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ISO 20623

Second edition
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Petroleum and related products — Determination of the extreme-pressure and anti-wear properties of lubricants — Four-ball method (European conditions)

Pétrole et produits connexes — Détermination des propriétés extrême pression et anti-usure des lubrifiants — Essai quatre billes (conditions Européennes)

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 28, *Petroleum and related products, fuels and lubricants from natural or synthetic sources*.

This second edition cancels and replaces the first edition (ISO 20623:2003), which has been technically revised.

The main changes compared to the previous edition are as follows:

— this document has been extended to all types of liquid lubricants and greases, whereas previously it applied only to fire-resistant hydraulic fluids;

— the procedures have been technically revised but the essentials remain the same;

— the test balls have been better specified (see Annex A) and calculations for the wear test have been included;

— the calibration procedure of the friction recorder springs has been deleted and reference is now made to the manufacturer's instructions.

Introduction

The four-ball machine is widespread and commonly used to assess the anti-wear properties of all types of liquid lubricants, lubricating greases and other consistent lubricants.

An electrical motor, the rotational speed of which depends on the frequency of the current, actuates the four-ball machine. So, depending on the country where the machines are used, the results obtained cannot be compared.

ASTM has standardized several procedures with these methods, based on the use of the four-ball machine:

— ASTM D2266;

— ASTM D4172;

— ASTM D2596;

— ASTM D2783.

The Energy Institute has standardized IP 239.

DIN has standardized DIN 51350, divided into five parts:

— Part 1: General working principles;

— Part 2: Determination of the welding load of liquid lubricants;

— Part 3: Determination of the wearing characteristics of liquid lubricants;

— Part 4: Determination of the welding load of consistent lubricants;

— Part 5: Determination of the wearing characteristics of consistent lubricants.

DIN, ASTM and Energy Institute test methods stipulate different rotational speeds.

Table 1 summarizes the test conditions for the above standards.

Table 1 — Test conditions of the various four-ball standards

Standard	Lubricant	Type of test	Load (N)	Duration	Rotational speed r/min	Temperature °C
ASTM D2266	Grease	Wear	392	60 min	1 200	75
ASTM D4172	Oil	Wear	147 (A) 392 (B)	60 min	1 200	75 75
ASTM D2596	Grease	Extreme pressure	59 to 7 848	10 s	1 770	19 to 35
ASTM D2783	Oil	Extreme pressure	59 to 7 848	10 s	1 760	18 to 35
IP 239	Grease — oil	Extreme pressure + wear	60 to 7 940	Wear: 60 min EP: 10 s or 60 s	1 450	Not specified
DIN 51350-2	Oil	Weld load	2 000 to 12 000	60 s	1 450	18 to 40

Table 1 *(continued)*

Standard	Lubricant	Type of test	Load (N)	Duration	Rotational speed r/min	Temperature °C
DIN 51350-3	Oil	Wear	150 (A) 300 (B)	60 min	1 450	18 to 40
DIN 51350-4	Consistent lubricant	Weld load	2 000 to 12 000	60 s	1 450	18 to 40
DIN 51350-5	Consistent lubricant	Wear	150 (C) 300 (D) 1 000 (E)	60 min 60 min 60 s	1 450	18 to 40

The lubricants' properties defined by the various test methods are also different. They are defined in Table 2.

Table 2 — Lubricant properties evaluation by the different methods

Standard	Lubricant property
ASTM D2262	MWSD (mm) under 392 N load
ASTM D4172	MWSD (mm) under 147 N of 392 N
ASTM D2596	WL (N), LWI (N), LNSL (last non-seizure load) (N)
ASTM D2783	WL (N), LWI (N)
IP 239	WL (N), LWI (10 s or 60 s), ISL (N), MWSD (mm) (10 s, 60 s or 60 min)
DIN 51350-2	WL (N)
DIN 51350-3	MWSD (150 N or 300 N, 60 min)
DIN 51350-4	WL (N)
DIN 51350-5	MWSD (150 N, 300 N or 1 000 N)

The purpose of this document is to propose a single standard to evaluate the extreme-pressure and the anti-wear properties of all types of lubricants, with the 4-ball machine, based on a single rotational speed of 1 450 r/min.

The operating procedures take into account all the features present on the machines available on the market.

The lubricants' properties involved are as follows:

a) initial seizure load (ISL);

b) weld load (WL);

c) wear-load curve;

d) Load-Wear Index (LWI);

e) anti-wear characteristics short duration (MWSD) (10 s or 60 s) and long duration (60 min).

Petroleum and related products — Determination of the extreme-pressure and anti-wear properties of lubricants — Four-ball method (European conditions)

WARNING — The use of this document can involve hazardous materials, operations and equipment. This document does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of users of this document to take appropriate measures to ensure the safety and health of personnel prior to the application of this document, and to determine the applicability of any other restrictions.

1 Scope

This document specifies procedures for the measurement of the extreme pressure (EP) and anti-wear properties of liquid lubricants (categories C, D, F, G, H, M, P of ISO 6743-99), lubricating greases (ISO 6743-9, category X) and other consistent lubricants. The test conditions are not intended to simulate particular service conditions, but to provide information over a range of standard conditions for the purpose of research, development, quality control and fluid ranking. The output is used in lubricant specifications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3290-1, *Rolling bearings — Balls — Part 1: Steel balls*

ISO 3170, *Petroleum liquids — Manual sampling*

ASTM D4057, *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
wear
<Four-ball method> removal of metal from the test pieces

Note 1 to entry: Under conditions of low load and low friction, wear causes only small circular scars on the three stationary balls and a ring on the rotating ball. The diameters of these scars are slightly larger than the diameter of the indentation due to the static load (Hertz diameter).

3.2
seizure
<Four-ball method>localized fusion of metal between the rubbing surfaces of the test pieces

Note 1 to entry: Seizure is indicated by an increase in friction and wear, and results in roughened scars and a ring on the balls.

3.3
weld
<Four-ball method>fusion of metal between the rubbing surfaces sufficient for metal to merge and the balls to weld together in the form of a pyramid

3.4
Load-Wear Index
LWI
<Four-ball method>index of the ability of a lubricant to minimize *wear* (3.1) at applied load (load-carrying property of a lubricant)

Note 1 to entry: The LWI is expressed in newtons.

3.5
wear-load curve
logarithmic plot of the load against the *mean wear scar diameter* (3.7)

3.6
initial seizure load
ISL
lowest load at which *seizure* (3.2) occurs

3.7
mean wear scar diameter
MWSD
<Four-ball method>mean of six wear scar diameter measurements, two from each of the stationary balls, taken in the direction of rubbing of the balls and at right angles to this

4 Principle

A single ball is rotated in contact with three fixed balls, with the lubricant under test being used to lubricate the balls. A lever enables loads to be applied and resulting measurements of wear, friction and weld are obtained.

Depending on the result to be reported, this document specifies three different test conditions as follows:

a) Test A for the Load-Wear Index (LWI); see 10.1;

b) Test B for the wear-load curve; see 10.2;

c) Test C for the wear; see 10.3.

5 Cleaning solvents

In order to ensure thorough cleaning, suitable solvents shall be used (it can be necessary to use multiple cleaning steps). The best-suited solvent can depend to a significant extent on the type of material being tested.

NOTE As an example, light hydrocarbons or acetone are acceptable choices; whereas, for some hydraulic fluids, an alcohol with low molecular mass can assist in the first cleaning step.

6 Apparatus

6.1 Four-ball extreme-pressure lubricant testing machine, consisting of a device by means of which a bearing ball is rotated in contact with three fixed bearing balls immersed in the fluid under test.

A sectional view is illustrated in Figure 1. Loads are applied to the balls by means of various possible devices like discs on a load lever, electrical jacks, hydraulic or pneumatic devices. The upper rotating ball is held in a special ball clamp (see Figure 2) at the lower end of the vertical spindle of an electrical motor. The driving motor should be capable of maintaining a rotational speed of 1 450 min^{-1} to 1 500 min^{-1}. The lower fixed balls are held against each other in a steel cup by means of a clamping ring and locking nut. The cup assembly is supported above the loading device by a disc that rests on a thrust bearing, thus allowing horizontal displacement and automatic alignment of the three lower balls against the upper ball. The frictional torque exerted on the three lower balls may be optionally measured by means of devices that are specific to the various four-ball machine manufacturers (see 6.2).

NOTE It is important to distinguish between the four-ball extreme-pressure lubricant testing machine specified in this document, and the four-ball wear tester that is limited to loads of 500 N or less.

6.2 Friction recording device, optional, capable of monitoring the friction behaviour of the four-ball system during test. It shall be calibrated according to the recommendations given in the individual manufacturer's manual.

6.3 Load masses, consisting of a series of masses designed for the application of loads from 60 N to 8 kN, for those machines operating with disks loading systems.

NOTE Some robust machines can support loads up to 12 kN.

For machines equipped with a load lever arm, the masses consist of a set of rings of different values which locate into notches or holes machined into the lever arm. The notches or holes are identified with the resultant force that is applied if the mass is located at a particular position

6.4 Microscope, equipped with a calibrated measuring scale capable of measuring with an accuracy of ±0,01 mm.

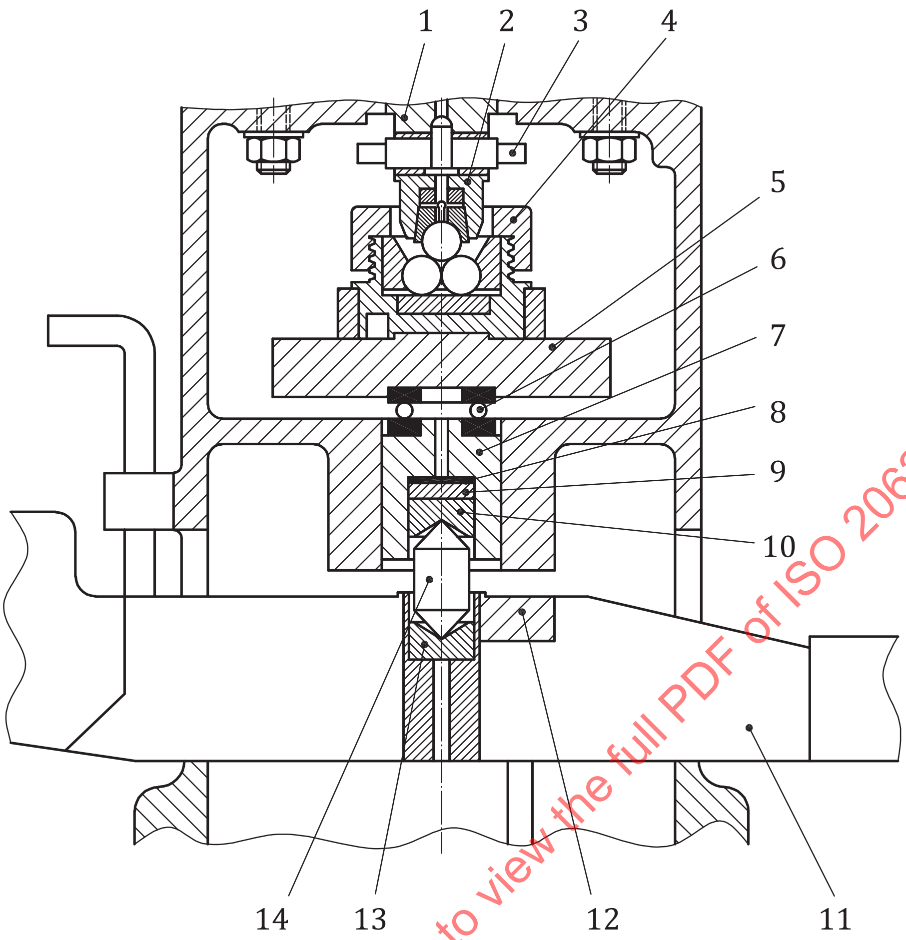
6.5 Timer, manual or electronic, capable of reading to the nearest 0,2 s.

NOTE Some machines are equipped with precise timers, automatically stopping the motor when the selected test duration is reached.

6.6 Test balls, see Annex A.

6.7 Assembly device, consisting of a suitable device bolted firmly to a bench to facilitate the assembly and removal of the lower balls in the ball cup. The ball cup shall be fixed in such way as to enable the locking nut to be tightened or loosened without the cup turning.

Dimensions in millimetres

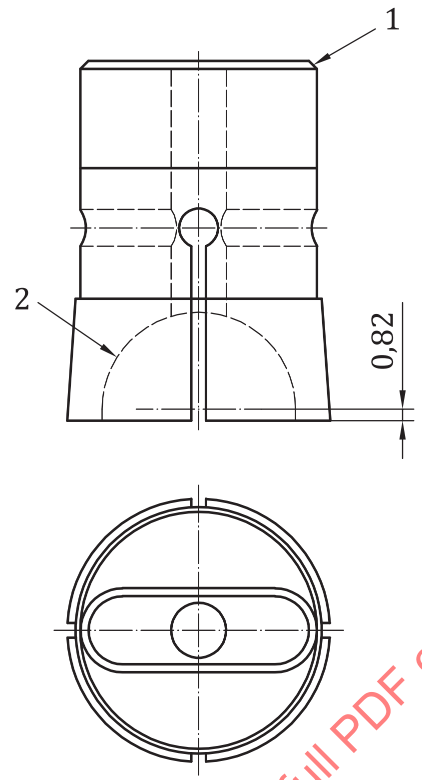


Key

1	ball clamp holder
2	ball clamp
3	ball clamp fixing device
4	ball cup assembly
5	ball cup mounting disk
6	thrust bearing
7	pressure ram
8	brass disks
9	rubber disc
10	step bearing
11	weight beam with counter weight
12	fulcrum
13	step bearing
14	pressure pin

NOTE In some equipment, electrical, pneumatic or hydraulic devices, applying the load on the pressure ram, can replace the weight beam.

Figure 1 — Illustrative sectional view of the four-ball EP testing machine



Key

1 external dimensions to suit the machine

2 ground and lapped to provide a tight fit for test ball

NOTE Material is tool steel (EN 10027).

Figure 2 — Upper ball clamp

7 Samples and sampling

Unless otherwise specified, liquid samples shall be taken in accordance with ISO 3170.

Greases shall be sampled in accordance with ASTM D4057.

8 Preparation of apparatus

8.1 Before starting a series of tests, run the machine (6.1) without load for a minimum of 15 min. Clean all appropriate parts of the machine with the cleaning solvent (Clause 5) and dry in a stream of dry air, or with a clean, dry, lint-free cloth.

8.2 Clean four new test balls (6.6) for each run with the cleaning solvent and dry with a clean, dry, lint-free cloth.

9 General procedure

9.1 Place the ball cup on the assembly device (6.7). Put three clean balls into the cup, hold them in position with the clamping ring, and secure the assembly by tightening the locknut to a torque of 68 Nm ± 7 Nm. Introduce sufficient liquid sample (8 ml to 10 ml) to cover the fixed balls to a depth of at least 3 mm. When testing solid to semi-solid dispersions (grease), completely fill the cup, avoiding the inclusion of air pockets. Imbed the three test balls in the grease. Place the clamping ring, screw down the lock nut and scrape off the excess of grease pushed onto the lock nut.

NOTE 1 Use four new balls and a fresh test portion for each run.

NOTE 2 An alternative method to apply the torque is to fasten the screw nut by hand, and then a further 60° using a wrench.

9.2 Fit a clean ball into the upper ball clamping device and check that it cannot be rotated by hand within the clamping device. Reject clamping devices in which the ball is loose. Fit the clamping device into the taper at the end of the motor spindle.

9.3 Mount the ball cup assembly centrally under the spindle in contact with the fourth ball. Place the mounting disc between the thrust bearing and the cup so that, when the cup is lowered into position, it sits squarely on the disc and is free to rotate with it.

9.4 For machines equipped with a load lever arm, the masses consist of a set of rings of different values which locate into notches or holes machined into the lever arm. The notches or holes are identified with the resultant force that is applied if the mass is located in a particular position.

9.5 If an indication of friction is required, set the friction recording device (6.2) according to the equipment manufacturer's instructions.

9.6 Apply the load using the loading device fitted on the machine (load lever plus weights, electric jacks, hydraulic or pneumatic devices), taking care to avoid shock loading as this can deform the balls permanently. Check that the three lower balls centre themselves against the upper ball.

NOTE Some machines are fitted with a release lever acting upon the load lever; this offers the possibility to regulate the time taken to apply the full load.

It is permissible for rotation to commence prior to the application of the full load. The timer and friction recording device should be started when the full load is applied. This has the effect of reducing the distress on the contact areas during the first rotations of the upper ball and avoids vibrations. The way of load application influences the shape and the definition of the edges of the wear scar.

9.7 Start the motor operating at 147 rad/s to 157 rad/s (1 450 r/min to 1 500 r/min), the timer (6.5) and the friction recording device, if required. For the machines fitted with integrated timers, select the required test duration. Switch on the drive motor and timer simultaneously; the friction recorder should also be switched on at the same time, where applicable. Check to ensure that the rotational speed is within the range 1 450 min^{-1} to 1 500 min^{-1} (147 $rad \cdot s^{-1}$ to 157 $rad \cdot s^{-1}$).

9.8 Allow the machine to run for the appropriate length of time, either stopping the machine manually or using the integrated timer. Switch off the recorder if running, and remove the load from the balls by removing the load applied (raising the lever arm and locking it in position, or deactivating the loading device). Some machines are equipped with automatic shut-off devices to prevent excessive wear of the ball clamp, in case of welding, as the ball clamp will spin around the top ball.

9.9 Disconnect the friction recorder if connected. Remove the cup from the machine. Pour out the test portion from the cup and rinse the assembly with cleaning solvent. Remove the balls (see NOTE), wash again with cleaning solvent, dry and place in a suitably marked container for safe keeping and subsequent measurement of scar diameters.

NOTE If the test requires measurement of scar diameters, this may be carried out either before or after removing the balls from the cup, according to the type and optical axis of the microscope being used. It is helpful to etch or engrave the surface of the balls to indicate the position of the wear scars, particularly when these are very small; otherwise, it can be difficult to find the scars again.

9.10 If values for the coefficient of friction are required, record the values from the friction recording device.

9.11 Clean the lock nut, lock ring, etc., in preparation for the next test. Remove the upper ball clamp from the machine and knock the ball out of the chuck by means of a hardened-steel pin and a hammer. Clean the ball clamp thoroughly.

9.12 Repeat the above procedure, using four new balls and a fresh test portion for each run, for all the determinations and different loads required to complete a specified test procedure.

10 Test procedures

10.1 Test A — Load-Wear Index (LWI)

10.1.1 A specimen data sheet for the recording of results is given in Annex B. The applied loads are given in newtons (N) in Table B.1.

Test machines with loading disks that use kilograms (kg) should have their results expressed in newtons (N) using the conversion factor 9,806 N = 1 kg force.

Users should use the series of loads that most closely correspond to the examples given in Annex B and work out the load correction factors using Formula (2). For example, for the base load, 40 kg added to the 1 kg disc-hanger mass gives an applied load of 402,05 N.

10.1.2 Carry out a series of runs applying a starting load of 400 ± 5 N (marked “base”) and allowing the machine to run under load for the specified time period of 10,0 s ± 0,2 s or 60,0 s ± 0,5 s. Carry out subsequent runs at successively higher loads until welding of the balls occurs.

NOTE The choice of run time depends upon the fluid type and the specification requirement.

10.1.3 Switch the machine off immediately when welding occurs to prevent excessive wear on the chuck.

10.1.4 Carry out two check runs at the weld load. If welding does not occur in the second run, carry out a run at the next higher load and check that welding occurs.

10.1.5 If the verified welding occurs at or below 3,55 kN, carry out additional runs at successive decrements of about 400 N below the welding load to provide a total of 20 runs exclusive of the welding load. If welding occurs above 3,55 kN, do not carry out any additional runs below 400 N.

10.1.6 After each run, measure, using the microscope (6.4), the two wear scar diameters to the nearest 0,01 mm in the direction of rubbing and at right angles to it, on each of the three lower balls and record the dimensions in columns 1 to 6 on the data sheet, an example of which is given in Table B.1 (see 9.9).

Several different types of wear scar can be found. At low loads before seizure has occurred, the wear scar is normally circular with well-defined edges and its measurement presents no difficulty. At light higher loads after seizure, the wear scar is still approximately circular, but the edges are frequently ragged and sometimes can be obscured by metal worn off during the run, adhering to the scar on the trailing edge. This obstruction should be carefully removed with a sharp, hand-held blade to reveal the true edge.

10.2 Test B — Wear-load curve, welding load, and initial seizure load

10.2.1 Carry out a series of runs of 10 s ± 0,2 s or 60 s ± 0,5 s with loads in 100 N steps up to 1 000 N, then in 250 N steps up to 3 000 N, and finally in 500 N steps up to 8 000 N. The lowest load shall be such that at least three runs are carried out below the initial seizure load, and the highest load shall be the welding load, which is confirmed by additional runs 100 N below the welding load.

The results from the Load-Wear Index runs may be used as part of the plot of the wear-load curve, but additional runs are required to define more closely the shape of the curve.

10.2.2 Measure the wear scar diameters as described in 10.1.6.

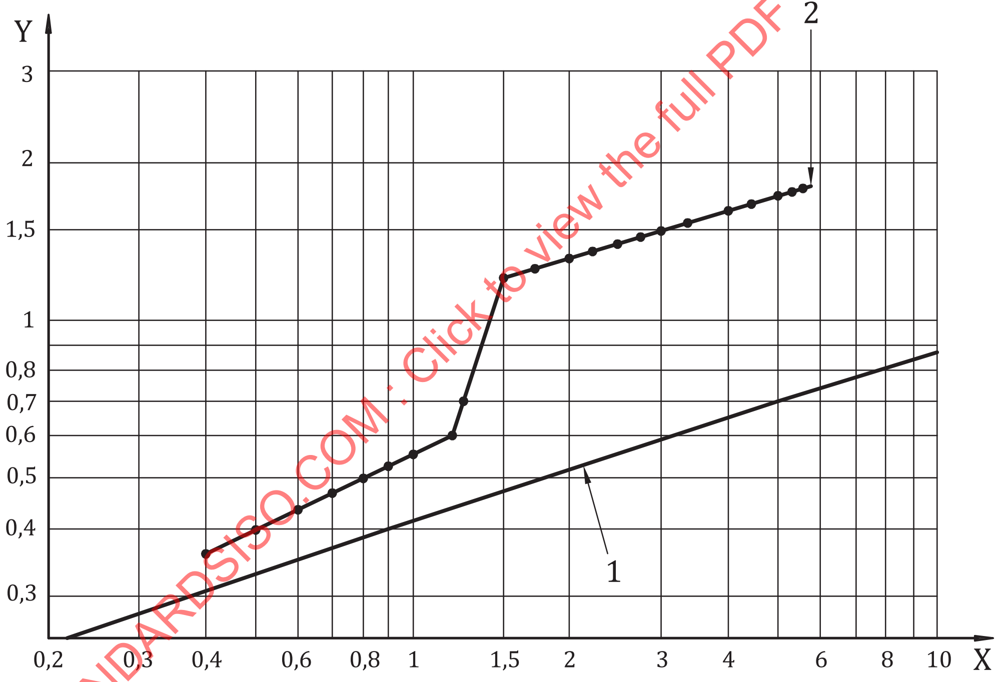
10.2.3 Plot a wear-load curve as shown in Figure 3 or Figure 4.

The initial seizure load may be confirmed by the output of the friction recording device, if used. If the 2,5 s seizure delay is required, the use of the friction recording device becomes mandatory.

10.3 Test C — Wear test

10.3.1 Select the duration of the run, the applied load and the temperature in accordance with the specified requirements and carry out the run in the manner described in Clause 9.

10.3.2 Measure the wear scar diameters as described in 10.1.6.



Key

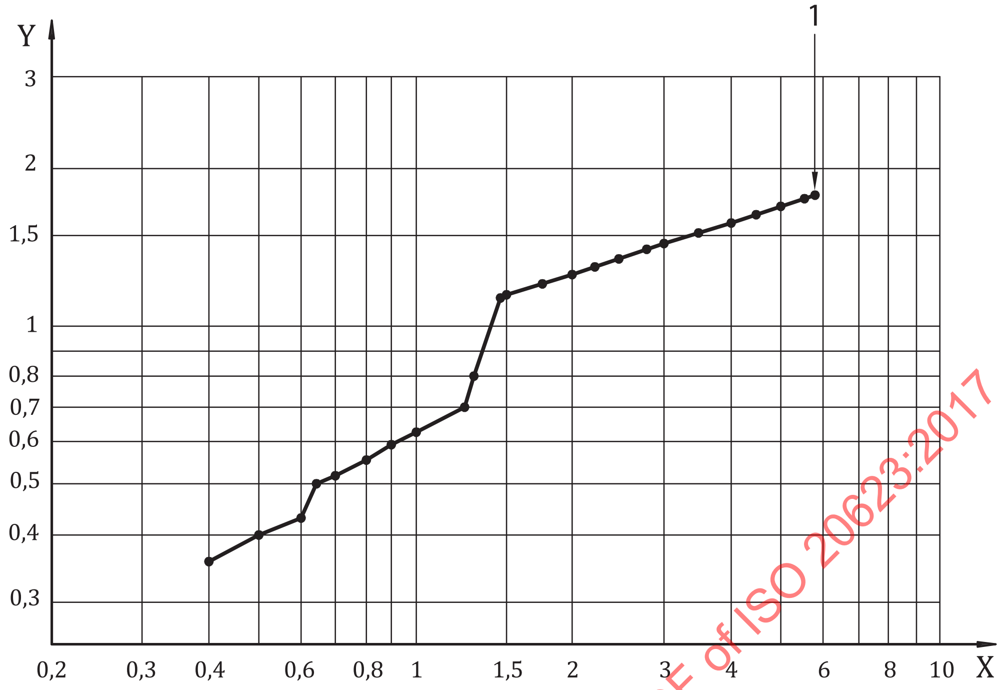
X load, in kN

Y wear scar diameter, in mm

1 Hertz line

2 welding load

Figure 3 — Wear-load curve



Key

X load, in kN

Y wear scar diameter, in mm

1 welding load

Figure 4 — Wear-load curve

11 Calculations

11.1 General

Where spherical balls are in contact under load, the theoretical diameter of the circular area of contact produced by elastic deformation of the material is the Hertz diameter, H. A plot of Hertz diameter against load on a log/log basis is a straight line as shown in Figure 3, and is known as the Hertz line. Two suitable reference points for this line as applied to the four-ball machine are the Hertz diameters at 392 N and 3,10 kN, which are equal to 0,300 mm and 0,597 mm, respectively.

11.2 Test A — Load wear index

11.2.1 The corrected load, L_c, is obtained by reducing the actual load by the factor $\frac{H}{D_m}$ as given in Formula (1):

$$L_c = L_a \times \left(\frac{H}{D_m} \right) \tag{1}$$

where

L_a is the actual load;

H is the Hertz diameter;

D_m is the mean wear scar diameter.

The Hertz diameter, H, is calculated by Formulae (2) or (3), depending on the unit of the load:

$$H_N = 4,1 \times 10^{-2} \times L_{aN}^{1/3} \tag{2}$$

where L_{aN} is the actual load in N.

$$H_k = 8,73 \times 10^{-2} \times L_{ak}^{1/3} \tag{3}$$

where L_{ak} is the actual load in kg.

Since the actual loads and the corresponding Hertz diameters, H, are known, their product can be used as a factor, $L \cdot H$, in calculating the corrected loads from the measured scar diameters.

Calculate the Load-Wear Index (LWI) (see B.1).

11.3 Test B — Wear-load curve, initial seizure load

11.3.1 Plot the results in accordance with 10.2.3 to obtain a curve as shown in Figure 3 or Figure 4.

11.3.2 Read the initial seizure load from the curve at the point at which there is a sharp increase in wear. If there is any doubt, such as for the curve shown in Figure 4, the friction recorder chart, which, if used, indicates a significant temporary increase in friction during seizure conditions, can provide additional information.

11.4 Test C — Wear test

11.4.1 For the wear tests of either 10 s or 60 s duration, report the mean wear scar diameters (MWSD) as a function of the load, the temperature and the duration.

11.4.2 For the 1 h test duration, the reference loads are given in the Table 3.

Table 3 — Reference loads for the 1 h duration test

Type of lubricant	Load (N)	Condition
Liquid	150	C1
	300	C2
Solid to semi-solid dispersions (greases)	150	C3
	300	C4
	1 000	C5

Report the mean wear scar diameter (MWSD), the temperature and the condition.

If other loads and/or durations are applied, report the scar diameter, the load, the temperature and the duration.

12 Expression of results

12.1 Report the weld load to the nearest 100 N as WL (10 s) or WL (60 s), as appropriate.

12.2 Report the Load-Wear Index (LWI) to the nearest 10 N as LWI (10 s) or LWI (60 s), designation "Test A", as appropriate.

12.3 Report the initial seizure load (ISL) to the nearest 50 N as ISL (10 s) or ISL (60 s), as appropriate.

12.4 Report the mean wear scar diameter (MWSD), designation "Test C", to the nearest 0,01 mm from the wear test (10.3) as MWSD with either the duration, load and temperature following in parentheses, e.g. MWSD (1 h, 150 N, 20 °C), or with the condition and temperature, e.g. MWSD (C2, 20 °C).

12.5 If required, supply the wear-load curve, with the designation "Test B".

13 Precision

13.1 General

The precision, as determined by statistical examination in accordance with ISO 4259[1] of the inter-laboratory test results on a matrix of lubricating oils and greases using the test balls specified in 6.6, is given in 13.2 and 13.3. These precision estimates were first published in 1997.

13.2 Repeatability

The difference between two test 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 values given in Table 1 in only one case in 20.

13.3 Reproducibility

The difference between two single and independent test results obtained by different operators working in different laboratories on identical test material would in the long run, in the normal and correct operation of the test method, exceed the values given in Table 4 in only one case in 20.

Table 4 — Precision values

Characteristic	Repeatability[a]	Reproducibility[a]
Weld load (N)	0,004 77 $X^{1,5}$	0,00897 $X^{1,5}$
ISL (N)	0,150 X	0,381 X
LWI (N)	0,013 4 $X^{1,5}$	0,028 4 $X^{1,5}$
MWSD (mm)	0,176 X	0,296 X

a X is the average value of the results being compared.

14 Test report

The test report shall contain at least the following information:

a) a reference to this document, i.e. ISO 20623:2017;

b) the type and complete identification of the product tested;

c) the result of the test (see Clause 12);

d) any deviation, by agreement or otherwise, from the procedure specified;

e) the date of test.

Annex A
(normative)

Test ball specifications

Test balls specifications shall be as follows:

Material: chromium steel AISI 52100 — EN 10027 100CR6 (1.3505)

Chemical composition:

	% (m/m)					
	C	Si	Mn	P	S	Cr
Min	0,95	0,15	0,25	—	—	1,35
Max	1,05	0,35	0,45	0,030	0,025	1,65

Balls:

Size	mm	12,700 0
Hardness	HRC	60 to 66
Specification and grade		ISO 3290-1, **Grade 20**
Diameter tolerance	µm	0,5
Diameter variation	µm	0,5
Deviation from spherical form	µm	0,5
Surface roughness	µm	0,032
Allowable lot diameter	µm	1