Designation: D6891 – 09

# Standard Test Method for Evaluation of Automotive Engine Oils in the Sequence IVA Spark-Ignition Engine[1]

This standard is issued under the fixed designation D6891; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method measures the ability of crankcase oil to control camshaft lobe wear for spark-ignition engines equipped with an overhead valve-train and sliding cam followers. This test method is designed to simulate extended engine idling vehicle operation. The Sequence IVA Test Method uses a Nissan KA24E engine. The primary result is camshaft lobe wear (measured at seven locations around each of the twelve lobes). Secondary results include cam lobe nose wear and measurement of iron wear metal concentration in the used engine oil. Other determinations such as fuel dilution of crankcase oil, non-ferrous wear metal concentrations, and total oil consumption, can be useful in the assessment of the validity of the test results.[2]

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.2.1 *Exceptions*—Where there is no direct SI equivalent such as pipe fittings, tubing, NPT screw threads/diameters, or single source equipment specified.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See Annex A5 for specific safety precautions.

## 2. Referenced Documents

2.1 *ASTM Standards:*[3]

D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)
D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)
D381 Test Method for Gum Content in Fuels by Jet Evaporation
D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D525 Test Method for Oxidation Stability of Gasoline (Induction Period Method)
D3525 Test Method for Gasoline Diluent in Used Gasoline Engine Oils by Gas Chromatography
D4485 Specification for Performance of Engine Oils
D5185 Test Method for Determination of Additive Elements, Wear Metals, and Contaminants in Used Lubricating Oils and Determination of Selected Elements in Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D5302 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation and Wear in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions[4]
D5844 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID)[4]
E230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples

2.2 *API Standard:*

API 1509 Engine Oil Licensing and Certification System[5]

2.3 *SAE Standards:*

SAE J183 Engine Oil Performance and Engine Service Classification[6]
SAE J254 Instrumentation and Techniques for Exhaust Gas Emissions Measurement[6]

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[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0 on Automotive Lubricants.

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[2] The ASTM Test Monitoring Center will update changes in this test method by means of Information Letters. Information letters may be obtained from the ASTM Test Monitoring Center (TMC), 6555 Penn Ave., Pittsburgh, PA 15206-4489, Attention: Administrator. www.astmtmc.cmu.edu. This edition incorporates all Information Letters through No. 06–1.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from The American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.

[6] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

2.4 *ASME Standard:*

B46.1 Standard for Surface Texture (Surface Roughness, Waviness, and Lay)[7]

2.5 *JASO Standard:*

M 328-95 Valve-train Wear Test Procedure for Evaluating Automobile Gasoline Engine Oils[8]

2.6 *CEC Standard:*

CEC-L-38-A-94 Peugeot TU-3M/KDX Valve-train Scuffing Wear Test[9]

## 3. Terminology

3.1 *Definitions:*

3.1.1 *blowby*, *n—in internal combustion engines*, the combustion products and unburned air-and-fuel mixture that enter the crankcase. **D5302**

3.1.2 *calibration test stand*, *n*—a test stand on which the testing of reference material(s), conducted as specified in the standard, provided acceptable results. **Sub. B Glossary[10]**

3.1.2.1 *Discussion*—In several automotive lubricant standard test methods, the ASTM Test Monitoring Center provides testing guidance and determines acceptability.

3.1.3 *reference oil*, *n*—an oil of known performance characteristics, used as a basis for comparison.

3.1.3.1 *Discussion*—Reference oils are used to calibrate testing facilities, to compare the performance of other oils, or to evaluate other materials (such as seals) that interact with oils. **D5844**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *assessment length*, *n*—the length of surface over which measurements are made.

3.2.2 *break-in*, *n*—initial engine operation to reach stabilization of the engine performance after new parts are installed in the engine.

3.2.3 *cam lobe wear*, *n*—the sum of the wear determined at the following locations (nose is zero location): (*1*) 14 cam degrees before the nose, (*2*) 10° before the nose, (*3*) 4° before the nose, (*4*) at the nose, (*5*) 4° after the nose, (*6*) 10° after the nose, (*7*) 14° after the nose.

3.2.4 *cam nose wear*, *n*—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.

3.2.5 *flushing*, *n*—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.

3.2.5.1 *Discussion*—Flushing may be carried out in an iterated process to ensure a more thorough process of reducing previous oil remnants.

3.2.6 *reference line*, *n*—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.

3.2.7 *valve-train*, *n*—a mechanical engine subsystem comprised of the camshaft, the rocker arms, hydraulic lash adjusters, the poppet valves, and valve-springs.

3.2.8 $waveness_{total}$, *n*—the maximum excursion of the worn surface as graphically measured normal to the reference line.

## 4. Summary of Test Method

4.1 *Test Numbering Scheme*—Use the test numbering scheme shown below:

AAAAA–BBBBB–CCCCC

AAAAA represents the stand number. BBBBB represents the number of tests since the last calibration test on that stand. CCCCC represents the total number of Sequence IVA tests conducted on that stand. For example, 6-10-175 represents the 175th Sequence IVA test conducted on test stand 6 and the tenth test since the last calibration test. Consecutively number all tests. Number the stand calibration tests beginning with zero for the BBBBB field. Multiple-length Sequence IVA tests are multiple runs for test numbering purposes, such as double-length tests which are counted as two runs and triple-length tests which are counted as three runs. For example, if test 1-3-28 is a doubled-length test, number the next test conducted on that stand 1-5-30.



4.2 *Test Engine*—This procedure uses a fired 1994 model Nissan KA24E, in-line 4-cylinder, 4-cycle, water-cooled, port fuel-injected gasoline engine with a displacement of 2.389 L.[11,12] 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.

4.3 *Test Stand*—Couple the test engine (devoid of alternator, cooling fan, water pump, clutch and transmission) to an eddy-current dynamometer for precise control of engine speed and torque. Specify the combined inertia of the driveline and dynamometer to ensure reproducible transient ramping of engine speed and torque. Control the intake air, provided to the engine air filter housing, for temperature, pressure, and humidity. Mount the engine similar to its vehicle orientation (tilted up 5.5° in front; sideways 10° up on intake manifold side; bottom of oil sump horizontal). Modify the engine ECM wiring harness, sensors, and actuators. The test stand plumbing shall conform to the diagrams shown in Annex A3. Install the engine on a test stand equipped with computer control of engine speed, torque, various temperatures, pressures, flows, and other parameters outlined in the test procedure (see Section 11).

4.4 *Test Sequence*—After engine break-in or after the completion of a previous test, install a new test camshaft and rocker arms. Charge the fresh test oil to the engine and conduct

[7] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[8] Available from Japanese Standards Organization (JSA), 4-1-24 Akasaka Minato-Ku, Tokyo, 107-8440, Japan.

[9] Available from the Coordinating European Council for the Development of Performance Tests Transportation Fuels, Lubes, and other Fluids, Madou Plaza , 25 Floor Place, Madou B-1210, Brussels, Belgium.

[10] Available from ASTM Test Monitoring Center (TMC), 6555 Penn Avenue, Pittsburgh, PA 15206-4489, Attention: Administrator.

[11] The sole source of supply of the apparatus known to the committee at this time is Nissan North American, Inc., P.O. Box 191, Gardena, CA 90248-0191.

[12] If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [1], which you may attend.

two flushes. After completing both flushes, drain the used oil, and weigh and install the fresh test oil and filter. Conduct the test for a total of 100 h, with no scheduled shutdowns. There are two operating conditions, Stage I and Stage II; Stage I for 50 min and Stage II for 10 min comprise one test cycle. The test length is 100 cycles.

4.5 *Analyses Conducted*—After test, measure the camshaft lobes using a surface profilometer. From these graphical profile measurements, determine the maximum wear at seven locations on the cam lobe. Determine individual cam lobe wear by summing the seven location wear measurements. Average the wear from the twelve cam lobes for the final, primary test result. After test completion, determine the oil consumption by the mass of used oil versus the fresh oil charged to the engine (including oil filter). Analyze the end of test used oil for fuel dilution, kinematic viscosity, and wear metals. Retain a final drain sample of 1 L for 90 days. Retain the camshaft and rocker arms for six months.

## 5. Significance and Use

5.1 This test method was developed to evaluate automotive lubricant's effect on controlling cam lobe wear for overhead valve-train equipped engines with sliding cam followers.

NOTE 1—This test method may be used for engine oil specifications, such as Specification D4485, API 1509, SAE J183, and ILSC GF 3.

## 6. Apparatus

NOTE 2—Coordination with the ASTM Committee D02, Subcommittee B, 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. Figures are provided throughout the test method to suggest appropriate design details and depict some of the required apparatus.

6.1 *Test Engine*—This test method uses a fired 1994 model Nissan KA24E, in-line 4-cylinder, 4-cycle, water-cooled, port fuel-injected gasoline engine with a displacement of 2.389 L.[11,12]. See Annex A2 for a parts lists. Nominal oil sump volume is 3.5 L. 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. Rate the engine at 198 N·m torque at 4400 r/min. The ignition timing and multi-port fuel injection system is ECM. Fuel the engine with a specially blended, non-detergent unleaded reference gasoline. Make the EGR non-operable.

6.1.1 *Engine Buildup and Measurement Area*—The ambient atmosphere of the engine buildup and measurement areas shall be reasonably free of contaminants and maintained at a uniform temperature. Maintain the specific humidity at a uniform level to prevent the accumulation of rust on engine parts. Use uniform temperatures to ensure repeatable dimensional measurements. Use a sensitive surface profilometer instrument to measure the wear of the cam lobes, and place the profilometer on a base-plate free of external vibrations.

6.1.2 *Engine Operating Area*—The laboratory ambient atmosphere shall be reasonably free of contaminants and general wind currents, especially if and when the valve-train parts are installed while the engine remains in the operating area. The temperature and humidity level of the operating area is not specified.

6.1.3 *Parts Cleaning Area*—This test method does not specify the ambient atmosphere of the parts cleaning area (**Warning—**Use adequate ventilation in areas while using solvents and cleansers).

6.2 *External Engine Modifications*—Modify the test engine for the valve-train wear test. Make the exhaust gas recirculation non-operable. Disable the swirl control actuator. Disable the fast idle system and the auxiliary air control (AAC) valve. Replace the engine coolant temperature sensor by a fixed resistor. Modify the engine water-pump to incorporate an external electric-driven water-pump. Do not use the water-pump fan blade and cooling radiator. Remove the alternator. Install an oil cooler (water-to-oil heat exchanger) at the oil filter housing, as shown in Annex A3. Modify the engine wiring harness. Install fittings for various temperature and pressure measurements as required by the test method. Place the Nissan production rocker cover with a specially manufactured aluminum jacketed rocker cover. Route the engine coolant through this jacket. Install a fitting in the front engine cover to allow a portion of the crankcase ventilation air to bypass the rocker cover. Install fittings for various temperature and pressure measurements as required by this test method.

6.2.1 *Non-Operable EGR*—This test method does not use an EGR valve. Cover the EGR port with the supplied 3 mm thickness block-off (blind) plate (see Annex A3). Remove the hose from the exhaust manifold to the EGR. Plug the EGR supply port in the rear of the exhaust manifold with a pipe fitting.

6.2.2 *Swirl Control Actuator*—Disable the swirl control actuator by removing the harness connector and vacuum line. Plug the vacuum line source.

6.2.3 *Fast Idle Disabling*—To disable the fast idle system, remove the fast idle cam on the throttle body.

6.2.4 *Engine Coolant Temperature Sensor*—Substitute the variable input of the coolant temperature sensor to the ECM at the wiring harness of the ECM with a fixed resistance of 300 Ω.

6.2.5 *Utility Engine Water-pump*—Modify the engine water-pump shown in Fig. 1 to serve as a dummy housing on the engine, and use an electric motor-driven, external water pump for this test.

6.2.5.1 Support two surfaces, 180° 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.

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

6.2.5.3 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 water-pump shaft.

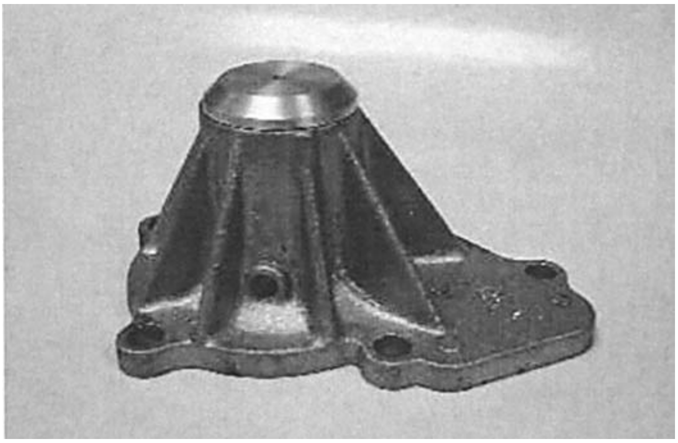

**FIG. 1 Modified Water Pump**

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

6.2.5.5 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.

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

6.2.5.7 Fabricate a water pump bore plug (see Annex A3) 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 °C and the fabricated bore plug cooled to approximately 0 °C. This will allow easy installation of the bore plug.

6.2.5.8 Preheat the aluminum alloy pump body (with plug installed) to approximately 200 °C.

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

6.2.5.10 Allow to cool, then perform final cleaning before installation on the engine.

6.2.6 *Coolant Bypass Hose*—Disconnect the coolant bypass hose at the intake manifold. The connection ends are plugged to prevent bypass flow. Remove the thermostat.

6.2.7 *Oil Cooler*—Insert a water-to-oil heat exchanger (see Annex A3) between the engine oil filter adapter block and the oil filter, using a gasket as shown in Annex A3. See Annex A3 for installation details. Plumb the water outlet to the cooler fitting and orient to the same axis as the oil filter. Orient the cooler for both water fittings to face the rear of the engine. To connect process water to the oil cooler, use flexible hoses (16 mm diameter) of approximately 500 mm length. Control the oil temperature by metering the flow of the process water outlet. A control system valve with Flow Coefficient (Cv) of 0.32 produces satisfactory control. Replace the oil cooler (see Annex A2) when the short-block is replaced. Replace all hoses to the oil cooler when installing a new cooler.

**TABLE 1 ECM Wiring Harness Modifications**[A]

| 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 Temperature Sensor | 65M (Install 300Ω resistor) |
| Throttle Position Sensor | 66M |
| Injectors 1–4 | 72M, 73M, 74M, 75M |
| Intake Air Temperature Sensor | 18M |
| Body Ground | 275M |
| Engine Ground | 60M, 61M |
| Connector Description | Connector Number(s) |
| Fuel Pump Relay[B] | 5M |
| ECCS Relay[C] | 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[D] | add and utilize |
| Keep-Alive wire | add and utilize |
| Ignition wire | add and utilize |
| Ground wire[D] | add and utilize |

[A] See modified wiring diagram in Annex A3.
[B] Modify the fuel pump relay connector (5M) to provide a nominal 13 V to the fuel pump only when turning on the ignition power switch. See Annex A3 for the wiring details.
[C] The ECCS relay uses the 6M connector. Connect it to the battery through a fusible link.
[D] Attach the wiring harness grounds to the front engine-lifting bracket.



6.2.8 *Ignition Power Supply*—Use a 15 A dc power supply to provide (13.4 to 14.2) V dc to the ECM that powers the engine ignition system (a Lambda Electronics Corporation Model No. LFS-43-15 has been found useful).[12,13] Provide a separate power source for the starter motor circuit. Use an automotive battery equipped with a low-amperage battery charger.

6.2.9 *ECM Wiring Harness Modifications*—Remove the connectors and wires from the electronic control module wiring harness except those shown in Table 1.

6.3 *Test Stand and Laboratory Equipment*—This engine-dynamometer test is designed for operation using computer control instrumentation and computer data acquisition. Provide an intake air system for the precise control of engine intake air humidity, temperature, and cleanliness.

6.3.1 *Computer Data Acquisition System*—The procedure shown in 6.3.1.1-6.3.1.3 details the test stand log operational data with a computer data acquisition system using sensor configurations, and is in compliance with Data Acquisition and

[13] The sole source of supply of the apparatus known to the committee at this time is Lambda Electronics Corporation, 515 Broad Hollow Road, Melville, NY 11747-3700.