



BSI Standards Publication

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

Part 3: Method for motors

National foreword

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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

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Foreword

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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 document 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).

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

This second edition cancels and replaces the first edition (ISO 10767-3:1999), which has been technically revised.

The main changes are as follows:

- the upper limit of 400 Hz on motoring frequency has been removed;
- spacing between pressure transducers has been increased for method 2 (5.5.6);
- a detailed procedure is given for frequency analysis (B.3);
- modelling of source impedance has been replaced with linear interpolation of source reflection coefficient (8.5.4);
- additional rating quantities are included: anechoic flow ripple (8.6) and anechoic power (8.7), to replace anechoic pressure ripple;
- extensive editorial changes have been made, to aid clarity and avoid ambiguity.

A list of all parts in the ISO 10767 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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 ripple and structure-borne vibrations are generated.

The pressure ripple and the 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 document isolates the motor flow ripple and pressure ripple from the effects of such circuit interactions, by mathematical processing of pressure ripple measurements (see References [4] to [11]). A figure of merit is obtained which allows motors of different types and manufacturer to be compared as pressure ripple generators. This enables the motor designer to evaluate the effect of design modifications on the pressure ripple levels produced by the motor in service. It also enables the hydraulic system designer to avoid selecting motors having high pressure ripple levels.

Results are produced from this document in different forms, including amplitude and phase spectra and single figures of merit, as the following:

- a) the source flow ripple amplitude, in m^3/s , and phase, in degrees, up to the tenth harmonic of motoring frequency or 3,5 kHz, whichever is the lower;
- b) the source impedance amplitude, in $(\text{Pa}\cdot\text{s})/\text{m}^3$, and phase, in degrees, up to the tenth harmonic of motoring frequency or 3,5 kHz, whichever is the lower;
- c) anechoic flow ripple amplitude, in m^3/s , and phase, in degrees, up to the tenth harmonic of motoring frequency or 3,5 kHz, whichever is the lower;
- d) the time history wave form of the anechoic flow ripple, in m^3/s ;
- e) the anechoic power, in watts, up to the tenth harmonic of motoring frequency or 3,5 kHz, whichever is the lower;
- f) the overall anechoic power, in watts;
- g) the blocked acoustic pressure ripple amplitude, in pascals, up to the tenth harmonic of motoring frequency or 3,5 kHz, whichever is the lower;
- h) the overall root mean square (RMS) blocked acoustic pressure ripple, in pascals.

A description of the different forms of rating and their purpose is given in [Annex D](#).

The method is based upon the application of plane wave transmission line theory to the analysis of pressure ripple in hydraulic systems^[12]. 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 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.

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

Part 3: Method for motors

1 Scope

This document 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 bidirectional motors.

This document is applicable to all types of positive-displacement motor operating under steady-state conditions, irrespective of size, for frequencies from 50 Hz to 3 500 Hz. It is applicable for the inlet port of positive-displacement motors.

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 5598, *Fluid power systems and components — Vocabulary*

3 Terms and definitions

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

ISO and IEC maintain terminology 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 flow ripple

fluctuating component of flow rate in the hydraulic fluid

3.2 pressure ripple

fluctuating component of pressure in the hydraulic fluid

3.3 impedance

complex ratio of the *pressure ripple* (3.2) to the *flow ripple* (3.1) occurring at a given point in a hydraulic system and at a given frequency

3.4 “Norton” model

representation of a source consisting of a *flow ripple* (3.1) in parallel with an *impedance* (3.3)

3.5

source flow ripple

flow ripple (3.1) produced by the motor which is independent of the characteristics of the connected circuit in the standard “Norton” model (3.4)

Note 1 to entry: The source flow ripple is implicitly assumed to be generated at the motor inlet, see [Figure 1 a](#)).

3.6

internal flow ripple

flow ripple (modified model)

flow ripple (3.1) produced by the motor represented internally at or close to the point of generation

Note 1 to entry: See [Figure 1 b](#)).

3.7

anechoic flow ripple

flow ripple (3.1) 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

3.8

anechoic pressure ripple

pressure ripple (3.2) 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

3.9

anechoic power

fluid-borne acoustic power 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, equal to the absolute value of half of the product of *anechoic flow ripple* (3.1) and *anechoic pressure ripple* (3.8)

3.10

blocked acoustic pressure ripple

pressure ripple (3.2) that would be generated at the motor inlet port when supplied via a circuit of infinite impedance (3.3)

3.11

source impedance

impedance (3.3) of a motor at the inlet port in the standard “Norton” model (3.4)

3.12

harmonic

sinusoidal component of the *flow ripple* (3.1) or *pressure ripple* (3.2) occurring at an integer multiple of the motoring frequency

Note 1 to entry: A harmonic can be represented by its amplitude and phase, or alternatively by its real and imaginary components.

3.13

number of motoring elements

number of active displacement devices

Note 1 to entry: Active displacement devices can be cylinders for a piston motor, vanes for a vane motor, gear teeth on the output shaft of a gear motor.

Note 2 to entry: This represents the number of times the output flow cycle repeats itself per revolution of the motor output shaft.

3.15

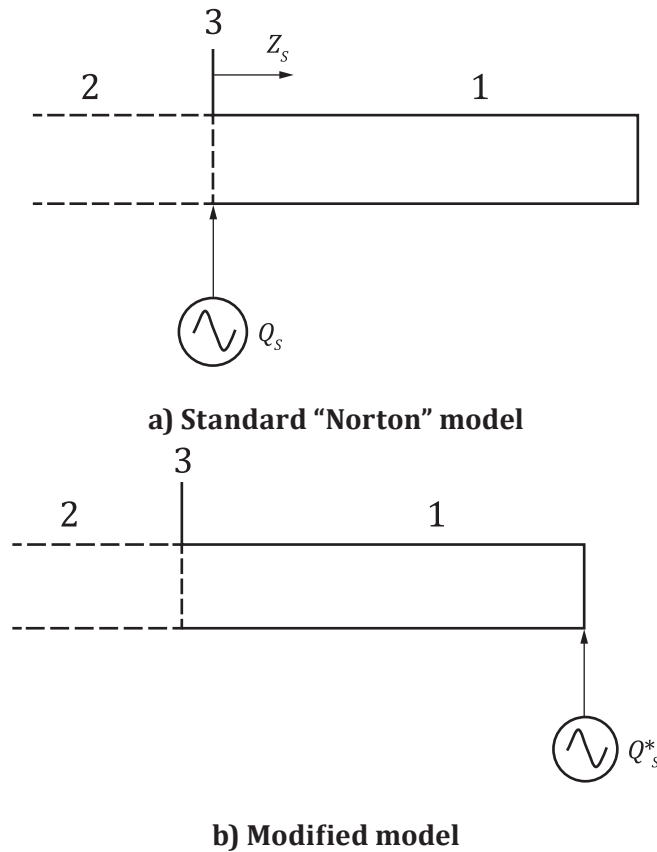
motoring frequency

frequency, expressed in hertz, given by the product of motor shaft rotational speed, expressed in revolutions per minute, and the *number of motoring elements* (3.13) on that shaft, divided by 60

3.16

secondary source

device that generates pressure ripple in the system independently of the test motor

**Key**

- 1 internal inlet passageway
- 2 supply line
- 3 motor inlet port

Figure 1 — Modelling of motor pulsation source

4 Symbols and subscripts

Table 1 — Symbols and descriptions

Symbol ^a	Description	Unit
$S_a - S_f$	Complex coefficients	—
A, B	Terms of admittance matrix	$\text{m}^3/(\text{Pa} \cdot \text{s})$
B_{fluid}	Isentropic tangent bulk modulus of fluid	Pa
B_{eff}	Effective bulk modulus in pipeline	Pa
c	Speed of sound	m/s
C_k, D_k	Terms of transmission matrix	—
d	Internal diameter of measurement pipe	m
d_p	Diameter of motor inlet port	m
E	Young's modulus of pipeline	Pa

^a For definition of subscripts, see [Table 2](#).

Table 1 (continued)

Symbol ^a	Description	Unit
f	Frequency	Hz
f_B	Frequency band	Hz
$f_{\max}$	Maximum harmonic frequency	Hz
f_{motoring}	Motoring frequency	Hz
$f_{\text{motoring,min}}$	Minimum motoring frequency	Hz
f_{sample}	Sample frequency	Hz
f_{2S}	Secondary source frequency	Hz
h	Thickness of reference pipe wall	m
l	Length of reference pipe	m
n_{elements}	Number of motoring elements	—
N	Number of samples	—
N_{motor}	Motor shaft rotational speed	r/min
$n_{2S_elements}$	Number of secondary source elements	—
p	Mean pressure	Pa
p_1, p_2, p_3	Measured pressure ripples at pressure transducers 1, 2 and 3	Pa
P_a	Anechoic pressure ripple harmonic (complex number)	Pa
P_b	Blocked acoustic pressure ripple harmonic (complex number)	Pa
$P_{b,RMS}$	Blocked acoustic pressure ripple overall RMS value	Pa
P_k	Pressure ripple harmonic (complex number)	Pa
P_0	Pressure ripple harmonic at motor inlet port (complex number)	Pa
q	Mean flow rate	m ³ /s
Q_a	Anechoic flow ripple harmonic (complex number)	m ³ /s
$Q_{a,RMS}$	Anechoic flow ripple overall RMS value	m ³ /s
Q_s	Source flow ripple harmonic (complex number)	m ³ /s
Q_s^*	Internal (modified) flow ripple harmonic (complex number)	m ³ /s
Q_0	flow ripple harmonic at motor inlet port (complex number)	m ³ /s
R	Source reflection coefficient	—
S	Sum of squares error	Pa ²
t	Time	s
T	Duration of measurement	s
w_n	Windowing function weighting at n^{th} sample point	—
$W_{a,i}$	Anechoic power harmonic amplitude	W
W_{ao}	Overall anechoic power summed over harmonics	W
x_1, x_2, x_3	Distances of pressure transducers from motor inlet port	m
$Z_{c,i}$	Characteristic impedance of reference pipe	Pa·s/m ³
Z_{cp}	Characteristic impedance of pipe of same internal diameter as motor inlet port	Pa·s/m ³
Z_e	Entry impedance	Pa·s/m ³
Z_s	Source impedance	Pa·s/m ³
β	Wave propagation coefficient (complex number)	m ⁻¹

^a For definition of subscripts, see Table 2.

Table 1 (continued)

Symbol ^a	Description	Unit
ε	Error	Pa
θ	Temperature	°C
ν	Kinematic viscosity	m ² /s
ξ	Frequency-dependent friction coefficient (complex number)	-
ρ	Fluid density	kg/m ³
ω	Angular frequency	rad/s

^a For definition of subscripts, see [Table 2](#).

Table 2 — Subscripts and descriptions

Subscript	Description
H	Value at higher frequency for interpolation
<i>i</i>	Harmonic index
I	Imaginary part
<i>k</i>	Pressure transducer index
L	Value at lower frequency for interpolation
<i>n</i>	Sample index
R	Real part

5 Test rig

5.1 General

An example of a hydraulic test circuit is shown in [Figure 2](#) (graphic symbols in accordance with ISO 1219-1[1]). The test rig shall include all fluid filters, fluid coolers, reservoirs, loading system and any ancillary pumps required to meet the motor operating conditions. Specific features are described in [5.2](#) to [5.10](#).

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