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

*Pétrole et produits connexes — Détermination des propriétés extrême
pression et anti-usure des fluides — Essai quatre billes (conditions
européennes)*

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 20623 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*.

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

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

1 Scope

This International Standard specifies procedures for the measurement of the extreme-pressure (EP) and anti-wear properties of lubricating oils and fluids by means of the four ball machine. The conditions of test are those that apply in Europe and other areas that have similar electrical supply characteristics (200 V to 250 V, 50 Hz). In North America, the conditions of test are slightly different, but provide a similar ranking of the lubricating properties of fluids. 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 referenced documents are indispensable for the application 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 683-17:1999, *Heat-treated steels, alloy steels and free-cutting steels — Part 17: Ball and roller bearing steels*

ISO 3170:—¹⁾, *Petroleum liquids — Manual sampling*

3 Terms and definitions

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

3.1

wear

removal of metal from the test pieces

NOTE 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).

¹⁾ To be published. (Revision of ISO 3170:1988)

3.2

seizure

localized fusion of metal between the rubbing surfaces of the test pieces

NOTE Seizure is indicated by an increase in friction and wear, and results in roughened scars and a ring on the balls.

3.3

weld

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

mean Hertz load

MHL

single number representation, of the overall wear-load diagram that covers loads from well below seizure to welding

NOTE The MHL is expressed in newtons.

3.5

wear-load curve

logarithmic plot of the load against the mean wear-scar diameter

3.6

flash temperature parameter

FTP

single number representation of the critical flash temperature above which a given fluid will fail under given conditions

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NOTE Under the conditions of this International Standard, the FTP is given by:

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$$FTP = \frac{10m}{d^{1,4}}$$

where

m is the applied load, expressed in newtons;

d is the wear-scar diameter at load $10m$, expressed in millimetres.

3.7

initial seizure delay load

lowest load at which seizure occurs

3.8

2,5 second seizure delay load

load corresponding to a 2,5 s delay between the start of the run and the onset of seizure

4 Principle

A single ball is rotated in contact with three fixed balls, the fluid 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.

5 Reagents and materials

5.1 Cleaning solvents

Solvents appropriate to the material last tested. For mineral oils, light hydrocarbons and acetone are suitable. For some hydraulic fluids, an alcohol of low molecular mass will assist in the first cleaning stage.

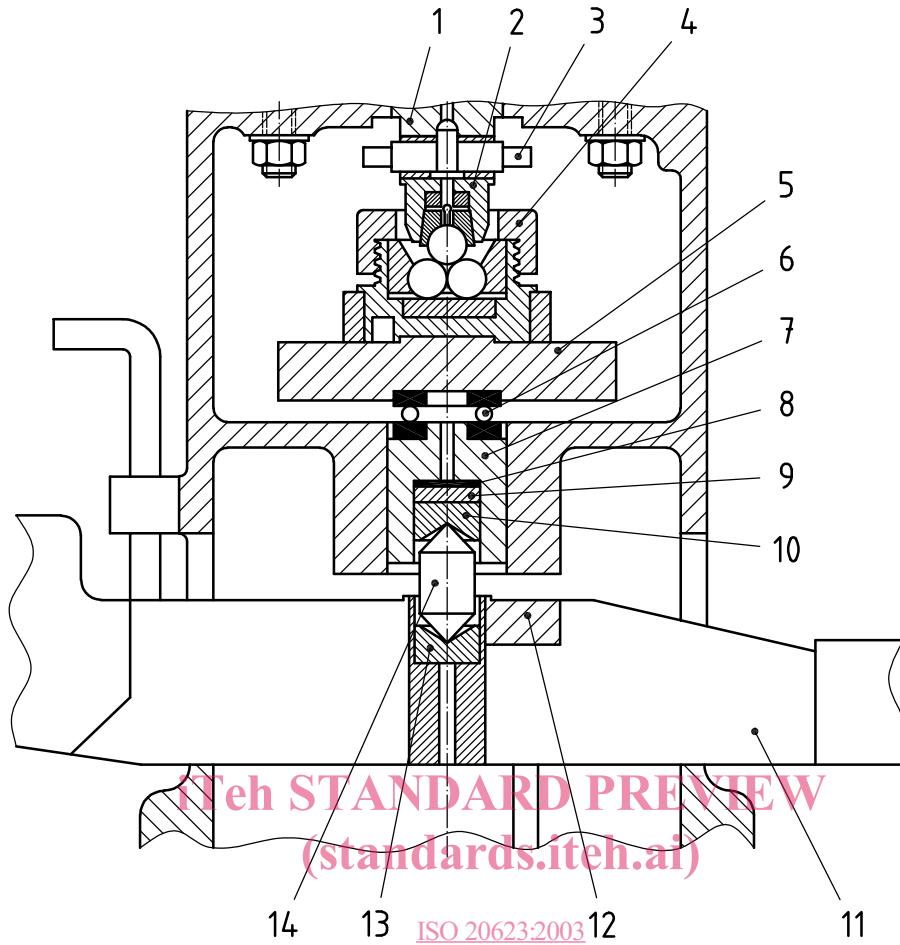
6 Apparatus

WARNING — The apparatus requires the use of heavy mass discs and due care shall be exercised when applying them or removing them from the load lever. The apparatus also contains unguarded rotating components, and due care shall be taken to avoid contact with the shaft, or entrainment of clothing or hair.

6.1 Four-ball extreme-pressure lubricant testing machine

Essentially a device by means of which a bearing ball may be rotated in contact with three fixed bearing balls immersed in the fluid under test, with no provision for temperature control. A sectional view is illustrated in Figure 1. Loads are applied to the balls by means of discs on a load lever. The upper rotating ball is held in a special chuck (see Figure 2) at the lower end of the vertical spindle of a constant-speed electric motor, operating at 147 rad/s to 157 rad/s (1 450 r/min to 1 500 r/min). 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 load lever, by a disc which 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 is measured by means of a calibrated arm, attached to the cup assembly, which is connected to the spring of a friction recording device (6.2).

NOTE It is important to distinguish between the four-ball extreme-pressure lubricant testing machine specified in this International Standard, and the four ball wear tester, which is limited to loads of up to 500 N.

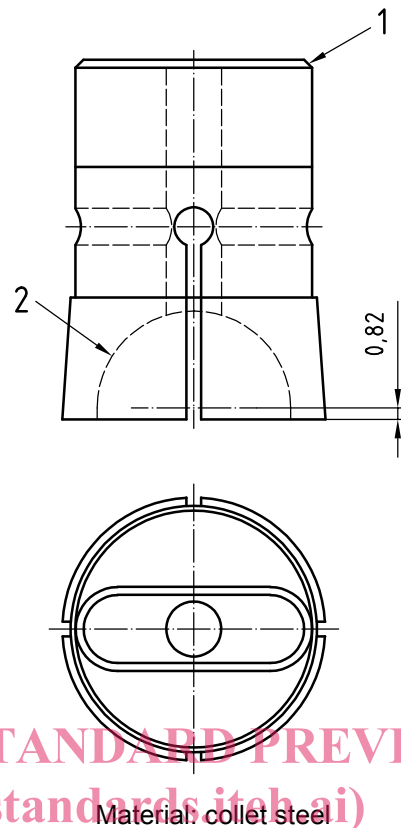


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Key

- | | |
|-------------------------------|-------------------------------|
| 1 ball chuck holder | 8 brass shims |
| 2 ball chuck | 9 rubber disc |
| 3 cam for removing ball chuck | 10 step bearing |
| 4 ball pot assembly | 11 counter-weighted lever arm |
| 5 ball pot mounting disc | 12 fulcrum |
| 6 thrust bearing | 13 step bearing |
| 7 cross head | 14 pressure pin |

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

**Key**

- 1 external dimensions to suit the machine
- 2 6,33/6,35 spherical radius, ground and lapped to provide a tight fit for SKF steel ball No. RB 12.7/3-10995A

Figure 2 — Upper ball chuck**6.2 Friction recording device (optional)**

A device mounted on a calibrated guide bar and consisting of a spring with one end anchored with the other end attached, by a wire, to the calibrated arm on the cup assembly. The extension of the spring in resisting the frictional torque is transmitted through a link mechanism to a pen which records its travel at a drum rotating at approximately 0,1 rad/s (0,8 r/min to 1,0 r/min). The spring stiffness required and the distance of the recorder from the vertical axis of the upper ball is variable, and dependent upon the coefficient of friction and the loads applied. The spring shall be calibrated by the procedure described in Annex B.

NOTE Three standard spring stiffnesses are available, namely weak, medium and strong, and each spring needs to be recalibrated when attached to a different recorder.

6.3 Loading discs

A series of masses designed for the application of loads from 60 N to 8 kN.

6.4 Microscope

Equipped with a calibrated measuring scale capable of measuring with an accuracy of $\pm 0,01$ mm.

6.5 Timer

Manual or electronic, capable of reading to the nearest 0,2 s.

6.6 Test balls

Lime polished, chrome alloy steel balls of $12,700\ 0\ \text{mm} \pm 0,000\ 5\ \text{mm}$ diameter, conforming to the requirements of ISO 683-17:1999, type 1. The balls shall be specially supplied for four ball testing.

NOTE Balls are available from a single supplier or their distributors under the SKF designation RB 12.7/3-10995A. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of these products.

6.7 Assembly device

A plate with three pins bolted firmly to a bench, to facilitate the assembly and removal of the lower balls in the ball cup. The pins locate with holes in the underside of the cup to enable the locking nut to be tightened or loosened without the cup turning.

7 Samples and sampling

Unless otherwise specified, samples shall be taken by the procedure described in ISO 3170.

8 Preparation of apparatus

8.1 Before starting a series of tests, run the machine (6.1) unloaded for a minimum of 15 min. Clean all appropriate parts of the machine with the cleaning solvent (5.1) 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.

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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 $68\ \text{N}\cdot\text{m} \pm 7\ \text{N}\cdot\text{m}$. Pour in sufficient sample (8 ml to 10 ml) to cover the balls to a depth of at least 3 mm.

9.2 Fit a clean ball into the upper ball chuck and check that it cannot be rotated by hand within the chuck. Reject chucks in which the ball is loose. Fit the chuck 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 Suspend the disc hanger, which has a mass of 1 kg, from the appropriate notch on the load lever, and place the required masses (6.3) on it to give the desired load.

9.5 If an indication of friction is required, set the friction recording device (6.2) at a scale reading on its guide bar equivalent to the load. Similarly, set the clip on the calibrated arm to the same scale reading and link to the friction recorder. At loads of 1 kN and less, set the friction recorder and clip at position 100, in which case the apparent value of coefficient of friction shall be multiplied by 100/applied load. Wrap a new chart paper around the recorder drum, oscillate the spring to obtain its position of zero deflection, and rotate the drum through one revolution to obtain a zero-friction reference line on the chart.

9.6 Release the load lever and apply the load slowly to the balls, taking care to avoid shock loading as this may deform the balls permanently. Check that the three lower balls centre themselves against the upper ball.

9.7 Start the main motor, the timer (6.5), and the friction recorder drum if required.

9.8 Allow the machine to run for the appropriate length of time, stop the motor, switch off the recorder if running, and remove the load from the balls by raising the lever arm and locking it in position.

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 the following note), wash again with cleaning solvent, dry and place in a suitable marked container for safe keeping and subsequent measurement of scar diameters.

NOTE When the test requires measurement of scar diameters, this may be done 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 mark the surface of the balls with an electric etcher to indicate the position of the wear scars, particularly when these are very small, otherwise there may be difficulty in finding the scars again.

9.10 If values for the coefficient of friction are required, read and record the pen deflections, expressed in millimetres, from the friction chart.

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

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10.1 Mean Hertz load (MHL)

10.1.1 A specimen data sheet for the recording of results is given in Annex A. The applied loads are given in newtons (N), although the actual loading disc masses are likely to be in kilograms. 1 kgf \approx 9,806 N.

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Users should use a series of masses that most closely correspond to the examples given in Annex A and work out the load correction factors using the equation given in Clause 11. For example, for the base load, an added 40 kg 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 N \pm 5 N (marked “base”) and allowing the machine to run under load for the specified time period of 10,0 s \pm 0,2 s or 60,0 s \pm 0,5 s. Carry out subsequent runs at successively higher loads until welding of the balls occurs.

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

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

NOTE At the point of weld, the chuck will spin round on the top ball.

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 successively lower loads below 400 N 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 the two wear-scar diameters using the microscope (6.4) 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 them in columns 1 to 6 on the data sheet, an example of which is given in Annex A (see the note to 9.9).

NOTE Several different types of wear scar may be found. At low loads before seizure has occurred, the wear scar is normally circular with well-defined edges and measurement presents no difficulty. At light loads after seizure, the wear scar is still approximately circular, but the edges are frequently ragged, and sometimes may be obscured by metal worn