

# INTERNATIONAL STANDARD

# ISO 7986

First edition  
1997-07-15

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## Hydraulic fluid power — Sealing devices — Standard test methods to assess the performance of seals used in oil hydraulic reciprocating applications

*Transmissions hydrauliques — Dispositifs d'étanchéité — Méthodes d'essai  
normalisées d'évaluation des performances des joints utilisés dans des  
applications alternatives à l'huile hydraulique*

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Reference number  
ISO 7986:1997(E)

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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.

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.

International Standard ISO 7986 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 7, *Sealing devices*.

Annexes A, B and C form an integral part of this International Standard. Annex D is for information only.

## Introduction

### 0.1 General

It is widely recognized that the results from reciprocating seal testing can be unpredictable. The background research carried out in support of the preparation of this International Standard has demonstrated that this unpredictability is primarily a function of lack of control of critical variables affecting seal installation and operation. In order to carry out direct comparisons of seal performance, it is necessary to control these variables to closer limits than may be normal in industrial practice. The major variables that can affect seal performance, often even within normal manufacturing tolerance ranges, are listed in subclause 0.3.

### 0.2 Purpose of the test

The purpose of the test is to provide comparative data on individual reciprocating shaft seal designs and to provide a basis for the preliminary selection of seals based on their relative performance. To achieve this, it is necessary to carry out the tests under strictly defined operating conditions. This International Standard therefore defines standard values of speed, pressure, temperature and surface finish. This will permit comparison of seal test results from sources worldwide.

To make the test results as useful as possible, a range of operating conditions has been provided, so that the most appropriate conditions can be selected as a basis for comparison for initial seal selection.

The pressures are standard working pressures, selected from ISO 2944:1974, 6,3 MPa (63 bar<sup>1</sup>), 16 MPa (160 bar), and 31,5 MPa (315 bar).

The speeds have been selected to include slow speed (where stick-slip and high wear may be problems), medium speed for general purpose hydraulics and a representative high speed.

The constraints on installation and operation in this procedure have been proved by research (primarily carried out at BHR Group in the United Kingdom, under sponsorship from European companies) and international round robin seal tests to be necessary to achieve repeatable results. Any departure from the standard operating conditions and installation criteria cannot be considered a standard test.

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1) 1 bar = 0,1 MPa = 10<sup>5</sup> Pa.

### 0.3 Factors affecting seal performance

Factors affecting seal performance include:

- a) installation;
  - sealing system, i.e., design of bearing(s), seal(s) and wiper seal;
  - installation tolerances, including seal groove, shaft and bearings, extrusion gap;
  - shaft material and hardness;
  - surface finish of the shaft; variations of surface finish outside the range of  $Ra$  0,08  $\mu\text{m}$  to  $Ra$  0,015  $\mu\text{m}$ , or greater than  $Rt$  1,5  $\mu\text{m}$ , can significantly affect seal performance. Different seal materials also have significantly varying requirements for the optimum surface finish;
  - surface finish of the groove surfaces. This must be less than  $Ra$  0,8  $\mu\text{m}$  to avoid static leakage and wear of the seal during pressure cycles;
  - bearing material, including its effects on shaft texture and boundary layer.
- b) operation;
  - fluid, i.e., viscosity, lubricity, compatibility with seal material, including additives and contamination level;
  - pressure, including pressure cycle;
  - speed, especially speed cycle;
  - speed/pressure cycle, i.e., stop-start conditions;
  - stroke, especially short strokes (two times the seal contact widths or less), which prevent formation of a lubricant film;
  - temperature, i.e., its effect on viscosity and seal material properties;
  - external environment.

It is necessary to consider all the above factors and their potential effect on seal performance when comparing potential seal performance in an actual application to results obtained from the standard test.

# Hydraulic fluid power — Sealing devices — Standard test methods to assess the performance of seals used in oil hydraulic reciprocating applications

## 1 Scope

This International Standard defines the test conditions and methods for assessing the performance of seals used in oil hydraulic reciprocating applications.

The resulting specified characteristics may be published in manufacturer's literature to enable a direct comparison of seal performance.

The seal under test may be a single seal or a combination seal package.

## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 286-2:1988, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts.*

ISO 1052:1982, *Steels for general engineering purposes.*

ISO 1629:1995, *Rubber and latices — Nomenclature.*

ISO 2944:1974, *Fluid power systems and components — Nominal pressures.*

ISO 3274:1996, *Geometrical Product Specification (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments.*

ISO 4288:1996, *Geometrical Product Specification (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture.*

ISO 6743-4:1982, *Lubricants, industrial oils and related products (class L) — Classification — Part 4: Family H (Hydraulic systems).*

ISO 10766:1996, *Hydraulic fluid power — Cylinders — Housing dimensions for rectangular-section-cut bearing rings for pistons and rods.*

### 3 Symbols

See table 1.

**Table 1 — Symbols, quantities and units**

Symbol	Quantity	Unit
$d$	Seal lip inside diameter	mm
$D$	Nominal seal housing diameter	mm
$E$	Seal length	mm
$F$	Friction force	N
$d_h$	Seal heel inside diameter	mm
$l$	Leakage	ml
$L$	Seal housing length	mm
$p_{test}$	Test pressure (forward stroke)	MPa
$p_{return}$	Return pressure (return stroke)	MPa
$S_l$	Radial seal section – lip	mm
$S_h$	Radial seal section – heel	mm
$v$	Test speed	m/s
$W$	Leakage collection zone	mm
$Ra$	Shaft surface texture, arithmetical mean deviation	$\mu\text{m}$
$Rt$	Shaft surface texture, total height of the surface profile	$\mu\text{m}$

### 4 Test installation

#### 4.1 General

**4.1.1** The tests described in this specification shall be conducted using a suitable test rig possessing the features shown in figure 1 and detail assembly as shown in figure 2.

**4.1.2** The bearing housing shall be designed and constructed as detailed in figure 3 and figure 4 and shall be made of steel. Bearing material shall be polyester fabric/polyester material and shall contain no glass, ceramic, metallic or other potentially abrasive filler. The bearing shall comply with ISO 10766.

**4.1.3** A circuit comprising components capable of cycling the pressure and controlling the flow to the specifications given in table 2 shall be provided to circulate the test fluid through the test seal housing.

**Table 2 — Circuit specification**

Characteristic	Specification
Fluid flow	4 l/min to 10 l/min
Filtration	10 $\mu\text{m}$ absolute (through which fluid is continuously circulated)
Fluid reservoir	20 l to 50 l
Filter change	after every 1 000 h test running
Test oil change	after every 3 000 h test running

New test oil shall be circulated through a new filter for 5 h prior to beginning a test with new oil.

## 4.2 Mechanical details

### 4.2.1 Test rig rod

A test rod complying with table 3 shall be used.

**Table 3 — Test rod specification**

Parameter	Specification
Diameter	36 mm, tolerance f8 (per ISO 286-2)
Material	Shaft material in accordance with ISO 1052, induction hardened before coating with hard chrome with a coating thickness of 0,015 mm to 0,03 mm
Surface texture	Ground and polished to $Ra$ 0,08 to $Ra$ 0,15 $\mu\text{m}$ when measured in accordance with 9.1.1

### 4.2.2 Test rig stroke

The length of stroke shall be limited to 500 mm  $\pm$  20 mm.

### 4.2.3 Test seal housing dimensions

Housings for the test seals shall comply with the dimensions specified in figure 2.

### 4.2.4 Leakage collection and drain

**4.2.4.1** Rod seal (see figures 1 and 2): At the atmospheric extremity of each seal beyond which a wiper seal is installed, a leakage zone,  $W$ , of 20 mm  $\pm$  5 mm shall be provided. Provision shall be made for the collection from within this zone of any leakage that has drained away, for subsequent measurement (see 4.2.4.2). The wiper seals shall be made of nitrile (NBR) rubber (see ISO 1629) with a hardness of 70 IRHD to 75 IRHD and shall conform with the dimensions given in figure 7. New wiper seals shall be installed for each test.

**4.2.4.2** Drain: Leakage drains having a minimum bore of 6 mm shall be provided.

## 5 Test parameters

### 5.1 Test fluid

Test fluid shall be synthetic hydrocarbon hydraulic oil, poly-alpha-olefin ISO-L-HS 32 in accordance with ISO 6743-4. [An example of an oil that conforms to this specification is Mobil SHC 524 2).]

### 5.2 Test fluid temperature

The temperature of the test fluid throughout the tests shall be maintained at 60 °C to 65 °C when measured in the centre of the pressure chamber. The test fluid temperature shall be measured with a suitable thermocouple at the position specified in figure 2.

### 5.3 Test housing rod bearings

Rod bearings as specified in 4.1.2 shall be used in housings that comply with figure 3 and ISO 10766.

2) This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.



## 5.4 Test fluid pressure

The appropriate test pressure,  $p_{\text{test}}$ , shall be selected from the following list, as appropriate to the intended application, in each case with a tolerance of  $\pm 2\%$ :

- 6,3 MPa (63 bar);
- 16 MPa (160 bar);
- 31,5 MPa (315 bar).

## 5.5 Speed of linear actuator

The speed of the reciprocating rod shall be limited to one of the specified linear speeds below, in each case with a tolerance of  $\pm 5\%$ :

- 0,05 m/s;
- 0,15 m/s;
- 0,5 m/s.

## 5.6 Pressure and stroke cycle for dynamic test

The test pressures and strokes shall be cycled as follows:

- a) a forward stroke at constant pressure,  $p_{\text{test}}$ ;
- b) a return stroke at constant pressure,  $p_{\text{return}}$ .

The pressure cycle shall be maintained within the specification given in figure 5 and stroke cycle within the specification given in figure 6.

## 6 Assembly and dismantling of seals

All test seals shall be installed in their housings in the manner prescribed by the seal manufacturer. Lightly wipe test oil onto the test shaft and seal before assembly. After assembly, wipe excess oil from the test shaft to avoid erroneous leakage measurements and excess lubrication.

## 7 Methods of measurement and measuring apparatus

### 7.1 Seal leakage

Measuring cylinders of a maximum capacity of 10 ml and an accuracy of 0,1 ml shall be used at the start of each test. If leakage exceeds 10 ml during the test, then larger measuring cylinders with an accuracy of 1 ml shall be used.

### 7.2 Seal friction

#### 7.2.1 Load cell

The load cell shall be installed on the test rig between the linear actuator and rod and shall be capable of measuring the tensile and compressive forces induced by the friction of the seal. The load cell shall be connected to a suitable conditioning apparatus and chart recorder so that a permanent record of the seal friction may be taken. A chart recorder that has a suitable frequency response and is capable of determining the amplitude of the stick/slip forces shall be used.

## 7.2.2 Determination of dynamic seal friction

**7.2.2.1** The inherent total friction of the sliding bearing surfaces and of any leakage collection wipers,  $F_i$ , shall be determined at the beginning of each test programme (see 4.1 and 4.2.4.1).

**7.2.2.2** The mean frictional forces (in newtons) of the test seals from the chart recorder trace (see figure 8 and figure 9) shall be subsequently determined by the following formula:

$$F_S = \frac{F_T - F_i}{4}$$

where

$F_S$  is the mean mid-stroke value of forward stroke and return stroke friction forces of each seal under test, in newtons;

$F_i$  is the inherent total friction at mid-stroke of the test rig only (see 7.2.2.1), in newtons;

$F_T$  is the sum of the friction at mid-stroke of the test rig for two test seals on the forward and return strokes, in newtons.

NOTE — Because  $F_S$  is a mean value, it cannot be taken as an absolute indication of actual friction for one seal for a given stroke.

## 7.2.3 Procedure for determining breakout friction

**7.2.3.1** Set test circuit to pressure for the required static test period, e.g. 16 h.

**7.2.3.2** On completion of the static test period, set drive circuit to zero pressure.

**7.2.3.3** Set drive pump to test speed.

**7.2.3.4** Set direction to give rod travel with rod extending at seal A.

**7.2.3.5** Start chart recorder (see 7.2.1).

**7.2.3.6** Gradually adjust drive circuit pressure to give shaft motion.

**7.2.3.7** Record friction at the instant of shaft movement on test data sheet (see figure 9).

**7.2.3.8** Increase drive circuit pressure to overcome any increase in the running friction and continue dynamic test.

## 7.3 Pressure measurement

### 7.3.1 Pressure gauge

A pressure gauge with a suitable pressure range shall be used and shall be installed to ensure that the gauge is reliable in a cyclic pressure condition.

### 7.3.2 Pressure transducer

A suitable pressure transducer shall be installed in the seal housing as specified in figure 2 to provide a record of the test pressure cycle. The pressure transducer shall have temperature compensation to provide accurate measurement to  $\pm 0,5\%$  at  $65\text{ }^\circ\text{C}$ .

## 7.4 Surface roughness

A surface roughness measuring instrument that complies with ISO 3274 and includes an electric wave filter shall be used.

## 7.5 Temperature measurement

A thermocouple shall be installed in the test housing as specified in figure 2 and shall be capable of withstanding the maximum circuit pressure [i.e. 31,5 MPa (315 bar)]. The thermocouple shall be calibrated to a repeatability of  $\pm 0,25$  °C.

## 8 Calibration

The following instrumentation and measuring equipment used to perform the tests shall be calibrated annually against a traceable national standard, and the relevant calibration certificate and data shall be recorded on all test data sheets:

- test temperature thermocouple;
- test pressure gauge;
- test pressure transducer;
- test friction load cell;
- surface texture measurement.

The most recent calibration against any in-house calibration standards shall also be recorded on the test data sheet.

## 9 Test procedure

### 9.1 Test programme

**9.1.1** Measure the surface roughness  $R_a$  and  $R_t$  of the test shaft axially along the shaft, using the procedures specified in ISO 4288, with a sampling length of 0,8 mm and an evaluation length of 4 mm.

**9.1.2** Measure dimensions  $d$ ,  $d_h$ ,  $S_l$ ,  $S_h$ , and  $E$  of the new test seals, using a suitable non-contracting measuring instrument with a resolution of 0,02 mm.

**9.1.3** Install the new test seals (see clause 6) and two new leakage collection wiper seals (see 4.2.4.1).

**9.1.4** Bring fluid up to test temperature (see 5.2).

**9.1.5** Set the test rig reciprocating at a linear speed,  $v$  (see 5.5), and maintain the fluid pressure,  $p_{\text{test}}$ , constant for a period of 1 h.

**9.1.6** At the end of this period, record trace of friction forces for a minimum of one cycle and record friction value  $F_T$ .

**9.1.7** Stop reciprocation and maintain pressure for 16 h at  $p_{\text{test}}$  and test temperature.

**9.1.8** Carry out breakout friction measurement per 7.2.3.

**9.1.9** Continue reciprocating the test rig under the conditions used in 9.1.5 above but with the pressure fluctuating between  $p_{\text{test}}$  for forward stroke and  $p_{\text{return}}$  for return stroke, i.e. following the test cycle specified in 5.6.

**9.1.10** Continue procedure per 9.1.5 without interruption for a total of 200 000 cycles at linear speed  $v$  (60 000 cycles at 0,05 m/s). If cycling is interrupted, ignore restart leakage until equilibrium conditions are established.

**9.1.11** Throughout 9.1.10, at the end of each 24 h period and at 200 000 cycles, collect, measure and record leakage from each seal.

**9.1.12** At the conclusion of 9.1.10, repeat the procedures per 9.1.5 and 9.1.6 (measurement of friction at constant pressure).

- 9.1.13** At the conclusion of 9.1.12, continue reciprocating the test rig with pressure fluctuating as in 9.1.9.
- 9.1.14** Continue the procedure per 9.1.13 without interruption until a total of 300 000 cycles have been completed. Tests at 0,05 m/s shall be run for a total of 100 000 cycles.
- 9.1.15** At the conclusion of 9.1.14, repeat 9.1.5 and 9.1.6 (measurement of friction at constant pressure).
- 9.1.16** Stop test rig and repeat breakout friction measurement per 9.1.7 and 9.1.8.
- 9.1.17** On completion of breakout friction measurement (see 7.2.3), stop test.
- 9.1.18** Remove seals, repeat seal measurement per 9.1.2 on the used seals and photograph and record seal condition.

## 9.2 Repeat series

Because the performance of seals can be erratic, to obtain acceptable data, a minimum of six tests shall be carried out to comprise a test series for each seal type.

## 10 Presentation of results

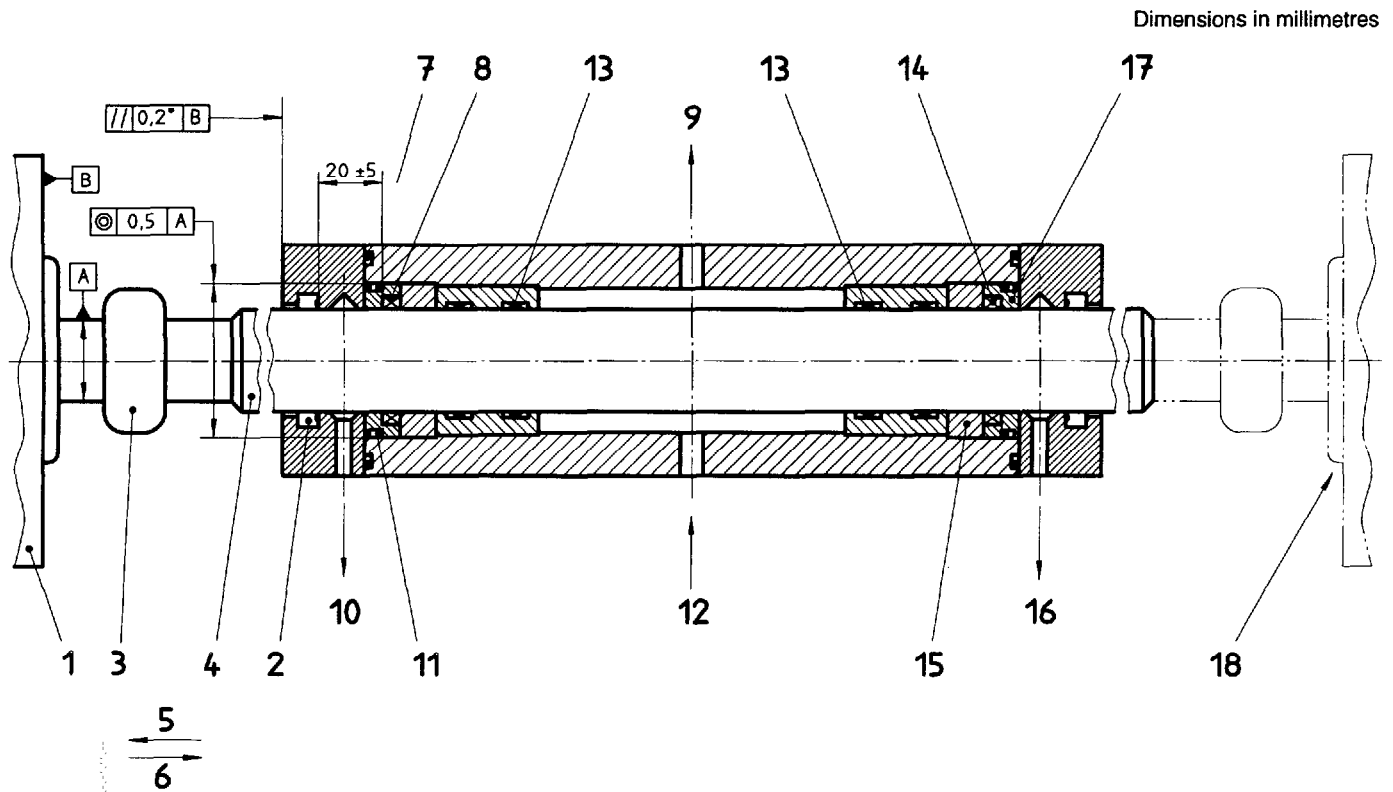
The results of each test conducted in accordance with 9.1 shall be recorded as follows:

- a) individual seal and housing dimensions for each test shall be recorded on the seal and seal housing data forms given in annex A;
- b) individual seal test results shall be recorded on the test log given in annex B;
- c) a test series report for each seal type shall be compiled as shown in annex C.

## 11 Identification statement (Reference to this International Standard)

Use the following statement in test reports, catalogues and sales literature when electing to comply with this International Standard:

*"Performance test procedure in accordance with ISO 7986:1997, Hydraulic fluid power — Sealing devices — Standard test methods to assess the performance of seals used in oil hydraulic reciprocating applications."*

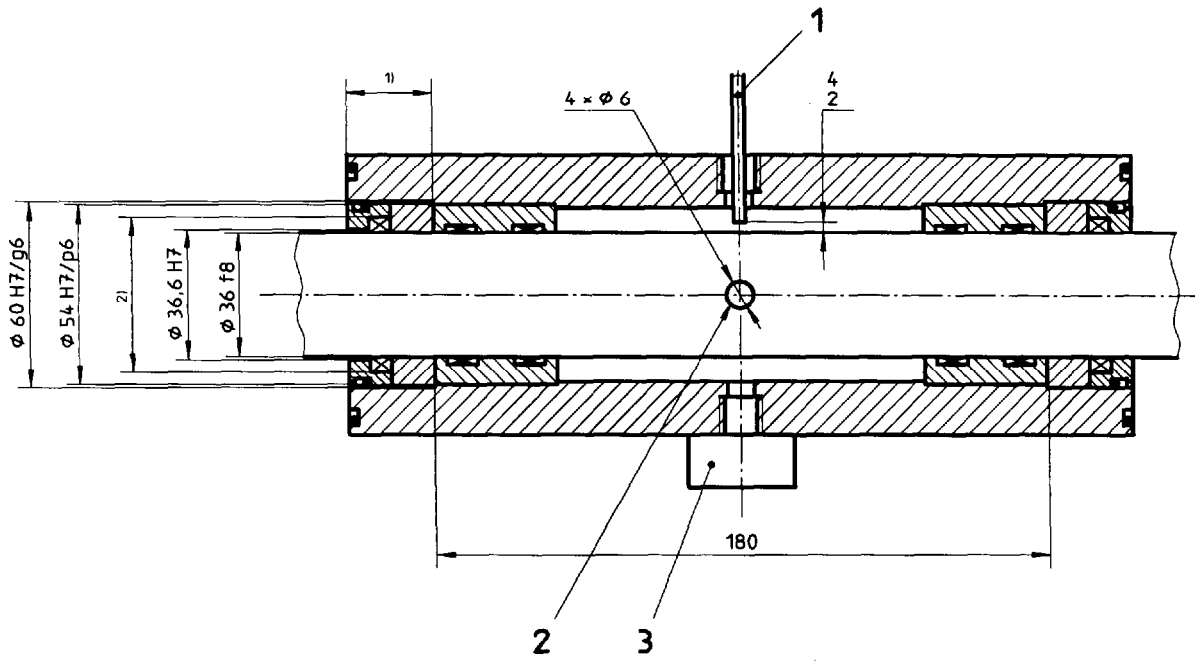


**Key**

- |                                |  |
|--------------------------------|--|
| 1 Linear actuator              | 10 Leakage 1                                   |
| 2 Wiper seal                   | 11 Static O-ring and back-up-ring              |
| 3 Load cell                    | 12 Fluid inlet P                               |
| 4 Test rig piston rod          | 13 Bearing rings                               |
| 5 Pressure stroke              | 14 Test seal B                                 |
| 6 Return stroke                | 15 Spacer                                      |
| 7 Leakage zone (see figure 10) | 16 Leakage 1                                   |
| 8 Test seal A                  | 17 Test seal housing                           |
| 9 Fluid outlet                 | 18 Optional position of actuator and load cell |

**Figure 1 — Test arrangement, vertical section**

Dimensions in millimetres



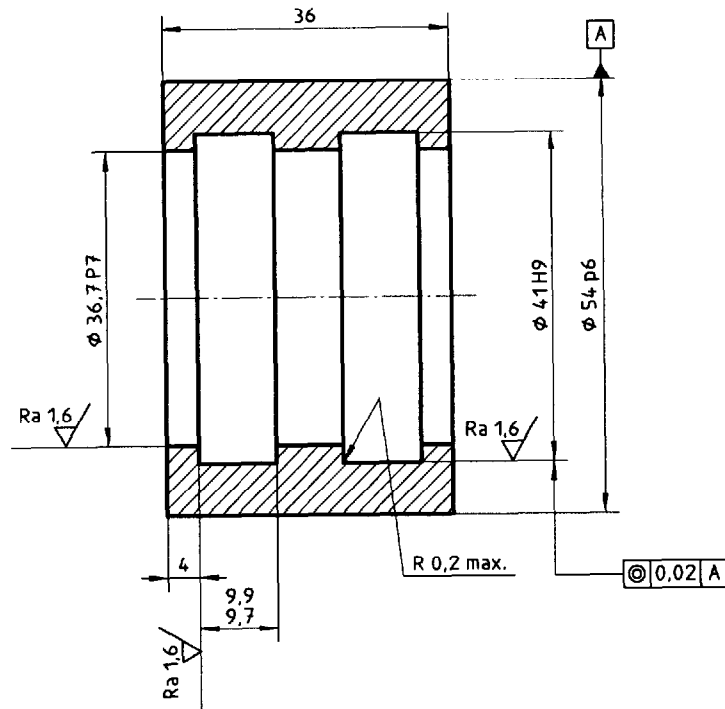
- 1) Recess Length (= seal housing length + spacer length)  $-0,2$ .
- 2) Nominal seal diameter H7.

**Key**

- 1 Thermocouple
- 2 Test oil — inlet bottom  
                  outlet top
- 3 Pressure transducer

**Figure 2 — Plan detail of seal housing assembly**

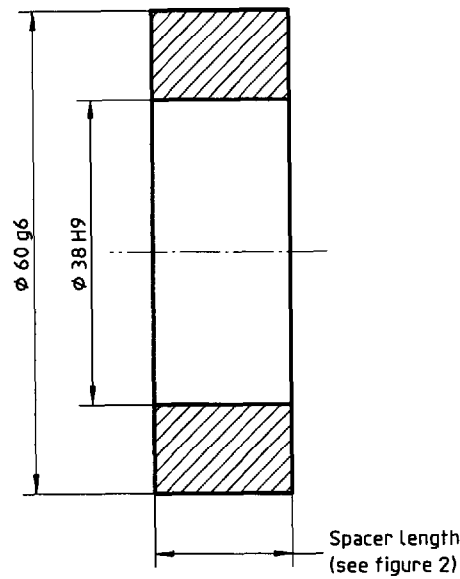
Dimensions in millimetres  
Surface roughness in micrometres



Material: steel

Figure 3 — Detail of bearing assembly

Dimensions in millimetres



Material: phosphor bronze

Figure 4 — Housing spacer

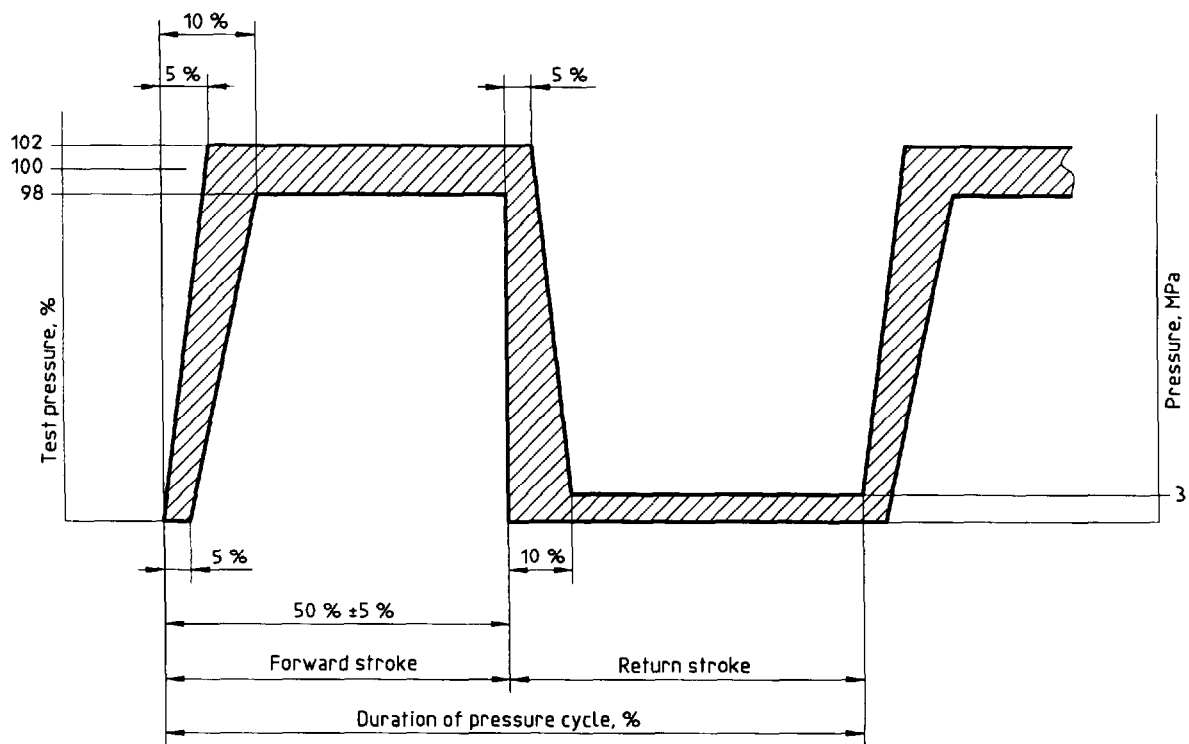


Figure 5 — Pressure cycle

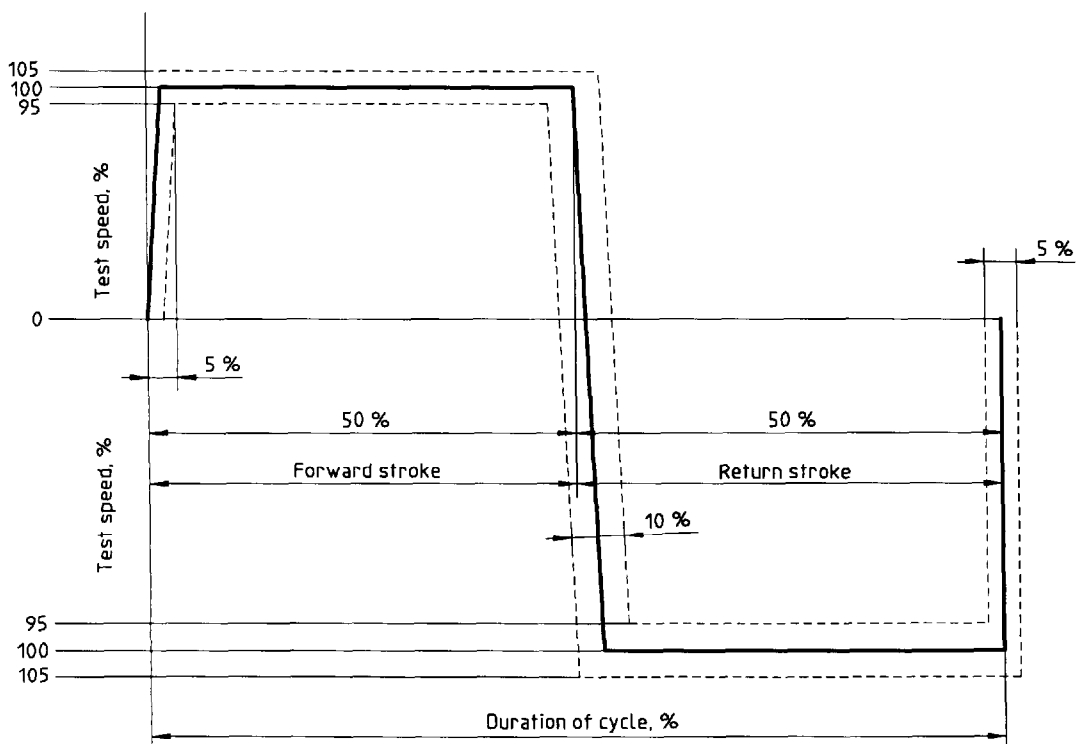
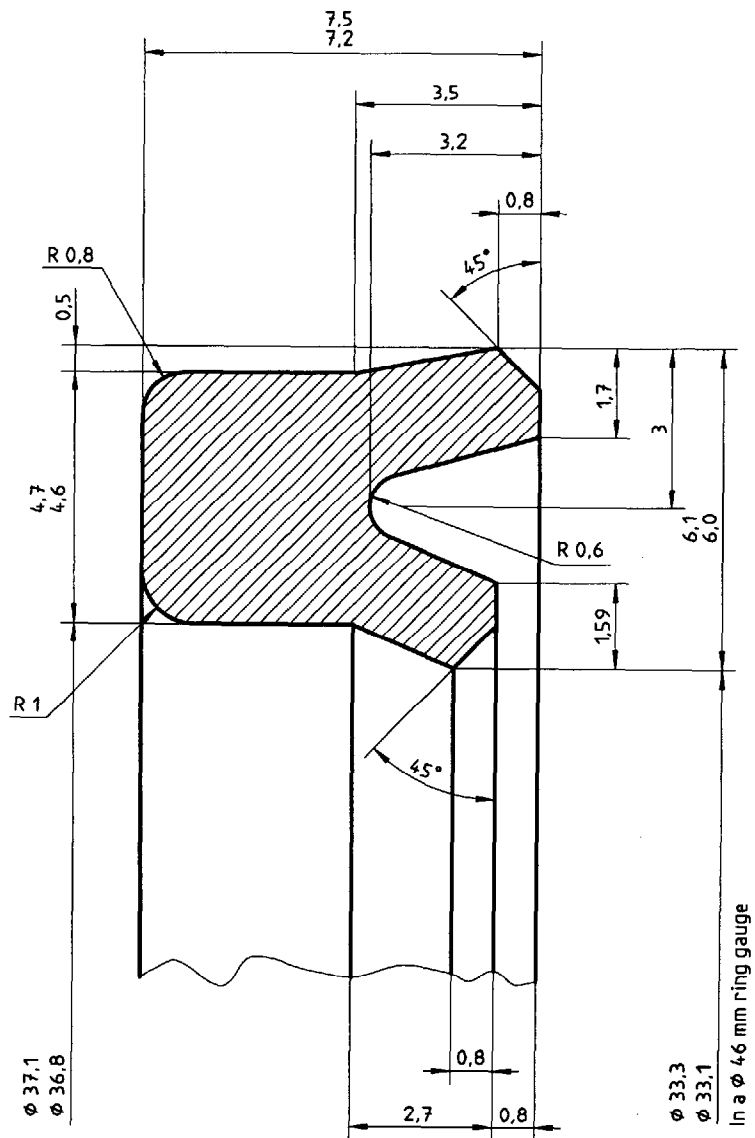


Figure 6 — Speed cycle



Dimensions in millimetres



Material: nitrile rubber, hardness 70 – 75 IRHD

Figure 7 — Wiper seal

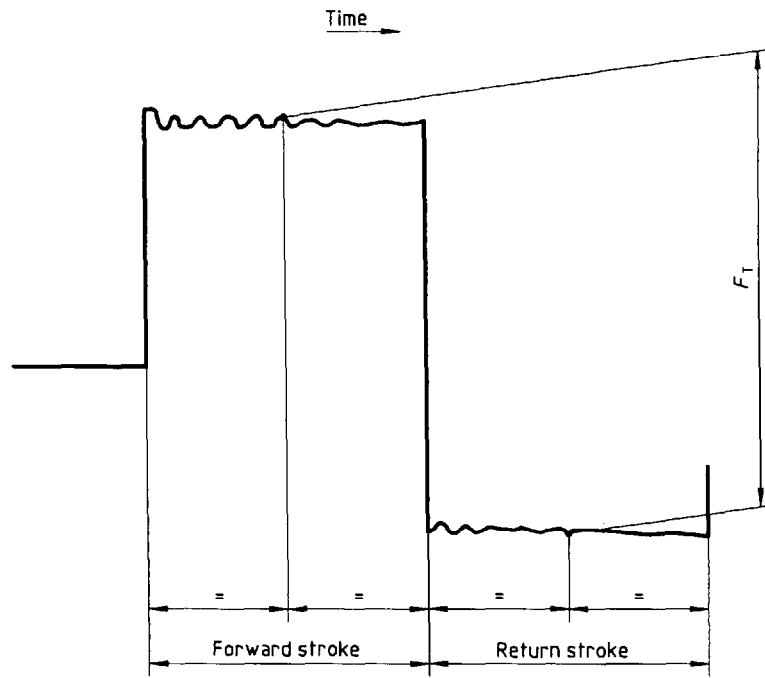


Figure 8 — Typical friction trace on chart recorder

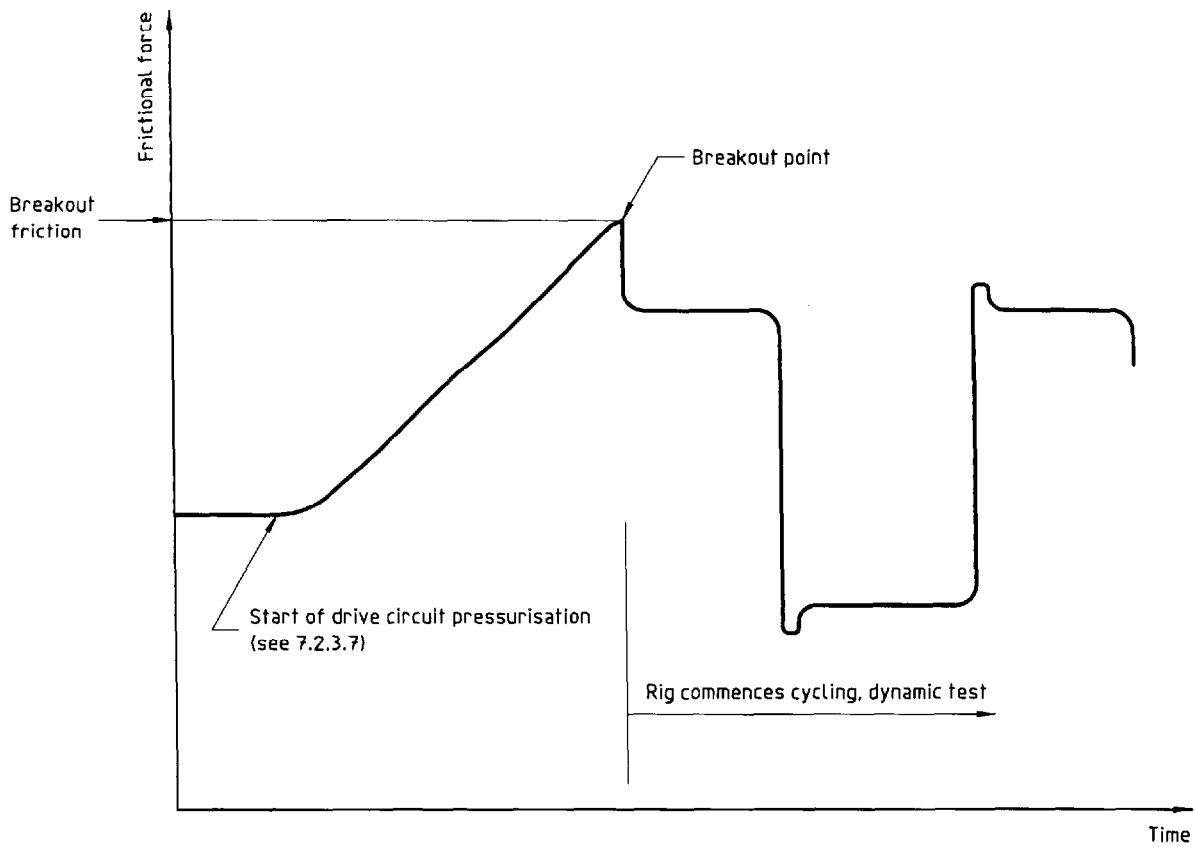
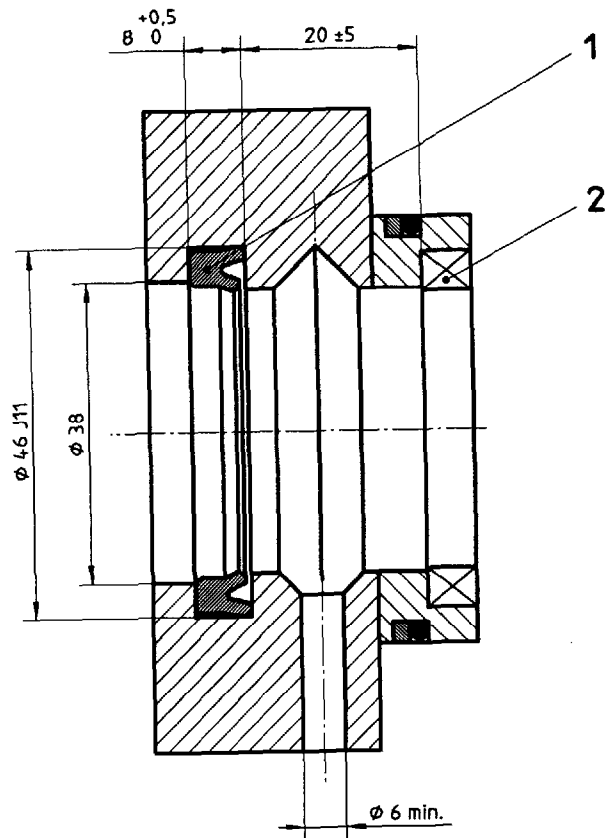


Figure 9 — Breakout friction measurement

Dimensions in millimetres



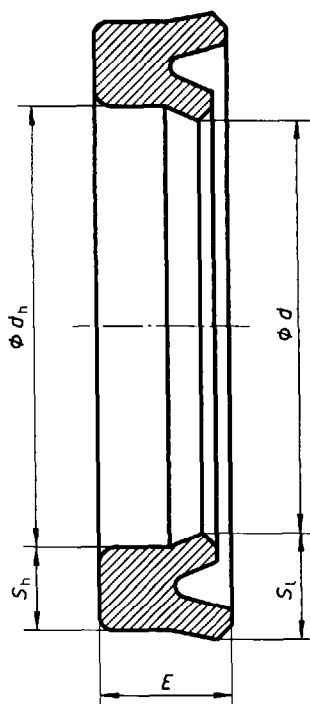
**Key**

- 1 Leak collection wiper
- 2 Test seal

**Figure 10 — Leakage collection zone**

## Annex A (normative)

### Seal and seal housing dimension data forms



**Figure A.1 — Typical seal**

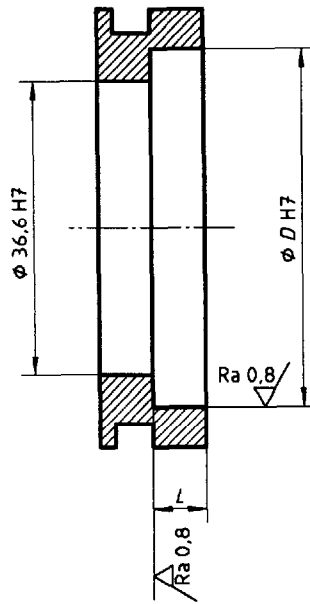
**Table A.1 — Seal dimension data**

Dimensions in millimetres

Dimension		$d$	$S_l$	$d_h$	$S_h$	$E$
Seal A	Before test					
	After test					
	Variation (+ or -)					
Seal B	Before test					
	After test					
	Variation (+ or -)					

**NOTE —** For multipart seals, e.g. V-ring sets or elastomer-energized plastic seals, measure each part of the seal.

Dimensions in millimetres  
Surface roughness in micrometres



Material: phosphor bronze

Figure A.2 — Typical seal housing

Table A.2 — Seal housing data

Dimensions in millimetres

Dimensions	<i>D</i>	<i>L</i>
Seal housing A		
Seal housing B		
NOTE — For tandem seal sets, record dimensions of both housings.		

## Annex B (normative)

### Test results

**Table B.1 — Test log**

Organisation: .....			Test technician: .....				Rig No.: .....		Test No.: .....		
Speed: ..... m/s			Pressure: ..... MPa ( ..... bar)				Stroke: 500 mm				
Test rod No.: .....			Test rod supplier: .....				Test rod Surface texture: Ra ..... µm (calibration date: .....)		Diameter: ..... mm		
Date	Hours counter	Test hours	Cycles	Distance km	Pressure (calibration date) MPa (bar)	Temp- erature °C	Cumulative leakage		Mean dynamic friction per seal N	Mean breakout friction N	Comments
							Seal A	Seal B			

## Annex C (normative)

### Seal performance report

Seal type: ..... Test speed: ..... m/s  
 Part number: ..... Pressure: ..... MPa (.... bar)  
 Material: ..... Rod surface texture: *Ra* ..... µm; *Rt* ..... µm

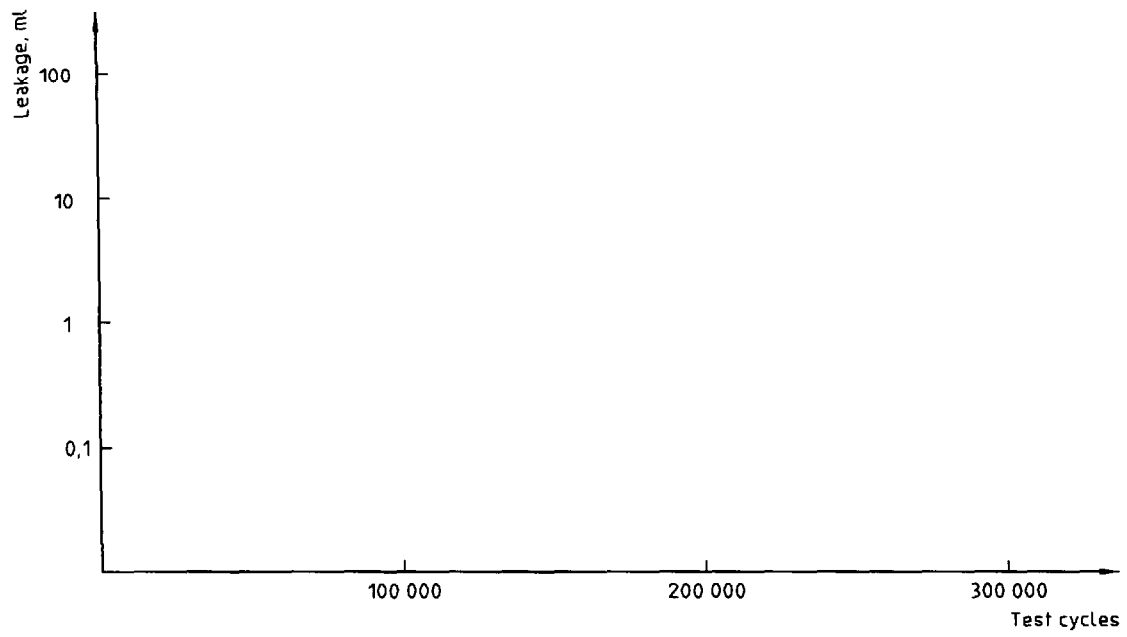
**Table C.1 — Friction**

	Mean value N	Number of tests	Standard deviation
Dynamic friction			
0 cycles			
100 000 cycles			
200 000 cycles (60 000 at 0,05 m/s)			
300 000 cycles (100 000 at 0,05 m/s)			
Breakout friction			
0 cycles			
300 000 cycles			

**Table C.2 — Seal dimension data**

		<i>d</i>			<i>S<sub>l</sub></i>			<i>d<sub>h</sub></i>			<i>S<sub>h</sub></i>			<i>E</i>		
		Mean value 1)	No. of measure- ments	Standard deviation	Mean value 1)	No. of measure- ments	Standard deviation	Mean value 1)	No. of measure- ments	Standard deviation	Mean value 1)	No. of measure- ments	Standard deviation	Mean value 1)	No. of measure- ments	Standard deviation
Seal A	Before test															
	After test															
	Change															
Seal B	Before test															
	After test															
	Change															

1) For mean value, enter the average value obtained from all the tests performed, e.g. recommended six tests.



**Figure C.1 — Test cycles or metres of travel**



## Annex D (informative)

### Bibliography

- [1] ISO 286-1:1988, *ISO systems of limits and fits — Part 1: Bases of tolerances, deviations and fits.*
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- [3] ISO 5597:1987, *Hydraulic fluid power — Cylinders — Housings for piston and rod seals in reciprocating applications — Dimensions and tolerances.*

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**Descriptors:** hydraulic fluid power, fluid circuits, seals (stoppers), oil seals, tests, performance tests.

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