Designation: D7421 – 16

Standard Test Method for Determining Extreme Pressure Properties of Lubricating Oils Using High-Frequency, Linear-Oscillation (SRV) Test Machine[1]

This standard is issued under the fixed designation D7421; 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 covers a procedure for determining extreme pressure properties of lubricating oils for hydraulics, gears, and engines under high-frequency linear-oscillation motion using the SRV test machine.

NOTE 1—This test method was developed and the international round robin tests were jointly performed with the DIN 51834 working group. This procedure is based on the 2005 revision of Test Method D5706 for greases and differs regarding the stroke length and the cleaning solvent.

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

1.3 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A295/A295M Specification for High-Carbon Anti-Friction Bearing Steel

D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

D5706 Test Method for Determining Extreme Pressure Properties of Lubricating Greases Using a High-Frequency, Linear-Oscillation (SRV) Test Machine

E45 Test Methods for Determining the Inclusion Content of Steel

G40 Terminology Relating to Wear and Erosion

2.2 *DIN Standards:*[3]

DIN 51631:1999–04 Mineral spirits; special boiling point spirits; requirements

DIN EN ISO 683-17 Heat-treated Steels, alloy steels and free-cutting steels—Part 17 : Ball and roller bearing steels [Replaces DIN 17230-1980]

DIN EN ISO 13565-2:1998 Geometrical Product Specifications (GPS)—Surface texture: Profile method; Surfaces having stratified functional properties—Part 2: Height characterization using linear material ratio curve [Replacement of DIN 4776:1990: Measurement of surface roughness; parameters R_K, R_{PK}, R_{VK}, M_{r1}, M_{r2} for the description of the material portion]

3. Terminology

3.1 *Definitions:*

3.1.1 *break-in, n—in tribology*, an initial transition process occurring in newly established wearing contacts, often accompanied by transients in coefficient of friction or wear rate, or both, which are uncharacteristic of the given tribological system's long-term behavior. **G40**

3.1.2 *coefficient of friction,* μ or f, *n—in tribology*, the dimensionless ratio of the friction force (*F*) between two bodies to the normal force (*N*) pressing these bodies together. **G40**

3.1.3 *Hertzian contact area, n*—apparent area of contact between two nonconforming solid bodies pressed against each other, as calculated from Hertz's equations of elastic deformation published in 1881. **G40**

3.1.4 *Hertzian contact pressure, n*—magnitude of the pressure at any specified location in a Hertzian contact area, as calculated from Hertz's equations of elastic deformation. The Hertzian contact pressure can also be calculated and reported as maximum value P_{max} in the centre of the contact or as $P_{average}$ as average over the total contact area. **D4175**

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.L0 on Industrial Lubricants and Engineering Sciences of High Performance Fluids and Solids.

Current edition approved Oct. 1, 2016. Published February 2017. Originally approved in 2008. Last previous edition approved in 2011 as D7421 – 11. DOI: 10.1520/D7421-16.

[2] 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.

[3] Available from Beuth Verlag GmbH (DIN, Deutsches Institut fur Normung e.V.), Burggrafenstrasse 6, 10787, Berlin, Germany, http://www.en.din.de.

***A Summary of Changes section appears at the end of this standard**

3.1.5 *lubricant, n*—any material interposed between two surfaces that reduces the friction or wear, or both between them. D4175

3.1.6 *Ra (C.L.A.), n—in measuring surface finish*, the arithmetic average of the absolute distances of all profile points from the mean line for a given distance.[4]

3.1.6.1 *Discussion*—C.L.A. means center line average, and it is the synonym to Ra.

3.1.7 *Rpk, n*—Reduced peak height according to DIN EN ISO 13565-2:1998. Rpk is the mean height of the peak sticking out above the core profile section.

3.1.8 *Rvk,, n*—Reduced valley height according to DIN EN ISO 13565-2:1998. Rvk is the mean depth of the valley reaching into the material below the core profile section.

3.1.9 *Rz (DIN), n—in measuring surface finish*, the average of all Ry values (peak to valley heights) in the assessment length.[4]

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *extreme pressure, adj—in lubrication*, characterized by metal surfaces in contact under high-stress rubbing conditions. It is not limited to metallic materials.

3.2.2 *seizure, n*—localized fusion of metal between the rubbing surfaces of the test pieces. D5706

3.2.2.1 *Discussion*—In this test method, seizure is indicated by a sharp rise in the coefficient of friction, over steady state, of >0.2 for over 20 s. In severe cases, a stoppage in the motor will occur. (These criteria were believed to be right, because this test method is related to liquid lubricants.)

3.3 *Abbreviations:*

3.3.1 *SRV, n*—Schwingung, Reibung, Verschleiß (German); oscillating, friction, wear (English translation).

4. Summary of Test Method

4.1 This test method is performed on an SRV test machine using a steel test ball oscillating against a stationary steel test disk with lubricant between them. Test load is increased in 100 N increments until seizure occurs. The load, immediately prior to the load at which seizure occurs, is measured and reported as O.K.-load, which can be converted in Hertzian contact pressures.

NOTE 2—Test frequency, stroke length, temperature, and ball and disk material can be varied to simulate field conditions. The test ball yields point-contact geometry. To obtain line or area contact, test pieces of differing configurations can be substituted for the test balls.

NOTE 3—With regard to the test chamber and the operating conditions, SRV models III, IV, and V are identical. However, the SRV IV and V allow to incline the axis of movement. Both models are fully computer controlled. In SRV IV and V models, the test described here is run horizontally and without inclination. SRV I and II models can also perform this test, but they are limited with regard to maximum load and stroke. As modern and high performance oils may exceed an O.K.-load of 1200 N, seizure may not be reached. Optimol Instruments supplies an upgrade kit to allow for SRV I and SRV II models to be operated at 1600 N, if needed. SRV III test machines after 1995 reach 2000 N. SRV IV and SRV V models can be equipped with a maximum test load unit of 2500 N.

[4] Amstutz, Hu, "Surface Texture: The Parameters," Bulletin MI-TP-003-0785, Sheffield Measurement Division, Warner and Swasey, 1985.

FIG. 1 SRV Test Machine (Model III)

5. Significance and Use

5.1 This laboratory test method can be used to quickly determine extreme pressure properties of lubricating oils at selected temperatures specified for use in applications where not only high-speed vibrational or start-stop motions are present with high Hertzian point contact. This test method has found wide application in qualifying lubricating oils used in constant velocity joints of front-wheel-drive automobiles, gear-hydraulic circuit, rear axles, gears and engine components. Users of this test method should determine whether results correlate with field performance or other applications.

6. Apparatus

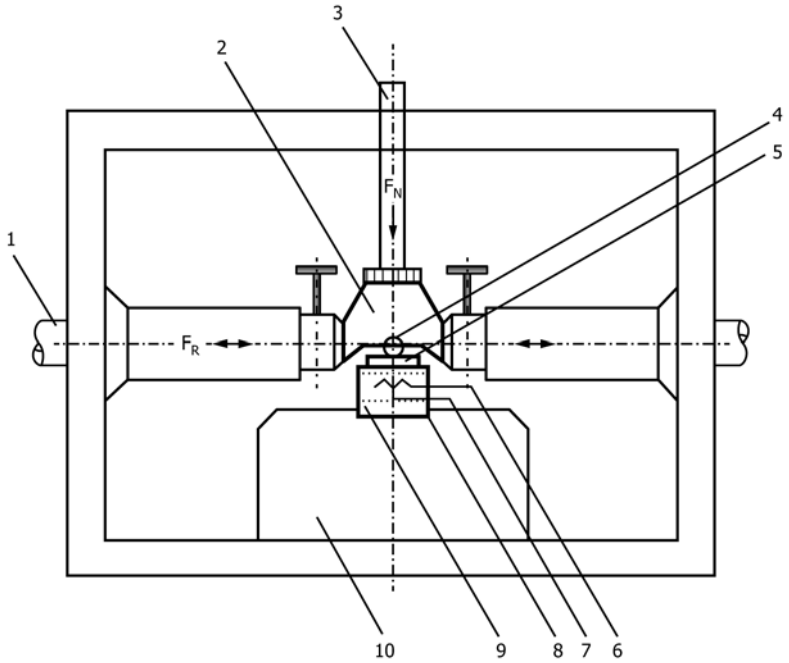
6.1 *SRV Test Machine,* [5] illustrated in Figs. 1-4.

6.2 *Test Balls,* [5] 52100 steel, 60 HRC ± 2 HRC hardness, 0.025 µm ± 0.005 µm Ra surface finish, 10 mm diameter.

6.3 *Lower Test Disk,* vacuum arc remelted (VAR) AISI 52100 steel with a inclusion rating using Method D, Type A, and a severity level number of 0.5 according to Specification A295/A295M or Test Methods E45 or an inclusion sum value K1 ≤ 10 in accordance with DIN EN ISO 683-17 and spherodized annealed to obtain globular carbide, 60 HRC ± 2 HRC hardness, with the surfaces of the disk being lapped and free of lapping raw materials. The topography of the disk will be determined by four values, 24 mm diameter by 7.85 mm thick:

0.5 µm < Rz (DIN) < 0.650 µm
0.035 µm < C.L.A. (Ra) < 0.050 µm
0.020 µm < Rpk < 0.035 µm
0.050 µm < Rvk < 0.075 µm

[5] The sole source of supply of the apparatus known to the committee at this time is Optimol Instruments GmbH, Westendstr. 125, D-80339 Munich, Germany. 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.



1. Oscillation drive rod
2. Test Ball Holder
3. Load Rod
4. Test Ball
5. Test Disk
6. Electrical Resistance Thermometer
7. Resistance Thermometer
8. Test Disk Holder
9. Piezoelectric Measuring Device
10. Receiving Block

FIG. 2 Test Chamber Elements of SRV III

7. Reagents and Materials

7.1 *Cleaning Solvent*—single boiling point spirit type 2-A according to DIN 51631:1999 (published in English). (**Warning—**Flammable. Health hazard.)

NOTE 4—In the case of unavailability, please refer to Specification D235 regarding Type I, Class C (with less than 2 % by volume of aromatics), mineral spirits.

8. Preparation of Apparatus

Preparation of SRV III, SRV IV, and SRV V Models

8.1 When using SRV III, SRV IV, and SRV V models, clean and install the specimens as specified under 9.1 to 9.7. Turn on the test machine and the PC and allow to warm up for 15 min prior to running tests.

8.2 Create a set point profile in the SRV control software with the following parameters:

NOTE 5—Depending on the software version, names and availability of the parameters can vary.

8.2.1 Start conditions:

Temperature: for example, 50 °C ± 1 K or 80 °C ± 1 K or 120 °C ± 1 K
Test load: 50 N ± 1 N
Start delay: 300 s (is displayed by all versions of the SRV software).

8.2.2 Cut-off criteria for friction:

FIG. 3 SRV Test Machine (Model IV)

Coefficient of friction, f (cut-off value for permanent increase of level): 0.3 during t > 20 s
Coefficient of friction, f (cut-off value for one-off increase of level): 0.35

8.2.3 Test parameters:

Frequency: 50 Hz
Stroke: 2.00 mm
Temperature: for example, 50 °C or 80 °C or 120 °C
Pre-load: 50 N for 30 s
Test load: running-in under 100 N for 15 min, then steps of 100 N with a duration of 2 min until the maximum test load (usually 2000 N) has been reached. Total test duration: up to 53.5 min

NOTE 6—Because a 30 s break-in at 50 N is used, the load increase times will occur on the half minute of even minutes.

NOTE 7—For optimal comparability with older SRV models I and II, the test load should be set as a ramp function with a gradient of 7.5 N⁄s.

8.2.4 Sample rates for result-relevant measurement channels:

Coefficient of friction, f: ≤32 ms.
Stroke: ≤2 s
Test load: ≤2 s
Frequency: ≤2 s
Temperature: ≤2 s
After that, apply a load increment of 100 N every 2 min

NOTE 8—For SRV V models, it is recommended to do one sampling per period (that is, 20 ms) for coefficient of friction and stroke.

9. Procedure for All SRV Models

9.1 SRV III, SRV IV, and SRV V models are fully computer-controlled and allow automated tests.

9.2 Using solvent resistant gloves, clean the test ball and disk by wiping the surfaces with laboratory tissue soaked with the cleaning solvent. Repeat wiping until no dark residue appears on the tissue. Immerse the test ball and disk in a beaker of the cleaning solvent under ultrasonic vibration for 10 min. Dry the test ball and disk with a clean tissue to ensure no streaking occurs on the surface.

9.3 Ensure that the test load unit is in the release position (refer to operating manual for details).

9.4 Place the cleaned ball, using the tweezers, in the disassembled, cleaned, and dried ball holder. Tighten the fastening screw until resistance just begins. Install the ball holder, and test ball in the test chamber

9.5 Then install the disk (place on the block). Tighten the fastening screw until resistance just begins.

9.6 Place 0.3 mL of the lubricating oil to be tested on the cleaned disk in to the center.

9.7 Make sure that an oil meniscus is clearly visible between ball and disk.

9.8 Open the Assistant for starting a test in the SRV control software. Select the created setpoint profile and, if necessary (for example, SRV V), the data logger configuration and proceed through the Assistant until the pre-load has been applied.

9.9 Then set the test load unit to 50 N and release and re-tighten the ball and disk clamps to a torque of 2.5 Nm.

9.10 The heater control starts automatically and heats up to the pre-set and desired temperature. 50 °C, 80 °C, or 120 °C.

9.11 Follow the directions in the Assistant for starting a test in the SRV control software until the automated test run mode (waiting for reaching start conditions) is started. The test starts automatically when the pre-set delay (for example, 300 s) has expired. The test can also be started manually.

9.12 The test is ended when the last test load step has been passed or when failure occurs. Failure is indicated by a sharp rise in the coefficient of friction of greater than 0.2 over steady state for over 20 s or a stoppage in the oscillating of the test machine. If no stoppage occurs, the O.K./pass load needs to be determined manually by reading the recording chart for the coefficient of friction (and stroke).

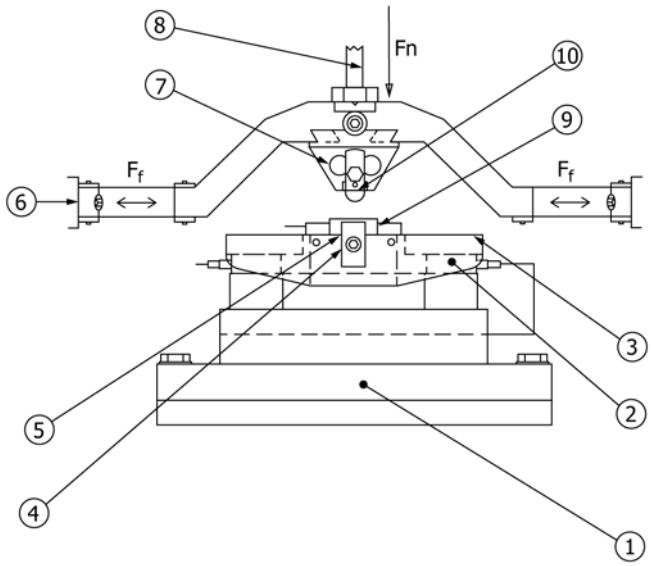
NOTE 9—Because a 30 s break-in at 50 N is used, the test load increase times will occur on the half minute of even minutes.

10. Report

10.1 Report the following information:
10.1.1 Temperature, °C,
10.1.2 Stroke, mm,
10.1.3 Frequency, Hz,
10.1.4 Test ball material,
10.1.5 Test disk material, and
10.1.6 Lubricating oil test specimen (internal code or designation name, brand name, performance level).

10.2 Report the highest test load (pass/O.K.-load) at which no seizure occurred and when required by specification, include a copy of the friction recording (sample recording chart), which is generally recommended. In SRV models III, IV, and V, friction and stroke can be recorded and displayed simultaneously

NOTE 10—The evolution of the friction force signal is dependent on the type of the grease or oil under test. Different manifestations of the friction



1. Base of the Receiving Block
2. Piezo Force Measurement Elements
3. Supporting Surface (Head Plate) of the Receiving Block
4. Lower Specimen Holder
5. Position of the Electrical Resistance Heating Resistance Thermometer
6. Oscillation Drive Rods
7. Upper Specimen Holder
8. Drive Rods of the Load Unit
9. Test Disk
10. Test Ball
F_n Normal Force (Test Load)
F_f Friction Force

FIG. 4 Test Chamber Elements of SRV Models IV and V

force curve need not necessarily be indicative of adhesion having occurred. In Test Method D5706 gives some typical examples to guide the user to determine the moment of seizure. These figures were approved by the DIN 51834 working group and ASTM D02.G0 in 2003. The working groups believed that the figures also apply to oils.

11. Precision and Bias[6]

11.1 Twenty-eight cooperators tested in an international round robin test in 2006 three oils (SRV-Calibration oil, HLP 46 hydraulic oil, factory fill, hydrocarbon-based SAE 5W-30 engine oil) at two temperatures having average load carrying capacities in the SRV apparatus ranging from approximately 800 N to approximately 1800 N (see Table 1). Of these cooperators, 73 % used single boiling point spirit as cleaning solvent. The statistical analysis of data from this interlaboratory test program appears in the research report.[6]

11.1.1 Twelve co-operators determined in a round robin test in 2014 the extreme pressure properties four different hydraulic oils according to D7421 (T= 80 °C; Δx = 2 mm).[7]

11.2 The following criteria should be used for judging the acceptability of results (95 % probability) for lubricating oils, which have pass load carrying capacities of 1900 N or less in the SRV apparatus using 2.0 mm of stroke.

11.2.1 *Repeatability*—The difference between successive results obtained by the same operator with the same apparatus under constant operating conditions on identical test material would, in the long run, in the normal and correct operation of the test method exceed the following values only in one case in twenty.

For tests run at 80 °C: 0.33 X

For tests run at 120 °C: 0.25 X

where: X = the average of two results, N.

11.2.2 *Reproducibility*—The difference between two single and independent results obtained by different operators working in different laboratories on identical test materials would, in the long run, exceed the following values only in one case twenty.

For tests run at 80 °C: 0.47 X

For tests run at 120 °C: 0.44 X

where: X = the average of two results, N.

11.3 *Bias*—The evaluation of load-carrying capacity of lubricating oils by this test method has no bias because load-carrying capacity can be defined only in terms of the test method.

NOTE 11—This test can also be performed using 1 mm of stroke. The round robin data justifying the precision statements are summarized in Table 1 using the same test oils as for 2 mm of stroke.

NOTE 12—The precision values (r, R) in 11.2 represent the median value for each oil type tested in the round robin. (See Table 1.)

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1606. Contact ASTM Customer Service at service@astm.org.

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1851. Contact ASTM Customer Service at service@astm.org.

TABLE 1 Precision Data

NOTE 1—Extreme pressure pass loads of oils without outliers (Ø = 10 mm Ball; Stroke = 1 or 2 mm; 100 N load increment every 2 min; υ = 50 Hz, data per 15.10.2006; SRV I, SRV II, SRV III, and SRV IV models).

NOTE 2—The repeatability and the reproducibility were calculated using the ASTM software (ADJD6300 D2PP). Values in parentheses represent an initial, average (mean) Hertzian contact pressure using the mean test load and the initial test geometry at the beginning of the test.

DIN E51834–5/ASTM D7421	Oil I SRV	Oil I SRV	Oil I SRV	Oil I SRV	Oil II HLP46	Oil II HLP46	Oil II HLP46	Oil II HLP46	Oil III 5W-30	Oil III 5W-30	Oil III 5W-30	Oil III 5W-30
Test-T	80 °C	80 °C	120 °C	120 °C	80 °C	80 °C	120 °C	120 °C	80 °C	80 °C	120 °C	120 °C
Stroke, mm	1	2	1	2	1	2	1	2	1	2	1	2
Number of Results	30	52	30	54	30	46	30	46	30	48	30	54
Degree of Freedom	17	28	16	33	17	27	19	29	17	36	16	36
Higheset test load (N) mean (MPa)	890 (<3006)	1129 (<3255)	890 (<3006)	1013 (<3139)	790 (<2889)	1521 (<3598)	873 (<2987)	1477 (<3567)	1146 (<3270)	1223 (<3342)	970 (<3093)	1092 (<3218)
Standard Deviation	±322	±186	±335	±172	±250	±217	±256	±217	±275	±203	±293	±150
Reproducibility, R	961	540	1006	494	747	629	758	629	821	584	880	430
Repeatability, r	422	185	352	247	325	292	426	334	339	410	306	250

12. Keywords

12.1 extreme pressure; lubricating oils; oscillating; SRV

SUMMARY OF CHANGES

Subcommittee D02.L0 has identified the location of selected changes to this standard since the last issue (D7421 – 11) that may impact the use of this standard. (Approved Oct. 1, 2016.)

(1) Updated procedures to include software-controlled SRV IV and V models.

(2) Included new Research Report footnote; precision statements are unchanged.