TECHNICAL REPORT

ISO/TR 10771-2

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Hydraulic fluid power — Fatigue pressure testing of metal pressure-containing envelopes —

Part 2:
Rating methods

Transmissions hydrauliques — Essais de fatigue des enveloppes métalliques sous pression —

Partie 2: Méthodes de classement

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.

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.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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/TR 10771-2 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 8, *Product testing*.

ISO/TR 10771 consists of the following parts, under the general title *Hydraulic fluid power — Fatigue pressure testing of metal pressure-containing envelopes*:

— *Part 1: Test method*

— *Part 2: Rating methods*

Introduction

In hydraulic fluid power systems, power is transmitted and controlled under pressure within a closed circuit. It is important for the manufacturer and user of hydraulic components to have information on their global reliability because of the importance of the fatigue failure mode and the relationship with their functional safety and service life. This part of ISO 10771 provides a method for fatigue-testing in order to verify the rating of a pressure-containing envelope.

During operation, components in a system can be subjected to loads that arise from:

- internal pressure;
- external forces;
- inertia and gravitational effects;
- impact or shock;
- temperature changes or gradients.

The nature of these loads can vary from a single static application to continuously varying amplitudes, repetitive loadings and even shocks. It is important to know how well a component can withstand these loads, but this part of ISO 10771 addresses only the loads due to internal pressure.

There are several International Standards already in existence for pressure rating of individual components (e.g. for determining maximum allowable rated pressure) and this part of ISO 10771 is not intended to replace them. Instead, a method of fatigue verification is provided.

This part of ISO 10771 describes a universal verification test to give credibility to the many in-house and other methods of determining the pressure rating of the components. Credibility is based upon the fundamental nature of metal fatigue with its statistical treatment and a mathematical theory of statistical verification. Nevertheless, it is necessary to have design knowledge of the component and its representative specimens to maximize accuracy of the verification method. The use of this test method can reduce the risk of fatigue failure for a hydraulic component regardless of sample size.

In order to rate components in accordance with this part of ISO 10771, it is necessary to propose a rating for the component, select test specimens and select a test pressure. A fatigue test is then conducted in accordance with ISO 10771-1. If the test is successful, the proposed rating is verified for the family of components represented by the sample.

This part of ISO 10771 is based on ANSI/(NFPA) T 2.6.1, a standard which was developed and has been used in the United States for over 25 years and has been adopted for use in Japan as JSME S006-1985. If sufficient experience is gained in other parts of the world, and additional data on materials are obtained, this part of ISO 10771 might be re-drafted as an International Standard in the future.

It should be noted that the test factors in Annex A are based on material data obtained from sources originating in the USA. One of the objectives in issuing this part of ISO 10771 is to obtain material data from other countries. The test factors are based only on the material properties and not on any tolerances of the elements in the pressure-containing envelope.

Annex C describes a possible method for accelerating testing. The example shows how material property data can be used to determine an acceleration factor and shows that they have to be carefully chosen. Another objective of this part of ISO 10771 is to seek additional data as described in Annex C. Contributors are asked to submit any available data to the secretary of ISO TC 131/SC 8.

Hydraulic fluid power — Fatigue pressure testing of metal pressure-containing envelopes —

Part 2: Rating methods

1 Scope

This part of ISO 10771 specifies a test method for fatigue rating of the pressure-containing envelopes of components used in hydraulic fluid power systems, as tested under steady internal cyclic pressure loads in accordance with ISO 10771-1.

This part of ISO 10771 is only applicable to components whose failure mode is the fatigue of any element in the pressure-containing envelope, and that:

— are manufactured from metals;

— are operated at temperatures that exclude creep and low-temperature embrittlement;

— are only subjected to pressure-induced stresses;

— are not subjected to loss of strength due to corrosion or other chemical action;

— can include gaskets, seals and other non-metallic components; however, these are not considered part of the pressure-containing envelope being tested (see note 3 of 5.5 of ISO 10771-1:2002).

This part of ISO 10771 does not apply to piping as defined in ISO 4413 (i.e. connectors, hose, tubing, pipe).

NOTE See ISO 19879, ISO 6803 and ISO 6605 for methods of fatigue testing of tube connectors, hoses and hose assemblies.

This part of ISO 10771 establishes a general rating method that can be applied to many hydraulic fluid power components. In addition, EN 14359 has been developed for accumulators.

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 5598, *Fluid power systems and components — Vocabulary*

ISO 10771-1:2002, *Hydraulic fluid power — Fatigue pressure testing of metal pressure-containing envelopes — Part 1: Test method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598, ISO 10771-1 and the following apply.

3.1
rated fatigue pressure
P_{RF}
maximum pressure that a component pressure-containing envelope, selected at random, has been verified to sustain for the rated cycle life without failure, with a known probability

3.2
assurance level
probability that the fatigue strength of a randomly selected test specimen exceeds its rated fatigue pressure

3.3
verification level
probability that the fatigue strength of a randomly selected test specimen is not less than its cyclic test pressure

3.4
coefficient of variation
k_o
standard deviation of the fatigue strength distribution of a material at a given fatigue life, divided by its mean

NOTE Adapted from ISO 3534-1:2006 [1].

3.5
variability factor
K_V
ratio of cyclic test pressure to rated fatigue pressure

3.6
element
part of a component; for example, tie rods on a cylinder, end caps on a valve, bolts on a pump housing

4 Selection of material factors

4.1 Select a coefficient of variation, k_o, for each type of material in the pressure-containing envelope. The k_o factor should be obtained from fatigue tests on coupons for the particular temper of material used in the pressure-containing envelope. The fatigue test method used to obtain this data should be in accordance with a recognized national or International Standard.

4.2 As an alternative to testing the specific material, coefficients described in Annex A can be used for the k_o factor.

5 Determination of cyclic test pressure

5.1 Select an assurance level for the fatigue pressure rating. A nominal value is 90 %.

5.2 Select a verification level for the fatigue pressure rating. A nominal value is 90 %.

NOTE See Annex D for a tutorial that describes these terms.

5.3 Select a number of component specimens to be tested, then determine the number of element specimens that will be tested in the components.

NOTE The verification is independent of sample size because the test pressure compensates for different quantities.

5.4 Determine the variability factor, K_V, for each element in the component using Table 1 and the procedure described in the example given in Annex B. Use the largest K_V factor so obtained, for the calculations described in the example.

5.5 Propose a rated fatigue pressure for the pressure-containing envelope of the component.

5.6 Calculate the cyclic test pressure, P_{CT}, using Equation (1):

$$P_{CT} = K_V \times P_{RF} \quad (1)$$

where

K_V is the variability factor;

P_{RF} is the rated fatigue pressure of the component pressure-containing envelope.

Table 1 — Variability factor, K_V (at a verification level of 90 %)

Assurance level	No. of specimens n [a]	Material coefficient of variation, k_o [b]															
		0	0,02	0,04	0,06	0,08	0,10	0,12	0,14	0,16	0,18	0,20	0,22	0,24	0,26	0,28	0,30
99,9 %	1	1,00	1,09	1,20	1,32	1,46	1,63	1,83	2,08	2,38	2,77	3,29	—	—	—	—	—
	2	1,00	1,08	1,16	1,26	1,38	1,52	1,68	1,88	2,13	2,45	2,87	—	—	—	—	—
	3	1,00	1,07	1,15	1,23	1,34	1,46	1,61	1,78	2,01	2,29	2,66	3,18	—	—	—	—
	4	1,00	1,06	1,13	1,22	1,31	1,42	1,56	1,72	1,93	2,19	2,54	3,02	—	—	—	—
	5	1,00	1,06	1,13	1,20	1,29	1,40	1,53	1,68	1,87	2,12	2,44	2,89	—	—	—	—
99 %	1	1,00	1,08	1,16	1,25	1,35	1,47	1,60	1,75	1,92	2,12	2,35	2,63	2,96	—	—	—
	2	1,00	1,06	1,12	1,20	1,28	1,37	1,47	1,58	1,72	1,87	2,05	2,26	2,52	2,85	—	—
	3	1,00	1,05	1,11	1,17	1,24	1,32	1,40	1,50	1,62	1,75	1,90	2,09	2,31	2,59	2,94	—
	4	1,00	1,05	1,10	1,15	1,21	1,28	1,36	1,45	1,55	1,67	1,81	1,98	2,18	2,43	2,74	3,16
	5	1,00	1,04	1,09	1,14	1,20	1,26	1,33	1,41	1,51	1,62	1,75	1,90	2,08	2,31	2,60	2,98
90 %	1	1,00	1,05	1,11	1,17	1,23	1,29	1,36	1,44	1,52	1,60	1,69	1,79	1,89	2,00	2,12	2,25
	2	1,00	1,04	1,07	1,11	1,16	1,20	1,25	1,30	1,35	1,41	1,47	1,54	1,61	1,69	1,77	1,86
	3	1,00	1,03	1,06	1,09	1,12	1,16	1,19	1,23	1,28	1,32	1,37	1,42	1,48	1,54	1,60	1,67
	4	1,00	1,02	1,05	1,07	1,10	1,13	1,16	1,19	1,23	1,26	1,30	1,34	1,39	1,44	1,49	1,55
	5	1,00	1,02	1,04	1,06	1,08	1,11	1,13	1,16	1,19	1,22	1,25	1,29	1,33	1,37	1,41	1,46

[a] Test twice the number of specimens if a 99 % verification level is chosen.

[b] Use an interpolation of k_o values between those tabulated here, or calculate K_V from Equation (D.14) in Annex D.

6 Conduct of fatigue test

6.1 Determine the number of cycles, between 1×10^5 and 1×10^7, for which the component will be rated.

6.2 Subject the test specimens to a fatigue pressure test in accordance with ISO 10771-1 for the number of cycles determined in 6.1, using the P_{CT} calculated from Equation (1).

6.3 The fatigue pressure test is successful if all of the element specimens selected in 5.3 do not fail as described in ISO 10771-1:2002, Clause 8.

7 Rating by similarity

It is permitted to extend a verified P_{RF} to other components of similar shape if it can be shown that differences between those components and the components tested do not result in any reduction of their fatigue strength capabilities. Examples of this are components that have smaller ports or different axial lengths but are otherwise identical in geometry to the component tested.

8 Rating declaration

The P_{RF} proposed in 5.5 will be verified if the requirements of 6.3 are met. A code should be applied to the component to declare its rating as:

$P_{RF} = P_{RF}$ (in megapascals)/assurance level/verification level/K_V in the test/number of test cycles

EXAMPLE The rated fatigue pressure (12,5 MPa) of a component's pressure-containing envelope that was tested at an assurance level of 99 %, a verification level of 90 %, a K_V of 1,36 for 2×10^6 cycles, would be declared as:

P_{RF} = 12,5 MPa/ 99 %/ 90 %/ 1,36/ 2×10^6 cycles

9 **Identification statement** (reference to this part of ISO 10771)

Use the following statement in test reports, catalogues and sales literature when complying with this part of ISO 10771:

"Method for fatigue pressure rating conforms to ISO TR 10771-2:2008, *Hydraulic fluid power — Fatigue pressure testing of metal pressure-containing envelopes — Part 2: Rating methods*".

Annex A
(informative)

Material factor database

A.1 Values of coefficient of variation, k_o, for commonly used metals

Table A.1 tabulates data calculated from the sources listed in the bibliography.

Table A.1 — Values of coefficient of variation, k_o, for commonly used metals

Metal		k_o
Steel	Alloy, low	0,14
	Carbon, plain	0,08
	Nickel	0,10
	Stainless	0,09
	Tool	0,10
Iron		0,14
Nonferrous	Aluminium (except unalloyed)	0,13
	Unalloyed aluminium	0,23
	Cobalt	0,13
	Copper	0,09
	Magnesium	0,17
	Monel[1)]	0,27
	Titanium	0,12

A.2 Procedures used to establish values of coefficient of variation, k_o, for the metals listed in Table A.1

A.2.1 Values of k_o were calculated from fatigue test data on test coupons that were published in the references cited in the bibliography. The types of data taken from these references were one of the following:

a) Means, μ, and standard deviations, σ, of normal distributions;

b) parameters of Weibull distributions;

c) raw data points on S-N curves. From these data, individual coefficients of variation, k_o, were calculated at 10^6 cycles for:

1) normal distributions; k_o equals the standard deviation divided by the mean;

1) This is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

2) Weibull distributions; k_o were calculated from a formula given in Reference [12]. The formula includes a gamma function, the value of which was selected as a constant at 0,89 because its variations were generally less than ± 2 % in the range of interest (a few data points went to a difference of ± 4 %);

3) *S*-*N* curves; the references had either included limit bands (assumed to be two sigma from the mean) or actual standard deviation points. These were then used to calculate k_o in the same manner as a normal distribution.

A.2.2 The resulting k_o values (shown as individual values in Table A.2 to Table A.13) include a mix of notched and unnotched specimens, several different tempers, plus different methods of testing (e.g. axial, rotating beam). However, only those tested at room temperature were used. No attempt was made to segregate these data. It is reasoned that the components to be tested will have a variety of tempers and notches, so an application of these published data to components can only be justified if the data are treated statistically at a conservative value.

A.2.3 Therefore, the values given in Table A.1 were derived by assuming that all k_o data for a particular metal group are part of a normal distribution, and a value that is greater than 90 % of this distribution was selected. This ensures that the selection is substantially conservative. However, this part of ISO 10771 allows the use of a more accurate k_o value, which is representative of the specific alloy and temper of the elements being tested, if sufficient testing is performed to obtain those data, as described in 4.1. This approach will likely yield a value that would be more advantageous for a particular application, but less than the conservative values presented in Table A.1.

A.2.4 Table A.2 to Table A.13 describe all of the k_o calculations made from the data obtained from Reference [10], Reference [11], and Reference [13] to Reference [17]. Most of the data are based on the strength distribution at 10^6 cycles, but some data are at the endurance limit and these are identified in each table, if applicable.

Table A.2 — Summary of k_o calculations for iron

Type	Reference	Number of distributions	k_o values [a]
Armco[1)]	[11]	1	0,0220
Pearlitic (grey)	[15];[17]	8	0,0402; 0,042[a]; 0,044[a]; 0,0652; 0,126[a]; 0,146[a]; 0,137[a]
Ferritic (malleable)	[15];[17]	7	0,055[a]; 0,0596; 0,0649; 0,065[a]; 0,075[a]; 0,109[a]
Nodular	[15]	10	0,029[a]; 0,040[a]; 0,049[a]; 0,065[a]; 0,086[a]; 0,094[a]; 0,095[a]; 0,098[a]; 0,173[a]; 0,185[a]
Fe; 5,5 % Mo; 2,5 % Cr; 0,5 % C	[13]	2	0,0286; 0,0477
Summary of all data above	[13];[15];[11];[17]	28	(k_o) 90 % = 0,1335; (μ = 0,0771; σ = 0,0440) Conclusion: k_o value selected = 0,14

[a] Data from reference [15] are at endurance limit.

Table A.3 — Summary of k_o calculations for aluminium

Alloy	Reference	Number of distributions	k_o values [a]
Duraluminum[1)]	[13]	1	0,0720
356	[15]	2	0,038; 0,042
355	[14]	1	0,0766
1100	[14]	2	0,1742; 0,2377
2014	[14];[15]	13	0,017; 0,0400; 0,0527; 0,0534; 0,0541; 0,0556; 0,0702; 0,0732; 0,1152; 0,1164; 0,1215; 0,1386; 0,1400
2024	[14];[15]	14	0,026; 0,0498; 0,0542; 0,0561; 0,0613; 0,0708; 0,0717; 0,0765; 0,0825; 0,0974; 0,1039; 0,1190; 0,1404; 0,1840
2025	[14]	3	0,0347; 0,0549; 0,0947
2026	[14]	2	0,0507; 0,0834
2219	[14]	2	0,0701; 0,0705
5052	[14]	2	0,0845; 0,0914
5056	[14]	1	0,0947
5086	[14]	1	0,0640
5154	[14]	1	0,0662
5456	[14];[15]	2	0,012; 0,0708
6061	[14];[15]	4	0,018; 0,027; 0,0478; 0,087
7039	[14]	1	0,1405
7075	[14];[15]	8	0,040; 0,0505; 0,059; 0,0615; 0,0689; 0,0906; 0,1686; 0,2157
7076	[10]	2	0,0413[a]; 0,0593[a]
7079	[14]	3	0,0560; 0,0942; 0,1486
7178	[14]	2	0,0484; 0,0881
R303	[14]	1	0,0434
5 Mg Al	[14]	2	0,0934; 0,1302
7,5 Zn 2,5 Mg Al	[14]	1	0,0570
Summary of all data above	[13];[14];[15];[10]	71	(k_o) 90 % = 0,1390; μ = 0,0811; σ = 0,0452
Remove the 1100 data		69	(k_o) 90 % = 0,1288; μ = 0,0775; σ = 0,0400 Conclusion: select k_o = 0,13 for alloyed aluminium; select k_o = 0,23 for unalloyed aluminium

[a] Data from reference [10] are at endurance limit.

