
**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)*

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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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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:

- initial seizure load (ISL);
- weld load (WL);
- wear-load curve;
- Load-Wear Index (LWI);
- 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 $\pm 0,01$ mm.

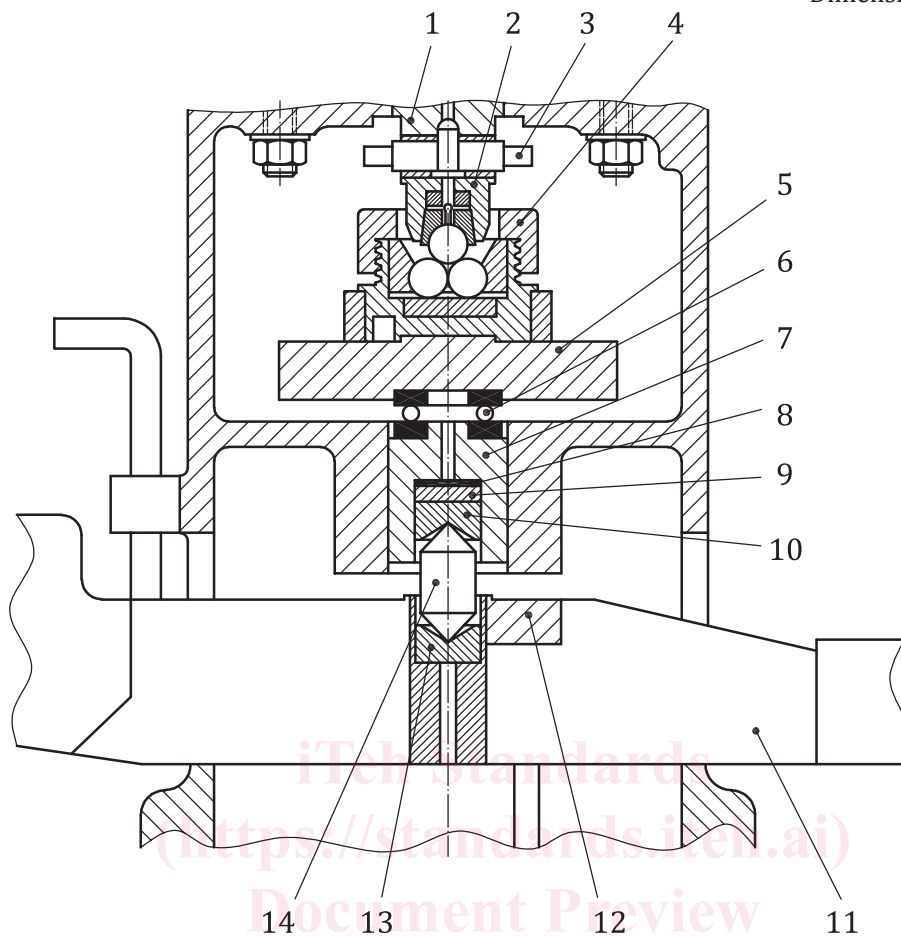
6.5 Timer, manual or electronic, capable of reading to the nearest 0,2 s.

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 | ISO 806 brass disks |
| 2 ball clamp | 9 rubber disc |
| 3 ball clamp fixing device | 10 step bearing |
| 4 ball cup assembly | 11 weight beam with counter weight |
| 5 ball cup mounting disk | 12 fulcrum |
| 6 thrust bearing | 13 step bearing |
| 7 pressure ram | 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