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Hydraulic fluid power — Determination of the fluid-borne noise characteristics of components and systems —

Part 3: Measurement of hydraulic impedance

Transmissions hydrauliques — Évaluation des caractéristiques du bruit liquidien des composants et systèmes —

Partie 3: Mesurage de l'impédance hydraulique

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.

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 15086-3 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 8, *Product testing*.

ISO 15086 consists of the following parts, under the general title *Hydraulic fluid power — Determination of the fluid-borne noise characteristics of components and systems*:

— *Part 1: Introduction*

— *Part 2: Measurement of the speed of sound in a fluid in a pipe*

— *Part 3: Measurement of hydraulic impedance*

Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within a closed circuit. During the process of converting mechanical power into fluid power, fluid-borne noise (flow fluctuations and pressure fluctuations) is generated, which in turn leads to structure-borne noise and airborne noise. The transmission of fluid-borne noise is influenced by the impedance of the components installed in the hydraulic circuit.

This part of ISO 15086 adopts the concepts of ISO 15086-1 which describe the basis for the methods of measurement that make it possible to determine the characteristics of fluid-borne noise emitted or transmitted by hydraulic transmission systems.

Clause 6 of this part of ISO 15086 describes the method for measuring the hydraulic impedance of a single-port component (local hydraulic impedance) and Clause 7 describes the method for measuring the hydraulic impedance matrix of a two-port hydraulic component.

Hydraulic fluid power — Determination of the fluid-borne noise characteristics of components and systems —

Part 3: Measurement of hydraulic impedance

1 Scope

This part of ISO 15086 describes the procedure for the determination of the impedance characteristics of hydraulic components, by means of measurements from pressure transducers mounted in a pipe.

This part of ISO 15086 is applicable to passive components, irrespective of size, operating under steady-state conditions, over a frequency range from 10 Hz to 3 kHz.

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 1000, *SI units and recommendations for the use of their multiples and of certain other units*

ISO 5598, *Fluid power systems and components — Vocabulary*

ISO 1219-1, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols for conventional use and data-processing applications*

ISO 15086-1:2001, *Hydraulic fluid power — Determination of the fluid-borne noise characteristics of components and systems — Part 1: Introduction*

ISO 15086-2: 2000, *Hydraulic fluid power — Determination of the fluid-borne noise characteristics of components and systems — Part 2: Measurement of the speed of sound in a fluid in a pipe*

3 Terms and definitions

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

3.1
flow ripple
fluctuating component of flow rate in hydraulic fluid

3.2
pressure ripple
fluctuating component of pressure in hydraulic fluid

3.3
wide-band pulse generator
hydraulic component generating a periodic flow ripple and consequently pressure ripple in a circuit, or an hydraulic component generating a pressure ripple and, consequently, a flow ripple in a circuit

3.4
fundamental frequency
lowest frequency of pressure ripple (or flow ripple) considered in a theoretical analysis or measured by an instrument

EXAMPLE An hydraulic pump or motor with a shaft frequency of N revolutions per second can be taken to have a fundamental frequency of N Hz. Alternatively, for a pump or motor with k displacement elements, the fundamental frequency can be taken to be Nk Hz, provided that the measured behaviour does not deviate significantly from cycle to cycle.

3.5
harmonic
sinusoidal component of a signal that occurs at an integer multiple of the fundamental frequency

NOTE An harmonic can be represented by its amplitude and phase, or by its real and imaginary parts.

3.6
impedance
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
admittance
reciprocal of impedance

3.8
characteristic impedance
⟨of a pipeline⟩ impedance of an infinitely long pipeline of constant cross-sectional area

3.9
hydro-acoustic energy
fluctuating part of the energy in a liquid

3.10
wide-band noise
hydro-acoustic energy distributed over the frequency spectrum

3.11
port-to-port symmetry
property of a two-port component in which the wave propagation characteristics remain the same when the port connections to the circuit are reversed

4 Symbols

The symbols used in this part of ISO 15086 are defined as shown in Table 1.

Table 1 — Symbols

Symbol	Description	Unit
A_e	Complex coefficient (term of admittance matrix between transducer PT3 and component 0)	$m^3 \cdot s^{-1} \cdot Pa^{-1}$
A_x	Complex coefficient (term of admittance matrix between transducers PTx and PT3)	$m^3 \cdot s^{-1} \cdot Pa^{-1}$
A_{xy}	Terms of admittance matrix (for x and y equal to 1 or 2)	$m^3 \cdot s^{-1} \cdot Pa^{-1}$
B_e	Complex coefficient (term of admittance matrix between transducer PT3 and component 0)	$m^3 \cdot s^{-1} \cdot Pa^{-1}$
B_x	Complex coefficient (term of admittance matrix between transducers PTx and PT3)	$m^3 \cdot s^{-1} \cdot Pa^{-1}$
c	Speed of sound in the fluid	$m \cdot s^{-1}$
f_min	Minimum frequency	Hz
f_max	Maximum frequency	Hz
H_{x3}	Transfer function between pressure ripples P_x and P_3	—
L	Distance between transducers	m
p_m	Mean test pressure	MPa
P_e	Fourier transform of pressure ripple at upstream port of component	Pa
P_s	Fourier transform of pressure ripple at downstream port of component	Pa
P_x	Fourier transform of pressure ripple at location x , where x is the number of the pressure transducer, equal to 1, 2 or 3, corresponding to PT1, PT2 or PT3, respectively	Pa
P_1, P_2 and P_3	Fourier transform of pressure ripple at the location of pressure transducer 1 (PT1), pressure transducer 2 (PT2) and pressure transducer 3 (PT3), respectively	Pa
$Q_{\mathrm{e}\rightarrow 0}$	Fourier transform of flow ripple into upstream port of component (0)	$m^3 \cdot s^{-1}$
$Q_{\mathrm{s}\rightarrow 0}$	Fourier transform of flow ripple into downstream port of component (0)	$m^3 \cdot s^{-1}$
x	Number of the pressure transducer, equal to 1, 2 or 3, corresponding to PT1, PT2 or PT3, respectively	—
Z_e	Impedance	
ν	Kinematic viscosity	cSt (1 cSt = $10^{-6} \cdot m^2 \cdot s^{-1}$)
θ	Phase of harmonic component (pressure or flow ripple, as appropriate)	degree (°)
dθ	Phase precision of the Fourier analyser	degree (°)

Units used in this part of ISO 15086 are in accordance with ISO 1000.

Graphical symbols are in accordance with ISO 1219-1 unless otherwise stated.

5 Test conditions and accuracy of instrumentation

5.1 Test conditions (permissible variations)

5.1.1 General

The required operating conditions shall be maintained throughout each test within the limits specified in Table 2.

Table 2 — Permissible variations in test conditions

Test parameter	Permissible variation
Mean flow	± 2 %
Mean pressure	± 2 %
Temperature	± 2 °C

5.1.2 Fluid temperature

The temperature of the fluid shall be that measured at the measuring pipe inlet.

5.1.3 Fluid density and viscosity

The density and viscosity of the fluid shall be known to an accuracy within the limits specified in Table 3.

Table 3 — Required accuracy of fluid property data

Property	Required accuracy %
Density	± 2
Viscosity	± 5

5.1.4 Mean fluid pressure

The mean fluid pressure of the fluid shall be that measured at the measuring pipe inlet.

5.1.5 Mean flow measurement

The mean flow measurement shall be measured downstream of the measuring pipe (e.g. in cases where the mean flow influences the terms of the admittance or impedance matrix).

5.2 Instrumentation precision

5.2.1 Steady-state accuracy class

The accuracy required shall be in accordance with the values given in ISO 15086-1:2001, Annex A.

5.2.2 Dynamic-state accuracy class

The accuracy required shall be in accordance with the values given in ISO 15086-1:2001, Annex B.

6 Measurement of the impedance of a single-port passive component

6.1 Local impedance — Measurement principle

The hydraulic impedance, Z_e, of a component with a single-port connection is defined by Equation (1) and shown diagrammatically in Figure 1:

$$Z_{e \to 0} = \frac{P_e}{Q_{e \to 0}} \tag{1}$$

where

P_e is the Fourier transform of the pressure ripple at the component inlet;

$Q_{e \to 0}$ is the Fourier transform of the flow ripple entering the component and regarded as positive when entering the 0 component.

In the high-frequency ranges (> 10 Hz), no convenient systems exist to measure the flow $Q_{e \to 0}$.

To enable a pulsating flow to be inferred, this test method requires the use of a rigid hydraulic pipe fitted with dynamic pressure transducers having a sufficiently high bandwidth and with the distances between the transducers selected according to the frequency range of interest.

Key

1 component 0

Figure 1 — Key parameters in the measurement of impedance of a single-port component

6.2 Hydraulic impedance

6.2.1 Measurement principle

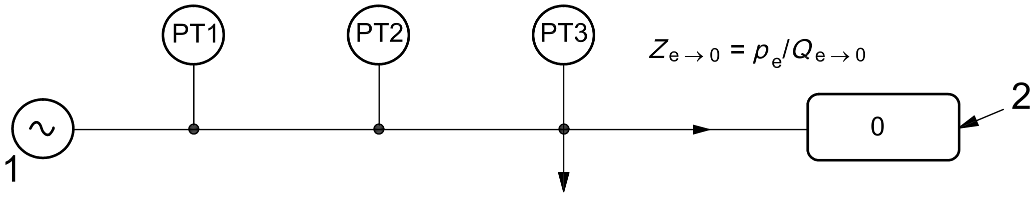
Figure 2 illustrates the principle for measuring the impedance, Z_e, at the inlet of the single-port component (0).

NOTE It is important to remember that a passive component is not itself a generator of hydro-acoustic energy.

Three dynamic pressure transducers (PT1 to PT3) are connected to the rigid pipe constituting the flow-ripple measuring pipe at transducer PT3.

It is assumed that appropriate technical measures have been taken to ensure that the speed of sound in the fluid between PT1 and PT3 is uniform. This requires that the mean temperature of the fluid in the measuring pipe be uniform to within 2 °C along its length.

The speed of the sound in the measuring pipes can be determined by means of the three pressure transducers, PT1 to PT3, in accordance with the algorithm described in ISO 15086-2.



Key

1 pulse generator

2 component 0

PT1, PT2, PT3 location of pressure transducers 1, 2 and 3, respectively

Figure 2 — Principle of measuring the impedance of a single port component

6.2.2 Simplified algorithm for determining the component of the local hydraulic impedance

The flow being determined at the upstream port of component (0) is $Q_{3\to 0}$.

A_x and B_x are the elements of the admittance matrix describing the pipe between PTx and PT3 where x is 1 or 2 depending on the transducers selected to determine the flows.

A_e and B_e are the elements of the admittance matrix describing the pipe between the inlet of the single-port component (0) and PT3.

By referring to ISO 15086-1, which provides the basic definitions, the algebraic relationships shown in Equations (2) to (5) are obtained.

$$Q_{3\to 0} = -Q_{3\to x} = -(A_x P_3 + B_x P_x) \tag{2}$$

$$Q_{e\to 0} = -\frac{A_e Q_{3\to 0}}{B_e} + \left(A_e^2 - B_e^2\right) P_3 \tag{3}$$

$$P_e = \frac{Q_{3\to 0}}{B_e} - \frac{A_e P_3}{B_e} \tag{4}$$

$$\begin{aligned} Z_{e\to 0} &= \frac{P_e}{Q_{e\to 0}} \\ &= \frac{Q_{3\to 0} - A_e P_3}{\left(A_e^2 - B_e^2\right) P_3 - A_e Q_{3\to 0}} \\ &= \frac{-\left(A_x P_3 + B_x P_x\right) - A_e P_3}{\left(A_e^2 - B_e^2\right) P_3 + A_e \left(A_x P_3 + B_x P_x\right)} \end{aligned} \tag{5}$$

Equation (6) for the measurement of the component hydraulic impedance, $Z_{e\to 0}$, is derived by dividing the numerator and the denominator of Equation (5) by P_3:

$$Z_{e\to 0} = \frac{-A_x - A_e - B_x \dfrac{P_x}{P_3}}{A_e^2 - B_e^2 + A_e A_x + A_e B_x \dfrac{P_x}{P_3}} \tag{6}$$

where x is equal to 1 or 2 according to the frequency ranges being measured.