod and cap correspond to each cylinder.**
- **After assembly, make sure connecting rod swings smoothly.**

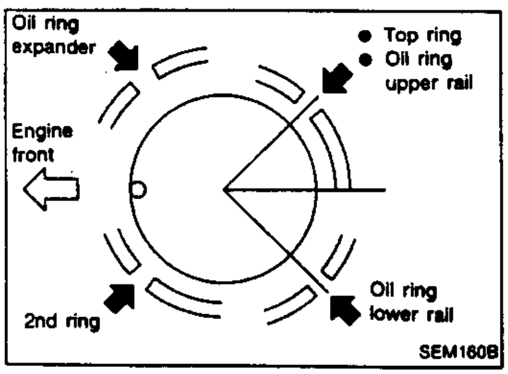


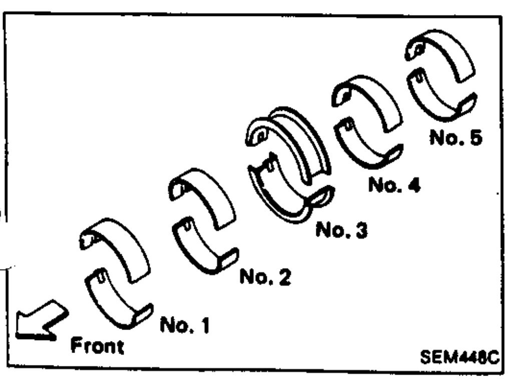


2. Set piston rings as shown.

CAUTION:

- **When piston rings are not replaced, make sure that piston rings are mounted in their original positions.**
- **When piston rings are being replaced and no punchmark is present, piston rings can be mounted with either side up.**



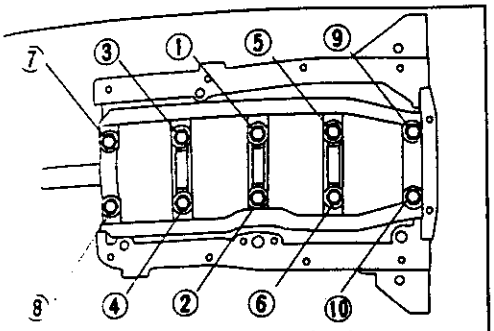


CRANKSHAFT

1. Set main bearings in their proper positions on cylinder block and main bearing beam.

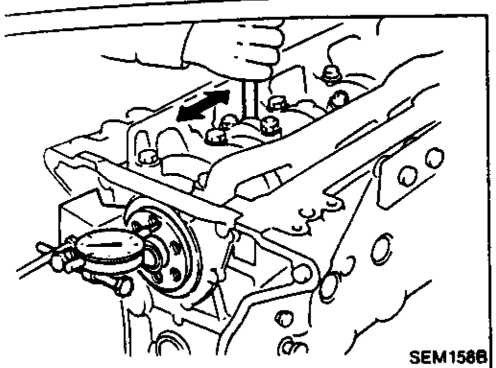
- **Confirm that correct main bearings are used. Refer to "Inspection" of this section.**

Assembly (Cont'd)



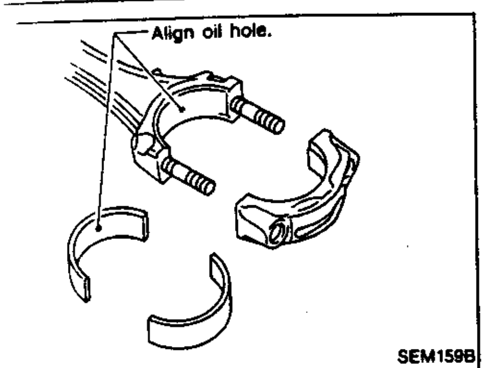
Tighten in numerical order. SEM549E

2. Install crankshaft and main bearing beam and tighten bolts to the specified torque.
- **Prior to tightening bearing cap bolts, place bearing cap in its proper position by shifting crankshaft in the axial direction.**
- **Tighten bearing cap bolts gradually in two or three stages. Start with center bearing and move outward sequentially.**
- **After securing bearing cap bolts, make sure crankshaft turns smoothly by hand.**


SEM158B

3. Measure crankshaft end play.
   Crankshaft end play:
   Standard
   0.05 - 0.18 mm (0.0020 - 0.0071 in)
   Limit
   0.3 mm (0.012 in)

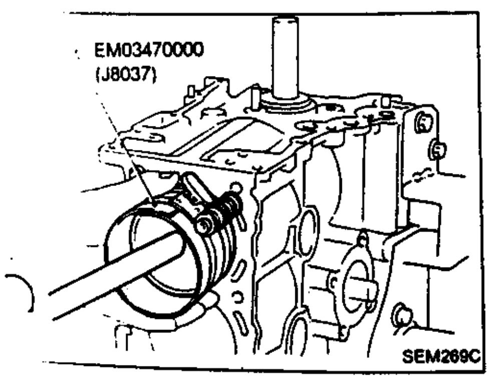
If beyond the limit, replace bearing with a new one.



SEM159B

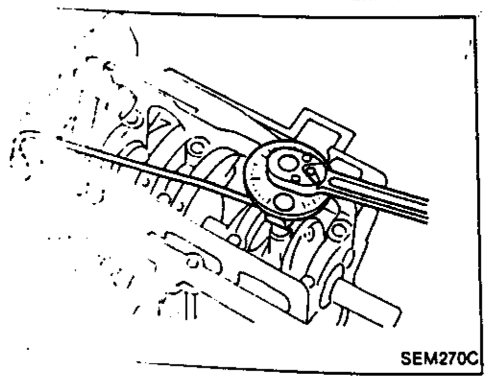
4. Install connecting rod bearings in connecting rods and connecting rod caps.
- Confirm that correct bearings are used.

Refer to "Inspection".
- Install bearings so that oil hole in connecting rod aligns with oil hole of bearing.



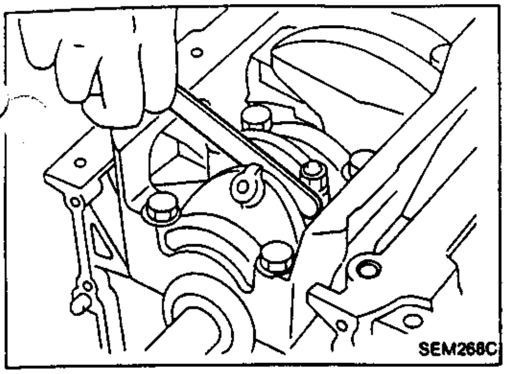
SEM269C

5. Install pistons with connecting rods.
a. Install them into corresponding cylinders with Tool.
- **Be careful not to scratch cylinder wall by connecting rod.**
- **Arrange so that front mark on piston head faces toward front of engine.**


SEM270C

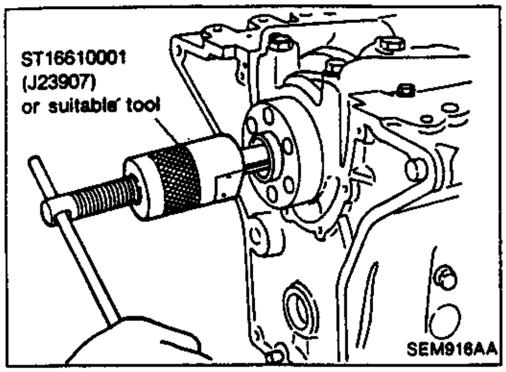
b. Install connecting rod bearing caps.
   Tighten connecting rod bearing cap nuts to the specified torque.
   Connecting rod bearing nut:
   (1) Tighten to 14 to 16 N·m (1.4 to 1.6 kg-m, 10 to 12 ft-lb).
   (2) Tighten bolts 60 to 65 degrees clockwise with an angle wrench, or if an angle wrench is not available, tighten them to 38 to 44 N·m (3.9 to 4.5 kg-m, 28 to 33 ft-lb).

Assembly (Cont'd)



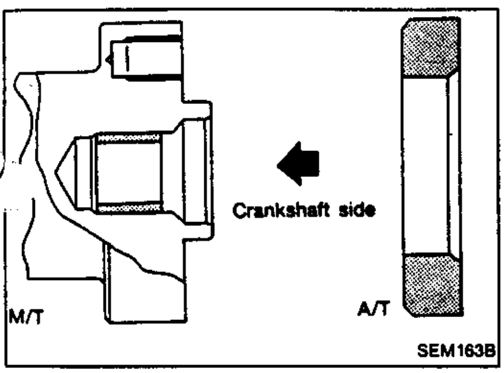
6. Measure connecting rod side clearance.
   Connecting rod side clearance:
   Standard
   0.2 - 0.4 mm (0.008 - 0.016 in)
   Limit
   0.6 mm (0.024 in)

If beyond the limit, replace connecting rod and/or crankshaft.



REPLACING PILOT BUSHING

1. Remove pilot bushing (M/T) or pilot convertor (A/T).



2. Install pilot bushing (M/T) or pilot convertor (A/T).

General Specifications

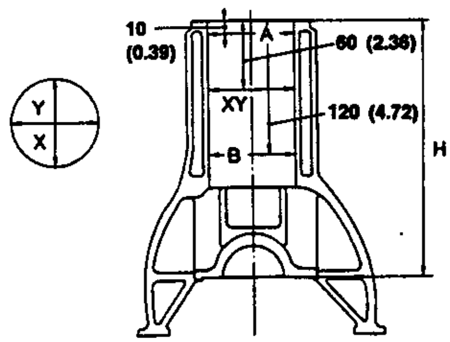
Cylinder arrangement	4, in-line
Displacement cm³ (cu in)	2,389 (145.78)
Bore x stroke mm (in)	89 x 96 (3.50 x 3.78)
Valve arrangement	OHC
Firing order	1-3-4-2
Number of piston rings	
Compression	2
Oil	1
Number of main bearings	5
Compression ratio	8.6

Unit: kPa (kg/cm², psi)/rpm

Compression pressure	
Standard	1,324 (13.5, 192)/300
Minimum	981 (10, 142)/300
Differential limit between cylinders	98 (1.0, 14)/300

Inspection and Adjustment

CYLINDER BLOCK



SEM400E

Unit: mm (in)

			Standard	Limit
Distortion			—	0.1 (0.004)
Cylinder bore	Inner diameter	Grade 1	89.000 - 89.010 (3.5039 - 3.5043)	0.2 (0.008)*
		Grade 2	89.010 - 89.020 (3.5043 - 3.5047)	
		Grade 3	89.020 - 89.030 (3.5047 - 3.5051)	
	Out-of-round (X – Y)		Less than 0.015 (0.0006)	—
	Taper (A – B)		Less than 0.015 (0.0006)	—
Difference in inner diameter between cylinders			Less than 0.05 (0.0020)	0.2 (0.008)
Piston-to-cylinder clearance			0.020 - 0.040 (0.0008 - 0.0016)	—
Cylinder block height (From crankshaft center)			246.95 - 247.05 (9.7224 - 9.7264)	0.2 (0.008)**

* Wear limit
** Total amount of cylinder head resurfacing and cylinder block resurfacing

CYLINDER HEAD

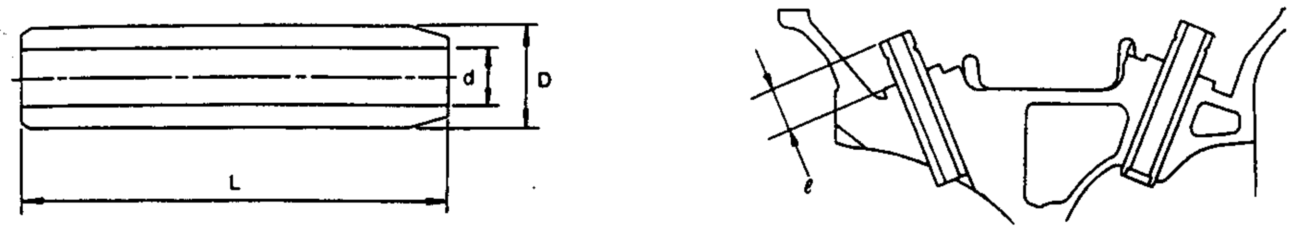
Unit: mm (in)

	Standard	Limit
Height (H)	98.8 - 99.0 (3.890 - 3.898)	0.2 (0.008)*
Surface distortion	0.03 (0.0012)	0.1 (0.004)

* Total amount of cylinder head resurfacing and cylinder block resurfacing

Inspection and Adjustment (Cont'd)

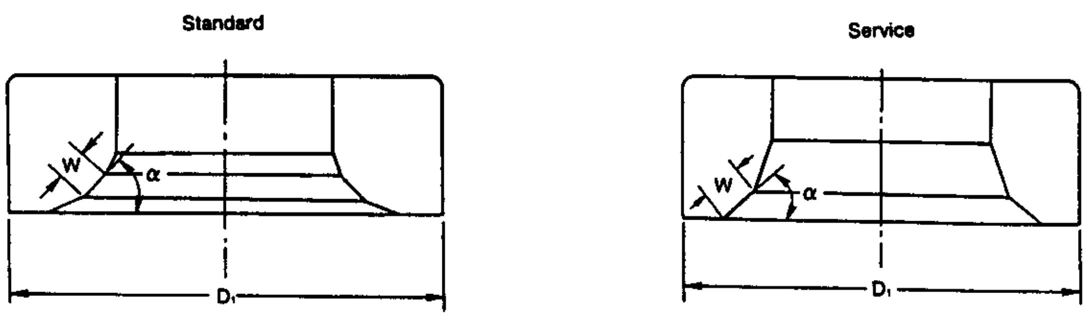
VALVE GUIDE



SEM401E

Unit: mm (in)

	Standard		Service		Limit
	Intake	Exhaust	Intake	Exhaust	—
Length (L)	52.6 (2.071)	56.0 (2.205)	52.6 (2.071)	56.0 (2.205)	—
Outer diameter (D)	11.023 - 11.034 (0.4340 - 0.4344)	12.023 - 12.034 (0.4733 - 0.4738)	11.223 - 11.234 (0.4418 - 0.4423)	12.223 - 12.234 (0.4812 - 0.4817)	—
Inner diameter (d) (Finished size)	7.000 - 7.018 (0.2756 - 0.2763)	8.000 - 8.018 (0.3150 - 0.3157)	7.000 - 7.018 (0.2756 - 0.2763)	8.000 - 8.018 (0.3150 - 0.3157)	—
Cylinder head hole diameter	10.975 - 10.996 (0.4321 - 0.4329)	11.975 - 11.996 (0.4715 - 0.4723)	11.175 - 11.196 (0.4400 - 0.4408)	12.175 - 12.196 (0.4793 - 0.4802)	—
Interference fit	0.027 - 0.059 (0.0011 - 0.0023)				—
Stem to guide clearance	0.020 - 0.053 (0.0008 - 0.0021)	0.040 - 0.070 (0.0016 - 0.0028)	0.020 - 0.053 (0.0008 - 0.0021)	0.040 - 0.070 (0.0016 - 0.0028)	0.1 (0.004)
Tapping length (ℓ)	14.9 - 15.1 (0.587 - 0.594)				



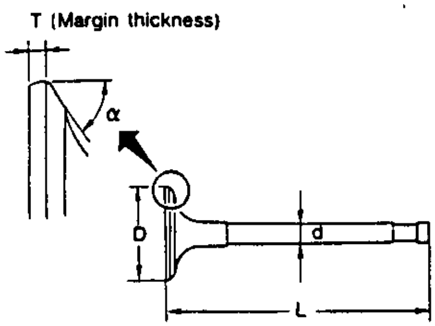
SEM402E

Unit: mm (in)

	Standard		Service	
	Intake	Exhaust	Intake	Exhaust
Cylinder head seat recess diameter	36.000 - 36.016 (1.4173 - 1.4179)	42.000 - 42.016 (1.6535 - 1.6542)	36.500 - 36.516 (1.4370 - 1.4376)	42.500 - 42.516 (1.6732 - 1.6739)
Valve seat outer diameter (D_1)	36.080 - 36.096 (1.4205 - 1.4211)	42.080 - 42.096 (1.6567 - 1.6573)	36.580 - 36.596 (1.4402 - 1.4408)	42.580 - 42.596 (1.6764 - 1.6770)
Face angle (α)	45°	45°	45°	45°
Contacting width (W)	1.6 - 1.7 (0.063 - 0.067)	1.7 - 2.1 (0.067 - 0.083)	1.6 - 1.7 (0.063 - 0.067)	1.7 - 2.1 (0.067 - 0.083)

Inspection and Adjustment (Cont'd)

VALVE



SEM188A

Unit: mm (in)

		Standard	Limit
Valve head diameter (D)	In.	34.0 - 34.2 (1.339 - 1.346)	—
	Ex.	40.0 - 40.2 (1.575 - 1.583)	—
Valve length (L)	In.	119.9 - 120.2 (4.720 - 4.732)	—
	Ex.	120.67 - 120.97 (4.7508 - 4.7626)	—
Valve stem diameter (d)	In.	6.965 - [illegible] (0.2742 - 0.2748)	—
	Ex.	7.948 - 7.960 (0.3129 - 0.3134)	—
Valve face angle (α)	In.	45°30'	—
	Ex.	45°30'	—
Valve head margin (T)	In.	1.15 - 1.45 (0.0453 - 0.0571)	0.5 (0.020)
	Ex.	1.35 - 1.65 (0.0531 - 0.0650)	
Valve clearance		0 (0)	

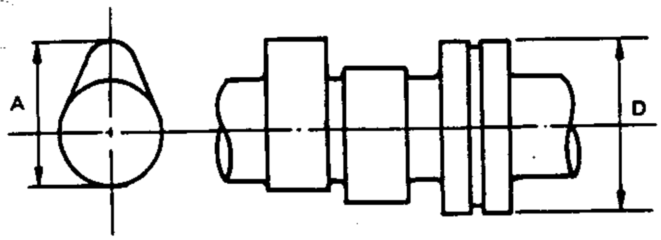
VALVE SPRING

Unit: mm (in)

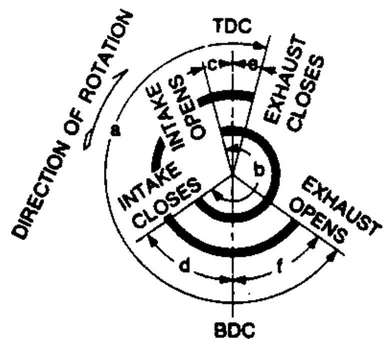
		Standard		Limit	
		Intake	Exhaust	Intake	Exhaust
Free height (H)	Outer	57.44 (2.2614)	53.21 (2.0949)	—	—
	Inner	53.34 (2.1000)	47.954 (1.8878)	—	—
Pressure N (kg, lb) at height	Outer	[illegible] (61.6, 135.8) at 37.6 (1.480)	640.4 (65.3, 144.0) at 34.1 (1.343)	567.8 (57.9, 127.7) at 37.6 (1.480)	620.8 (63.3, 139.6) at 34.1 (1.343)
	Inner	284.4 (29.0, 63.9) at 32.6 (1.283)	328.5 (33.5, 73.9) at 29.1 (1.146)	266.8 (27.2, 60.0) at 32.6 (1.283)	318.7 (32.5, 71.7) at 29.1 (1.146)
Out-of-square	Outer	—	—	2.5 (0.098)	2.3 (0.091)
	Inner	—	—	2.3 (0.091)	2.1 (0.083)

Inspection and Adjustment (Cont'd)

CAMSHAFT AND CAMSHAFT BEARING



SEM568A



EM120

Unit: mm (in)

		Standard	Limit
Cam height (A)		44.839 - 45.029 (1.7653 - 1.7728)	—
Valve lift (h)		9.86 (0.3882)	—
Wear limit of cam height		—	0.2 (0.008)
Camshaft journal to bearing clearance		0.045 - 0.090 (0.0018 - 0.0035)	0.12 (0.0047)
Inner diameter of camshaft bearing		33.000 - 33.025 (1.2992 - 1.3002)	—
Outer diameter of camshaft journal (D)		32.935 - 32.955 (1.2967 - 1.2974)	—
Camshaft runout		0 - 0.02 (0 - 0.0008)	—
Camshaft end play		0.07 - 0.15 (0.0028 - 0.0059)	0.2 (0.008)
Valve timing (Degree on crankshaft)	a	248	—
	b	240	—
	c	3	—
	d	57	—
	e	12	—
	f	56	—

ROCKER ARM AND ROCKER SHAFT

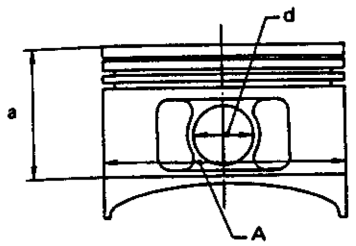
Unit: mm (in)

Rocker arm to shaft clearance	0.012 - 0.050 (0.0005 - 0.0020)
Rocker shaft diameter	21.979 - 22.000 (0.8653 - 0.8661)
Rocker arm rocker shaft hole diameter	22.012 - 22.030 (0.8666 - 0.8673)

Inspection and Adjustment (Cont'd)

PISTON, PISTON RING AND PISTON PIN

Piston



SEM444C

Unit: mm (in)

Piston skirt diameter (A)	Standard	Grade No. 1	88.970 - 88.980 (3.5027 - 3.5031)
		Grade No. 2	88.980 - 88.990 (3.5031 - 3.5035)
		Grade No. 3	88.990 - 89.000 (3.5035 - 3.5039)
	Service (Oversize)	0.5 (0.020)	89.470 - 89.500 (3.5224 - 3.5236)
		1.0 (0.039)	89.970 - 90.000 (3.5421 - 3.5433)
Dimension (a)			Approximately 52 (2.05)
Piston pin hole diameter (d)			21.002 - 21.008 (0.8268 - 0.8271)
Piston-to-cylinder bore clearance			0.020 - 0.040 (0.0008 - 0.0016)

Piston pin

Unit: mm (in)

	Standard
Piston pin outer diameter	20.994 - 20.996 (0.8265 - 0.8266)
Pin to piston pin hole clearance	0.008 - 0.012 (0.0003 - 0.0005)
Piston pin to connecting rod clearance	−0.015 to −0.033 (−0.0006 to −0.0013)

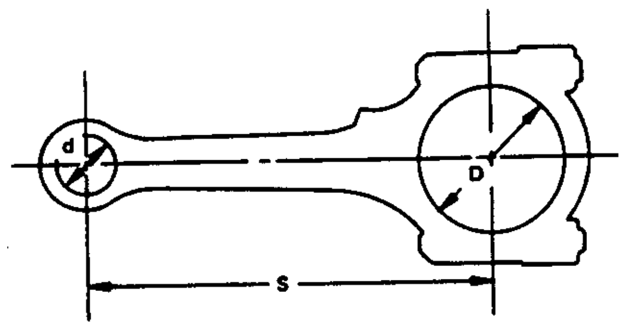
Piston ring

Unit: mm (in)

		Standard	Limit
Side clearance	Top	0.040 - 0.080 (0.0016 - 0.0031)	0.1 (0.004)
	2nd	0.030 - 0.070 (0.0012 - 0.0028)	0.1 (0.004)
	Oil	0.065 - 0.135 (0.0026 - 0.0053)*	0.1 (0.004)
Ring gap	Top	0.28 - 0.52 (0.0110 - 0.0205)	0.5 (0.020)
	2nd	0.45 - 0.69 (0.0177 - 0.0272)	0.5 (0.020)
	Oil (rail ring)	0.20 - 0.69 (0.0079 - 0.0272)	0.5 (0.020)

*: Riken-make

CONNECTING ROD



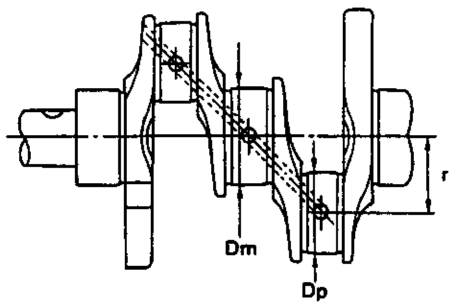
SEM216E

Unit: mm (in)

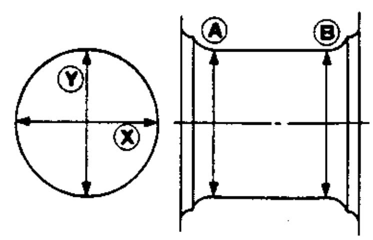
	Standard	Limit
Center distance (S)	164.95 - 165.05 (6.4941 - 6.4980)	—
Bend [per 100 mm (3.94 in)]	—	0.15 (0.0059)
Torsion [per 100 mm (3.94 in)]	—	0.3 (0.012)
Small end inner diameter (d)	20.948 - 20.978 (0.8247 - 0.8259)	—
Connecting rod big end inner diameter (D)	53.000 - 53.013 (2.0866 - 2.0871)	—
Side clearance	0.2 - 0.4 (0.008 - 0.016)	0.6 (0.024)

Inspection and Adjustment (Cont'd)

CRANKSHAFT



SEM394



EM715

Unit: mm (in)

Main journal diameter (Dm)	Grade	No. 0	63.645 - 63.652 (2.5057 - 2.5060)	
		No. 1	63.652 - 63.663 (2.5060 - 2.5064)	
		No. 2	63.663 - 63.672 (2.5064 - 2.5068)	
Pin journal diameter (Dp)			59.951 - 59.975 (2.3603 - 2.3612)	
Center distance (r)			47.97 - 48.03 (1.8886 - 1.8909)	
			Standard	Limit
Taper of journal and pin [Ⓐ - Ⓑ]		Journal	—	0.01 (0.0004)
		Pin	—	0.005 (0.0002)
Out-of-round of journal and pin [Ⓧ - Ⓨ]		Journal	—	0.01 (0.0004)
		Pin	—	0.005 (0.0002)
Runout [TIR]*			—	0.10 (0.0039)
Free end play			0.05 - 0.18 (0.0020 - 0.0071)	0.3 (0.012)
Fillet roll			More than 0.1 (0.004)	

* Total indicator reading

BEARING CLEARANCE

Unit: mm (in)

	Standard	Limit
Main bearing clearance	[illegible] (0.0008 - 0.0019)	0.1 (0.004)
Connecting rod bearing clearance	[illegible] (0.0004 - 0.0014)	0.09 (0.0035)

Inspection and Adjustment (Cont'd)

AVAILABLE MAIN BEARING

Standard

Grade number	Thickness mm (in)	Identification color
0	1.821 - 1.825 (0.0717 - 0.0719)	Black
1	1.825 - 1.829 (0.0719 - 0.0720)	Brown
2	1.829 - 1.833 (0.0720 - 0.0722)	Green
3	1.833 - 1.837 (0.0722 - 0.0723)	Yellow
4	1.837 - 1.841 (0.0723 - 0.0725)	Blue

Undersize (service)

Unit: mm (in)

	Thickness	Main journal diameter "Dm"
0.25 (0.0098)	1.952 - 1.960 (0.0769 - 0.0772)	Grind so that bearing clearance is the specified value.

AVAILABLE CONNECTING ROD BEARING

Standard

Grade number	Thickness mm (in)	Identification color
0	1.505 - 1.508 (0.0593 - 0.0594)	—
1	1.508 - 1.511 (0.0594 - 0.0595)	Brown
2	1.511 - 1.514 (0.0595 - 0.0596)	Green

Undersize (service)

Unit: mm (in)

	Thickness	Crank pin journal diameter "Dp"
0.08 (0.0031)	1.540 - 1.548 (0.0606 - 0.0609)	Grind so that bearing clearance is the specified value.
0.12 (0.0047)	1.560 - 1.568 (0.0614 - 0.0617)	
0.25 (0.0098)	1.625 - 1.633 (0.0640 - 0.0643)	

MISCELLANEOUS COMPONENTS

Unit: mm (in)

Camshaft sprocket runout [TIR]*	Less than 0.12 (0.0047)
Flywheel runout [TIR]*	Less than 0.1 (0.004)
Drive plate runout [TIR]*	Less than 0.1 (0.004)

* Total indicator reading

ENGINE LUBRICATION & COOLING SYSTEMS

SECTION LC

GI
MA
EM
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EF & EC
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AT
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PD
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RA
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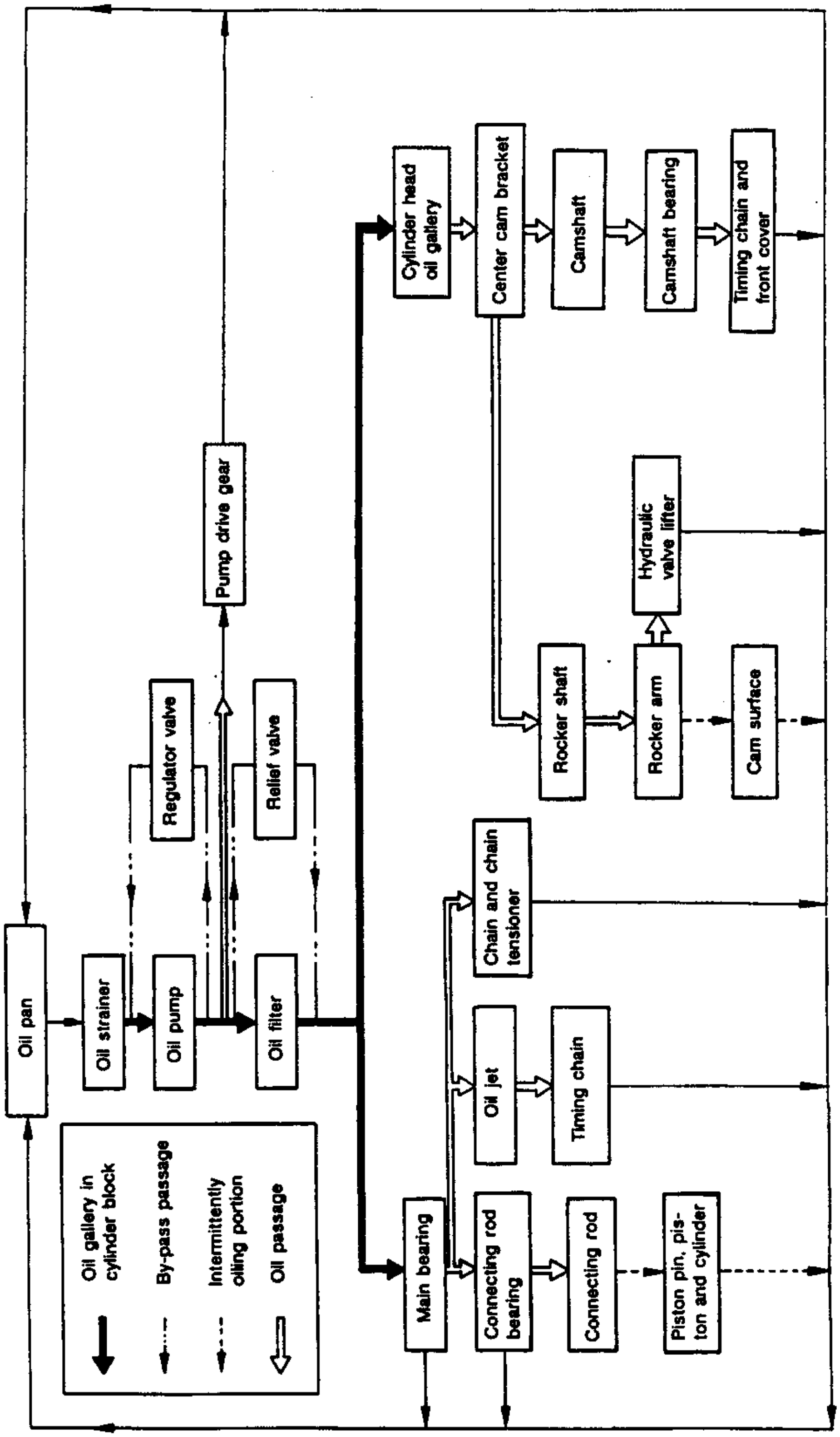
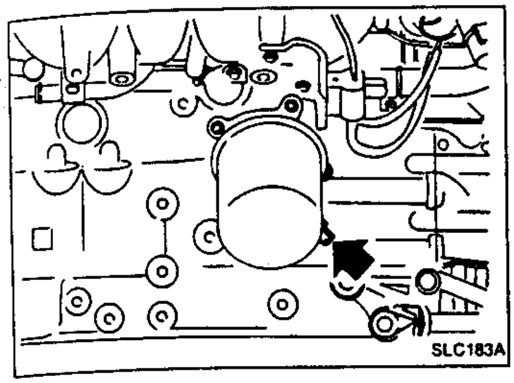
IDX

CONTENTS

Lubrication Circuit



SLC182A



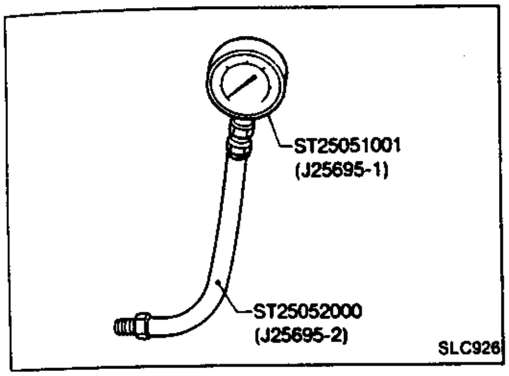
SLC183A

Oil Pressure Check

WARNING:

- **Be careful not to burn yourself, as the engine and oil may hot.**
- **Oil pressure check should be done in "Neutral" gear position.**

1. Check oil level.
2. Remove oil pressure switch.
3. Install pressure gauge.



SLC926

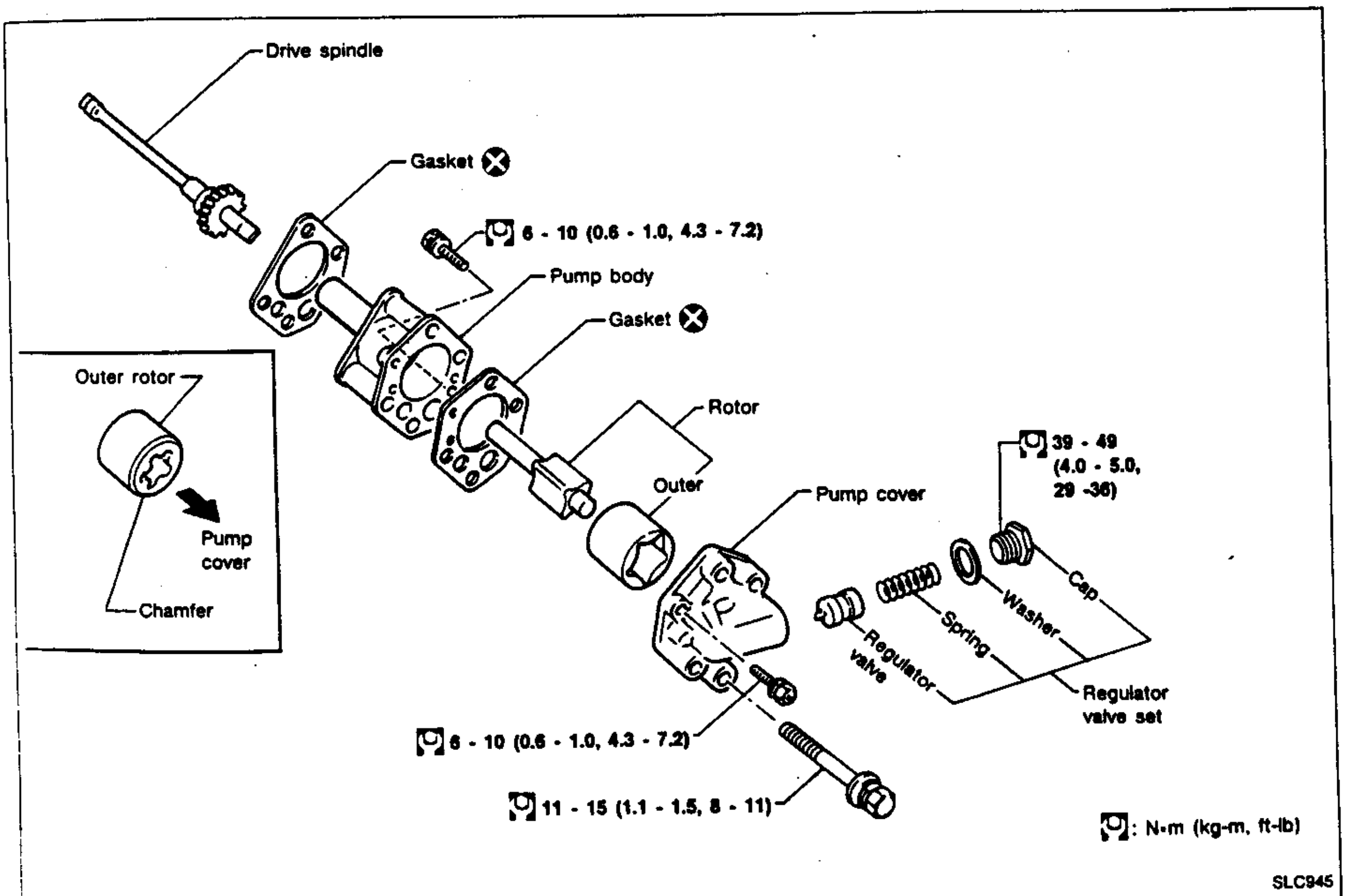
4. Start engine and warm it up to normal operating temperature.
5. Check oil pressure with engine running under no-load.

Engine speed rpm	Approximate discharge pressure kPa (kg/cm², psi)
Idle speed	More than 78 (0.8, 11)
3,000	412 - 481 (4.2 - 4.9, 60 - 70)

If difference is extreme, check oil passage and oil pump for oil leaks.

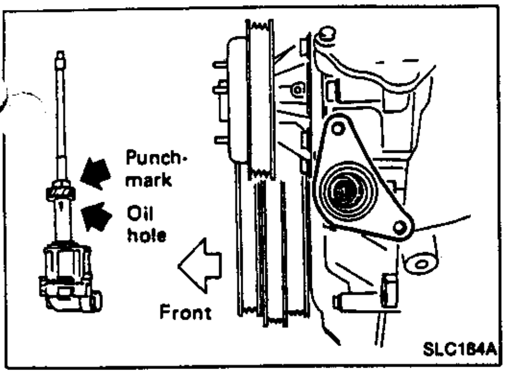
6. Install oil pressure switch with sealant.

Oil Pump

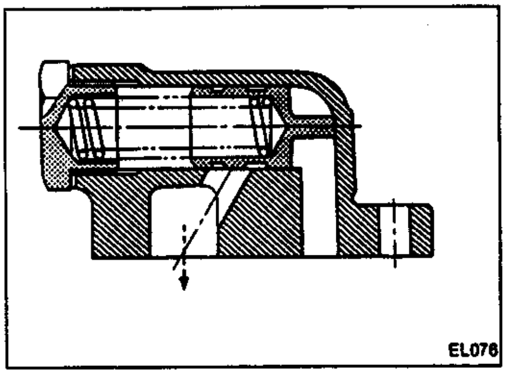


SLC945

Oil Pump (Cont'd)



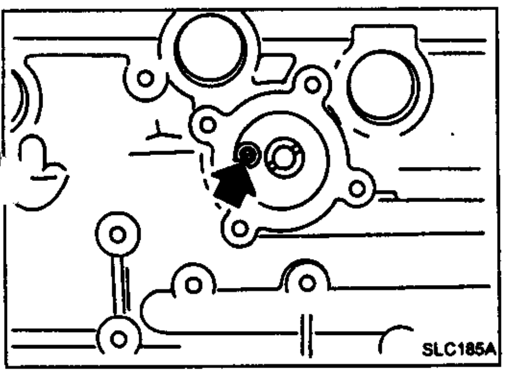
- **Always replace with new oil seal and gasket.**
- **When removing oil pump, turn crankshaft so that No. 1 piston is at TDC on its compression stroke.**
- **When installing oil pump, align punchmark on drive spindle and oil hole on oil pump.**



REGULATOR VALVE INSPECTION

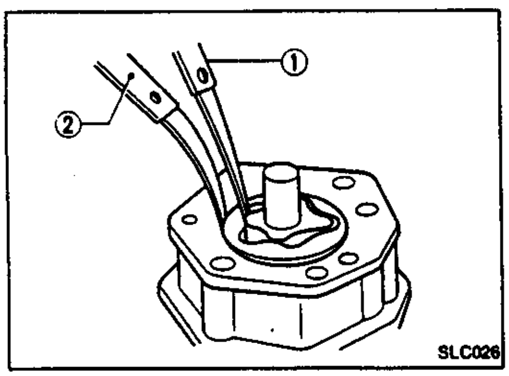
1. Visually inspect components for wear and damage.
2. Check oil pressure regulator valve sliding surface and valve spring.
3. Coat regulator valve with engine oil and check that it falls smoothly into the valve hole by its own weight.

If damaged, replace regulator valve set or oil pump assembly.



OIL PRESSURE RELIEF VALVE INSPECTION

Inspect oil pressure relief valve for movement, cracks and breaks by pushing the ball. If replacement is necessary, remove valve by prying it out with suitable tool.
Install a new valve in place by tapping it.



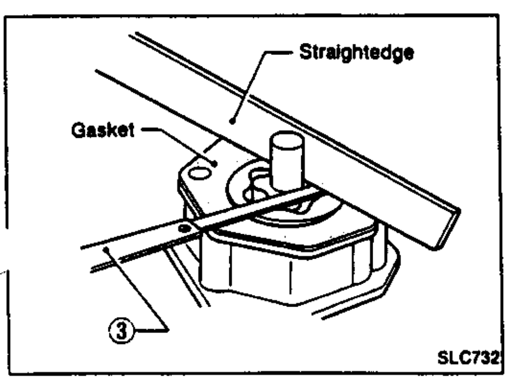
OIL PUMP INSPECTION

Using a feeler gauge, check the following clearance.

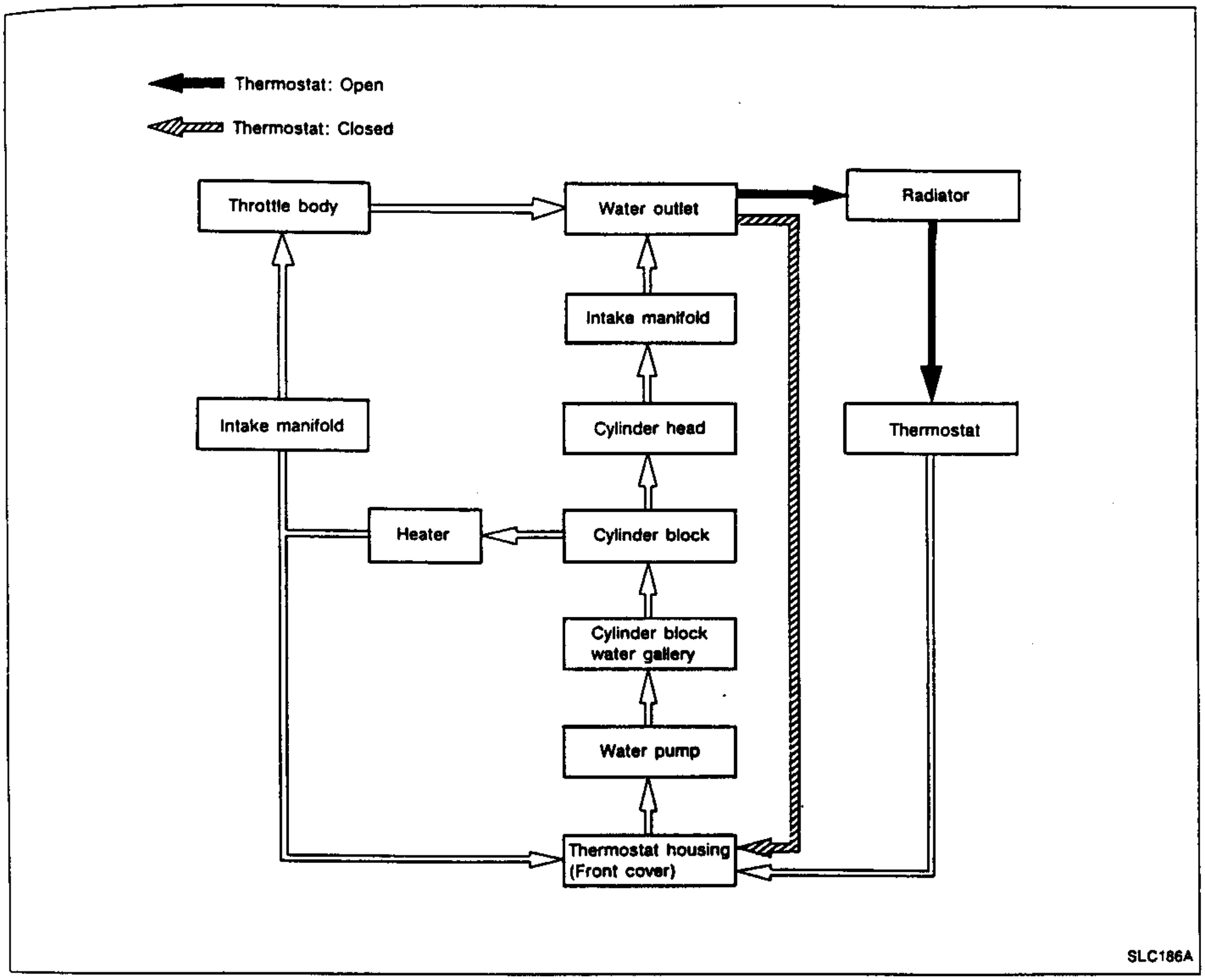
Unit: mm (in)

Rotor tip clearance ①	Less than 0.12 (0.0047)
Outer rotor to body clearance ②	0.15 - 0.21 (0.0059 - 0.0083)
Side clearance (with gasket) ③	0.04 - 0.08 (0.0016 - 0.0031)

If it exceeds the limit, replace gear set or entire oil pump assembly.



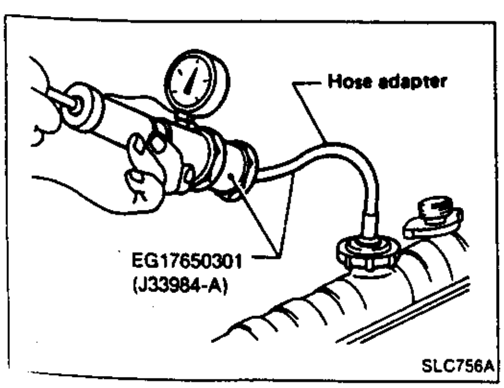
Cooling Circuit



SLC186A

System Check

WARNING:
Never remove the radiator cap when the engine is hot; serious burns could be caused by high pressure fluid escaping from the radiator.
Wrap a thick cloth around cap and carefully remove the cap by turning it a quarter turn to allow built-up pressure to escape and then turn the cap all the way off.



SLC756A

CHECKING COOLING SYSTEM HOSES

Check hoses for improper attachment, leaks, cracks, damage, loose connections, chafing and deterioration.

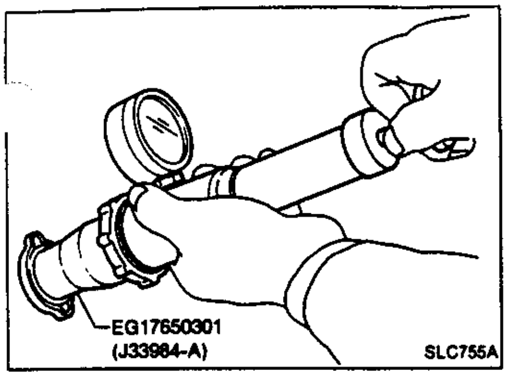
CHECKING COOLING SYSTEM FOR LEAKS

To check for leakage, apply pressure to the cooling system with a tester.

Testing pressure: 157 kPa (1.6 kg/cm^2, 23 psi)

CAUTION:
- **Higher than the specified pressure may cause radiator damage.**

System Check (Cont'd)



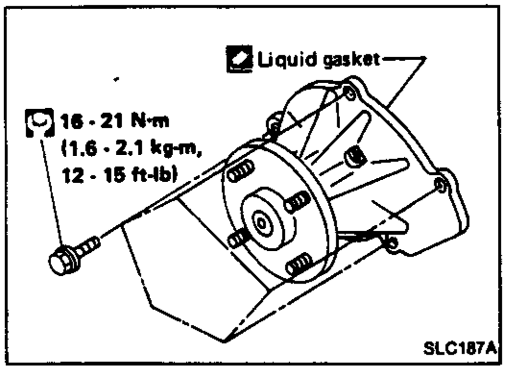
CHECKING RADIATOR CAP

To check radiator cap, apply pressure to cap with a tester.

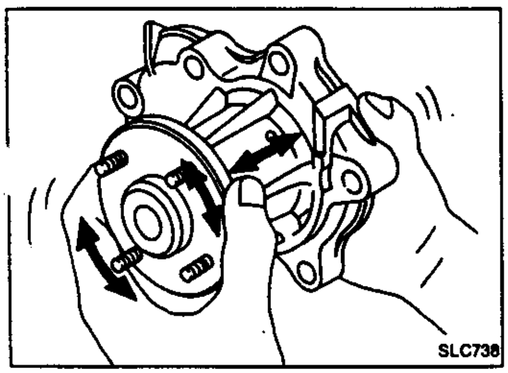
Radiator cap relief pressure:

78 - 98 kPa (0.8 - 1.0 kg/cm², 11 - 14 psi)

Water Pump

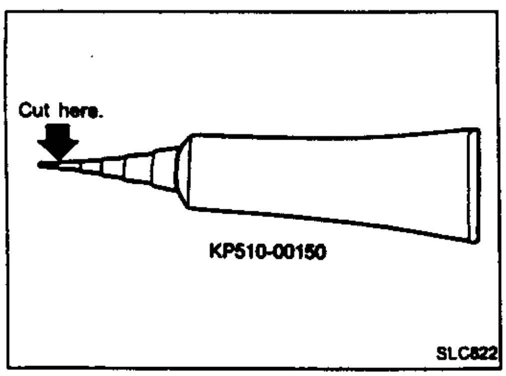


INSPECTION

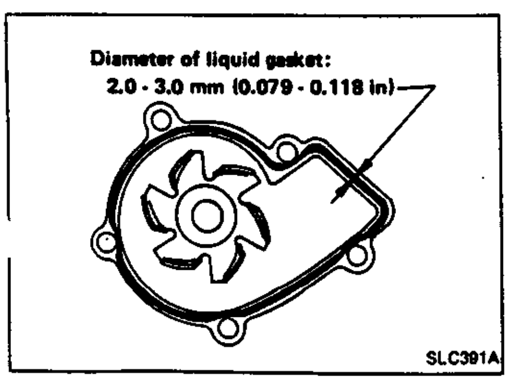


Check for excessive end play and rough operation.

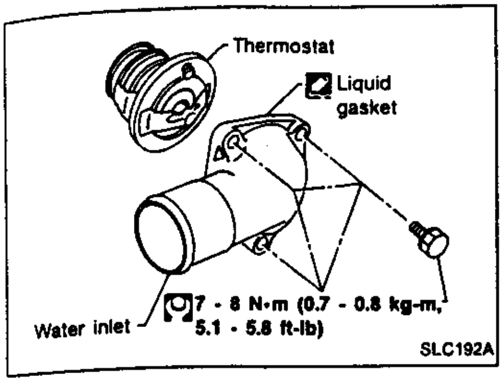
INSTALLATION



- Remove liquid gasket from mating surface of pump housing using a scraper.
  Be sure liquid gasket in grooves is also removed.
- Remove liquid gasket from mating surface of cylinder block.
- Clean all traces of liquid gasket using white gasoline.
- Cut off tip of nozzle of liquid gasket tube at point shown in figure.
- Use Genuine Liquid Gasket or equivalent.



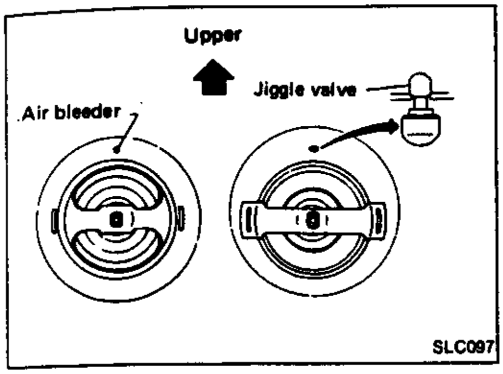
- Apply a continuous bead of liquid gasket to mating surface of pump housing as shown.



Thermostat

INSPECTION

1. Check for valve seating condition at ordinary temperatures. It should seat tightly.

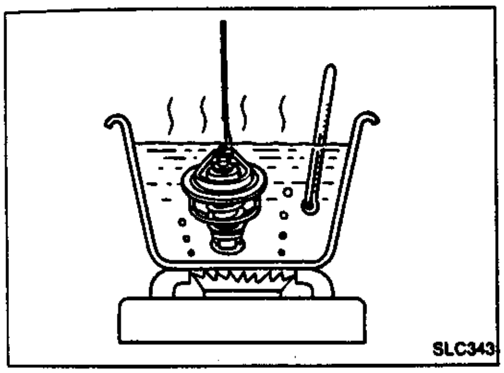


2. Check valve opening temperature and maximum valve lift.

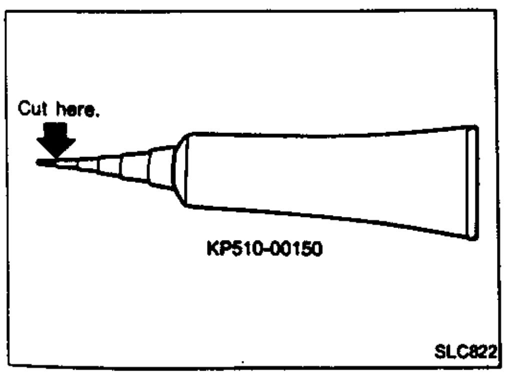
Valve opening temperature	°C (°F)	76.5 (170)
Max. valve lift	mm/°C (in/°F)	8/90 (0.31/194)

3. Then check if valve closes at 5°C (9°F) below valve opening temperature.

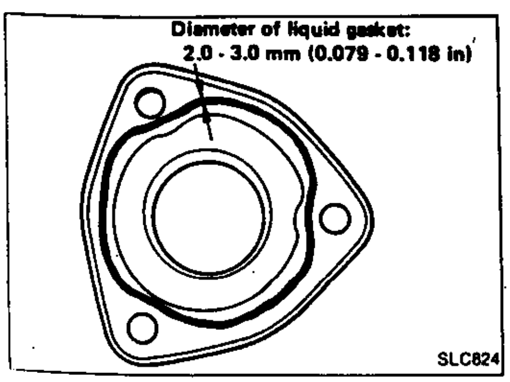
- **After installation, run engine for a few minutes, and check for leaks.**



INSTALLATION

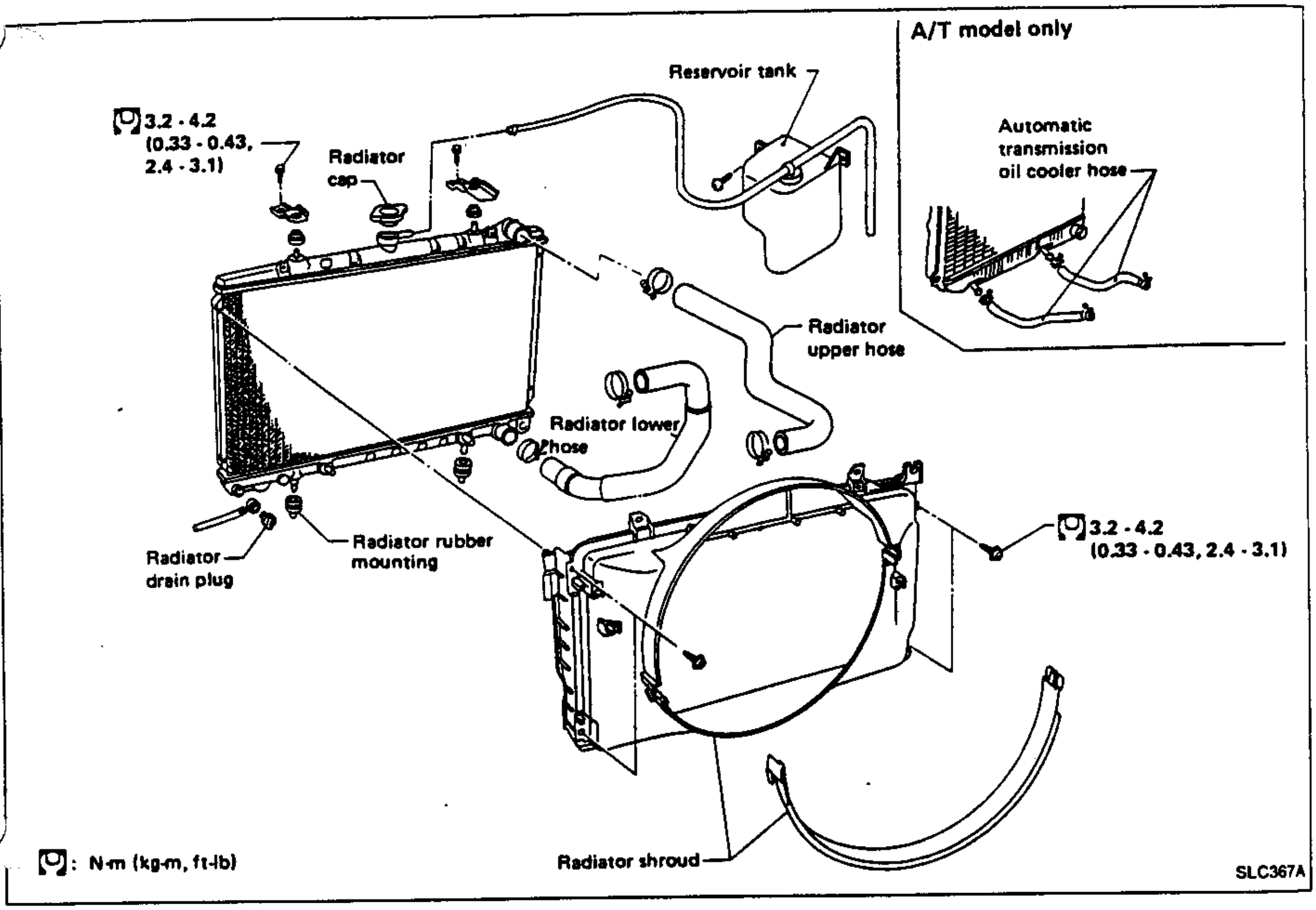


- Remove liquid gasket from mating surface of thermostat using a scraper.
- Similarly, remove liquid gasket from mating surface of cylinder block.
- Clean all traces of liquid gasket using white gasoline.
- Cut off tip of nozzle of liquid gasket tube at point shown in figure.
- Use Genuine Liquid Gasket or equivalent.



- Apply a continuous bead of liquid gasket to mating surface of water inlet.

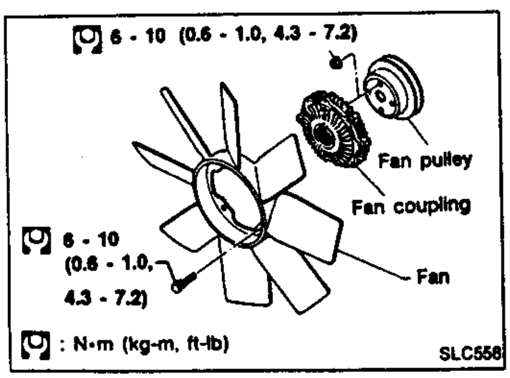
Radiator



CAUTION:
When filling radiator with coolant, refer to MA section.

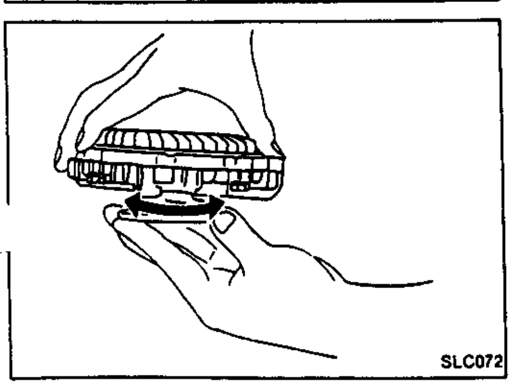
Cooling Fan

DISASSEMBLY AND ASSEMBLY



INSPECTION

Check fan coupling for rough operation, oil leakage or bent bimetal.



Engine Lubrication System (VG30E)

Oil pressure check

Engine speed rpm	Approximate discharge pressure kPa (kg/cm², psi)
Idle speed	More than 59 (0.6, 9)
3,200	363 - 451 (3.7 - 4.6, 53 - 65)

Oil pump

Unit: mm (in)

Body to outer gear clearance	0.11 - 0.20 (0.0043 - 0.0079)
Inner gear to crescent clearance	0.12 - 0.23 (0.0047 - 0.0091)
Outer gear to crescent clearance	0.21 - 0.32 (0.0083 - 0.0126)
Housing to inner gear clearance	0.05 - 0.09 (0.0020 - 0.0035)
Housing to outer gear clearance	0.05 - 0.11 (0.0020 - 0.0043)

Engine Cooling System (VG30E)

Thermostat

Valve opening temperature	°C (°F)	76.5 (170)
Maximum valve lift	mm/°C (in/°F)	10/90 (0.39/194)

Radiator

Unit: kPa (kg/cm², psi)

Cap relief pressure	78 - 98 (0.8 - 1.0, 11 - 14)
Leakage test pressure	157 (1.6, 23)

Engine Lubrication System (KA24E)

Oil pressure check

Engine speed rpm	Approximate discharge pressure kPa (kg/cm², psi)
Idle speed	More than 78 (0.8, 11)
3,000	412 - 481 (4.2 - 4.9, 60 - 70)

Oil pump

Unit: mm (in)

Rotor tip clearance	Less than 0.12 (0.0047)
Outer rotor to body clearance	0.15 - 0.21 (0.0059 - 0.0083)
Side clearance (with gasket)	0.04 - 0.08 (0.0016 - 0.0031)

Engine Cooling System (KA24E)

Thermostat

Valve opening temperature	°C (°F)	76.5 (170)
Max. valve lift	mm/°C (in/°F)	8/90 (0.31/194)

Radiator

Unit: kPa (kg/cm², psi)

Cap relief pressure	78 - 98 (0.8 - 1.0, 11 - 14)
Leakage test pressure	157 (1.6, 23)

Structure

構成	PART NAME	PART NUMBER	P/C	MAKER
	ENGINE COMPONENT KIT	A0001-78P25	01	B417
	PLATE ENG,RR	30411-W0402	01	H203
	GAUGE ASSY OIL LEVEL	11140-86G02	01	B110
	VALVE ASSY CONT,CRANKCASE	11810-86G00	01	G404
	HOSE,BLOWBY	11826-86G00	01	D209
	CLP,HOSE	16439-42L00	02	B207
	PULLEY ASSY CRANKSHAFT	12303-86G00	01	G602
	FLYWHEEL ASSY	12310-85G05	01	W000
	BOLT,FLYWHEEL	12315-42L11	06	K301
	MANIFOLD ASSY,INT	14001-0F300	01	B417
	ADAPTER,INT	14040-86G00	01	A603
	BOLT	14663-12G00	01	K103
	BOLT	14069-10C00	01	K301
	BOLT	14069-10C10	02	K301
	BOLT	08120-8011A	02	K301
	STUD	08223-84010	01	K107
	NUT	08911-2081A	02	K607
	WASHER	00915-41610	04	B426
	STUD	08223-83510	01	K107
	MANIFOLD,EXH	14004-86G07	01	A603
	PLUG,BLINDE	14052-21R00	01	G204
	WASHER	14037-V5005	08	B426
	STUD,EXH TUBE	14064-58Y00	03	K107
	STUD	14065-D0100	08	K107
	NUT	08912-8081A	08	K607
*	PLATE BLIND,EGR	14712-V6200	01	H203
	WASHER	36513-09400	02	B426
	BOLT	08120-8501A	02	K301
	NUT	08911-2081A	02	K607
	SUPPORT,AIR CLEANER	16574-86G00	01	H203
	BOLT	08120-8161E	02	K301
	BRACKET ASSY,OIL FILTER	15238-86G00	01	B415
	BOLT	08120-8251E	04	K301
	CHAMBER ASSY,THROT	16119-86G71	01	A608
	BOLT,THROT CHAMB	16122-40P00	04	K315
	BOLT	01111-01111	02	K801
	TUBE ASSY,FUEL	17520-86G00	01	B311
	REGULATOR ASSY,PRESSURE	22670-86G01	01	A608
	SCREW	08360-5101B	02	K419
	WASHER	08916-3381A	02	K406
	INJECTOR ASSY,FUELL	16600-86G10	04	A608
	INSULATOR,INJECTOR	16635-78A00	04	D418
	RUBBER,INSULATOR	16636-V5000	04	B106

次頁へ続く

構成	PART NAME	PART NUMBER	P/C	MAKER
┐	ENGINE COMPONENT KIT	A0001-76P25	01	B417
├	HOSE WATER,THROT CHAMBER	14056-0F300	01	B517
├	HOSE WATER,THROT CHAMBER	14056-0F310	01	B517
├	CLIP,HOSE	16439-56S00	04	B207
├	BOLT	08120-8201E	05	K301
├	PIPE ASSY.HEATER	14053-0F300	01	B311
├	HOSE,WATER	14056-86G00	01	B517
├	CLAMP	01555-00281	02	B207
├	HIGH TENSION CABE SET	22450-86G27	01	A306
├	CLAMP;HT CABLE	22472-W1100	01	D512
├	CLAMP,HT CABLE	22472-01N00	01	D512
├	CLAMP,HT CABLE	22472-62S00	01	D512
├	BRACKET,HT CABLE	22474-86G02	01	B207
├	BRACKET,HT CABLE	22474-86G11	01	B207
├	BOLT	08360-6121B	02	K419
├	SENSOR ASSY.TEMP	22630-51E00	01	B106
├	DISTRIBUTOR ASSY	22100-40F00	01	A608
├	SCREW	08360-8261D	02	K419
├	GALLERY ASSY,VACCUM	22310-0F303	01	B311
├	BOLT	08120-61228	01	K301
└	BOLT	08360-61422	01	K419

2/3
Attachment B 5/6

SET UP KIT構成表

構成	PART NAME	PART NUMBER	P/C	MAKER
	TEST STAND SET UP KIT.A	A1001-40F25	01	0001
	INSUL. ENGINE MOUNTING FRONT	11210-18G01KT	02	D420
	HOSE BLOW BY.B	11826-86G10KT	01	D420
	NUT	01225-00062KT	02	K607
	NUT FIX EXHAUST TUBE	20602-41G00KT	03	K607
	NUT	08911-3081AKT	02	K607
	BRACKET ENGINE MOUNT LH	11233-86G00KT	01	H804
	BRACKET ENGINE MOUNT RH	11232-86G00KT	01	H804
	PLATE HEAT SHIELD	11284-01G02KT	01	H804
	BOLT	08121-0251EKT	08	K301
	BOLT	08127-0201EKT	08	K301
	BOLT	08121-0351FKT	02	K301
	BOLT	08120-8201FKT	02	K301
	BOLT	08121-0201EKT	02	K301
	STUD	16525-86G02KT	02	K301
	AIR CLEANER	16500-86G50KT	01	B415
	STRAINER ASSY FUEL FOR GASOLIN	16400-72L00KT	01	B415
	COOLER ASSY OIL	21305-03E00KT	01	B415
	STUD OIL COOLER	21313-17F00KT	01	B415
	NUT WING	16551-W7000KT	02	B415
	TUBE ASSY EXHAUST,FRONT	20020-86G07KT	01	B517
	GASKET EXHAUST	20691-57E01KT	02	D413
	HOSE FUEL	A6440-N7685KT	02	D418
	CLAMP-HOSE	16439-53A00KT	09	B207
	CLAMP-HOSE,E	16439-V5001KT	02	B207
	PIPE ASSY-FUEL.A	17520-0F310KT	01	B311
	BOLT	08360-61422KT	01	K419
	BOLT	08360-8141DKT	01	K419
	SCREW	08360-62525KT	01	K419
	MOTOR ASSY STARTER	23300-18C03KT	01	A608
	ENGINE CONTROL MODULE	23710-86G03KT	01	A608
	WASHER	08915-1381AKT	02	K406
	COIL ASSY IGNITION	22448-56E12KT	01	B606
	O2 SENSOR ASSY	22690-06F00KT	01	B106
	FUEL PUMP	17011-R2200KT	01	B106
	NUT	20607-P6500KT	01	G204
	HOSE VACUUM CONTROL	B2318-N3301KT	01	D209
	HARNES ASSY ENGINE ROOM SUB	24077-66G00KT	01	B208
	RELAY LM	25230-C9980KT	02	B706
	SUPPORT MANIFOLD	14017-86G01KT	01	H203

SET UP KIT構成表

構成	PART NAME	PART NUMBER	P/C	MAKER
┐	TEST STAND SET UP KIT.B	B4001-40F26	01	A802
├	HARNES ASSY ENGINE ROOM	24010-57G00	01	A802
└	CABLE ASSY BATTERY EARTH	24080-86G00	01	A802

PARTS LIST:

QUANTITY	PART NUMBER	DESCRIPTION
1	A3020-40F01	Camshaft
1	13245-40F10	Rocker Shaft - Exhaust
1	13252-40F10	Rocker Shaft - Intake
4	A3257-40F06	Rocker Arm - Intake LH
4	A3257-40F07	Rocker Arm - Intake RH
2	A3257-40F16	Rocker Arm - Exhaust RH
2	A3257-40F17	Rocker Arm - Exhaust LH
4	22401-30R15	Spark Plug
3	15208-H8903	Oil Filter

TOOL LIST:

3/8" Drive Impact Gun
3/8" Drive Speed Handle
3/8" Drive Rachet
3/8" Drive 4" Extension
½" Drive Rachet
Medium Flat Head Screwdriver
Large Flat Head Screwdriver
5/8" Wrench, Combination
5/8" Spark Plug Socket, 3/8" Drive
27mm Deep Socket, ½" Drive
24mm Impact Deep Socket, 3/8" Drive
12mm Deep Socket, 3/8" Drive
10mm Deep Socket, 3/8" Drive
Digital Bore Gauge w/ Metric Head
Dial Indicator Set w/ Magnetic Base
Mounting Plate for Dial Indicator
1-2" Digital Micrometer
Spark Plug Gapping Tool
Suction Device (Syringe and Tubing)
Wooden Wedge Tool

ADDITIONAL NOTES:

ROCKER - VALVE LH
A3257 - 40F06
POSITION # I 1, 3, 5, 7

ROCKER - VALVE RH
A3257 - 40F07
POSITION # I 2, 4, 6, 8

ROCKER - VALVE RH
A3257 - 40F16
POSITION # E 1, 3

ROCKER - VALVE LH
A3257 - 40F17
POSITION # E 2, 4

Appendix D

D. Product Specification Information

Fuel specification charts
Texaco DexCool ethylene glycol coolant specification

A18-P3

PRODUCT: KA24E TEST FUEL

PRODUCT CODE: HF008

Batch No.: ______
TMO No.: ______
TMC No.: ______
Tank No.: ______
Analysis Date: ______
Shipment Date: ______

TEST	METHOD	UNITS	SPECIFICATIONS			RESULTS
			MIN	TARGET	MAX	
Distillation - IBP	ASTM D86	°F	75		95	
5%		°F				
10%		°F	120		135	
20%		°F				
30%		°F				
40%		°F				
50%		°F	200		230	
60%		°F				
70%		°F				
80%		°F				
90%		°F	300		325	
95%		°F				
Distillation - EP		°F	385		415	
Recovery		vol %		Report		
Residue		vol %		Report		
Loss		vol %		Report		
Gravity	ASTM D4052	°API	58.7		61.2	
Density	ASTM D4052	kg/l	0.734		0.744	
Reid Vapor Pressure	ASTM D323	psi	8.8		9.2	
Carbon	ASTM E191	wt fraction	0.8580		0.8667	
Carbon	ASTM D3343	wt fraction		Report		
Sulfur	ASTM D4294	wt %			0.1	
Lead	ASTM D3237	g/gal			0.05	
Phosphorous	ASTM D3231	g/gal			0.005	
Oxygen	ASTM D4815	wt %			0.05	
Composition, aromatics	ASTM D1319	vol %			35.0	
Composition, olefins	ASTM D1319	vol %	5.0		10.0	
Composition, saturates	ASTM D1319	vol %		Report		
Oxidation Stability	ASTM D525	minutes	1440			
Copper Corrosion	ASTM D130				1	
Gum content, washed	ASTM D381	mg/100ml			5.0	
Research Octane Number	ASTM D2699		97.0		97.5	
Motor Octane Number	ASTM D2700			Report		
R+M/2	D2699/2700			Report		
Sensitivity	D2699/2700		7.5			
Net Heat of Combustion	ASTM D240	btu/lb		Report		
Color	Visual			Green		

APPROVED BY: ______________ ANALYST ______________

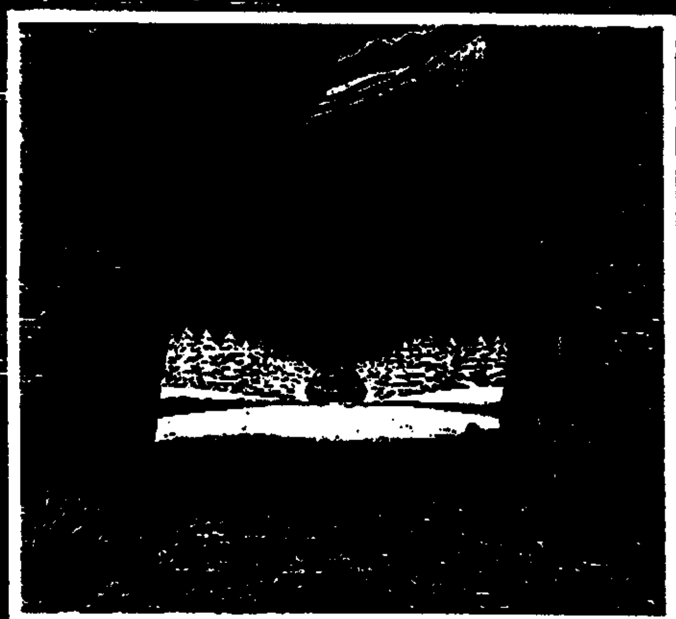
Finally, an antifreeze/coolant you can forget about.

Introducing

Havoline®

EXTENDED LIFE

Anti-Freeze/Coolant



DEX-COOL™

offers superior performance, Havoline® DEX-COOL™ is priced competitively.

...And your customers

It provides your customer with reduced maintenance costs due to longer change intervals and increases customer convenience because they no longer need to worry about frequent coolant system change outs. Its unique formulation provides superior heat exchange capabilities (cools better), improves water pump seal performance and enhances coolant system component durability. Havoline® DEX-COOL™ is simply a better coolant.

Environmentally, Havoline® DEX-COOL™'s longer service interval decreases the impact of "spent" coolants on the environment. Havoline® DEX-COOL™ is biodegradable and can be recycled.

The Havoline DEX-COOL™ advantage

Havoline® DEX-COOL™ is the only extended life antifreeze/coolant that provides all of the following:

- Outstanding hot surface aluminum protection.
- Superior protection in high operating temperatures.
- Improved water pump life due to reduced water pump seal wear.
- Effective long-term corrosion protection for aluminum, brass, cast iron, steel, solder and copper.
- Less "spent" coolant disposal means less environmental impact.
- Longer shelf life. (Minimum 5 years)
- Longer service interval - 5 years/

A color that's meant to get your attention...

The unique orange color of Havoline® DEX-COOL™ is designed to remind you that this is a five year/100,000 mile anti-freeze/coolant. To receive full benefits, it should not be mixed with conventional coolants (even though it is compatible with conventional antifreeze/coolants).

...And easy to find

Havoline® Extended Life Anti-Freeze/Coolant DEX-COOL™ Code 7994 is now available to distributors and retailers in gallon containers and drums. Havoline® Extended Life Anti-Freeze/Coolant DEX-COOL™ Pre-Mixed 50/50 Code 7995 is a 50/50 mixture of Havoline® Extended Life Anti-Freeze/Coolant and deionized water, is available in drums only.

Product Specifications

Product Code:	7994
UPC Code - Gallon Jug	07656803695
UPC Code - 6 Gal. Case	07656803696
Case Height	13 1/4"
Case Width	13 1/4"
Case Depth	16"
Case Cube	1.63 cft.
Case Weight	60 lbs.
Cases Per Pallet	36
Pallets Per Truck	20 (4,320 Gal.)

Order with any other Texaco Lubricants Company products.

For more information about Havoline® DEX-COOL™, or other outstanding Havoline® products, please call your Texaco Lubricants Customer Service Center at 1-800-STAR-TLC.

US Public and
Government Affairs
1111 Bagby
Houston TX 77002
713 752 4816

News from **TEXACO**

TEXACO INTRODUCES THE NEXT GENERATION ANTIFREEZE/COOLANT

**This Five Year Or 100,000 Mile Cooling System Protection
To Be Used In General Motors 1996 Automobiles**

FOR RELEASE: MONDAY, OCTOBER 2, 1995.

HOUSTON, Oct. 2 - Texaco Lubricants Company (TLC) announces the development of Havoline® Extended Life Anti-Freeze/Coolant, which has been validated by General Motors (GM) as DEX-COOL™, a revolutionary new product which provides automotive cooling system protection for five years or 100,000 miles. This extended life product is used as the initial factory fill for all GM 1996 model automobiles, carries the new GM approval label and meets GM's new extended life (100,000 miles) antifreeze/coolant specification, GM6277M.

Havoline DEX-COOL, developed exclusively by Texaco researchers, stands out from conventional antifreeze/coolant due to a patented carboxylate formula that will provide superior cooling system protection and an unconventional new orange color.

"Havoline Extended Life Anti-freeze/Coolant, which offers cooling system protection for 100,000 miles, is the next generation in coolant technology. The innovative formula was developed jointly by Texaco's research facilities in the United States and Europe," said S. Shariq Yosufzai, President, Texaco Lubricants Company. "After more than thirty years of being an industry leader in coolant/antifreeze research, Texaco Lubricants Company is proud that GM has decided to use this exciting new breakthrough in antifreeze technology."

Specifically formulated for automotive engines, Texaco's antifreeze/coolant product provides better long term rust and corrosion protection, extended water pump life, as well as superior heat exchange capabilities allowing for more effective engine cooling. Texaco's patented carboxylate inhibitors have been shown to remain above 95 percent of their original concentration after 100,000 miles in automobiles. This allows much longer intervals between coolant changes without worrying about loss of rust and corrosion protection.

- more -

Samples of the antifreeze/coolant that had already been in service for more than 100,000 miles were tested in laboratory controlled corrosion tests for new coolants. The used antifreeze/coolant passed the ASTM D 1384 requirements for glassware corrosion with results equivalent to new coolants, and also passed the ASTM D 4340 Aluminum Hot Surface Test for new coolant. No conventional coolant product is known to have passed these tests.

The product contains no silicates, nitrates, nitrites, borates, molybdates, phosphates, or amines. The elimination of these traditional disolved solid inhibitors provides many benefits, including extended water pump life due to reduced water pump seal wear. The absence of silicates promotes better heat transfer and since phosphates are not present, hard water scaling is greatly reduced.

In extensive fleet testing in vehicles with varying engine designs, over 66 million miles of service have been amassed without a single cooling system failure due to the coolant. The engines from several of the fleet-tested vehicles were disassembled and inspected, and overall cooling system protection was judged to be excellent.

- xxx -

Contact: Maripat Sexton
(713) 752-6461

Date Issued: 08-02-94
Supersedes: 08-02-94

TEXACO
MATERIAL SAFETY DATA SHEET

NOTE: Read and understand Material Safety Data Sheet before handling or disposing of product.

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

MATERIAL IDENTITY

Product Code and Name:
07994 TEXACO HAVOLINE EXTENDED LIFE ANTIFREEZE/COOLANT

Chemical Name and/or Family or Description:
Antifreeze

Manufacturer's Name and Address:
TEXACO LUBRICANTS COMPANY
A DIVISION OF TEXACO REFINING AND MARKETING INC.
P.O. Box 4427
Houston, TX 77210-4427

Telephone Numbers:

Transportation Emergency	-Company	: (914) 831-3400
	CHEMTREC	: (800) 424-9300
Health Emergency	-Company	: (914) 831-3400
General MSDS Assistance		: (914) 838-7204
Technical Information	-Fuels	: (914) 838-7336
	-Chemical	: (512) 459-6543
	-Lubricant/ Antifreezes	: (800) 782-7852
	-Additives	: (713) 235-6278
	-Solvents	: (800) 876-3738

2. COMPOSITION/INFORMATION ON INGREDIENTS

THE CRITERIA FOR LISTING COMPONENTS IN THE COMPOSITION SECTION IS AS FOLLOWS: CARCINOGENS ARE LISTED WHEN PRESENT AT 0.1 % OR GREATER; COMPONENTS WHICH ARE OTHERWISE HAZARDOUS ACCORDING TO OSHA ARE LISTED WHEN PRESENT AT 1.0 % OR GREATER; NON-HAZARDOUS COMPONENTS ARE LISTED AT 3.0 % OR GREATER. THIS IS NOT INTENDED TO BE A COMPLETE COMPOSITIONAL DISCLOSURE. REFER TO SECTION 14 FOR APPLICABLE STATES' RIGHT TO KNOW AND OTHER REGULATORY INFORMATION.

Product and/or Component(s) Carcinogenic According to:

OSHA	IARC	NTP	OTHER	NONE
-	-	-	-	X

Composition: (Sequence Number and Chemical Name)

Seq.	Chemical Name	CAS Number	Range in %
01 *	1,2 ethanediol	107-21-1	80.00-94.99
02	Water deionized	7732-18-5	3.00-9.99
03	Hexanoic acid, 2-ethyl-, potassium salt	3164-85-0	3.00-9.99

PRODUCT IS HAZARDOUS ACCORDING TO OSHA (1910.1200).
* COMPONENT IS HAZARDOUS ACCORDING TO OSHA.

Exposure Limits referenced by Sequence Number in the Composition Section

Seq.	Limit	
01	50	ppm CEILING-OSHA
01	50	ppm CEILING-ACGIH

3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW

Appearance:
Orange liquid

Odor:
Odorless

N.D. - NOT DETERMINED
< - LESS THAN
N.A. - NOT APPLICABLE
> - GREATER THAN
N.T. - NOT TESTED

3. HAZARD IDENTIFICATION (CONT)

WARNING STATEMENT

WARNING !
HARMFUL IF SWALLOWED
MAY CAUSE DIZZINESS AND DROWSINESS
MAY CAUSE EYE IRRITATION
ASPIRATION HAZARD IF SWALLOWED - CAN ENTER LUNGS AND CAUSE DAMAGE
FOR INDUSTRIAL USE ONLY
CAN CAUSE KIDNEY DAMAGE IF SWALLOWED
MAY CAUSE LIVER DAMAGE IF SWALLOWED BASED ON ANIMAL DATA

ATTENTION !
CONTAINS ETHYLENE GLYCOL WHICH MAY CAUSE BIRTH DEFECTS BASED ON ANIMAL DATA
CONTAINS 2-ETHYLHEXANOIC ACID OR ITS SALT WHICH MAY CAUSE ADVERSE REPRODUCTIVE EFFECTS AND BIRTH DEFECTS BASED ON ANIMAL DATA

HMIS				NFPA			
Health:	2	Reactivity:	0	Health:	2	Reactivity:	0
Flammability:	1	Special	: -	Flammability:	1	Special	: -

POTENTIAL HEALTH EFFECTS

Primary Route of Exposure:	EYE	SKIN	INHALATION	INGESTION
	X	X	X	_

EFFECTS OF OVEREXPOSURE

Acute:

Eyes:
May cause irritation, experienced as mild discomfort and seen as slight excess redness of the eye.

Skin:
Brief contact may cause slight irritation. Prolonged contact, as with clothing wetted with material, may cause more severe irritation and discomfort, seen as local redness and swelling.

Other than the potential skin irritation effects noted above, acute (short term) adverse effects are not expected from brief skin contact; see other effects, below, and Section 11 for information regarding potential long term effects.

Inhalation:
Vapors or mist, in excess of permissible concentrations, or in unusually high concentrations generated from spraying, heating the material or as from exposure in poorly ventilated areas or confined spaces, may cause irritation of the nose and throat, headache, nausea, and drowsiness.

Prolonged or repeated overexposure may result in the absorption of potentially harmful amounts of material.

Ingestion:
Contains ethylene glycol and/or diethylene glycol, which are toxic when swallowed. A lethal dose for an adult is 1-2 ml per kilogram, or about 4 ounces (one-half cup). Symptoms include headache, weakness, confusion, dizziness, staggering, slurred speech, loss of coordination, faintness, nausea and vomiting, increased heart rate, decreased blood pressure, difficulty breathing and seeing, pulmonary edema, unconsciousness, convulsions, collapse, and coma. Symptoms may be delayed. Decreased urine output and kidney failure may also occur. Severe poisoning may cause death.

Aspiration may occur during swallowing or vomiting, resulting in lung damage.

Sensitization Properties:
Unknown.

Chronic:
Repeated ingestion may cause kidney damage.

3. HAZARD IDENTIFICATION (CONT)

Medical Conditions Aggravated by Exposure:
Repeated overexposure may aggravate existing kidney disease.

Because of its irritating properties, repeated skin contact may aggravate an existing dermatitis (skin condition).

Other Remarks:
None

4. FIRST AID MEASURES

Eyes:
Immediately flush eyes with plenty of water for at least 15 minutes. Hold eyelids apart while flushing to rinse entire surface of eye and lids with water. Get medical attention.

Skin:
Wash skin with plenty of soap and water for several minutes. Get medical attention if skin irritation develops or persists.

Ingestion:
If person is conscious and can swallow, immediately give two glasses of water (16 oz.) but do not induce vomiting. If vomiting occurs, give fluids again. Have physician determine if condition of person will permit induction of vomiting or evacuation of stomach. Do not give anything by mouth to an unconscious or convulsing person.

Inhalation:
If irritation, headache, nausea, or drowsiness occurs, remove to fresh air. Get medical attention if breathing becomes difficult or respiratory irritation persists.

Other Instructions:
Ethylene (Diethylene) Glycol poisoning may initially produce behavior changes, drowsiness, vomiting, diarrhea, thirst, and convulsions. End stage signs of poisoning are renal damage/failure with metabolic acidosis. Immediate treatment, supplemented with hemodialysis if indicated, may limit the progression and severity of toxic effects. Intravenous Ethanol in sodium bicarbonate solution is a recognized antidotal treatment; other antidotal treatments also exist for Ethylene (Diethylene) glycol poisoning. Contact a Poison Center for further treatment information.

Aspiration of this product during induced emesis may result in severe lung injury. If evacuation of stomach is necessary, use method least likely to cause aspiration, such as gastric lavage after endotracheal intubation. Contact a Poison Center for additional treatment information.

5. FIRE-FIGHTING MEASURES

Ignition Temperature (degrees F):
Not determined.
Flash Point (degrees F):
260 (PMCC)
Flammable Limits (%):
Lower: Not determined.
Upper: Not determined.

Recommended Fire Extinguishing Agents And Special Procedures:
Use water spray, dry chemical, foam, or carbon dioxide to extinguish flames. Use water spray to cool fire-exposed containers. Water or foam may cause frothing.

Unusual or Explosive Hazards:
None

Extinguishing Media Which Must Not Be Used:
Not determined.

5. FIRE-FIGHTING MEASURES (CONT)

Special Protective Equipment for Firefighters:
Wear full protective clothing and positive pressure breathing apparatus. Approach fire from upwind to avoid hazardous vapors and toxic decomposition products.

6. ACCIDENTAL RELEASE MEASURES (Transportation Spills: CHEMTREC (800)424-9300)

Procedures in Case of Accidental Release, Breakage or Leakage:
Ventilate area. Avoid breathing vapor. Wear appropriate personal protective equipment, including appropriate respiratory protection. Contain spill if possible. Wipe up or absorb on suitable material and shovel up. Prevent entry into sewers and waterways. Avoid contact with skin, eyes or clothing.

If more than 1 pounds of product is spilled, then report spill according to SARA 304 and CERCLA 102(A) requirements.

7. HANDLING AND STORAGE

Precautions to be Taken in Handling:
Minimum feasible handling temperatures should be maintained.

Storage:
Periods of exposure to high temperatures should be minimized. Water contamination should be avoided.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Protective Equipment (Type)

Eye/Face Protection:
Safety glasses, chemical type goggles, or face shield recommended to prevent eye contact.

Skin Protection:
Workers should wash exposed skin several times daily with soap and water. Soiled work clothing should be laundered or dry-cleaned.

Respiratory Protection:
Airborne concentrations should be kept to lowest levels possible. If vapor, mist or dust is generated and the occupational exposure limit of the product, or any component of the product, is exceeded, use appropriate NIOSH or MSHA approved air purifying or air supplied respirator after determining the airborne concentration of the contaminant. Air supplied respirators should always be worn when airborne concentration of the contaminant or oxygen content is unknown.

Ventilation:
Adequate to meet component occupational exposure limits (see Section 2).

Exposure Limit for Total Product:
None established for product; refer to Section 2 for component exposure limits.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance:
Orange liquid

Odor:
Odorless

Boiling Point (degrees F):
228

Melting/Freezing point (degrees F):
Not applicable.

Specific Gravity (water=1):
1.13

PRODUCT CODE: 07994
NAME: TEXACO HAVOLINE EXTENDED LIFE ANTIFREEZE/COOLANT

Date Issued: 08-02-94
Supersedes: 06-02-94

9. PHYSICAL AND CHEMICAL PROPERTIES (CONT)

pH of undiluted product:
8.3

Vapor Pressure:
Not determined.

Viscosity:
8 cSt at 40.0 C

VOC Content:
Not determined.

Vapor Density (air=1):
2.1

Solubility in Water (%):
> 10

Other: None

10. STABILITY AND REACTIVITY

This Material Reacts Violently With:
(If Others is checked below, see comments for details)

Air	Water	Heat	Strong Oxidizers	Others	None of These
_	_	_	_	_	X

Comments:
None

Products Evolved When Subjected to Heat or Combustion:
Toxic levels of carbon monoxide, carbon dioxide, irritating aldehydes and ketones may be formed on burning. Heating in air may produce irritating aldehydes, acids, and ketones.

Hazardous Polymerizations: DO NOT OCCUR

11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL INFORMATION(ANIMAL TOXICITY DATA)
Median Lethal Dose
Oral:
Animal data does not reflect human toxicity; see Sections 3 & 11
Inhalation:
Not determined.
Dermal:
LD50 Believed to be > 1.00 - 3.00 g/kg (rabbit) slightly toxic
Irritation Index, Estimation of Irritation (Species)
Skin:
(Draize) Believed to be .50 - 3.00 /8.0 (rabbit) slightly irritating
Eyes:
(Draize) Believed to be 15.00 - 25.00 /110 (rabbit) slightly irritating
Sensitization:
Not determined.
Other:
Oral administration of ethylene glycol to pregnant experimental animals has been shown to cause birth defects in the offspring. These effects were not seen when ethylene glycol was administered by dermal application or by inhalation.
Continuous ingestion of a diet contaning 1% or 2% ethylene glycol for two years produced liver and kidney damage, and bladder stones in rats.

2-ethylhexanoic acid (2-EXA) caused an increase in liver size and enzyme levels when repeatedly administered to rats via the diet. When administered to pregnant rats by gavage or in drinking water, 2-EXA caused teratogencity (birth defects) and delayed postnatal development of the pups. Additionaly, 2-EXA impaired female fertility in rats. Birth defects were seen in the offspring of mice who were administered sodium 2-ethylhexanoate via intraperitoneal injection during pregnancy.

N.D. - NOT DETERMINED
< - LESS THAN
N.A. - NOT APPLICABLE
> - GREATER THAN
N.T. - NOT TESTED

12. DISPOSAL CONSIDERATIONS

Waste Disposal Methods

This product has been evaluated for RCRA characteristics and does not meet the criteria of a hazardous waste if discarded in its purchased form. Under RCRA, it is the responsibility of the user of the product to determine at the time of disposal, whether the product meets RCRA criteria for hazardous waste. This is because product uses, transformations, mixtures, processes, etc. may render the resulting materials hazardous.

Remarks

To prevent contamination of drinking water supplies, and poisoning of children, aquatic life, wildlife, and farm and domestic animals, ethylene glycol products such as used antifreeze solution, regardless of quantity, should never by discarded onto the ground, into surface waters, or into storm sewers.

13. TRANSPORT INFORMATION

Transportation

DOT:
Proper Shipping Name:
Not regulated

IMDG:
Proper Shipping Name:
Not evaluated

ICAO:
Proper Shipping Name:
Not evaluated

TDG:
Proper Shipping Name:
Not evaluated

14. REGULATORY INFORMATION

Federal Regulations:

SARA Title III:

Section 302/304 Extremely Hazardous Substances

Seq.	Chemical Name	CAS Number	Range in %
None			

Section 302/304 Extremely Hazardous Substances (CONT)

Seq.	TPQ	RQ
None		

Section 311 Hazardous Categorization:

Acute	Chronic	Fire	Pressure	Reactive	N/A
X	X	_	_	_	_

Section 313 Toxic Chemical

Chemical Name	CAS Number	Concentration
1,2 ethanediol	107-21-1	80.00-94.99

CERCLA 102(a)/DOT Hazardous Substances: (+ indicates DOT Hazardous Substance)

Seq.	Chemical Name	CAS Number	Range in %
01	1,2 ethanediol	107-21-1	80.00-94.99

CERCLA/DOT Hazardous Substances (Sequence Numbers and RQ's):

Seq.	RQ
01	1

TSCA Inventory Status:

This product is listed on the Toxic Substance Control Act (TSCA) Chemical Substance Inventory.

Other:

None.

N.D. - NOT DETERMINED N.A. - NOT APPLICABLE N.T. - NOT TESTED
< - LESS THAN > - GREATER THAN

14. REGULATORY INFORMATION (CONT)

State Regulations:

California Proposition 65:

The following detectable components of this product are substances, or belong to classes of substances, known to the State of California to cause cancer and/or reproductive toxicity.

Chemical Name	CAS Number
None	

States Right-to-know Regulations:

Chemical Name	State Right-to-know
1,2 ethanediol	FL,IL,LA,MA,NJ,PA,RI

State list: CT (Connecticut), FL (Florida), IL (Illinois), MI (Michigan) LA (Louisiana), MA (Massachusetts), NJ (New Jersey), PA (Pennsylvania), RI (Rhode Island),

International Regulations:

Export Notification (TSCA-12b):
section 12(b); contains:
1H-benzotriazole, methyl-
Diethylene glycol monobutyl ether

WHMIS Classification:

Class D, Div 1, Subdiv B: Toxic
Class D, Div 2, Subdiv A: Teratogenic

Canada Inventory Status:
N.D.

EINECS Inventory Status:
N.D.

Australia Inventory Status:
N.D.

Japan Inventory Status:
N.D.

15. ENVIRONMENTAL INFORMATION

Aquatic Toxicity:
Not determined.

Mobility:
Not determined.

Persistence and Biodegradability:
This product is estimated to have a moderate rate of biodegradation: greater than or equal to 30 % degradation over a test period of 28 days or less.

Potential to Bioaccumulate:
This product is estimated to have a low potential to bioconcentrate.

Remarks:
None

16. OTHER INFORMATION

Acute or chronic oral consumption of products containing ethylene glycol can produce significant adverse health effects, including death, in humans and animals. Keep out of reach of children and pets. Such products should not be used in potable (drinking) water systems or other systems where contamination of potable water supplies is possible (e.g., recreational vehicles, winterizing potable water systems).

Texaco recommends that all exposures to this product be minimized by strictly adhering to recommended occupational controls procedures to avoid any potential adverse health effects.

16. OTHER INFORMATION (CONT)

THE INFORMATION CONTAINED HEREIN IS BELIEVED TO BE ACCURATE. IT IS PROVIDED INDEPENDENTLY OF ANY SALE OF THE PRODUCT FOR PURPOSE OF HAZARD COMMUNICATION AS PART OF TEXACO'S PRODUCT SAFETY PROGRAM. IT IS NOT INTENDED TO CONSTITUTE PERFORMANCE INFORMATION CONCERNING THE PRODUCT. NO EXPRESS WARRANTY, OR IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE IS MADE WITH RESPECT TO THE PRODUCT OR THE INFORMATION CONTAINED HEREIN. DATA SHEETS ARE AVAILABLE FOR ALL TEXACO PRODUCTS. YOU ARE URGED TO OBTAIN DATA SHEETS FOR ALL TEXACO PRODUCTS YOU BUY, PROCESS, USE OR DISTRIBUTE AND YOU ARE ENCOURAGED AND REQUESTED TO ADVISE THOSE WHO MAY COME IN CONTACT WITH SUCH PRODUCTS OF THE INFORMATION CONTAINED HEREIN.

TO DETERMINE APPLICABILITY OR EFFECT OF ANY LAW OR REGULATION WITH RESPECT TO THE PRODUCT, USER SHOULD CONSULT HIS LEGAL ADVISOR OR THE APPROPRIATE GOVERNMENT AGENCY. TEXACO DOES NOT UNDERTAKE TO FURNISH ADVICE ON SUCH MATTERS.

Date: 08-02-94 New X Revised, Supersedes: 06-02-94
Date printed: 08-23-94

Inquiries regarding MSDS should be directed to:
Texaco Inc.
Manager, Product Safety
P.O. Box 509
Beacon, N.Y. 12508

PLEASE SEE NEXT PAGE FOR PRODUCT LABEL

N.D. - NOT DETERMINED N.A. - NOT APPLICABLE N.T. - NOT TESTED
< - LESS THAN > - GREATER THAN

PRODUCT CODE: 07994
NAME: TEXACO HAVOLINE EXTENDED LIFE ANTIFREEZE/COOLANT

Date Issued: 08-02-94
Supersedes: 06-02-94

17. PRODUCT LABEL

READ AND UNDERSTAND MATERIAL SAFETY DATA SHEET BEFORE HANDLING OR DISPOSING OF PRODUCT. THIS LABEL COMPLIES WITH THE REQUIREMENTS OF THE OSHA HAZARD COMMUNICATION STANDARD (29 CFR 1910.1200) FOR USE IN THE WORKPLACE. THIS LABEL IS NOT INTENDED TO BE USED WITH PACKAGING INTENDED FOR SALE TO CONSUMERS AND MAY NOT CONFORM WITH THE REQUIREMENTS OF THE CONSUMER PRODUCT SAFETY ACT OR OTHER RELATED REGULATORY REQUIREMENTS.

07994 TEXACO HAVOLINE EXTENDED LIFE ANTIFREEZE/COOLANT

WARNING STATEMENT

WARNING !
HARMFUL IF SWALLOWED
MAY CAUSE DIZZINESS AND DROWSINESS
MAY CAUSE EYE IRRITATION
ASPIRATION HAZARD IF SWALLOWED -
CAN ENTER LUNGS AND CAUSE DAMAGE
FOR INDUSTRIAL USE ONLY
CAN CAUSE KIDNEY DAMAGE IF SWALLOWED
MAY CAUSE LIVER DAMAGE IF SWALLOWED BASED ON ANIMAL DATA

ATTENTION !
CONTAINS ETHYLENE GLYCOL WHICH MAY CAUSE BIRTH DEFECTS BASED ON ANIMAL DATA
CONTAINS 2-ETHYLHEXANOIC ACID OR ITS SALT WHICH MAY CAUSE ADVERSE REPRODUCTIVE EFFECTS AND BIRTH DEFECTS BASED ON ANIMAL DATA

PRECAUTIONARY MEASURES

-Use only with adequate ventilation.
-Avoid breathing vapor, mist, or gas.
-Avoid contact with eyes, skin, and clothing.
-Keep container closed.
-Wash thoroughly after handling.

FIRST AID

Eye Contact:
Immediately flush eyes with plenty of water for at least 15 minutes. Hold eyelids apart while flushing to rinse entire surface of eye and lids with water. Get medical attention.

Skin Contact:
Wash skin with plenty of soap and water for several minutes. Get medical attention if skin irritation develops or persists.

Ingestion:
If person is conscious and can swallow, immediately give two glasses of water (16 oz.) but do not induce vomiting. If vomiting occurs, give fluids again. Have physician determine if condition of person will permit induction of vomiting or evacuation of stomach. Do not give anything by mouth to an unconscious or convulsing person.

Inhalation:
If irritation, headache, nausea, or drowsiness occurs, remove to fresh air. Get medical attention if breathing becomes difficult or respiratory irritation persists.

Note to Physician:
Ethylene (Diethylene) Glycol poisoning may initially produce behavior changes, drowsiness, vomiting, diarrhea, thirst, and convulsions. End stage signs of poisoning are renal damage/failure with metabolic acidosis. Immediate treatment, supplemented with hemodialysis if indicated, may limit the progression and severity of toxic effects. Intravenous Ethanol in sodium bicarbonate solution is a recognized antidotal treatment; other antidotal treatments also exist for Ethylene (Diethylene) glycol poisoning. Contact a Poison Center for further treatment information.
Aspiration of this product during induced emesis may result in severe lung injury. If evacuation of stomach is necessary, use method least likely to cause aspiration, such as gastric lavage after endotracheal intubation. Contact a Poison Center for additional treatment information.

FIRE

In case of fire, use water spray, dry chemical, foam or carbon dioxide. Water may cause frothing. Use water spray to cool fire-exposed containers.

If more than 1 pounds of product is spilled, then report spill according to SARA 304 and CERCLA 102(A) requirements.

	Chemical Name	CAS Number	Range in %
*	1,2 ethanediol	107-21-1	80.00-94.99
	Water deionized	7732-18-5	3.00-9.99
	Hexanoic acid, 2-ethyl-, potassium salt	3164-85-0	3.00-9.99

PRODUCT CODE: 07994
NAME: TEXACO HAVOLINE EXTENDED LIFE ANTIFREEZE/COOLANT

Date Issued: 08-02-94
Supersedes: 08-02-94

17. PRODUCT LABEL (CONT)

PRODUCT IS HAZARDOUS ACCORDING TO OSHA (1910.1200).
* COMPONENT IS HAZARDOUS ACCORDING TO OSHA.

Pennsylvania Special Hazardous Substance(s)	CAS Number	Range in %
None		

HMIS

Health: 2 Reactivity: 0
Flammability: 1 Special : -

NFPA

Health: 2 Reactivity: 0
Flammability: 1 Special : -

Transportation
DOT:
Proper Shipping Name:
Not regulated

CAUTION: Misuse of empty containers can be hazardous. Empty containers can be hazardous if used to store toxic, flammable, or reactive materials. Cutting or welding of empty containers might cause fire, explosion or toxic fumes from residues. Do not pressurize or expose to open flame or heat. Keep container closed and drum bungs in place.

Manufacturer's Name and Address:
TEXACO LUBRICANTS COMPANY
A DIVISION OF TEXACO REFINING AND MARKETING INC.
P.O. Box 4427
Houston, TX 77210-4427

TRANSPORTATION EMERGENCY Company: (914) 831-3400
CHEMTREC: (800) 424-9300

HEALTH EMERGENCY Company: (914) 831-3400

Appendix E

E. Test Reports

Report Forms
Electronic Data Dictionary

SEQUENCE IVA VALVE TRAIN WEAR EVALUATION
FINAL REPORT COVER SHEET

VERSION 19990716

CONDUCTED FOR

TSTSPON1

TSTSPON2

LABVALID	V = VALID I = INVALID

TSTOIL	NR = Non-reference Oil Test RO = Reference Oil Test

Test Number			
Test Stand: STAND	No. Tests Since Last Stand Calibration Test: STRUN		Laboratory Run Number: LABRUN
Lab Engine No.	ENGINE	Total Runs on Cylinder Head	TOTHDRUN
Lab Head Number	HEADSN	Lab Cam Number	CAMNO
Date Completed	DTCOMP	End of Test	EOTTIME
Oil Code	OILCODE	Fuel Batch	FUELBTID
Formulation/Stand Code	FORM		
Alternate Codes	ALTCODE1	ALTCODE2	ALTCODE3

In my opinion this test OPVALID been conducted in a valid manner in accordance with the ASTM Research Report RR-D2-XXXX and the appropriate amendments through the Information Letter system. The remarks included in the report describe the anomalies associated with this test.

SUBMITTED BY:

SUBLAB
Testing Laboratory

SUBSIGIM
Signature

SUBNAME
Typed Name

SUBTITLE
Title

Form 2

Sequence IVA Valve Train Wear Test

Table of Contents

Sequence IVA Valve Train Wear Test

FORM 3

Summary of Test Method

The Sequence IVA engine valve train wear test is a fired engine-dynamometer lubricant test which evaluates the ability of a test lubricant to reduce camshaft lobe wear. The test method is a low temperature cyclic test, with a total running duration of 100 hours.

A 1994 Nissan model KA24E water cooled, 4 cycle, in-line cylinder, 2.389 (2.4) liter engine is used as the test apparatus. The engine incorporates a single overhead cam (SOHC), three valves per cylinder (2 intake; 1 exhaust), and sliding follower valve train design. An engine shortblock is utilized for 12 tests; a cylinder head assembly for 6 tests; and the critical test parts (camshaft, rocker arms, rocker shafts) are replaced every test. A 95 minute break-in schedule is conducted whenever the long block or cylinder head is replaced (before tests 1 and 7).

The Sequence IVA test is a flush and run type of lubricant test. Each individual test consists of two 20-minute flushes, followed by the 100-hour cyclic test. The cyclic test is comprised of 100 hourly cycles. Each cycle consists of two stages. The idle speed Stage 1 duration is 50 minutes; the 1500 r/min stage 2 operates for 10 minutes. The stages of the test cycle are set at the following conditions:

Parameter	Units	Stage 1	Stage 2
Duration	min	50	10
Engine Speed	r/min	800	1500
Engine Torque	N-m	25	25
Coolant Out Temperature	°C	50	55
Oil Gallery Temperature	°C	50	60
Intake Air Temperature	°C	32	32
Intake Air Pressure	kPa	0.050	0.050
Intake Air Humidity	g/kg	11.5	11.5
Exhaust Pressure	kPa-abs	103.5	103.5
Coolant Flow	L/min	30	30

Upon test completion, the camshaft is removed from the engine and measured for individual lobe wear at seven prescribed locations (nose; 14 degrees before and after the nose; 10 degrees before and after the nose; 4 degrees before and after the nose). For each lobe, the seven locations are summed to determine the lobe wear. Then the twelve lobes are averaged to compute the final test result.

Sequence IVA Valve Train Wear Test
Form 4
Results Summary

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/ Stand Code: FORM		

Laboratory Oil Code	LABOCODE	Fuel Batch	FUELBTID	SAE Grade	SAEVISC
Date Started	DTSTRT	Date Completed	DTCOMP	Test Length	TESTLEN
Time Started	STRTTIME	Time Completed	EOTTIME	TMC Oil Code [A]	IND
Lab Engine Number	ENGINE				
Cam Lot Number	CAMLOT	Head Lot Number	HEADLOT	Rocker Arm Lot Number	RARMLOT

Average Camshaft Wear

Original Unit Result, µm		ACW
Transformed Result		TACW
Industry Correction Factor		ACWCF
Corrected Transformed Result		ACWCOR
Severity Adjustment (non-reference oil tests only)		ACWSA
Final Transformed Result		TACWFNL
Final Original Unit Result, µm		ACWFNL
Additional Camshaft Lobe Wear Measurements		
Intake Lobe	Maximum, µm	MCWI
	Average, µm	ACWI
Exhaust Lobe	Maximum, µm	MCWE
	Average, µm	ACWE
Nose	Maximum, µm	MNW
	Average, µm	ANW

Additional Information	
Total Oil Consumption @ EOT, g	OILCON
Fuel Dilution @ EOT, %	FUELH100
Fuel Consumption @ EOT, kg	FUELCON
Fe by ICP @ EOT, ppm	FEWMH100
Corr. Blowby, L/min @ hour 5	BLWBH005
Corr. Blowby, L/min @ hour 100	BLWBH100

Most Recent Stand Reference Oil Test History [B]			
Test Number	RSTAND -RSTRUN - RLABRUN		
Oilcode	ROILCODE		
Date Completed	RDTCOMP	TMC Oil Code	RIND
Final Average Camshaft Wear, µm	RACWFNL		

[A] Reference Oil Tests Only

[B] Non-reference Oil Tests Only

Sequence IVA Valve Train Wear Test

Form 5

Camshaft Lobe Wear

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

7-point measurement method

Position	Cylinder	Lobe Number	14° BTC Wear, μm	10° BTC Wear, μm	4° BTC Wear, μm	0° (Nose) Wear, μm	4° ATC Wear, μm	10° ATC Wear, μm	14° ATC Wear, μm	Lobe Wear, μm
Intake	1	1	W14B01	W10B01	W04B01	WN01	W04A01	W10A01	W14A01	CAMW01
		3	W14B03	W10B03	W04B03	WN03	W04A03	W10A03	W14A03	CAMW03
	2	4	W14B04	W10B04	W04B04	WN04	W04A04	W10A04	W14A04	CAMW04
		6	W14B06	W10B06	W04B06	WN06	W04A06	W10A06	W14A06	CAMW06
	3	7	W14B07	W10B07	W04B07	WN07	W04A07	W10A07	W14A07	CAMW07
		9	W14B09	W10B09	W04B09	WN09	W04A09	W10A09	W14A09	CAMW09
	4	10	W14B10	W10B10	W04B10	WN10	W04A10	W10A10	W14A10	CAMW10
		12	W14B12	W10B12	W04B12	WN12	W04A12	W10A12	W14A12	CAMW12
	Max. of Intake		MW14BI	MW10BI	MW04BI	MWNI	MW04AI	MW10AI	MW14AI	MCWI
	Avg. of Intake		**AW14BI**	**AW10BI**	**AW04BI**	**AWNI**	**AW04AI**	**AW10AI**	**AW14AI**	**ACWI**
Exhaust	1	2	W14B02	W10B02	W04B02	WN02	W04A02	W10A02	W14A02	CAMW02
	2	5	W14B05	W10B05	W04B05	WN05	W04A05	W10A05	W14A05	CAMW05
	3	8	W14B08	W10B08	W04B08	WN08	W04A08	W10A08	W14A08	CAMW08
	4	11	W14B11	W10B11	W04B11	WN11	W04A11	W10A11	W14A11	CAMW11
	Max. of Exhaust		MW14BE	MW10BE	MW04BE	MWNE	MW04AE	MW10AE	MW14AE	MCWE
	Avg. of Exhaust		**AW14BE**	**AW10BE**	**AW04BE**	**AWNE**	**AW04AE**	**AW10AE**	**AW14AE**	**ACWE**
Over-all Maximum			MW14B	MW10B	MW04B	MNW	MW04A	MW10A	MW14A	MCW
Over-all Average			**AW14B**	**AW10B**	**AW04B**	**ANW**	**AW04A**	**AW10A**	**AW14A**	**ACW**

Note: Plus direction is before top center of cam nose

Sequence IVA
Valve Train Wear Test
Form 6
Operational Summary

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

	Parameter	Units	QI Threshold	EOT QI	Target		Average		Samples[A]	BQD[B]	Over/Under Range[C]
Controlled Paramters	Speed	r/min	0.000	QRPM	800	1500	ARPM1	ARPM2	NRPM	BRPM	ORPM
	Torque	N-m	0.000	QTORQUE	25.0		ATORQUE1	ATORQUE2	NTORQUE	BTORQUE	OTORQUE
	Coolant Out	°C	0.000	QCOLOUT	50.0	55.0	ACOLOUT1	ACOLOUT2	NCOLOUT	BCOLOUT	OCOLOUT
	Humidity	g/kg	0.000	QHUMID	11.5		AHUMID		NHUMID	BHUMID	OHUMID
	Intake Air	°C	0.000	QINAIRT	32		AINAIRT		NINAIRT	BINAIRT	OINAIRT
	Intake Air	kPa	0.000	QINAIRP	0.05		AINAIRP		NINAIRP	BINAIRP	OINAIRP
	Exhaust - abs	kPa	0.000	QEXHBKP	103.5		AEXHBKP		NEXHBKP	BEXHBKP	OEXHBKP
	Engine Coolant	L/min	0.000	QCOLFRT	30.0		ACOLFRT		NCOLFRT	BCOLFRT	OCOLFRT
	Oil Gallery	°C	0.000	QOILT	50.0	60.0	AOILT1	AOILT2	NOILT	BOILT	OOILT

	Parameter	Units	Typical Values		Average				
Non-controlled Paramters	Oil Sump	°C	53.3 - 55.5	62.5 - 64.0	ASUMPT1	ASUMPT2			
	Oil Cylinder Head	°C	49 - 51	58 - 60	ACYLOT1	ACYLOT2			
	Coolant In	°C	44 - 46	49 - 50	ACOLIN1	ACOLIN2			
	Exhaust Gas	°C	306 - 332	414 - 434	AEXHT1	AEXHT2			
	Fuel Rail	°C	28.5 - 30.5	28.5 - 30.5	AFUELT1	AFUELT2			
	Oil Gallery	kPa	99.5 - 105.5	210.5 - 220.5	AOILPRS1	AOILPRS2			
	Oil Cylinder Head	kPa	30 - 50	50 - 80	ACYLOPR1	ACYLOPR2			
	Fuel	kPa	233 - 243	229 - 239	AFUELPR1	AFUELPR2			
	Manifold Vacuum	°C	57.7 - 59.9	63.8 - 65.8	AIMNVAC1	AIMNVAC2			
	Air-to-Fuel Ratio		14.1 - 14.7	14.1 - 14.7	AAFR1	AAFR2			
	Crankcase	kPa	-0.02 - -0.04	-0.02 - -0.04	ACCASEP1	ACCASEP2			
	Fuel Flow	kg/h	1.2 - 1.4	2.0 - 2.2	AFUELRT1	AFUELRT2			
	Ignition Timing	°BTDC	9 - 11	22 - 26	ASPKTIM1	ASPKTIM2			
	Ambient Temperature	°C	75 - 120	75 - 120	AAMBAT1	AAMBAT2			

[A] Total number of data points taken as determined from test length and sampling rate.

[B] Number of bad quality data points not used in the calculation of statistical measures.

[C] Number of points clipped by over under range limits of the statistical measures.

Sequence IVA Valve Train Wear Test

Form 7

Used Oil Analysis

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

Chemical Analysis: 0, 25, 50, 75 & 100 Hour Engine Oil

ASTM Method	Analysis Description	Units	TST_HNEW	TST_H025	TST_H050	TST_H075	TST_H100
D 445	Kinematic Viscosity @ 40°C	cSt	V040HNEW	---	---	---	V040H100
D 3525-M	Fuel Dilution, Gasoline	%	---	---	---	---	FUELH100
D 5185 (ICP)	Fe by ICP	ppm	---	FEWMH025	FEWMH050	FEWMH075	FEWMH100
D 5185 (ICP)	Cu by ICP	ppm	---	CUWMH025	CUWMH050	CUWMH075	CUWMH100

Sequence IVA Valve Train Wear Test

Form 8

Camshaft Bore/Journal Measurements

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

Camshaft Bearing Bore Diameter (mm)

Bore Gauge Set: 33.000 mm

Diameter (Standard): 33.000 - 33.025 mm

Bore Number	X		V		Y		Maximum Run-Out	
	F	R	F	R	F	R	F	R
1	CBFX001	CBRX001	CBFV001	CBRV001	CBFY001	CBRY001	XCBF001	XCBR001
2	CBFX002	CBRX002	CBFV002	CBRV002	CBFY002	CBRY002	XCBF002	XCBR002
3	CBFX003	CBRX003	CBFV003	CBRV003	CBFY003	CBRY003	XCBF003	XCBR003
4	CBFX004	CBRX004	CBFV004	CBRV004	CBFY004	CBRY004	XCBF004	XCBR004
5	CBFX005	CBRX005	CBFV005	CBRV005	CBFY005	CBRY005	XCBF005	XCBR005

Camshaft Bearing Journal Diameter (mm)

Diameter (Standard) 32.935 - 32.955 mm

Clearance (Limit) : 0.120 mm

Journal Number	v		h		Run-Out		Clearance @ V	
	F	R	F	R	F	R	F	R
1	CJFV001	CJRV001	CJFH001	CJRH001	XCJF001	XCJR001	CCF001	CCR001
2	CJFV002	CJRV002	CJFH002	CJRH002	XCJF002	XCJR002	CCF002	CCR002
3	CJFV003	CJRV003	CJFH003	CJRH003	XCJF003	XCJR003	CCF003	CCR003
4	CJFV004	CJRV004	CJFH004	CJRH004	XCJF004	XCJR004	CCF004	CCR004
5	CJFV005	CJRV005	CJFH005	CJRH005	XCJF005	XCJR005	CCF005	CCR005

Note: Calculate camshaft bearing clearance @ vertical bore diameter measurement.

Camshaft End Play, mm	CAMENDP

End Play (Limit): 0.20 mm

Camshaft Sprocket Run Out, mm	CAMSROUT

Run-Out (Limit): 0.12 mm

Camshaft Run-Out (Bend), mm	CAMBEND

Run-Out (Limit): 0.02 mm

Cylinder Compression (kPa)

Cylinder Number	1 (kPa)	2 (kPa)	3 (kPa)	4 (kPa)
Before Test	COMP1	COMP2	COMP3	COMP4

Sequence IVA Valve Train Wear Test

Form 9

Special Maintenance Record

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

Number of Downtime Occurrences	DWNOCR	

Test Hours	Date	Downtime	Reasons
DOWNH001	DDATH001	DTIMH001	DREAH001
		TOTLDOWN	Total Downtime

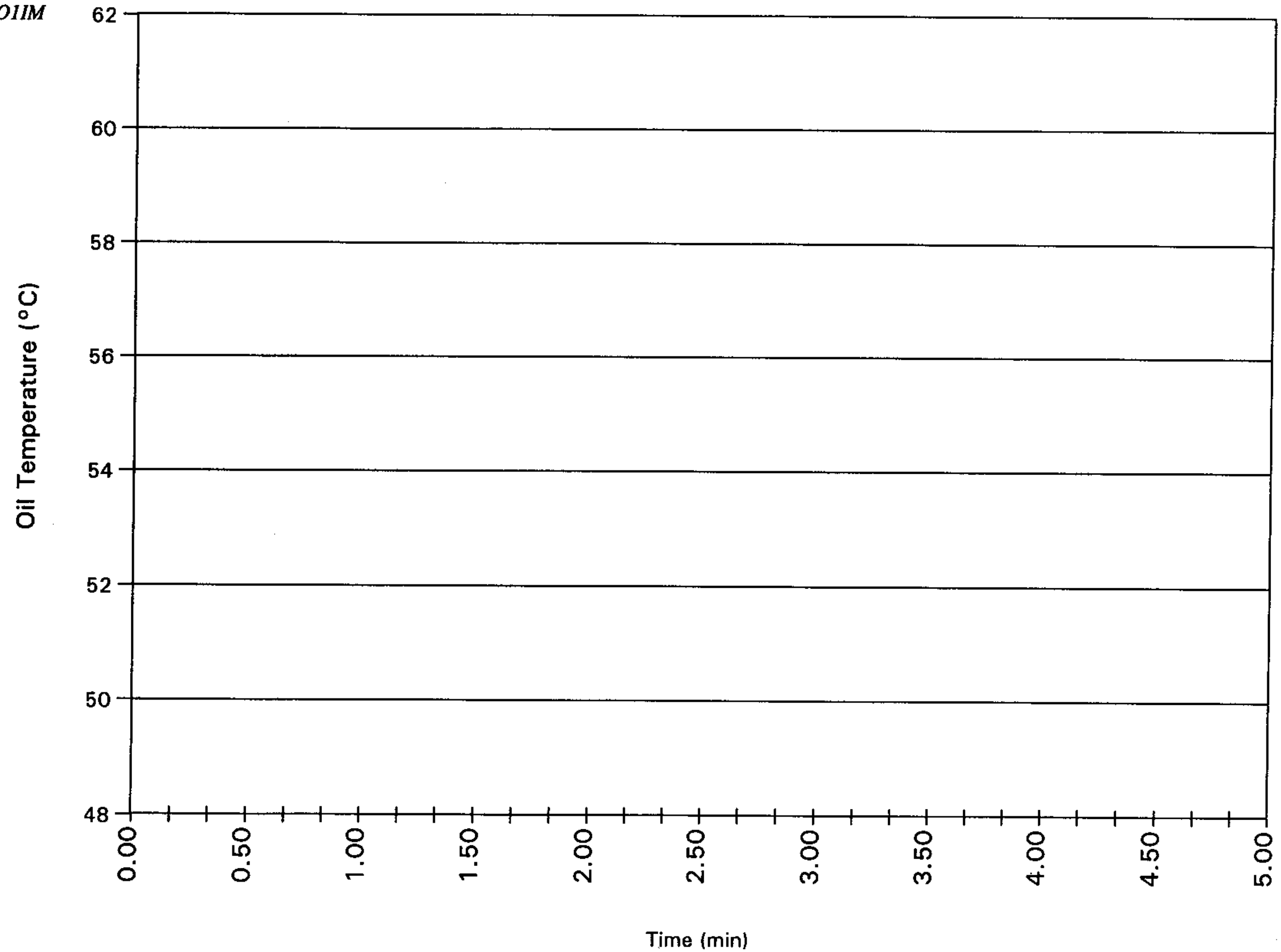
Other Comments		
Number of Comment Lines	TOTCOM	

OCOMH001

Sequence IVA Valve Train Wear Evaluation
Form 10
Stage 2 to 1 Transition: Oil Gallery Temperature
Cycle 5

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

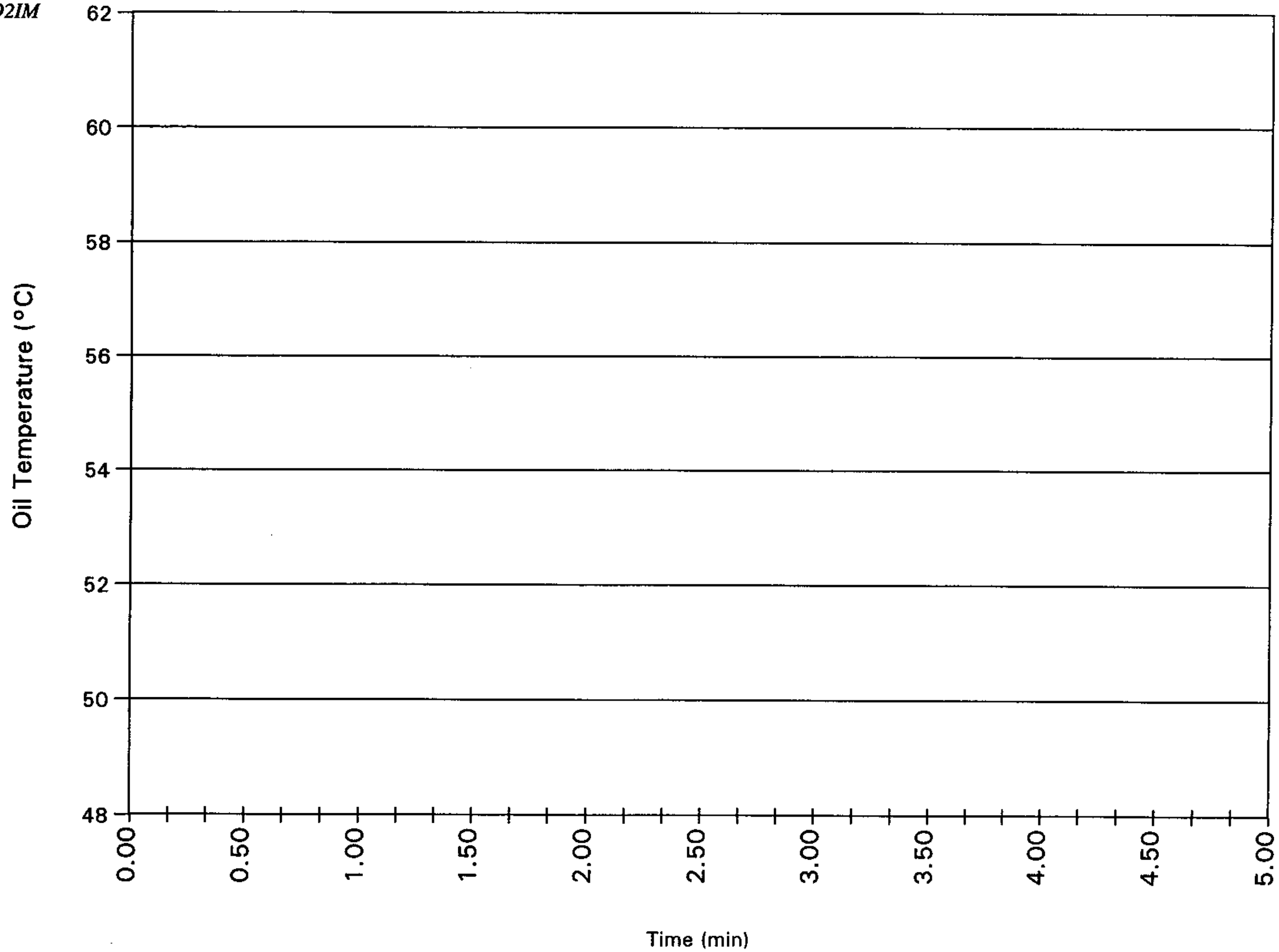
OG2TO1IM



Sequence IVA Valve Train Wear Evaluation
Form 11
Stage 1 to 2 Transition: Oil Gallery Temperature
Cycle 5

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

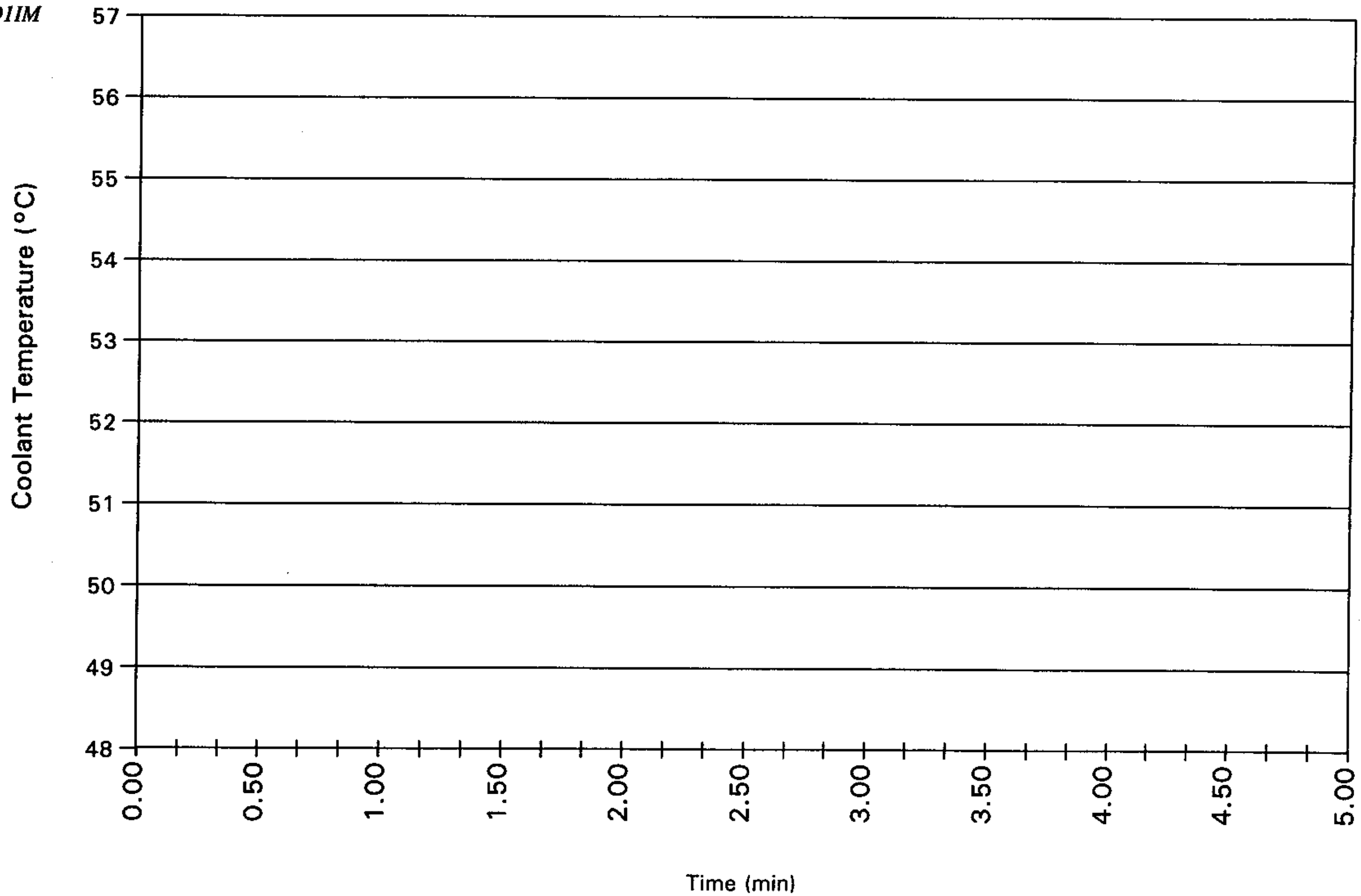
OG1TO2IM



Sequence IVA Valve Train Wear Evaluation
Form 12
Stage 2 to 1 Transition: Coolant Out Temperature
Cycle 5

Laboratory: LAB	Test Number: STAND - STRUN - LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

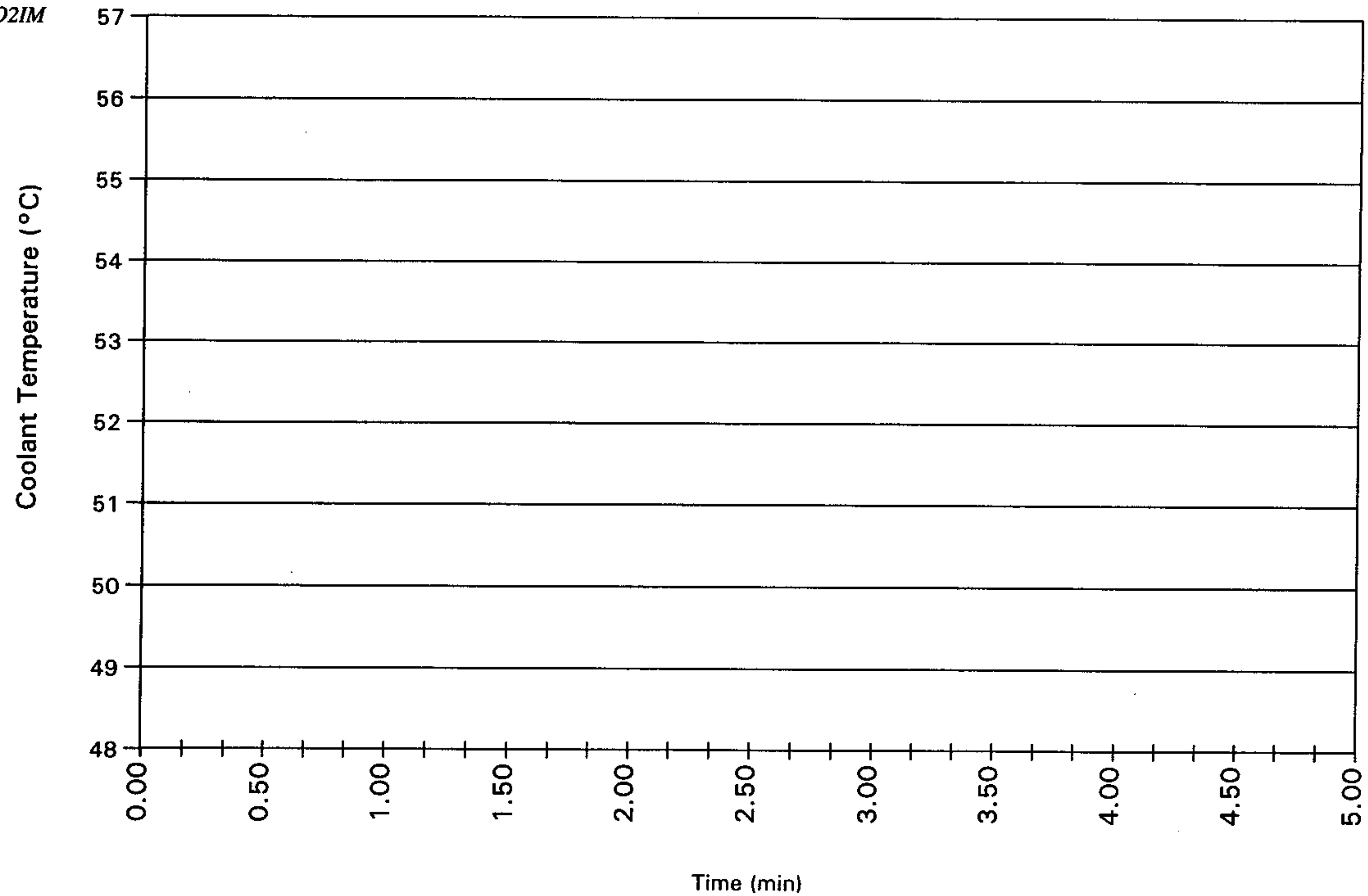
CO2TO1IM



Sequence IVA Valve Train Wear Evaluation
Form 13
Stage 1 to 2 Transition: Coolant Out Temperature
Cycle 5

Laboratory: LAB	Test Number: STAND - STRUN - LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

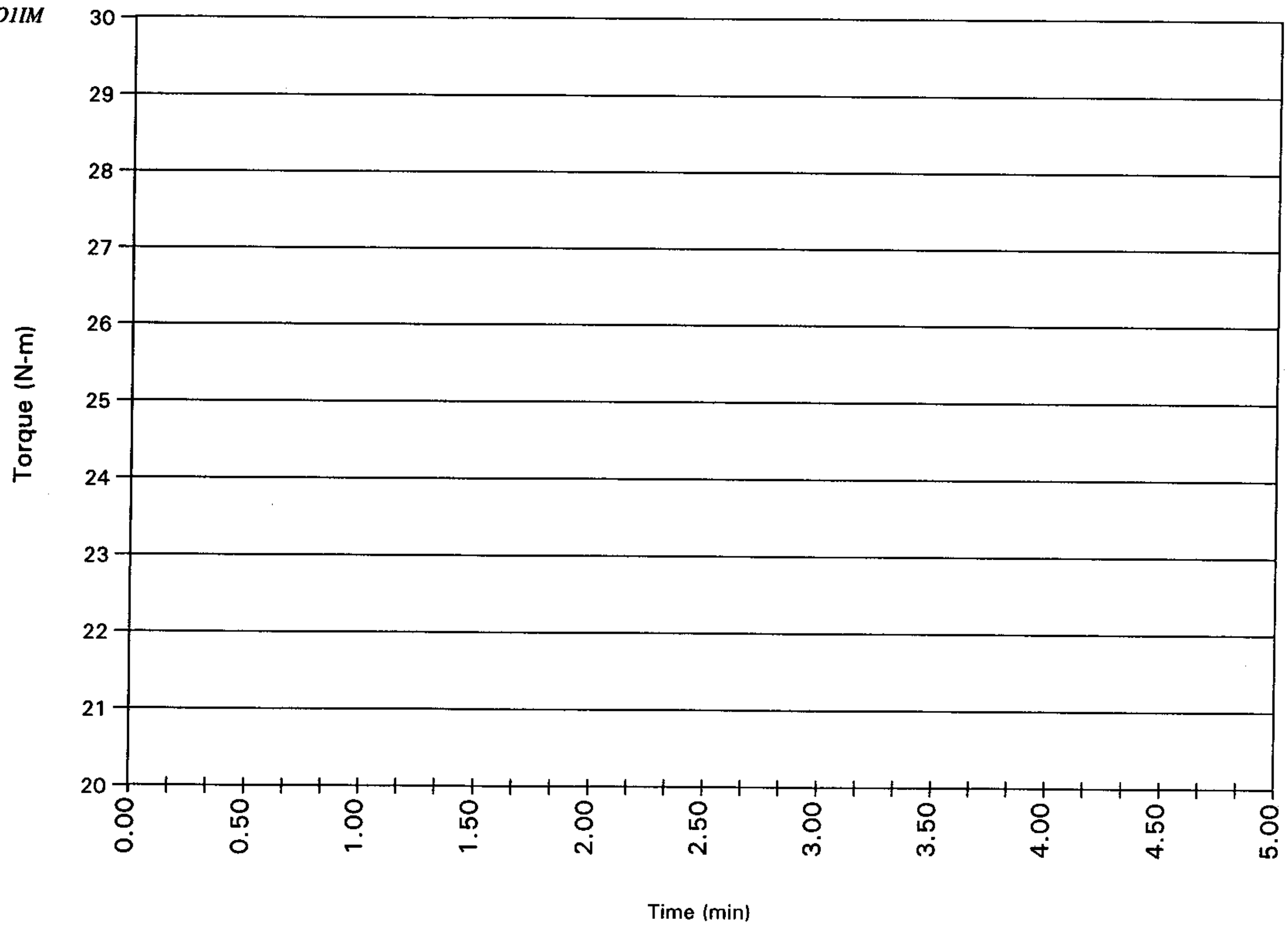
CO1TO2IM



Sequence IVA Valve Train Wear Evaluation
Form 14
Stage 2 to 1 Transition: Engine Torque
Cycle 5

Laboratory: LAB	Test Number: STAND - STRUN - LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

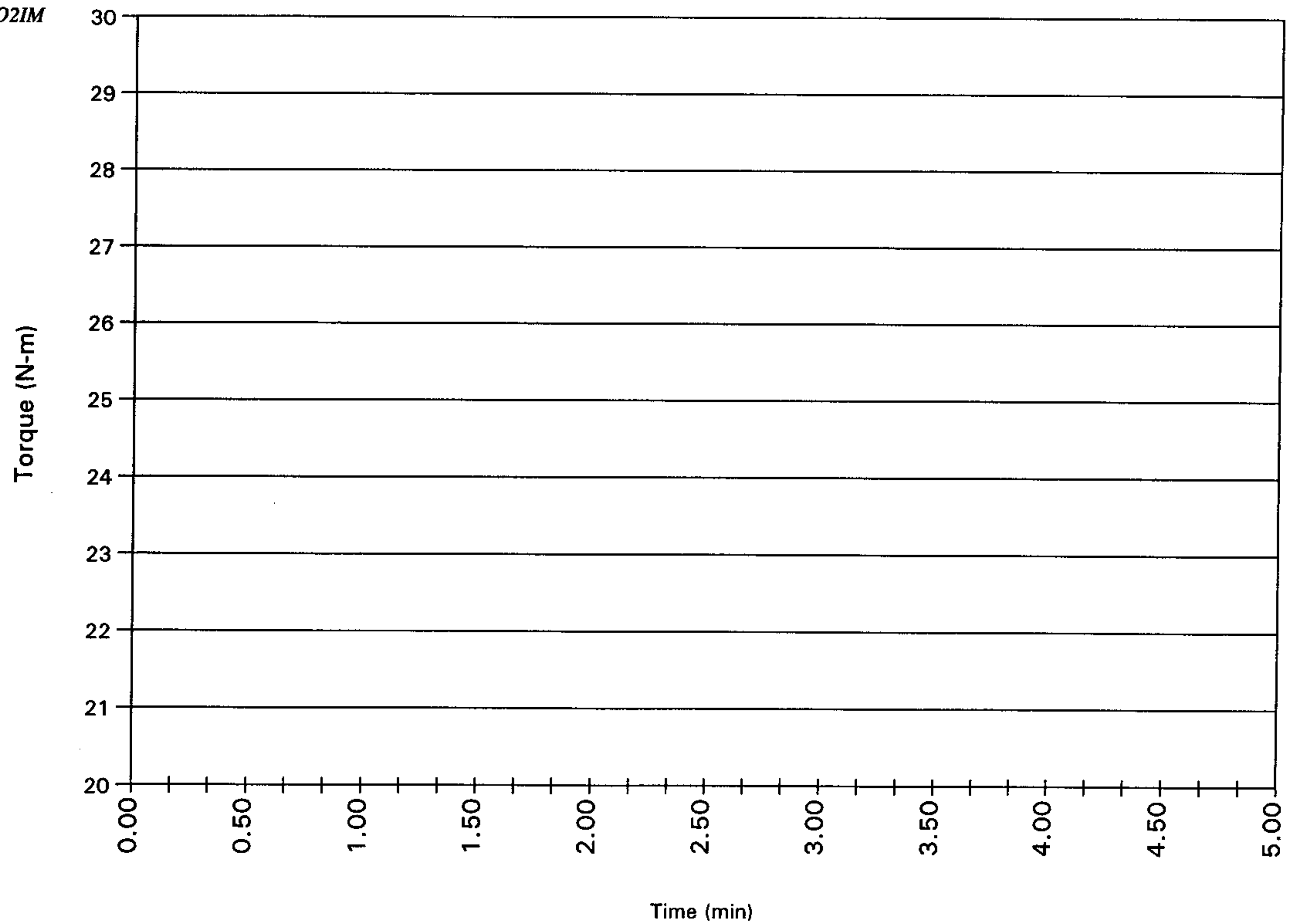
ET2TO1IM



Sequence IVA Valve Train Wear Evaluation
Form 15
Stage 1 to 2 Transition: Engine Torque
Cycle 5

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

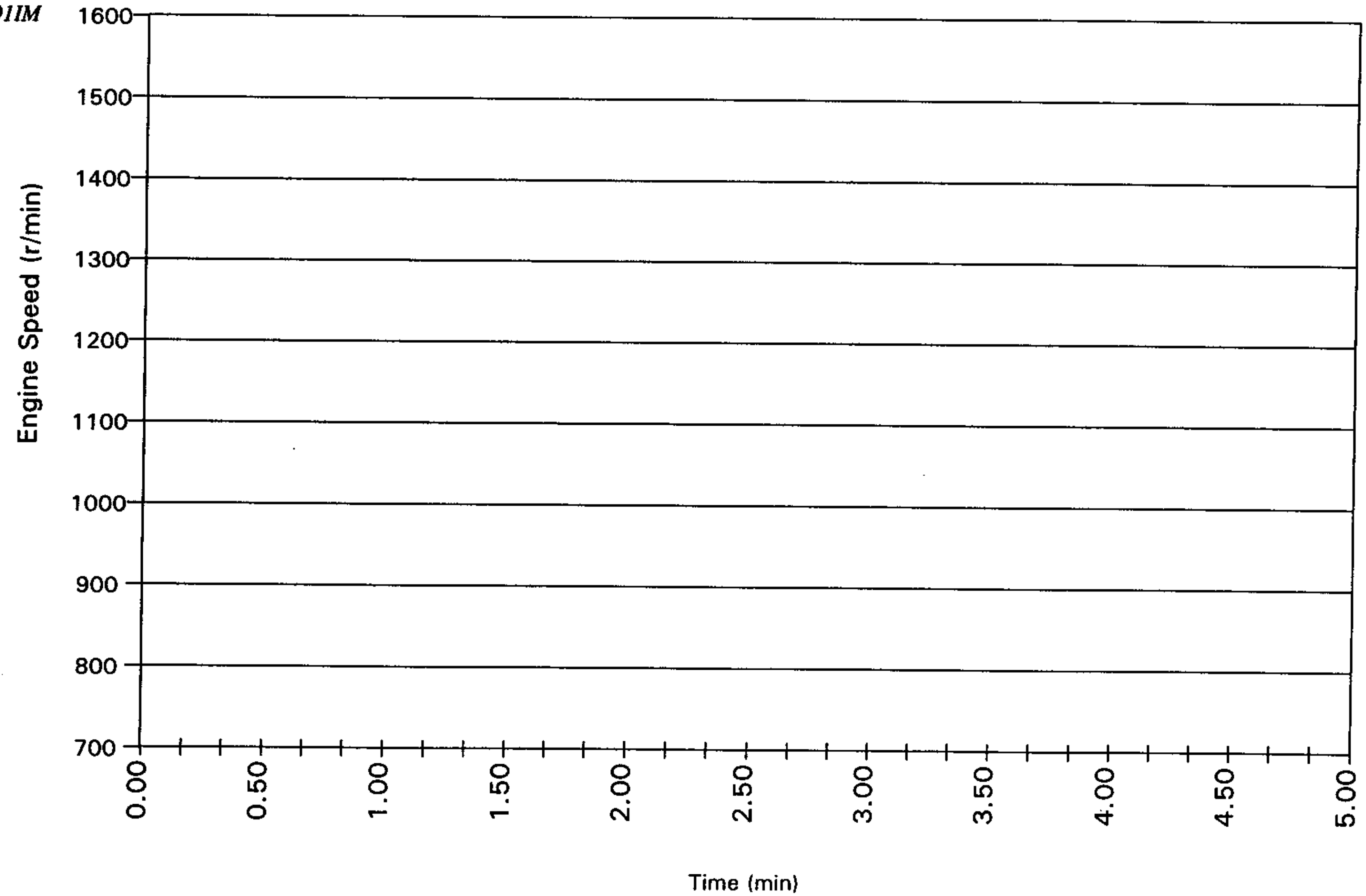
ET1TO2IM



Sequence IVA Valve Train Wear Evaluation
Form 16
Stage 2 to 1 Transition: Engine Speed
Cycle 5

Laboratory: LAB	Test Number: STAND -STRUN -LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

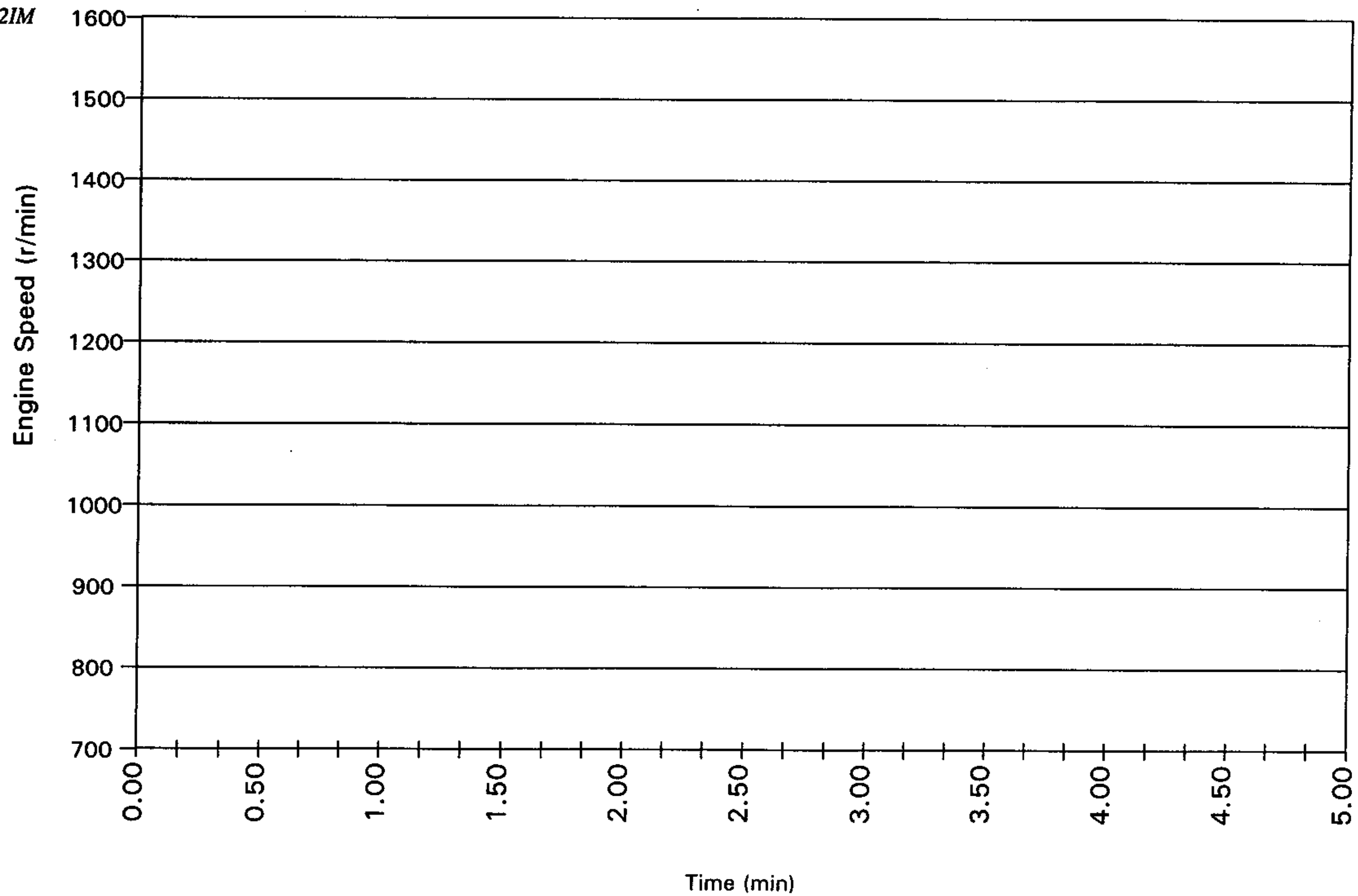
ES2TO1IM



Sequence IVA Valve Train Wear Evaluation
Form 17
Stage 1 to 2 Transition: Engine Speed
Cycle 5

Laboratory: LAB	Test Number: STAND - STRUN - LABRUN	Oil Code: OILCODE
Formulation/Stand Code: FORM		

ES1TO2IM



SEQUENCE IVA VALVE TRAIN WEAR EVALUATION
FINAL REPORT COVER SHEET

VERSION 19990716

CONDUCTED FOR

	V = VALID I = INVALID

	NR = Non-reference Oil Test RO = Reference Oil Test

Test Number					
Test Stand:	No. Tests Since Last Stand Calibration Test:		Laboratory Run Number:		
Lab Engine No.		Total Runs on Cylinder Head			
Lab Head Number		Lab Cam Number			
Date Completed		End of Test			
Oil Code		Fuel Batch			
Formulation/Stand Code					
Alternate Codes					

In my opinion this test been conducted in a valid manner in accordance with the ASTM Research Report RR-D2-XXXX and the appropriate amendments through the Information Letter system. The remarks included in the report describe the anomalies associated with this test.

SUBMITTED BY:

____
Testing Laboratory

____
Signature

____
Typed Name

____
Title

Form 2

Sequence IVA Valve Train Wear Test

Table of Contents

Sequence IVA Valve Train Wear Test

FORM 3

Summary of Test Method

The Sequence IVA engine valve train wear test is a fired engine-dynamometer lubricant test which evaluates the ability of a test lubricant to reduce camshaft lobe wear. The test method is a low temperature cyclic test, with a total running duration of 100 hours.

A 1994 Nissan model KA24E water cooled, 4 cycle, in-line cylinder, 2.389 (2.4) liter engine is used as the test apparatus. The engine incorporates a single overhead cam (SOHC), three valves per cylinder (2 intake; 1 exhaust), and sliding follower valve train design. An engine shortblock is utilized for 12 tests; a cylinder head assembly for 6 tests; and the critical test parts (camshaft, rocker arms, rocker shafts) are replaced every test. A 95 minute break-in schedule is conducted whenever the long block or cylinder head is replaced (before tests 1 and 7).

The Sequence IVA test is a flush and run type of lubricant test. Each individual test consists of two 20-minute flushes, followed by the 100-hour cyclic test. The cyclic test is comprised of 100 hourly cycles. Each cycle consists of two stages. The idle speed Stage 1 duration is 50 minutes; the 1500 r/min stage 2 operates for 10 minutes. The stages of the test cycle are set at the following conditions:

Parameter	Units	Stage 1	Stage 2
Duration	min	50	10
Engine Speed	r/min	800	1500
Engine Torque	N-m	25	25
Coolant Out Temperature	°C	50	55
Oil Gallery Temperature	°C	50	60
Intake Air Temperature	°C	32	32
Intake Air Pressure	kPa	0.050	0.050
Intake Air Humidity	g/kg	11.5	11.5
Exhaust Pressure	kPa-abs	103.5	103.5
Coolant Flow	L/min	30	30

Upon test completion, the camshaft is removed from the engine and measured for individual lobe wear at seven prescribed locations (nose; 14 degrees before and after the nose; 10 degrees before and after the nose; 4 degrees before and after the nose). For each lobe, the seven locations are summed to determine the lobe wear. Then the twelve lobes are averaged to compute the final test result.

Sequence IVA Valve Train Wear Test
Form 4
Results Summary

Laboratory:	Test Number: - -	Oil Code:
Formulation/ Stand Code:		

Laboratory Oil Code		Fuel Batch		SAE Grade	
Date Started		Date Completed		Test Length	
Time Started		Time Completed		TMC Oil Code [A]	
Lab Engine Number					
Cam Lot Number		Head Lot Number		Rocker Arm Lot Number	

Average Camshaft Wear

Original Unit Result, μm		
Transformed Result		
Industry Correction Factor		
Corrected Transformed Result		
Severity Adjustment (non-reference oil tests only)		
Final Transformed Result		
Final Original Unit Result, μm		
Additional Camshaft Lobe Wear Measurements		
Intake Lobe	Maximum, μm	
	Average, μm	
Exhaust Lobe	Maximum, μm	
	Average, μm	
Nose	Maximum, μm	
	Average, μm	

Additional Information	
Total Oil Consumption @ EOT, g	
Fuel Dilution @ EOT, %	
Fuel Consumption @ EOT, kg	
Fe by ICP @ EOT, ppm	
Corr. Blowby, L/min @ hour 5	
Corr. Blowby, L/min @ hour 100	

Most Recent Stand Reference Oil Test History [B]			
Test Number	- -		
Oilcode			
Date Completed		TMC Oil Code	
Final Average Camshaft Wear, μm			

[A] Reference Oil Tests Only

[B] Non-reference Oil Tests Only

Sequence IVA Valve Train Wear Test

Form 5

Camshaft Lobe Wear

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		

7-point measurement method

Position	Cylinder	Lobe Number	14° BTC Wear, μm	10° BTC Wear, μm	4° BTC Wear, μm	0° (Nose) Wear, μm	4° ATC Wear, μm	10° ATC Wear, μm	14° ATC Wear, μm	Lobe Wear, μm
Intake	1	1								
		3								
	2	4								
		6								
	3	7								
		9								
	4	10								
		12								
	Max. of Intake									
	Avg. of Intake									
Exhaust	1	2								
	2	5								
	3	8								
	4	11								
	Max. of Exhaust									
	Avg. of Exhaust									
Over-all Maximum										
Over-all Average										

Note: Plus direction is before top center of cam nose

Sequence IVA
Valve Train Wear Test
Form 6
Operational Summary

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		

	Parameter	Units	QI Threshold	EOT QI	Target		Average		Samples[A]	BQD[B]	Over/Under Range[C]
Controlled Paramters	Speed	r/min	0.000		800	1500					
	Torque	N-m	0.000		25.0						
	Coolant Out	°C	0.000		50.0	55.0					
	Humidity	g/kg	0.000		11.5						
	Intake Air	°C	0.000		32						
	Intake Air	kPa	0.000		0.05						
	Exhaust - abs	kPa	0.000		103.5						
	Engine Coolant	L/min	0.000		30.0						
	Oil Gallery	°C	0.000		50.0	60.0					

	Parameter	Units	Typical Values		Average	
Non-controlled Paramters	Oil Sump	°C	53.3 - 55.5	62.5 - 64.0		
	Oil Cylinder Head	°C	49 - 51	58 - 60		
	Coolant In	°C	44 - 46	49 - 50		
	Exhaust Gas	°C	306 - 332	414 - 434		
	Fuel Rail	°C	28.5 - 30.5	28.5 - 30.5		
	Oil Gallery	kPa	99.5 - 105.5	210.5 - 220.5		
	Oil Cylinder Head	kPa	30 - 50	50 - 80		
	Fuel	kPa	233 - 243	229 - 239		
	Manifold Vacuum	°C	57.7 - 59.9	63.8 - 65.8		
	Air-to-Fuel Ratio		14.1 - 14.7	14.1 - 14.7		
	Crankcase	kPa	-0.02 - -0.04	-0.02 - -0.04		
	Fuel Flow	kg/h	1.2 - 1.4	2.0 - 2.2		
	Ignition Timing	°BTDC	9 - 11	22 - 26		
	Ambient Temperature	°C	75 - 120	75 - 120		

[A] Total number of data points taken as determined from test length and sampling rate.

[B] Number of bad quality data points not used in the calculation of statistical measures.

[C] Number of points clipped by over under range limits of the statistical measures.

Sequence IVA Valve Train Wear Test

Form 7

Used Oil Analysis

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		

Chemical Analysis: 0, 25, 50, 75 & 100 Hour Engine Oil

ASTM Method	Analysis Description	Units					
D 445	Kinematic Viscosity @ 40°C	cSt		---	---	---	
D 3525-M	Fuel Dilution, Gasoline	%	---	---	---	---	
D 5185 (ICP)	Fe by ICP	ppm	---				
D 5185 (ICP)	Cu by ICP	ppm	---				

Sequence IVA Valve Train Wear Test

Form 8

Camshaft Bore/Journal Measurements

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		

Camshaft Bearing Bore Diameter (mm)

Bore Gauge Set: 33.000 mm

Diameter (Standard): 33.000 - 33.025 mm

Bore Number	X		V		Y		Maximum Run-Out	
	F	R	F	R	F	R	F	R
1								
2								
3								
4								
5								

Camshaft Bearing Journal Diameter (mm)

Diameter (Standard) 32.935 - 32.955 mm

Clearance (Limit) : 0.120 mm

Journal Number	v		h		Run-Out		Clearance @ V	
	F	R	F	R	F	R	F	R
1								
2								
3								
4								
5								

Note: Calculate camshaft bearing clearance @ vertical bore diameter measurement.

Camshaft End Play, mm	

End Play (Limit): 0.20 mm

Camshaft Sprocket Run Out, mm	

Run-Out (Limit): 0.12 mm

Camshaft Run-Out (Bend), mm	

Run-Out (Limit): 0.02 mm

Cylinder Compression (kPa)

Cylinder Number	1 (kPa)	2 (kPa)	3 (kPa)	4 (kPa)
Before Test				

Sequence IVA Valve Train Wear Test

Form 9

Special Maintenance Record

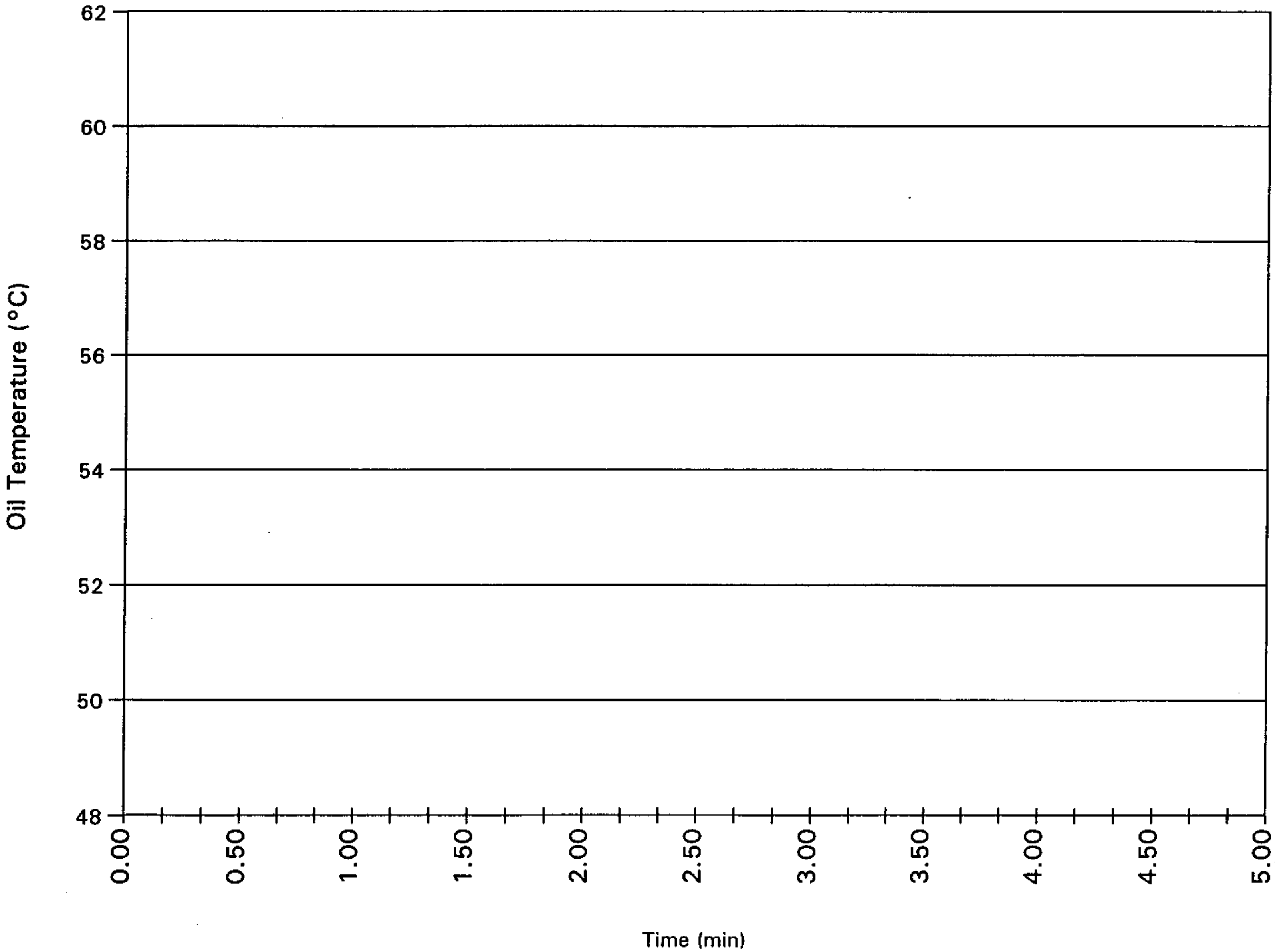
Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		

Number of Downtime Occurrences			
Test Hours	**Date**	**Downtime**	**Reasons**
			Total Downtime

Other Comments		
Number of Comment Lines		

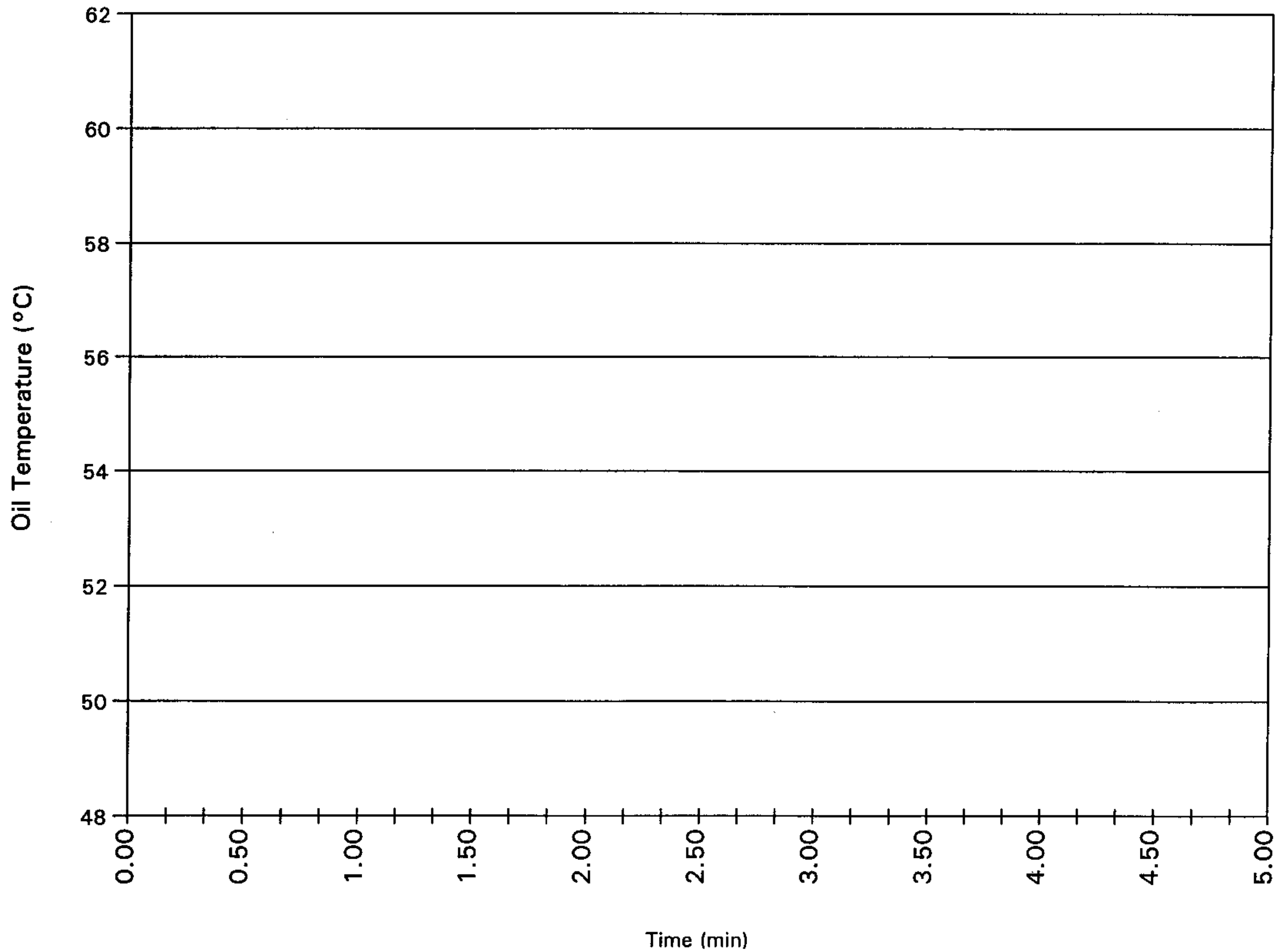
Sequence IVA Valve Train Wear Evaluation
Form 10
Stage 2 to 1 Transition: Oil Gallery Temperature
Cycle 5

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		



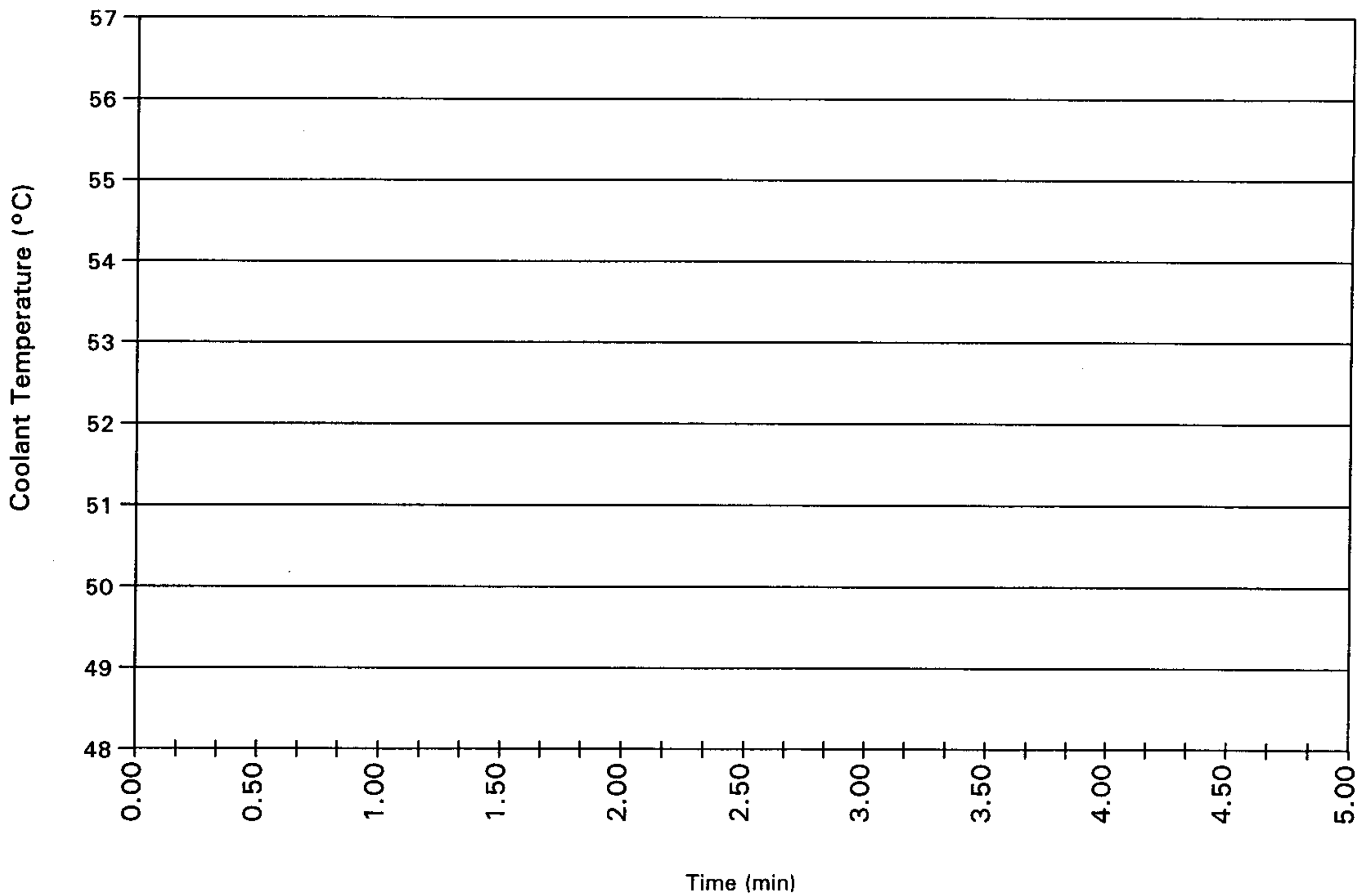
Sequence IVA Valve Train Wear Evaluation
Form 11
Stage 1 to 2 Transition: Oil Gallery Temperature
Cycle 5

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		



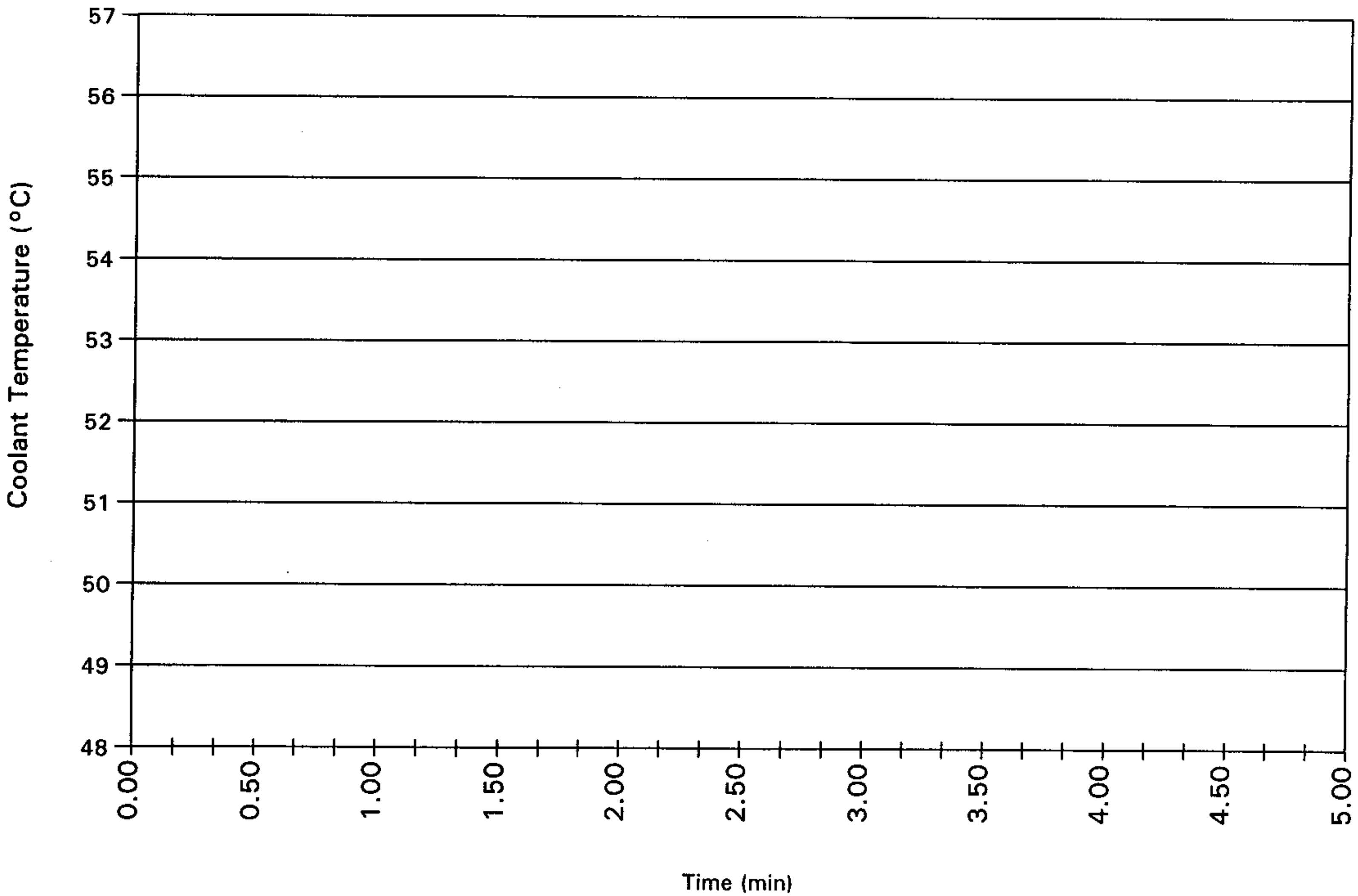
Sequence IVA Valve Train Wear Evaluation
Form 12
Stage 2 to 1 Transition: Coolant Out Temperature
Cycle 5

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		



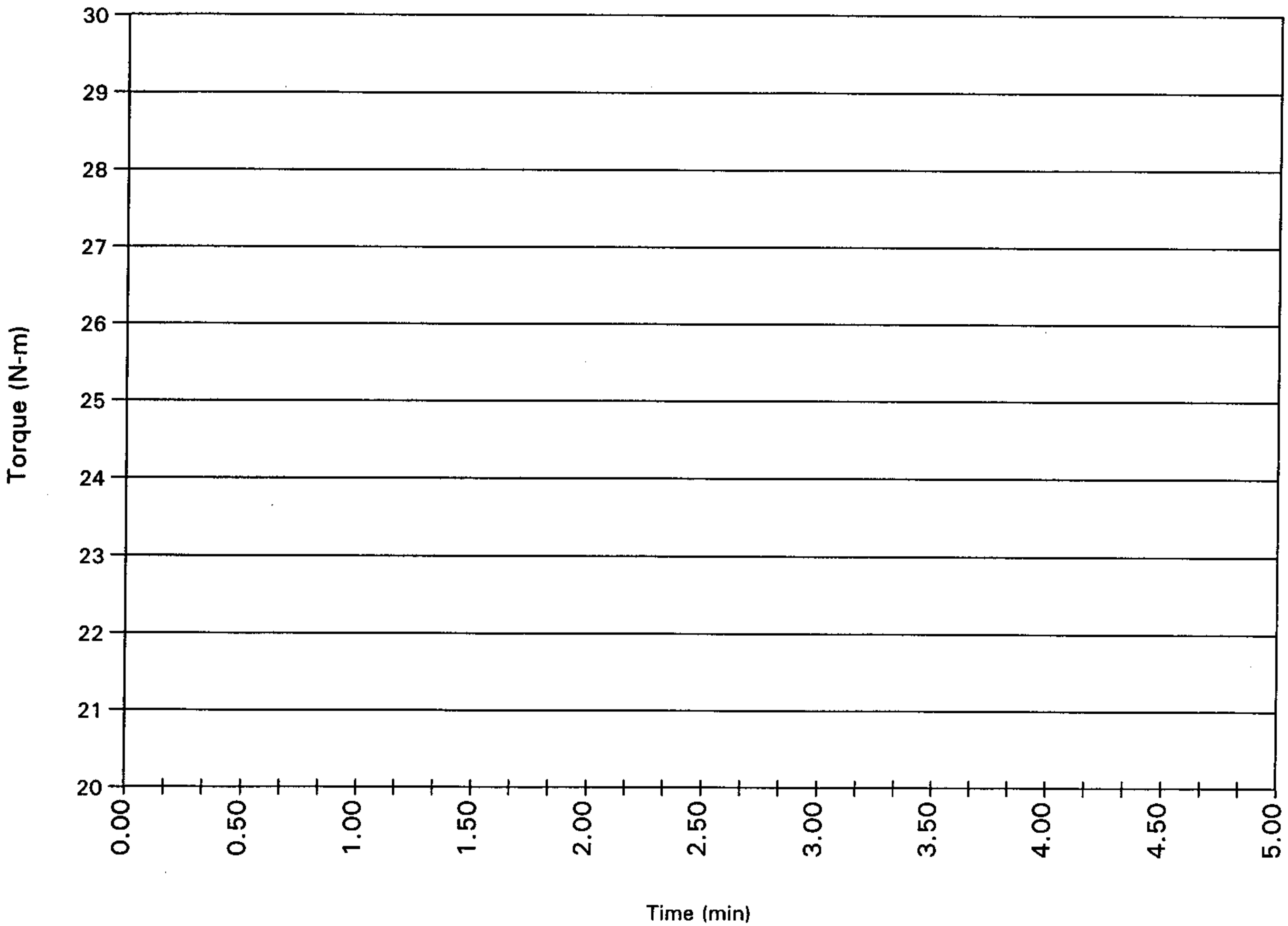
Sequence IVA Valve Train Wear Evaluation
Form 13
Stage 1 to 2 Transition: Coolant Out Temperature
Cycle 5

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		



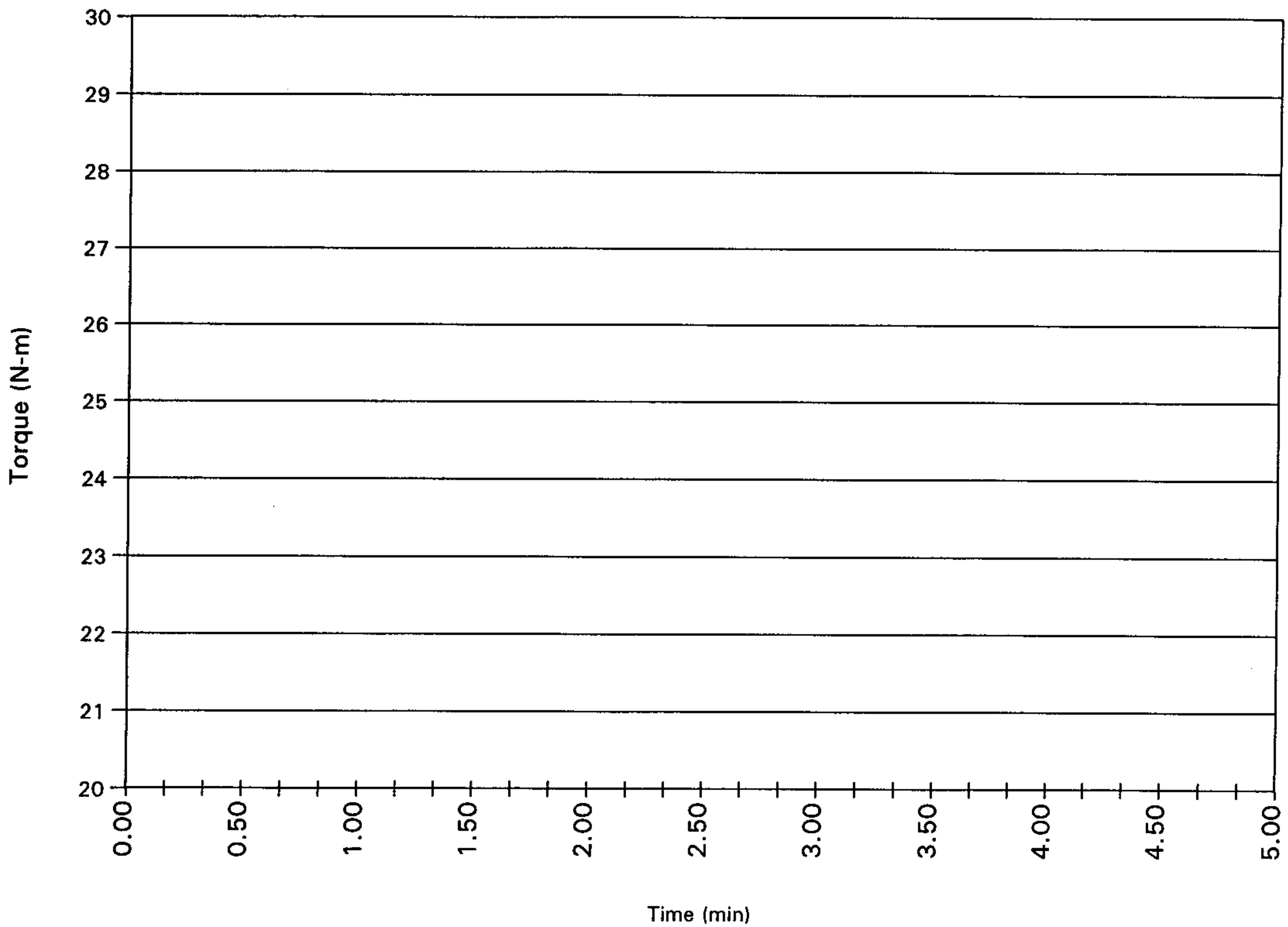
Sequence IVA Valve Train Wear Evaluation
Form 14
Stage 2 to 1 Transition: Engine Torque
Cycle 5

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		



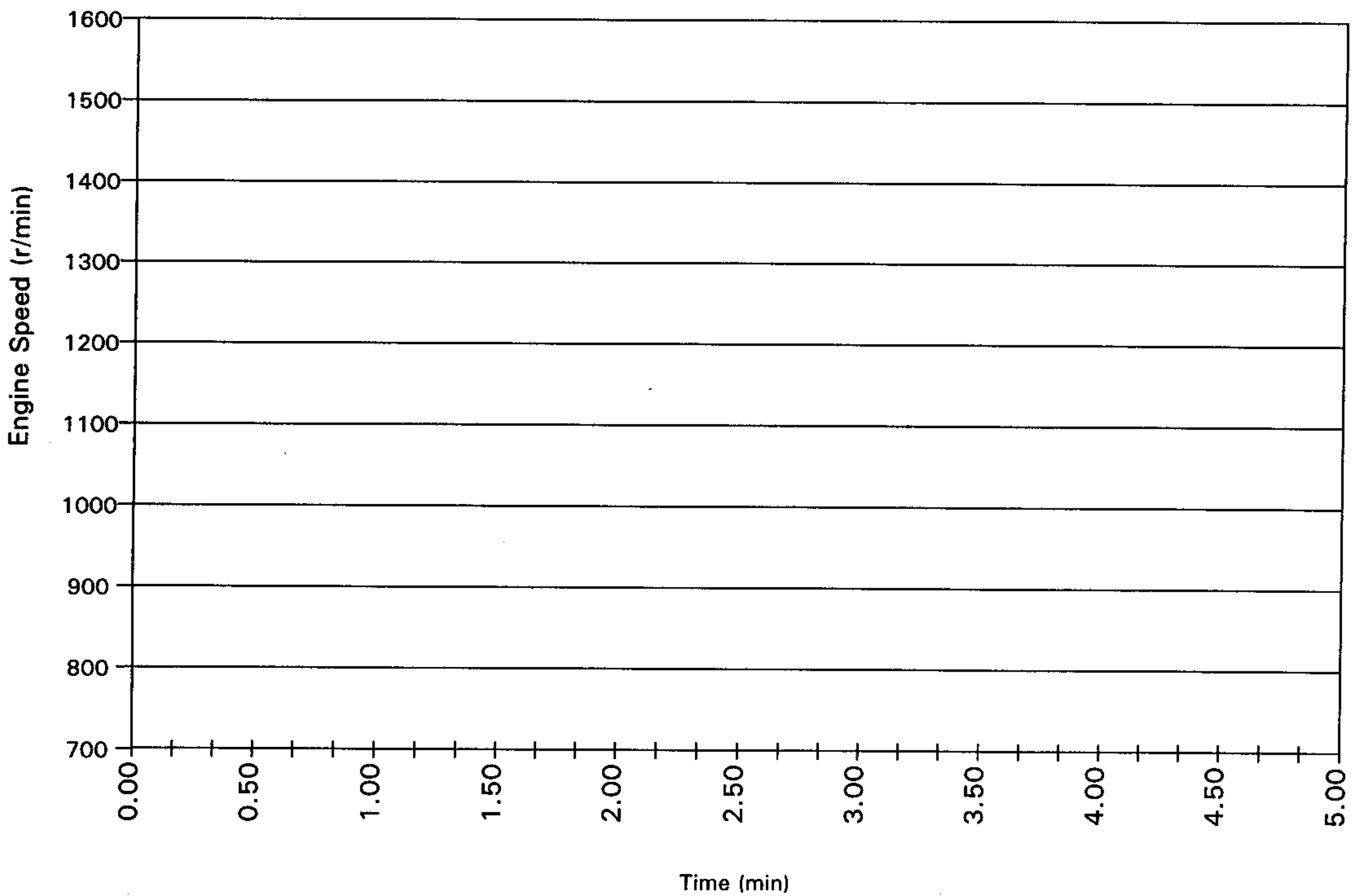
Sequence IVA Valve Train Wear Evaluation
Form 15
Stage 1 to 2 Transition: Engine Torque
Cycle 5

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		



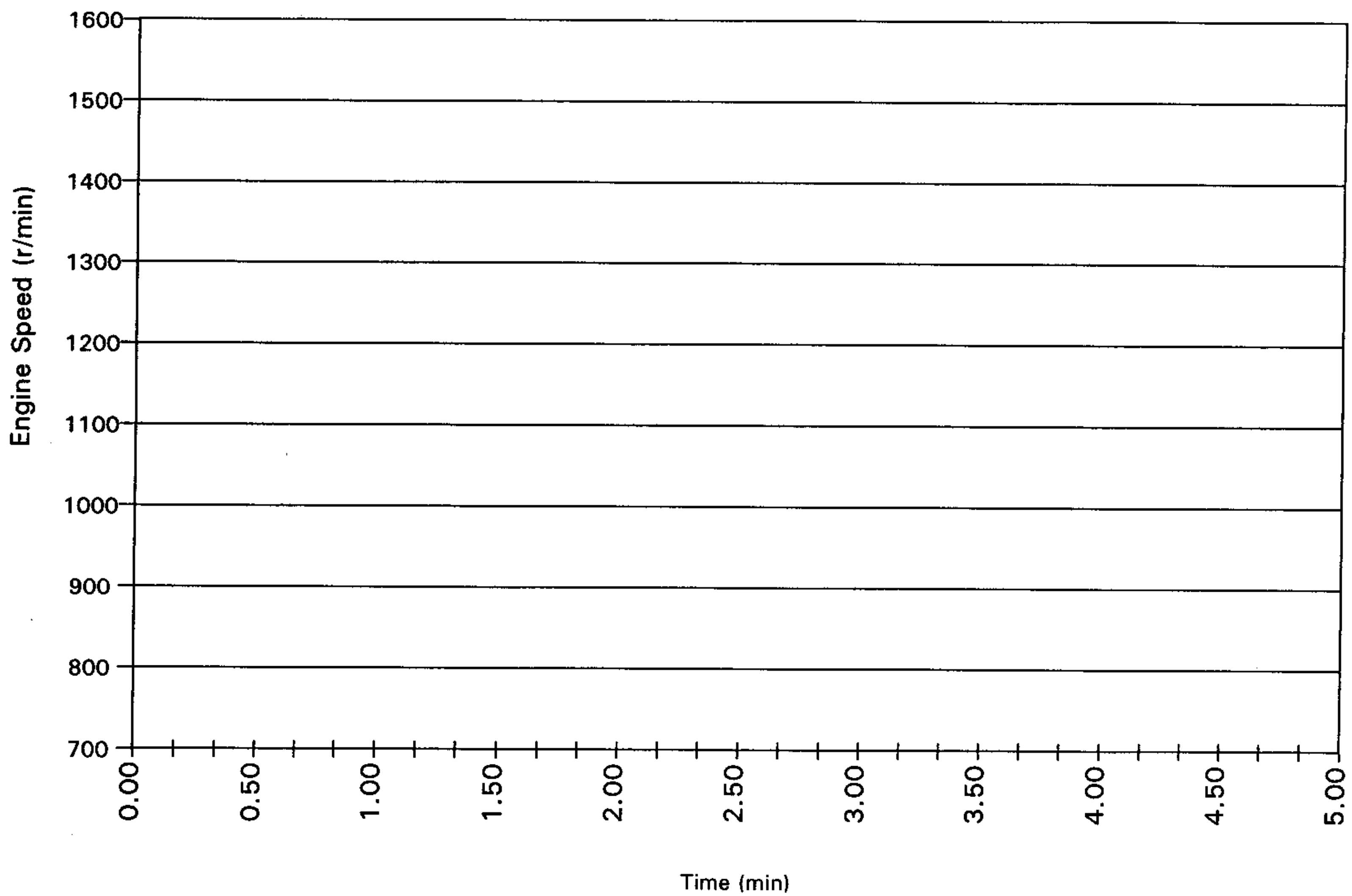
Sequence IVA Valve Train Wear Evaluation
Form 16
Stage 2 to 1 Transition: Engine Speed
Cycle 5

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		



Sequence IVA Valve Train Wear Evaluation
Form 17
Stage 1 to 2 Transition: Engine Speed
Cycle 5

Laboratory:	Test Number: - -	Oil Code:
Formulation/Stand Code:		



Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
10	1	IVA	VERSION	8	0	C	YYYYMMDD	IVA VERSION 19990716
20	1	IVA	TSTSPON1	40	0	C		CONDUCTED FOR, FIRST LINE
30	1	IVA	TSTSPON2	40	0	C		CONDUCTED FOR, SECOND LINE
40	1	IVA	LABVALID	1	0	C	V, I OR N	TEST LAB VALIDATION (V, I OR N)
50	1	IVA	TSTOIL	2	0	C	NR or RO	OIL TEST TYPE (NR or RO)
60	1	IVA	STAND	5	0	C		STAND
70	1	IVA	STRUN	4	0	C		TOTAL RUNS ON STAND
80	1	IVA	LABRUN	5	0	C		TOTAL NUMBER OF LAB RUNS
90	1	IVA	ENGINE	20	0	C		LAB ENGINE NUMBER
100	1	IVA	TOTHDRUN	5	0	C		TOTAL RUNS ON CYLINDER HEAD
110	1	IVA	HEADSN	20	0	C		LAB HEAD NUMBER
120	1	IVA	CAMNO	20	0	C		LAB CAM NUMBER
130	1	IVA	DTCOMP	8	0	C	YYYYMMDD	DATE COMPLETED (YYYYMMDD)
140	1	IVA	EOTTIME	5	0	C	HH:MM	TIME COMPLETED (HH:MM)
150	1	IVA	OILCODE	38	0	C		TEST OIL CODE
160	1	IVA	FUELBTID	8	0	C	YYMMnnn	FUEL BATCH IDENTIFIER (YYMMnnn)
170	1	IVA	FORM	38	0	C		FORMULATION/STAND CODE
180	1	IVA	ALTCODE1	10	0	C		ALTERNATE OIL CODE 1
190	1	IVA	ALTCODE2	10	0	C		ALTERNATE OIL CODE 2
200	1	IVA	ALTCODE3	10	0	C		ALTERNATE OIL CODE 3
210	1	IVA	OPVALID	8	0	C	HAS/HAS NOT	OPERATIONAL VALIDITY STATEMENT (HAS/HAS NOT)
220	1	IVA	SUBLAB	40	0	C		SUBMITTED BY: TESTING LABORATORY
230	1	IVA	SUBSIGIM	70	0	C		SUBMITTED BY: SIGNATURE IMAGE
240	1	IVA	SUBNAME	40	0	C		SUBMITTED BY: SIGNATURE TYPED NAME
250	1	IVA	SUBTITLE	40	0	C		SUBMITTED BY: TITLE
260	4	IVA	LAB	2	0	C		LAB CODE
270	4	IVA	LABOCODE	12	0	C		LABORATORY INTERNAL OIL CODE
280	4	IVA	SAEVISC	7	0	C		SAE VISCOSITY GRADE
290	4	IVA	DTSTRT	8	0	C	YYYYMMDD	START DATE (YYYYMMDD)
300	4	IVA	TESTLEN	3	0	Z	HHH	TEST LENGTH (HHH)
310	4	IVA	STRTTIME	5	0	C	HH:MM	START TIME (HH:MM)
320	4	IVA	IND	6	0	C		TMC OIL CODE
330	4	IVA	CAMLOT	6	0	C	YYMMDD	CAM LOT NUMBER (YYMMDD)
340	4	IVA	HEADLOT	6	0	C	YYMMDD	HEAD LOT NUMBER (YYMMDD)
350	4	IVA	RARMLOT	6	0	C	YYMMDD	ROCKER ARM LOT NUMBER (YYMMDD)
360	4	IVA	ACW	8	2	N	micrometre	AVERAGE CAM WEAR ORIGINAL UNIT RESULT (micrometre)
370	4	IVA	TACW	8	2	N	TRANS UNITS	AVERAGE CAM WEAR TRANSFORMED RESULT (TRANS UNITS)
380	4	IVA	ACWCF	7	3	N		AVERAGE CAM WEAR INDUSTRY CORRECTION FACTOR
390	4	IVA	ACWCOR	7	3	N		AVERAGE CAM WEAR CORRECTED TRANSFORMED RESULT
400	4	IVA	ACWSA	7	3	N		AVERAGE CAM WEAR SEVERITY ADJUSTMENT
410	4	IVA	TACWFNL	8	2	N	TRANS UNITS	AVERAGE CAM WEAR FINAL TRANSFORMED RESULT (TRANS UNITS)
420	4	IVA	ACWFNL	7	2	N	micrometre	AVERAGE CAM WEAR FINAL ORIGINAL UNIT RESULT (micrometre)
430	4	IVA	MCWI	7	2	N	micrometre	CAMSHAFT INTAKE LOBE WEAR MAXIMUM (micrometre)
440	4	IVA	ACWI	7	2	N	micrometre	CAMSHAFT INTAKE LOBE WEAR AVERAGE (micrometre)
450	4	IVA	MCWE	7	2	N	micrometre	CAMSHAFT EXHAUST LOBE WEAR MAXIMUM (micrometre)
460	4	IVA	ACWE	7	2	N	micrometre	CAMSHAFT EXHAUST LOBE WEAR AVERAGE (micrometre)
470	4	IVA	MNW	7	2	N	micrometre	CAMSHAFT NOSE WEAR MAXIMUM (micrometre)
480	4	IVA	ANW	7	2	N	micrometre	CAMSHAFT NOSE WEAR AVERAGE (micrometre)
490	4	IVA	OILCON	7	0	N	g	TOTAL OIL CONSUMPTION @ EOT (g)
500	4	IVA	FUELHxxx	7	2	N	%	D3525-M FUEL DILUTION HOUR XXX (%)
510	4	IVA	FUELCON	7	2	N	kg	FUEL CONSUMPTION @ EOT (kg)
520	4	IVA	FEWMHxxx	6	0	A	ppm	D5185 FE BY ICP HOUR XXX [<] (ppm)
530	4	IVA	BLWBHxxx	8	2	N	L/min	CORRECTED BLOW-BY @ HR XXX (L/min)

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
540	4	IVA	RSTAND	5	0	C		MOST RECENT STAND REFERENCE STAND
550	4	IVA	RSTRUN	4	0	C		MOST RECENT STAND REFERENCE TOTAL RUNS ON STAND
560	4	IVA	RLABRUN	5	0	C		MOST RECENT STAND REFERENCE TOTAL NUMBER OF LAB RUNS
570	4	IVA	ROILCODE	38	0	C		MOST RECENT STAND REFERNECE TEST OIL CODE
580	4	IVA	RDTCOMP	8	0	C	YYYYMMDD	MOST RECENT STAND REFERENCE DATE COMPLETED (YYYYMMDD)
590	4	IVA	RIND	6	0	C		MOST RECENT STAND REFERENCE TMC OIL CODE
600	4	IVA	RACWFNL	7	2	N	micrometre	MOST RECENT STAND REFERNCE AVG CAM WEAR FNL RES (micrometre)
610	5	IVA	W14B01	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 1, 14 ¯ BTC WEAR (micrometre)
620	5	IVA	W10B01	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 1, 10 ¯ BTC WEAR (micrometre)
630	5	IVA	W04B01	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 1, 4 ¯ BTC WEAR (micrometre)
640	5	IVA	WN01	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 1, 0 ¯ (micrometre)
650	5	IVA	W04A01	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 1, 4 ¯ ATC WEAR (micrometre)
660	5	IVA	W10A01	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 1, 10 ¯ ATC WEAR (micrometre)
670	5	IVA	W14A01	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 1, 14 ¯ ATC WEAR (micrometre)
680	5	IVA	CAMW01	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 1, LOBE WEAR (micrometre)
690	5	IVA	W14B03	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 3, 14 ¯ BTC WEAR (micrometre)
700	5	IVA	W10B03	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 3, 10 ¯ BTC WEAR (micrometre)
710	5	IVA	W04B03	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 3, 4 ¯ BTC WEAR (micrometre)
720	5	IVA	WN03	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 3, 0 ¯ (micrometre)
730	5	IVA	W04A03	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 3, 4 ¯ ATC WEAR (micrometre)
740	5	IVA	W10A03	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 3, 10 ¯ ATC WEAR (micrometre)
750	5	IVA	W14A03	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 3, 14 ¯ ATC WEAR (micrometre)
760	5	IVA	CAMW03	7	2	N	micrometre	INTAKE CYLINDER 1 LOBE 3, LOBE WEAR (micrometre)
770	5	IVA	W14B04	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 4, 14 ¯ BTC WEAR (micrometre)
780	5	IVA	W10B04	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 4, 10 ¯ BTC WEAR (micrometre)
790	5	IVA	W04B04	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 4, 4 ¯ BTC WEAR (micrometre)
800	5	IVA	WN04	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 4, 0 ¯ (micrometre)
810	5	IVA	W04A04	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 4, 4 ¯ ATC WEAR (micrometre)
820	5	IVA	W10A04	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 4, 10 ¯ ATC WEAR (micrometre)
830	5	IVA	W14A04	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 4, 14 ¯ ATC WEAR (micrometre)
840	5	IVA	CAMW04	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 4, LOBE WEAR (micrometre)
850	5	IVA	W14B06	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 6, 14 ¯ BTC WEAR (micrometre)
860	5	IVA	W10B06	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 6, 10 ¯ BTC WEAR (micrometre)
870	5	IVA	W04B06	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 6, 4 ¯ BTC WEAR (micrometre)
880	5	IVA	WN06	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 6, 0 ¯ (micrometre)
890	5	IVA	W04A06	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 6, 4 ¯ ATC WEAR (micrometre)
900	5	IVA	W10A06	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 6, 10 ¯ ATC WEAR (micrometre)
910	5	IVA	W14A06	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 6, 14 ¯ ATC WEAR (micrometre)
920	5	IVA	CAMW06	7	2	N	micrometre	INTAKE CYLINDER 2 LOBE 6, LOBE WEAR (micrometre)
930	5	IVA	W14B07	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 7, 14 ¯ BTC WEAR (micrometre)
940	5	IVA	W10B07	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 7, 10 ¯ BTC WEAR (micrometre)
950	5	IVA	W04B07	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 7, 4 ¯ BTC WEAR (micrometre)
960	5	IVA	WN07	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 7, 0 ¯ (micrometre)
970	5	IVA	W04A07	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 7, 4 ¯ ATC WEAR (micrometre)
980	5	IVA	W10A07	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 7, 10 ¯ ATC WEAR (micrometre)
990	5	IVA	W14A07	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 7, 14 ¯ ATC WEAR (micrometre)
1000	5	IVA	CAMW07	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 7, LOBE WEAR (micrometre)
1010	5	IVA	W14B09	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 9, 14 ¯ BTC WEAR (micrometre)
1020	5	IVA	W10B09	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 9, 10 ¯ BTC WEAR (micrometre)
1030	5	IVA	W04B09	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 9, 4 ¯ BTC WEAR (micrometre)
1040	5	IVA	WN09	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 9, 0 ¯ (micrometre)
1050	5	IVA	W04A09	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 9, 4 ¯ ATC WEAR (micrometre)
1060	5	IVA	W10A09	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 9, 10 ¯ ATC WEAR (micrometre)
1070	5	IVA	W14A09	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 9, 14 ¯ ATC WEAR (micrometre)

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1080	5	IVA	CAMW09	7	2	N	micrometre	INTAKE CYLINDER 3 LOBE 9, LOBE WEAR (micrometre)
1090	5	IVA	W14B10	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 10, 14 ¯ BTC WEAR (micrometre)
1100	5	IVA	W10B10	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 10, 10 ¯ BTC WEAR (micrometre)
1110	5	IVA	W04B10	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 10, 4 ¯ BTC WEAR (micrometre)
1120	5	IVA	WN10	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 10, 0 ¯ (micrometre)
1130	5	IVA	W04A10	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 10, 4 ¯ ATC WEAR (micrometre)
1140	5	IVA	W10A10	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 10, 10 ¯ ATC WEAR (micrometre)
1150	5	IVA	W14A10	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 10, 14 ¯ ATC WEAR (micrometre)
1160	5	IVA	CAMW10	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 10, LOBE WEAR (micrometre)
1170	5	IVA	W14B12	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 12, 14 ¯ BTC WEAR (micrometre)
1180	5	IVA	W10B12	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 12, 10 ¯ BTC WEAR (micrometre)
1190	5	IVA	W04B12	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 12, 4 ¯ BTC WEAR (micrometre)
1200	5	IVA	WN12	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 12, 0 ¯ (micrometre)
1210	5	IVA	W04A12	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 12, 4 ¯ ATC WEAR (micrometre)
1220	5	IVA	W10A12	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 12, 10 ¯ ATC WEAR (micrometre)
1230	5	IVA	W14A12	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 12, 14 ¯ ATC WEAR (micrometre)
1240	5	IVA	CAMW12	7	2	N	micrometre	INTAKE CYLINDER 4 LOBE 12, LOBE WEAR (micrometre)
1250	5	IVA	MW14BI	7	2	N	micrometre	MAXIMUM INTAKE, 14 ¯ BTC WEAR (micrometre)
1260	5	IVA	MW10BI	7	2	N	micrometre	MAXIMUM INTAKE, 10 ¯ BTC WEAR (micrometre)
1270	5	IVA	MW04BI	7	2	N	micrometre	MAXIMUM INTAKE, 4 ¯ BTC WEAR (micrometre)
1280	5	IVA	MWNI	7	2	N	micrometre	MAXIMUM INTAKE, 0 ¯ WEAR (micrometre)
1290	5	IVA	MW04AI	7	2	N	micrometre	MAXIMUM INTAKE, 4 ¯ ATC WEAR (micrometre)
1300	5	IVA	MW10AI	7	2	N	micrometre	MAXIMUM INTAKE, 10 ¯ ATC WEAR (micrometre)
1310	5	IVA	MW14AI	7	2	N	micrometre	MAXIMUM INTAKE, 14 ¯ ATC WEAR (micrometre)
1320	5	IVA	AW14BI	7	2	N	micrometre	AVERAGE INTAKE, 14 ¯ BTC WEAR (micrometre)
1330	5	IVA	AW10BI	7	2	N	micrometre	AVERAGE INTAKE, 10 ¯ BTC WEAR (micrometre)
1340	5	IVA	AW04BI	7	2	N	micrometre	AVERAGE INTAKE, 4 ¯ BTC WEAR (micrometre)
1350	5	IVA	AWNI	7	2	N	micrometre	AVERAGE INTAKE, 0 ¯ WEAR (micrometre)
1360	5	IVA	AW04AI	7	2	N	micrometre	AVERAGE INTAKE, 4 ¯ ATC WEAR (micrometre)
1370	5	IVA	AW10AI	7	2	N	micrometre	AVERAGE INTAKE, 10 ¯ ATC WEAR (micrometre)
1380	5	IVA	AW14AI	7	2	N	micrometre	AVERAGE INTAKE, 14 ¯ ATC WEAR (micrometre)
1390	5	IVA	W14B02	7	2	N	micrometre	EXHAUST CYLINDER 1 LOBE 2, 14 ¯ BTC WEAR (micrometre)
1400	5	IVA	W10B02	7	2	N	micrometre	EXHAUST CYLINDER 1 LOBE 2, 10 ¯ BTC WEAR (micrometre)
1410	5	IVA	W04B02	7	2	N	micrometre	EXHAUST CYLINDER 1 LOBE 2, 4 DEGS BTC WEAR (micrometre)
1420	5	IVA	WN02	7	2	N	micrometre	EXHAUST CYLINDER 1 LOBE 2, 0 ¯ (micrometre)
1430	5	IVA	W04A02	7	2	N	micrometre	EXHAUST CYLINDER 1 LOBE 2, 4 ¯ ATC WEAR (micrometre)
1440	5	IVA	W10A02	7	2	N	micrometre	EXHAUST CYLINDER 1 LOBE 2, 10 ¯ ATC WEAR (micrometre)
1450	5	IVA	W14A02	7	2	N	micrometre	EXHAUST CYLINDER 1 LOBE 2, 14 ¯ ATC WEAR (micrometre)
1460	5	IVA	CAMW02	7	2	N	micrometre	EXHAUST CYLINDER 1 LOBE 2, LOBE WEAR (micrometre)
1470	5	IVA	W14B05	7	2	N	micrometre	EXHAUST CYLINDER 2 LOBE 5, 14 ¯ BTC WEAR (micrometre)
1480	5	IVA	W10B05	7	2	N	micrometre	EXHAUST CYLINDER 2 LOBE 5, 10 ¯ BTC WEAR (micrometre)
1490	5	IVA	W04B05	7	2	N	micrometre	EXHAUST CYLINDER 2 LOBE 5, 4 ¯ BTC WEAR (micrometre)
1500	5	IVA	WN05	7	2	N	micrometre	EXHAUST CYLINDER 2 LOBE 5, 0 ¯ (micrometre)
1510	5	IVA	W04A05	7	2	N	micrometre	EXHAUST CYLINDER 2 LOBE 5, 4 ¯ ATC WEAR (micrometre)
1520	5	IVA	W10A05	7	2	N	micrometre	EXHAUST CYLINDER 2 LOBE 5, 10 ¯ ATC WEAR (micrometre)
1530	5	IVA	W14A05	7	2	N	micrometre	EXHAUST CYLINDER 2 LOBE 5, 14 ¯ ATC WEAR (micrometre)
1540	5	IVA	CAMW05	7	2	N	micrometre	EXHAUST CYLINDER 2 LOBE 5, LOBE WEAR (micrometre)
1550	5	IVA	W14B08	7	2	N	micrometre	EXHAUST CYLINDER 3 LOBE 8, 14 ¯ BTC WEAR (micrometre)
1560	5	IVA	W10B08	7	2	N	micrometre	EXHAUST CYLINDER 3 LOBE 8, 10 ¯ BTC WEAR (micrometre)
1570	5	IVA	W04B08	7	2	N	micrometre	EXHAUST CYLINDER 3 LOBE 8, 4 ¯ BTC WEAR (micrometre)
1580	5	IVA	WN08	7	2	N	micrometre	EXHAUST CYLINDER 3 LOBE 8, 0 ¯ (micrometre)
1590	5	IVA	W04A08	7	2	N	micrometre	EXHAUST CYLINDER 3 LOBE 8, 4 ¯ ATC WEAR (micrometre)
1600	5	IVA	W10A08	7	2	N	micrometre	EXHAUST CYLINDER 3 LOBE 8, 10 ¯ ATC WEAR (micrometre)
1610	5	IVA	W14A08	7	2	N	micrometre	EXHAUST CYLINDER 3 LOBE 8, 14 ¯ ATC WEAR (micrometre)

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1620	5	IVA	CAMW08	7	2	N	micrometre	EXHAUST CYLINDER 3 LOBE 8, LOBE WEAR (micrometre)
1630	5	IVA	W14B11	7	2	N	micrometre	EXHAUST CYLINDER 4 LOBE 11, 14 ¯ BTC WEAR (micrometre)
1640	5	IVA	W10B11	7	2	N	micrometre	EXHAUST CYLINDER 4 LOBE 11, 10 ¯ BTC WEAR (micrometre)
1650	5	IVA	W04B11	7	2	N	micrometre	EXHAUST CYLINDER 4 LOBE 11, 4 ¯ BTC WEAR (micrometre)
1660	5	IVA	WN11	7	2	N	micrometre	EXHAUST CYLINDER 4 LOBE 11, 0 ¯ (micrometre)
1670	5	IVA	W04A11	7	2	N	micrometre	EXHAUST CYLINDER 4 LOBE 11, 4 ¯ ATC WEAR (micrometre)
1680	5	IVA	W10A11	7	2	N	micrometre	EXHAUST CYLINDER 4 LOBE 11, 10 ¯ ATC WEAR (micrometre)
1690	5	IVA	W14A11	7	2	N	micrometre	EXHAUST CYLINDER 4 LOBE 11, 14 ¯ ATC WEAR (micrometre)
1700	5	IVA	CAMW11	7	2	N	micrometre	EXHAUST CYLINDER 4 LOBE 11, LOBE WEAR (micrometre)
1710	5	IVA	MW14BE	7	2	N	micrometre	MAXIMUM OF EXHAUST, 14 ¯ BTC WEAR (micrometre)
1720	5	IVA	MW10BE	7	2	N	micrometre	MAXIMUM OF EXHAUST, 10 ¯ BTC WEAR (micrometre)
1730	5	IVA	MW04BE	7	2	N	micrometre	MAXIMUM OF EXHAUST, 4 ¯ BTC WEAR (micrometre)
1740	5	IVA	MWNE	7	2	N	micrometre	MAXIMUM OF EXHAUST, 0 ¯ WEAR (micrometre)
1750	5	IVA	MW04AE	7	2	N	micrometre	MAXIMUM OF EXHAUST, 4 ¯ ATC WEAR (micrometre)
1760	5	IVA	MW10AE	7	2	N	micrometre	MAXIMUM OF EXHAUST, 10 ¯ ATC WEAR (micrometre)
1770	5	IVA	MW14AE	7	2	N	micrometre	MAXIMUM OF EXHAUST, 14 ¯ ATC WEAR (micrometre)
1780	5	IVA	AW14BE	7	2	N	micrometre	AVERAGE EXHAUST, 14 ¯ BTC WEAR (micrometre)
1790	5	IVA	AW10BE	7	2	N	micrometre	AVERAGE EXHAUST, 10 ¯ BTC WEAR (micrometre)
1800	5	IVA	AW04BE	7	2	N	micrometre	AVERAGE EXHAUST, 4 ¯ BTC WEAR (micrometre)
1810	5	IVA	AWNE	7	2	N	micrometre	AVERAGE EXHAUST, 0 ¯ WEAR (micrometre)
1820	5	IVA	AW04AE	7	2	N	micrometre	AVERAGE EXHAUST, 4 ¯ ATC WEAR (micrometre)
1830	5	IVA	AW10AE	7	2	N	micrometre	AVERAGE EXHAUST, 10 ¯ ATC WEAR (micrometre)
1840	5	IVA	AW14AE	7	2	N	micrometre	AVERAGE EXHAUST, 14 ¯ ATC WEAR (micrometre)
1850	5	IVA	MW14B	7	2	N	micrometre	OVERALL MAXIMUM, 14 ¯ BTC WEAR (micrometre)
1860	5	IVA	MW10B	7	2	N	micrometre	OVERALL MAXIMUM, 10 ¯ BTC WEAR (micrometre)
1870	5	IVA	MW04B	7	2	N	micrometre	OVERALL MAXIMUM, 4 ¯ BTC WEAR (micrometre)
1880	5	IVA	MW04A	7	2	N	micrometre	OVERALL MAXIMUM, 4 ¯ ATC WEAR (micrometre)
1890	5	IVA	MW10A	7	2	N	micrometre	OVERALL MAXIMUM, 10 ¯ ATC WEAR (micrometre)
1900	5	IVA	MW14A	7	2	N	micrometre	OVERALL MAXIMUM, 14 ¯ ATC WEAR (micrometre)
1910	5	IVA	MCW	7	2	N	micrometre	OVERALL MAXIMUM, 0 ¯ WEAR (micrometre)
1920	5	IVA	AW14B	7	2	N	micrometre	OVERALL AVERAGE, 14 ¯ BTC WEAR (micrometre)
1930	5	IVA	AW10B	7	2	N	micrometre	OVERALL AVERAGE, 10 ¯ BTC WEAR (micrometre)
1940	5	IVA	AW04B	7	2	N	micrometre	OVERALL AVERAGE, 4 ¯ BTC WEAR (micrometre)
1950	5	IVA	AW04A	7	2	N	micrometre	OVERALL AVERAGE, 4 ¯ ATC WEAR (micrometre)
1960	5	IVA	AW10A	7	2	N	micrometre	OVERALL AVERAGE, 10 ¯ ATC WEAR (micrometre)
1970	5	IVA	AW14A	7	2	N	micrometre	OVERALL AVERAGE, 14 ¯ ATC WEAR (micrometre)
1980	6	IVA	QRPM	7	2	N		ENGINE SPEED QUALITY INDEX
1990	6	IVA	ARPM1	8	2	N	r/min	AVG ENGINE SPEED STAGE 1 (r/min)
2000	6	IVA	ARPM2	8	2	N	r/min	AVG ENGINE SPEED STAGE 2 (r/min)
2010	6	IVA	NRPM	8	0	N		ENGINE SPEED NUMBER OF SAMPLES
2020	6	IVA	BRPM	8	0	N		BQD ENGINE SPEED
2030	6	IVA	ORPM	8	0	N		ENGINE SPEED OVER/UNDER
2040	6	IVA	QTORQUE	7	2	N		ENGINE TORQUE QUALITY INDEX
2050	6	IVA	ATORQUE1	8	2	N	N-m	AVG ENGINE TORQUE STAGE 1 (N-m)
2060	6	IVA	ATORQUE2	8	2	N	N-m	AVG ENGINE TORQUE STAGE 2 (N-m)
2070	6	IVA	NTORQUE	8	0	N		ENGINE TORQUE NUMBER OF SAMPLES
2080	6	IVA	BTORQUE	8	0	N		BQD ENGINE TORQUE
2090	6	IVA	OTORQUE	8	0	N		ENGINE TORQUE OVER/UNDER
2100	6	IVA	QCOLOUT	7	2	N		COOLANT OUT TEMPERATURE QUALITY INDEX
2110	6	IVA	ACOLOUT1	8	2	N	¯C	AVG COOLANT OUT TEMPERATURE STAGE 1 (¯C)
2120	6	IVA	ACOLOUT2	8	2	N	¯C	AVG COOLANT OUT TEMPERATURE STAGE 2 (¯C)
2130	6	IVA	NCOLOUT	8	0	N		COOLANT OUT TEMPERATURE NUMBER OF SAMPLES
2140	6	IVA	BCOLOUT	8	0	N		BQD COOLANT OUT TEMPERATURE
2150	6	IVA	OCOLOUT	8	0	N		COOLANT OUT TEMPERATURE OVER/UNDER

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
2160	6	IVA	QHUMID	7	2	N		INDUCTION HUMIDITY QUALITY INDEX
2170	6	IVA	AHUMID	8	2	N	g/kg	AVG INDUCTION HUMIDITY (g/kg)
2180	6	IVA	NHUMID	8	0	N		INDUCTION HUMIDITY NUMBER OF SAMPLES
2190	6	IVA	BHUMID	8	0	N		BQD INDUCTION HUMIDITY
2200	6	IVA	OHUMID	8	0	N		INDUCTION HUMIDITY OVER/UNDER
2210	6	IVA	QINAIRT	7	2	N		INTAKE AIR TEMPERATURE QUALITY INDEX
2220	6	IVA	AINAIRT	8	2	N	¯C	AVG INTAKE AIR TEMPERATURE (¯C)
2230	6	IVA	NINAIRT	8	0	N		INTAKE AIR TEMPERATURE NUMBER OF SAMPLES
2240	6	IVA	BINAIRT	8	0	N		BQD INTAKE AIR TEMPERATURE
2250	6	IVA	OINAIRT	8	0	N		INTAKE AIR TEMPERATURE OVER/UNDER
2260	6	IVA	QINAIRP	7	2	N		INTAKE AIR PRESSURE QUALITY INDEX
2270	6	IVA	AINAIRP	8	3	N	kPa	AVG INTAKE AIR PRESSURE (kPa)
2280	6	IVA	NINAIRP	8	0	N		INTAKE AIR PRESSURE NUMBER OF SAMPLES
2290	6	IVA	BINAIRP	8	0	N		BQD INTAKE AIR PRESSURE
2300	6	IVA	OINAIRP	8	0	N		INTAKE AIR PRESSURE OVER/UNDER
2310	6	IVA	QEXHBKP	7	2	N		EXHAUST BACK PRESSURE QUALITY INDEX
2320	6	IVA	AEXHBKP	8	2	N	kPa-ABS	AVG EXHAUST BACK PRESSURE (kPa-ABS)
2330	6	IVA	NEXHBKP	8	0	N		EXHAUST BACK PRESSURE NUMBER OF SAMPLES
2340	6	IVA	BEXHBKP	8	0	N		BQD EXHAUST BACK PRESSURE
2350	6	IVA	OEXHBKP	8	0	N		EXHAUST BACK PRESSURE OVER/UNDER
2360	6	IVA	QCOLFRT	7	2	N		COOLANT FLOW QUALITY INDEX
2370	6	IVA	ACOLFRT	8	2	N	L/min	AVG COOLANT FLOW (L/min)
2380	6	IVA	NCOLFRT	8	0	N		COOLANT FLOW NUMBER OF SAMPLES
2390	6	IVA	BCOLFRT	8	0	N		BQD COOLANT FLOW
2400	6	IVA	OCOLFRT	8	0	N		COOLANT FLOW OVER/UNDER
2410	6	IVA	QOILT	7	2	N		OIL GALLERY TEMPERATURE QUALITY INDEX
2420	6	IVA	AOILT1	8	2	N	¯C	AVG OIL GALLERY TEMPERATURE STAGE 1 (¯C)
2430	6	IVA	AOILT2	8	2	N	¯C	AVG OIL GALLERY TEMPERATURE STAGE 2 (¯C)
2440	6	IVA	NOILT	8	0	N		OIL GALLERY TEMPERTURE NUMBER OF SAMPLES
2450	6	IVA	BOILT	8	0	N		BQD OIL GALLERY TEMPERATURE
2460	6	IVA	OOILT	8	0	N		OIL GALLERY TEMPERTURE OVER/UNDER
2470	6	IVA	ASUMPT1	8	2	N	¯C	AVG OIL SUMP TEMPERATURE STAGE 1 (¯C)
2480	6	IVA	ASUMPT2	8	2	N	¯C	AVG OIL SUMP TEMPERATURE STAGE 2 (¯C)
2490	6	IVA	ACYLOT1	8	2	N	¯C	AVG OIL CYLINDER HEAD TEMPERATURE STAGE 1 (¯C)
2500	6	IVA	ACYLOT2	8	2	N	¯C	AVG OIL CYLINDER HEAD TEMPERATURE STAGE 2 (¯C)
2510	6	IVA	ACOLIN1	8	2	N	¯C	AVG COOLANT IN TEMPERATURE STAGE 1 (¯C)
2520	6	IVA	ACOLIN2	8	2	N	¯C	AVG COOLANT IN TEMPERATURE STAGE 2 (¯C)
2530	6	IVA	AEXHT1	8	2	N	¯C	AVG EXHAUST GAS TEMPERATURE STAGE 1 (¯C)
2540	6	IVA	AEXHT2	8	2	N	¯C	AVG EXHAUST GAS TEMPERATURE STAGE 2 (¯C)
2550	6	IVA	AFUELT1	8	2	N	¯C	AVG FUEL TEMPERATURE STAGE 1 (¯C)
2560	6	IVA	AFUELT2	8	2	N	¯C	AVG FUEL TEMPERATURE STAGE 2 (¯C)
2570	6	IVA	AOILPRS1	8	2	N	kPa	AVG OIL GALLERY PRESSURE STAGE 1 (kPa)
2580	6	IVA	AOILPRS2	8	2	N	kPa	AVG OIL GALLERY PRESSURE STAGE 2 (kPa)
2590	6	IVA	ACYLOPR1	8	2	N	kPa	AVG OIL CYLINDER HEAD PRESSURE STAGE 1 (kPa)
2600	6	IVA	ACYLOPR2	8	2	N	kPa	AVG OIL CYLINDER HEAD PRESSURE STAGE 2 (kPa)
2610	6	IVA	AFUELPR1	8	2	N	kPa	AVG FUEL PRESSURE STAGE 1 (kPa)
2620	6	IVA	AFUELPR2	8	2	N	kPa	AVG FUEL PRESSURE STAGE 2 (kPa)
2630	6	IVA	AIMNVAC1	8	2	N	kPa-VAC	AVG MANIFOLD VACUUM PRESSURE STAGE 1 (kPa-VAC)
2640	6	IVA	AIMNVAC2	8	2	N	kPa-VAC	AVG MANIFOLD VACUUM PRESSURE STAGE 2 (kPa-VAC)
2650	6	IVA	AAFR1	7	2	N		AVG AIR TO FUEL RATIO STAGE 1
2660	6	IVA	AAFR2	7	2	N		AVG AIR TO FUEL RATIO STAGE 2
2670	6	IVA	ACCASEP1	8	2	N	kPa	AVG CRANKCASE PRESSURE STAGE 1 (kPa)
2680	6	IVA	ACCASEP2	8	2	N	kPa	AVG CRANKCASE PRESSURE STAGE 2 (kPa)
2690	6	IVA	AFUELRT1	8	2	N	kg/h	AVG FUEL RATE STAGE 1 (kg/h)

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
2700	6	IVA	AFUELRT2	8	2	N	kg/h	AVG FUEL RATE STAGE 2 (kg/h)
2710	6	IVA	ASPKTIM1	8	2	N	¯ BTDC	AVG IGNITION TIMING STAGE 1 (¯ BTDC)
2720	6	IVA	ASPKTIM2	8	2	N	¯ BTDC	AVG IGNITION TIMING STAGE 2 (¯ BTDC)
2730	6	IVA	AAMBAT1	8	2	N	¯C	AVG AMBIENT TEMPERATURE STAGE 1 (¯C)
2740	6	IVA	AAMBAT2	8	2	N	¯C	AVG AMBIENT TEMPERATURE STAGE 2 (¯C)
2750	7	IVA	TST_Hxxx	3	0	C		TEST HOUR XXX
2760	7	IVA	V040Hxxx	7	2	N	cSt	D445 KINEMATIC VISCOSITY @ 40 ¯C HOUR XXX (cSt)
2770	7	IVA	CUWMHxxx	6	0	A	ppm	D5185 CU BY ICP HOUR XXX [<] (ppm)
2780	8	IVA	CBFX001	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT X, BORE 1 (mm)
2790	8	IVA	CBRX001	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR X, BORE 1 (mm)
2800	8	IVA	CBFV001	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT V, BORE 1 (mm)
2810	8	IVA	CBRV001	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR V, BORE 1 (mm)
2820	8	IVA	CBFY001	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT Y, BORE 1 (mm)
2830	8	IVA	CBRY001	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR Y, BORE 1 (mm)
2840	8	IVA	XCBF001	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT FRONT BORE 1 (mm)
2850	8	IVA	XCBR001	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT REAR BORE 1 (mm)
2860	8	IVA	CBFX002	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT X, BORE 2 (mm)
2870	8	IVA	CBRX002	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR X, BORE 2 (mm)
2880	8	IVA	CBFV002	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT V, BORE 2 (mm)
2890	8	IVA	CBRV002	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR V, BORE 2 (mm)
2900	8	IVA	CBFY002	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT Y, BORE 2 (mm)
2910	8	IVA	CBRY002	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR Y, BORE 2 (mm)
2920	8	IVA	XCBF002	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT FRONT BORE 2 (mm)
2930	8	IVA	XCBR002	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT REAR BORE 2 (mm)
2940	8	IVA	CBFX003	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT X, BORE 3 (mm)
2950	8	IVA	CBRX003	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR X, BORE 3 (mm)
2960	8	IVA	CBFV003	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT V, BORE 3 (mm)
2970	8	IVA	CBRV003	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR V, BORE 3 (mm)
2980	8	IVA	CBFY003	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT Y, BORE 3 (mm)
2990	8	IVA	CBRY003	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR Y, BORE 3 (mm)
3000	8	IVA	XCBF003	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT FRONT BORE 3 (mm)
3010	8	IVA	XCBR003	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT REAR BORE 3 (mm)
3020	8	IVA	CBFX004	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT X, BORE 4 (mm)
3030	8	IVA	CBRX004	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR X, BORE 4 (mm)
3040	8	IVA	CBFV004	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT V, BORE 4 (mm)
3050	8	IVA	CBRV004	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR V, BORE 4 (mm)
3060	8	IVA	CBFY004	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT Y, BORE 4 (mm)
3070	8	IVA	CBRY004	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR Y, BORE 4 (mm)
3080	8	IVA	XCBF004	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT FRONT BORE 4 (mm)
3090	8	IVA	XCBR004	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT REAR BORE 4 (mm)
3100	8	IVA	CBFX005	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT X, BORE 5 (mm)
3110	8	IVA	CBRX005	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR X, BORE 5 (mm)
3120	8	IVA	CBFV005	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT V, BORE 5 (mm)
3130	8	IVA	CBRV005	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR V, BORE 5 (mm)
3140	8	IVA	CBFY005	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, FRONT Y, BORE 5 (mm)
3150	8	IVA	CBRY005	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER, REAR Y, BORE 5 (mm)
3160	8	IVA	XCBF005	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT FRONT BORE 5 (mm)
3170	8	IVA	XCBR005	8	3	N	mm	CAMSHAFT BEARING BORE DIAMETER MAX RUN OUT REAR BORE 5 (mm)
3180	8	IVA	CJFV001	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT V, BORE 1 (mm)
3190	8	IVA	CJRV001	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR V, BORE 1 (mm)
3200	8	IVA	CJFH001	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT H, BORE 1 (mm)
3210	8	IVA	CJRH001	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR H, BORE 1 (mm)
3220	8	IVA	XCJF001	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT FRONT, BORE 1 (mm)
3230	8	IVA	XCJR001	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT REAR, BORE 1 (mm)

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
3240	8	IVA	CCF001	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. FRONT CLEAR. @ V, BORE 1 (mm)
3250	8	IVA	CCR001	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. REAR CLEAR. @ V, BORE 1 (mm)
3260	8	IVA	CJFV002	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT V, BORE 2 (mm)
3270	8	IVA	CJRV002	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR V, BORE 2 (mm)
3280	8	IVA	CJFH002	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT H, BORE 2 (mm)
3290	8	IVA	CJRH002	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR H, BORE 2 (mm)
3300	8	IVA	XCJF002	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT FRONT, BORE 2 (mm)
3310	8	IVA	XCJR002	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT REAR, BORE 2 (mm)
3320	8	IVA	CCF002	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. FRONT CLEAR. @ V, BORE 2 (mm)
3330	8	IVA	CCR002	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. REAR CLEAR. @ V, BORE 2 (mm)
3340	8	IVA	CJFV003	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT V, BORE 3 (mm)
3350	8	IVA	CJRV003	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR V, BORE 3 (mm)
3360	8	IVA	CJFH003	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT H, BORE 3 (mm)
3370	8	IVA	CJRH003	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR H, BORE 3 (mm)
3380	8	IVA	XCJF003	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT FRONT, BORE 3 (mm)
3390	8	IVA	XCJR003	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT REAR, BORE 3 (mm)
3400	8	IVA	CCF003	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. FRONT CLEAR. @ V, BORE 3 (mm)
3410	8	IVA	CCR003	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. REAR CLEAR. @ V, BORE 3 (mm)
3420	8	IVA	CJFV004	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT V, BORE 4 (mm)
3430	8	IVA	CJRV004	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR V, BORE 4 (mm)
3440	8	IVA	CJFH004	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT H, BORE 4 (mm)
3450	8	IVA	CJRH004	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR H, BORE 4 (mm)
3460	8	IVA	XCJF004	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT FRONT, BORE 4 (mm)
3470	8	IVA	XCJR004	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT REAR, BORE 4 (mm)
3480	8	IVA	CCF004	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. FRONT CLEAR. @ V, BORE 4 (mm)
3490	8	IVA	CCR004	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. REAR CLEAR. @ V, BORE 4 (mm)
3500	8	IVA	CJFV005	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT V, BORE 5 (mm)
3510	8	IVA	CJRV005	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR V, BORE 5 (mm)
3520	8	IVA	CJFH005	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., FRONT H, BORE 5 (mm)
3530	8	IVA	CJRH005	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM., REAR H, BORE 5 (mm)
3540	8	IVA	XCJF005	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT FRONT, BORE 5 (mm)
3550	8	IVA	XCJR005	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAMETER RUN OUT REAR, BORE 5 (mm)
3560	8	IVA	CCF005	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. FRONT CLEAR. @ V, BORE 5 (mm)
3570	8	IVA	CCR005	8	3	N	mm	CAMSHAFT BEARING JOURNAL DIAM. REAR CLEAR. @ V, BORE 5 (mm)
3580	8	IVA	CAMENDP	8	3	N	mm	CAMSHAFT END PLAY (mm)
3590	8	IVA	CAMSROUT	8	3	N	mm	CAMSHAFT SPROCKET RUN OUT (mm)
3600	8	IVA	CAMBEND	8	3	N	mm	CAMSHAFT RUN-OUT, BEND (mm)
3610	8	IVA	COMP1	6	0	N	kPa	CYLINDER COMPRESSION - CYLINDER 1 (kPa)
3620	8	IVA	COMP2	6	0	N	kPa	CYLINDER COMPRESSION - CYLINDER 2 (kPa)
3630	8	IVA	COMP3	6	0	N	kPa	CYLINDER COMPRESSION - CYLINDER 3 (kPa)
3640	8	IVA	COMP4	6	0	N	kPa	CYLINDER COMPRESSION - CYLINDER 4 (kPa)
3650	9	IVA	DWNOCR	2	0	Z		NUMBER OF DOWNTIME OCCURRENCES
3660	9	IVA	DOWNHxxx	6	0	C	HHH:MM	DOWNTIME TEST HOURS (HHH:MM)
3670	9	IVA	DDATHxxx	8	0	C	YYYYMMDD	DOWN TIME OCCURRENCE DATE (YYYYMMDD)
3680	9	IVA	DTIMHxxx	6	0	C	HHH:MM	DOWNTIME TIME (HHH:MM)
3690	9	IVA	DREAHxxx	60	0	C		DOWNTIME REASON
3700	9	IVA	TOTLDOWN	6	0	C	HHH:MM	DOWN TIME TOTAL (HHH:MM)
3710	9	IVA	TOTCOM	2	0	Z		TOTAL LINES OF COMMENTS & OUTLIERS
3720	9	IVA	OCOMHxxx	60	0	C		OTHER DOWNTIME COMMENTS XXX
3730	10	IVA	OG2TO1IM	70	0	C		CYCLE 5 STAGE 2 TO 1 TRANSITION: OIL GALLERY TEMP IMAGE
3740	11	IVA	OG1TO2IM	70	0	C		CYCLE 5 STAGE 1 TO 2 TRANSITION: OIL GALLERY TEMP IMAGE
3750	12	IVA	CO2TO1IM	70	0	C		CYCLE 5 STAGE 2 TO 1 TRANSITION: COOLANT OUT TEMP IMAGE
3760	13	IVA	CO1TO2IM	70	0	C		CYCLE 5 STAGE 1 TO 2 TRANSITION: COOLANT OUT TEMP IMAGE
3770	14	IVA	ET2TO1IM	70	0	C		CYCLE 5 STAGE 2 TO 1 TRANSITION: ENGINE TORQUE IMAGE

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
3780	15	IVA	ET1TO2IM	70	0	C		CYCLE 5 STAGE 1 TO 2 TRANSITION: ENGINE TORQUE IMAGE
3790	16	IVA	ES2TO1IM	70	0	C		CYCLE 5 STAGE 2 TO 1 TRANSITION: ENGINE SPEED IMAGE
3800	17	IVA	ES1TO2IM	70	0	C		CYCLE 5 STAGE 1 TO 2 TRANSITION: ENGINE SPEED IMAGE