INTERNATIONAL STANDARD

ISO 10767-3

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Hydraulic fluid power — Determination of pressure ripple levels generated in systems and components —

Part 3:
Method for motors

Transmissions hydrauliques — Détermination des niveaux d'onde de pression engendrés dans les circuits et composants —

Partie 3: Méthode pour les moteurs

Reference number
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Contents

Page

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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 3.

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 10767-3 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 8, *Product testing*.

ISO 10767 consists of the following parts, under the general title *Hydraulic fluid power — Determination of pressure ripple levels generated in systems and components*:

— *Part 1: Precision method for pumps*

— *Part 2: Simplified method for pumps*

— *Part 3: Method for motors*

Annexes A and B form a normative part of this part of ISO 10767. Annex C is given for information only.

Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. Positive displacement motors are components that convert hydraulic fluid power into rotary mechanical power. During the process of converting hydraulic power into rotary power, flow and pressure fluctuations and structure-borne vibrations are generated.

These fluid-borne and structure-borne vibrations, which are generated by the unsteady flow drawn in by the motor are transmitted through the system at levels depending upon the characteristics of the motor and the circuit. Thus, the determination of the pressure ripple generated by a motor is complicated by the interaction between the motor and the circuit. The method adopted to measure the pressure ripple levels of a motor should, therefore, be such as to eliminate this interaction.

The measurement technique described in this part of ISO 10767 isolates the motor flow and/or pressure ripple from the effects of such circuit interactions, by mathematical processing of pressure ripple measurements (see references [1] to [8] in the Bibliography). A figure of merit for the motor is obtained which allows motors of different types and manufacture to be compared as pressure ripple generators. This will enable the motor designer to evaluate the effect of design modifications on the pressure ripple levels produced by the motor in service. It will also enable the hydraulic system designer to avoid selecting motors having high pressure ripple levels.

The method is based upon the application of plane wave transmission line theory to the analysis of pressure fluctuations in hydraulic systems[9]. By evaluating the impedance characteristics of the circuit into which the motor is installed and the impedance of the motor itself, it is possible to isolate the source flow ripple and/or pressure ripple of the motor from the interactions of the circuit. The impedance characteristics of the circuit can be evaluated by analysis of pressure ripple measurements at two or more positions along a pipe, where the pipe is connected to the inlet port of the motor. However, to characterize the impedance of the system completely, it is not sufficient to measure the pressure ripple generated by the motor alone, as insufficient information is available for the impedance of the motor to be evaluated. The secondary-source method uses another source of pressure ripple at the opposite end of the supply line. The measurement of this pressure ripple enables the motor source impedance to be evaluated. Sufficient information is then available to evaluate the source flow ripple and pressure ripple of the motor.

Because of the complexity of the analysis, data processing is preferably carried out using a digital computer. Suitable software packages are available from two sources (see annex C).

Hydraulic fluid power — Determination of pressure ripple levels generated in systems and components —

Part 3:
Method for motors

1 Scope

This part of ISO 10767 specifies a procedure for the determination of a rating of the source flow ripple, source impedance and pressure ripple levels generated by positive-displacement hydraulic motors, including bi-directional motors. Ratings are obtained as the following:

a) the source flow ripple amplitude, in cubic metres per second, over ten individual harmonics of motoring frequency;

b) the source impedance amplitude, in newton seconds per metre to the power of five [(N·s)/m^5], and phase, in degrees, over ten individual harmonics of motoring frequency;

c) the anechoic pressure ripple amplitude, in pascals, over ten harmonics of motoring frequency;

d) the overall root mean square (r.m.s.) anechoic pressure ripple, in pascals;

e) the blocked acoustic pressure ripple amplitude, in pascals, over ten harmonics of motoring frequency;

f) the overall root mean square (r.m.s.) blocked acoustic pressure ripple, in pascals.

This part of ISO 10767 is applicable to all types of positive-displacement motor operating under steady-state conditions, irrespective of size, provided that the motoring frequency is in the range from 50 Hz to 400 Hz.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10767. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10767 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1219-1:1991, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols.*

ISO 5598:1985, *Fluid power systems and components — Vocabulary.*

3 Terms and definitions

For the purposes of this part of ISO 10767, the terms and definitions given in ISO 5598 and the following terms and definitions apply.

3.1
source flow ripple
fluctuating component of flowrate produced by the motor which is independent of the characteristics of the connected circuit

3.2
flow ripple
fluctuating component of flowrate in the hydraulic fluid, caused by interaction of the source flow ripple with the system

3.3
pressure ripple
fluctuating component of pressure in the hydraulic fluid, caused by interaction of the source flow ripple with the system

3.4
anechoic pressure ripple
pressure ripple that would be generated at the motor inlet port when supplied by an infinitely long rigid pipe of the same internal diameter as the motor inlet port

3.5
blocked acoustic pressure ripple
pressure ripple that would be generated at the motor inlet port when supplied via a circuit of infinite impedance

3.6
impedance
complex ratio of the pressure ripple to the flow ripple occurring at a given point in a hydraulic system and at a given frequency

3.7
source impedance
impedance of a motor at the inlet port

3.8
harmonic
sinusoidal component of the pressure ripple or flow ripple occurring at an integral multiple of the motoring frequency

NOTE A harmonic may be represented by its amplitude and phase, or alternatively by its real and imaginary components.

3.9
motoring frequency
frequency, expressed in hertz, given by the product of shaft rotational frequency and the number of motoring elements on that shaft

3.10
shaft rotational frequency
frequency, expressed in hertz, given by the shaft rotational speed, expressed in revolutions per minute, divided by 60

4 Instrumentation

4.1 Static measurements

The instruments used to measure

a) mean fluid flow,

b) mean fluid pressure,

c) shaft rotational speed, and

d) fluid temperature,

shall meet the requirements of “industrial class” accuracy of measurement, i.e. class C given in annex A.

4.2 Dynamic measurements

The instruments used to measure pressure ripple shall have the following characteristics:

a) resonant frequency $\geqslant$ 30 kHz;

b) linearity $< \pm$ 1 %.

The instruments need not respond to steady-state pressure, and it may be advantageous to filter out any steady-state signal component using a high-pass filter. This filter shall not introduce an additional amplitude or phase error exceeding 1 % or 2 %, respectively, over the frequency range from 50 Hz to 4 000 Hz.

4.3 Frequency analysis of pressure ripple

A suitable instrument shall be used to measure the amplitude and phase of the pressure ripple, for at least ten harmonics of the motoring frequency.

The instrument shall be capable of measuring the pressure ripple from two or three pressure transducers (7.7) such that, for a particular harmonic, the measurements from each transducer are synchronized in time with respect to each other. This may be achieved by sampling the pressure ripple from each pressure transducer simultaneously, or by sampling each pressure separately but with respect to a trigger signal obtained from a fixed reference on the motor shaft or secondary source drive, as appropriate.

The instruments shall have an accuracy and resolution for harmonic measurements as follows, over the frequency range from 50 Hz to 4 000 Hz:

a) amplitude within ± 1 %;

b) phase within ± 1°;

c) frequency within ± 0,5 %.

Compliance with the above tolerances will result in an uncertainty in the overall r.m.s. pressure ripple rating of within ± 10 %.

5 Motor installation

5.1 General

The motor shall be installed in the attitude recommended by the manufacturer and mounted in such a manner that the response of the mounting-to-motor vibration is minimized.

5.2 Drive vibration

If necessary, the motor and the loading system shall be decoupled to minimize vibration generated by the load.

5.3 Reference signal

A means of producing a reference signal relative to the motor shaft rotation shall be included. The signal shall be an electrical pulse occurring once per revolution, with sharply defined rising and falling edges. This signal is used as a measure of the shaft rotational speed and may be used, if necessary, to provide a trigger signal and/or phase reference for the pressure ripple analysis instrument.

6 Test conditions

6.1 General

The required operating conditions shall be maintained throughout each test within the limits specified in Table 1.

6.2 Fluid temperature

The temperature of the fluid shall be that measured at the motor outlet.

6.3 Fluid density and viscosity

The density and viscosity of the fluid shall be known to an accuracy within the limits specified in Table 2.

6.4 Fluid bulk modulus

The isentropic tangent bulk modulus of the fluid shall be known to an accuracy within the limits specified in Table 2. As this is not always feasible, B.4.2 details a method by which the bulk modulus may be evaluated with a sufficiently high accuracy.

Table 1 — Permissible variations in test conditions

Property	Required accuracy
Mean flow	± 2 %
Mean pressure	± 2 %
Motor shaft rotational frequency	± 1 %
Temperature	± 2 °C

Table 2 — Required accuracy of fluid property data

Property	Required accuracy
Density[a]	± 2 %
Viscosity[a]	± 5 %
Isentropic tangent bulk modulus[b]	± 5 %

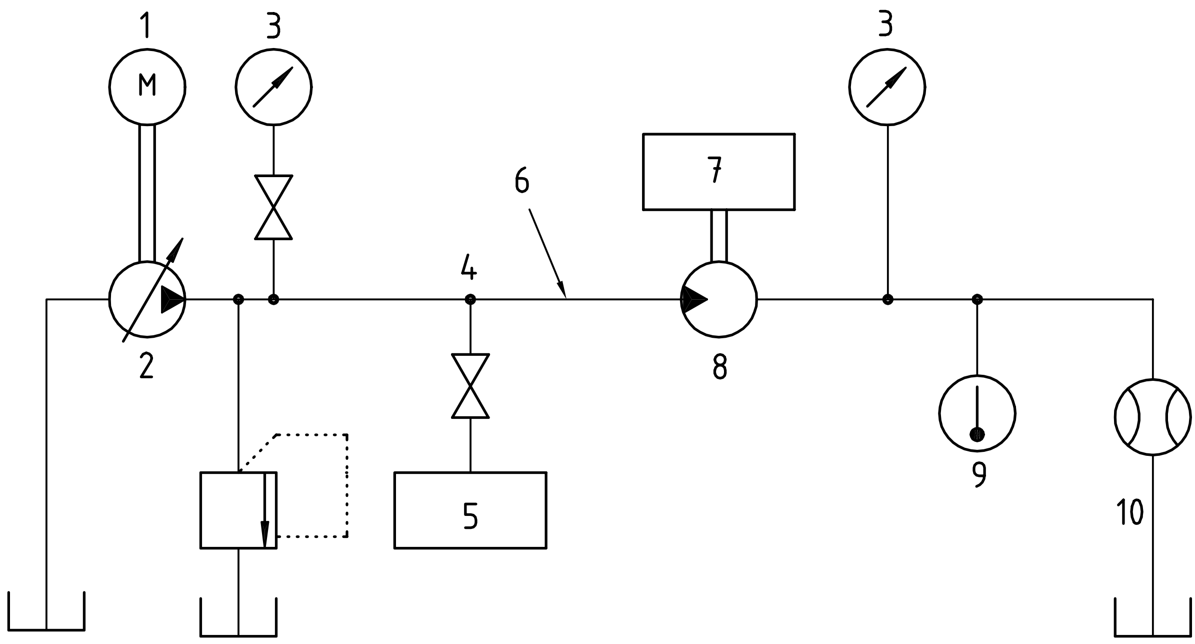
a See reference [10].
b See reference [11].

7 Test rig

7.1 General

A hydraulic test circuit similar to that shown in Figure 1 should be used (graphic symbols, in accordance with ISO 1219-1). The test rig shall include all fluid filters, fluid coolers, reservoirs, loading system and any ancillary pumps required to meet the motor hydraulic operating conditions. Specific features are described in 7.2 to 7.13.

For bidirection motors there may be some asymmetry in the behaviour according to the direction of rotation. Accordingly tests shall be performed in both directions of rotation.



Key

1 Electric motor	6 Straight rigid pipe (see Figure 2)
2 Pump	7 Loading system
3 Pressure gauge	8 Motor under test
4 Point “A”	9 Temperature indicator
5 Secondary source	10 Flowmeter

Figure 1 — Circuit diagram for secondary-source test rig

7.2 Test fluid

The type of test hydraulic fluid and the quality of filtration shall be in accordance with the motor manufacturer’s recommendations.

7.3 Motor

The motor shall be installed in the “as-delivered” condition.

7.4 Supply pump

The motor shall be supplied from a positive displacement pump. If the motor is to be tested at different speeds either a variable capacity pump or a variable speed prime mover shall be used.

7.5 Use of supply pump as a secondary source

It may be possible to use the supply pump to act as secondary source of pressure ripple (7.11). If this is the case, the pump shall be connected as close as possible to point “A” on Figure 1.

7.6 Motor inlet port connection

The adaptor connecting the motor inlet port to the supply pipe shall have an internal diameter which does not differ from the supply pipe diameter by more than 10 % at any point. Any such variations in internal diameter shall occur over a length not exceeding twice the internal diameter of the pipe. The adaptor shall be arranged in order to prevent the formation of air pockets in it. The supply pipe shall be mounted in line with the motor inlet port without any changes in direction.

7.7 Motor supply line

The supply pipe shall be a uniform, rigid, straight metal pipe. Pressure transducers shall be mounted along its length, as shown in Figure 2. The internal diameter of the pipe shall be between 80 % and 120 % of the diameter of the motor inlet port. The pipe shall be supported in such a manner that pipe vibration is minimized.

The pressure transducers shall be mounted such that their diaphragms are flush with the inner wall of the pipe to within ± 0,5 mm. No valves, pressure gauges or flexible hoses shall be installed between the motor inlet port and point “A” as shown in Figure 1.

Two alternative specifications for the motor supply line are given, depending on whether the isentropic tangent bulk modulus of the fluid is known within the limits specified in Table 2. These alternatives are henceforth known as “method 1” and “method 2”. Method 1 is acceptable for use in all situations. However, if the isentropic tangent bulk modulus is known within the limits specified in Table 2, economies can be made by using method 2.

If method 1 is used, set up the motor supply line as specified in 7.7.1. If method 2 is used, set it up as specified in 7.7.2.

7.7.1 Method 1

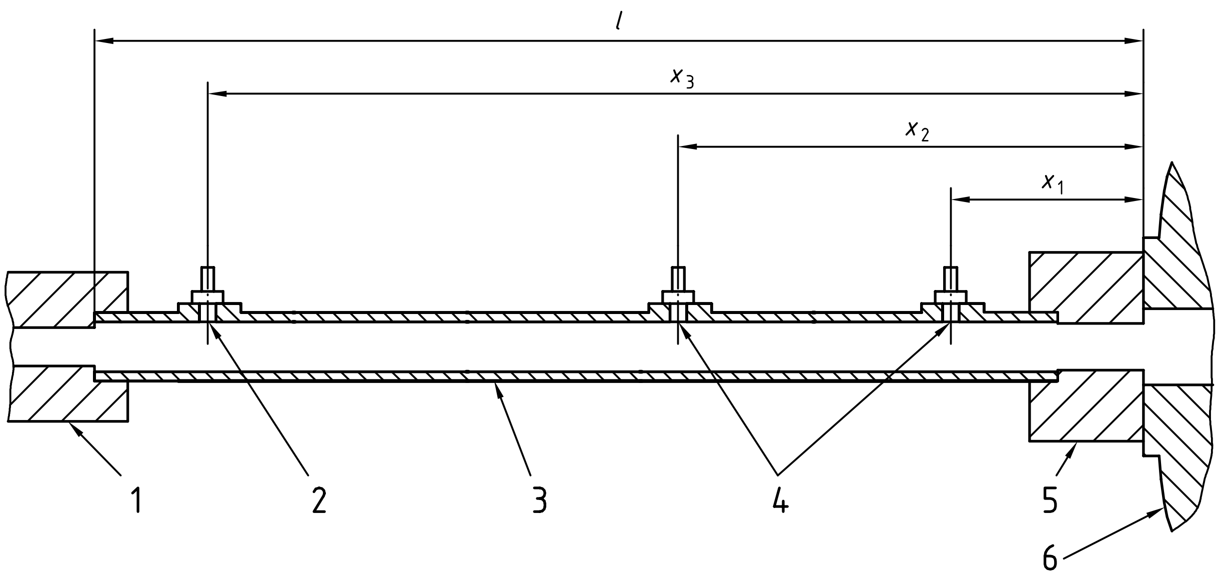
Three pressure transducers are required for this method, set up as shown in Figure 2. The dimensions of the supply pipe shall be selected according to the motoring frequency. When the series of tests includes a range of motor speeds, the dimensions shall be selected in relation to the minimum motoring frequency, $f_{0,min}$, in that series. The overall length of the supply pipe, l, and the distance of the pressure transducers from the motor, x_1, x_2 and x_3, are specified in Table 3.

Table 3 — Pipe length and transducer positions

Pipe length and transducer positions	**Minimum motoring frequency,** Hz	
	$50 \leqslant f_{0,min} \leqslant 100$	$100 < f_{0,min} \leqslant 400$
x_1	0,15 m ± 1 %	0,1 m ± 1 %
x_2	0,85 m ± 1 %	0,43 m ± 1 %
x_3	1,85 m ± 1 %	0,9 m ± 1 %
l	at least 2 m	at least 1 m

7.7.2 Method 2

Two pressure transducers are required for this method, set up as shown in Figure 2. The length of the supply pipe and the positions of the pressure transducers shall be selected according to the motoring frequency. When the series of tests includes a range of pumping frequencies, the dimensions shall be selected in relation to the maximum motoring frequency in that series. The ratio of maximum to minimum speed for a selected transducer spacing shall not exceed 4:1. If the speed range of a test series exceeds this limit, different transducer spacings will be required.



Key

1 Mounting block for connection at point ‘A’ on Figure 1
2 Pressure transducer (method 1 only)
3 Rigid straight pipe
4 Pressure transducers
5 Mounting block
6 Motor

Figure 2 — Arrangement of supply pipe

The distance between the pressure transducers shall be as given by the following equation, to within 1 %.

$$x_2 - x_1 = \frac{\sqrt{\left(B_{\text{eff}}/\rho\right)}}{\left(67 \times f_{0,\text{max}}\right)}$$

where

$f_{0,\text{max}}$ is the maximum motoring frequency, in hertz;

B_{eff} is the effective bulk modulus, in pascals (see B.3);

ρ is the density, in kilograms per cubic metre.

The first pressure transducer shall be located as close as possible to the motor flange and no more than $(x_2 - x_1)$ m away. The length l shall be at least $(x_2 + 10d)$ m, where d is the internal diameter of the pipe.

7.7.3 Calibration of pressure transducers

Calibration of the pressure transducers and signal conditioning is necessary. Relative calibration shall be performed by mounting the pressure transducers in a common block such that they measure the same pressure ripple. This common block shall be such that the pressure transducers are at the same axial position and not more than 20 mm apart.

Use the secondary source (7.11) to generate pressure ripple. Measure the amplitude and phase relationship between the pressure transducers for a range of frequencies spanning the complete range of interest (8.3.2) with one transducer used as a reference. For piezo-resistive transducers, the reference transducer can be calibrated statically using, for example, a dead-weight testing machine. If piezo-electric transducers and charge amplifiers are employed, a calibrated piezo-resistive transducer may be used as a reference for dynamic calibration purposes. The amplitude and phase differences at each frequency shall be known to an accuracy of within 3 % and 2° for method 1, or 3 % and 0,5° for method 2. These differences shall be corrected in the tests (see clause 8).

7.8 Load system

Loading of the motor shall be effected using a dynamometer. A positive displacement pump and load valve may be an appropriate means of meeting this requirement.

7.9 Relief valve

A relief valve shall be fitted for safety purposes. The valve shall be set to relieve at a pressure at least 20 % greater than the mean test pressure.

7.10 Pressure gauges

Pressure gauges shall be fitted as shown in Figure 1, together with a throttling valve to reduce gauge oscillation. Alternatively, pressure transducers may be used.

7.11 Secondary source

The test method requires the generation of pressure ripple in the circuit in addition to that generated by the motor.

The supply pump (7.4) may be a suitable secondary source of pressure ripple. A piston pump is likely to provide strong harmonic components over a broader frequency range than a gear pump, for example, and is thus likely to be more appropriate.

7.11.1 If the supply pump is not used as the secondary source, an auxiliary device capable of generating pressure ripple shall be used as shown in Figure 1.

7.11.2 The pressure ripple from the secondary source shall span the frequency range from the motoring frequency of the test motor to at least ten times the motoring frequency.

7.11.3 The pressure ripple from the secondary source shall have a periodic waveform. The secondary source may produce either a multi-harmonic pressure ripple waveform or a pressure ripple waveform which may be swept in discrete frequency steps to cover the range specified in 7.11.2. Pressure ripple shall be measurable at a minimum of ten frequencies over this range. The harmonic frequencies from the secondary source shall not vary by more than 0,5 % once a stable running condition has been achieved.

7.11.4 It is necessary that the frequencies of the components of the pressure ripple from the secondary source be different from those of the test motor in order that they may be measured with negligible interference.

NOTE If the supply pump (7.4) is used as a secondary source, it may be necessary to use a variable speed pump drive combined with a variable capacity pump. Otherwise, it may not be possible to achieve the above requirement at certain motor test speeds. If this requirement cannot be met, the supply pump is an inappropriate secondary source.

7.11.5 Auxiliary devices which are suitable for the secondary source include the following.

a) **Positive-displacement pump**: a piston pump is likely to provide strong harmonic components over a broader frequency range than, for example, a gear pump or vane pump, and is thus likely to be more suitable.

b) **Intermittent bleed-off**, such as valve with a rotating spool allowing flow to pass to the return line over part of its rotation.

c) **Electromechanical vibrator and piston arrangement**.

7.12 Ball valve

A ball valve shall be used to isolate the secondary source from the high-pressure part of the circuit. This valve shall be sufficiently large to present negligible restriction to flow when open, in order to prevent excessive attenuation of the pressure ripple from the secondary source.

7.13 Mounting

The supply pipe, valves and secondary source shall be mounted such as to prevent excessive vibration, and shall be adequately supported.