INTERNATIONAL STANDARD

ISO 15086-3

Second edition
2022-07

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
ISO 15086-3:2022(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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.

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 documents 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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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 15086-3:2008), which has been technically revised.

The main changes are as follows:

— the symbols P_y, y, $Q_{3\to x}$ and $Q_{3\to 0}$ have been added to Table 1;

— Formula (7) has been added;

— Formulae (3), (8), (13), (14), (16) and (17) have been corrected;

— Figures 1, 2, 3, 5, 6, 7 and 8 have been corrected;

— various additional editorial modifications have been made.

A list of all parts in the ISO 15086 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 a closed circuit. During the process of converting mechanical power into fluid power, fluid-borne noise (flow ripple and pressure ripple) is generated. This 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 document 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 document 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.

INTERNATIONAL STANDARD **ISO 15086-3:2022(E)**

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

Part 3:
Measurement of hydraulic impedance

1 Scope

This document describes the procedure for determining the impedance characteristics of hydraulic components by means of measurements from pressure transducers mounted in a pipe.

This document 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 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 80000-1, *Quantities and units — Part 1: General*

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

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

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.

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
fluctuation of flow rate in the hydraulic fluid

3.2
pressure ripple
fluctuating component of pressure in the hydraulic fluid, caused by interaction of the source *flow ripple* (3.1) with the system

3.3

pulse generator

hydraulic component generating a periodic *flow ripple* (3.1) and consequently *pressure ripple* (3.2) in a circuit, or a hydraulic component generating a pressure ripple and, consequently, a flow ripple in a circuit

3.4

fundamental frequency

lowest frequency of the *pressure ripple* (3.2) [or *flow ripple* (3.1)] considered in a theoretical analysis or measured by an instrument

EXAMPLE A 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* (3.4)

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

3.6

impedance

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

3.7

admittance

reciprocal of *impedance* (3.6)

3.8

hydro-acoustic energy

fluctuating part of the energy in a liquid

4 Symbols

Table 1 — Symbols

Symbol	Description	Unit
A_e	complex coefficient (term of admittance matrix between transducer PT3 and component 0)	$\mathrm{m^3 \cdot s^{-1} \cdot Pa^{-1}}$
A_x	complex coefficient (term of admittance matrix between transducers PTx and PT3)	$\mathrm{m^3 \cdot s^{-1} \cdot Pa^{-1}}$
A_{xy}	terms of admittance matrix (for x and y equal to 1 or 2)	$\mathrm{m^3 \cdot s^{-1} \cdot Pa^{-1}}$
B_e	complex coefficient (term of admittance matrix between transducer PT3 and component 0)	$\mathrm{m^3 \cdot s^{-1} \cdot Pa^{-1}}$
B_x	complex coefficient (term of admittance matrix between transducers PTx and PT3)	$\mathrm{m^3 \cdot s^{-1} \cdot Pa^{-1}}$
c	speed of sound in the fluid	$\mathrm{m \cdot s^{-1}}$
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

Table 1 *(continued)*

Symbol	Description	Unit
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_y	Fourier transform of pressure ripple at location y, where y is the number of the pressure transducer, equal to 4, 5 or 6, corresponding to PT4, PT5 or PT6, 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_m	mean flow rate	$\mathrm{l \cdot s^{-1}}$
$Q_{e \to 0}$	Fourier transform of flow ripple into upstream port of component (0)	$\mathrm{m^3 \cdot s^{-1}}$
$Q_{s \to 0}$	Fourier transform of flow ripple into downstream port of component (0)	$\mathrm{m^3 \cdot s^{-1}}$
$Q_{3 \to x}$	Fourier transform of flow ripple at the location of pressure transducer 3 (PT3), defined as positive when towards location of pressure transducer x	$\mathrm{m^3 \cdot s^{-1}}$
$Q_{3 \to 0}$	Fourier transform of flow ripple at the location of pressure transducer 3 (PT3), defined as positive when towards location of pressure transducer (0)	$\mathrm{m^3 \cdot s^{-1}}$
T_m	fluid mean temperature	°C
x	number of the pressure transducer, equal to 1, 2 or 3, corresponding to PT1, PT2 or PT3, respectively	—
y	number of the pressure transducer, equal to 4, 5 or 6, corresponding to PT4, PT5 or PT6, respectively	—
Z_e	hydraulic impedance	$\mathrm{Pa \cdot s \cdot m^{-3}}$
$Z_{e \to 0}$	hydraulic impedance of component (0)	$\mathrm{Pa \cdot s \cdot m^{-3}}$
ν	kinematic viscosity	$\mathrm{mm^2 \cdot s^{-1}}$ (cSt)
θ	phase of harmonic component (pressure or flow ripple, as appropriate)	degree (°)
$d\theta$	phase precision of the Fourier analyser	degree (°)

Units used in this document shall be in accordance with ISO 80000-1.

Graphical symbols used in this document shall be 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 %

Table 2 *(continued)*

Test parameter	Permissible variation
Temperature	±2 °C

5.1.2 Fluid temperature

The temperature of the fluid shall be 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 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, $Z_{e\rightarrow 0}$, of a component with a single-port connection is defined by Formula (1) and shown diagrammatically in Figure 1:

$$Z_{e\rightarrow 0} = \frac{P_e}{Q_{e\rightarrow 0}} \qquad (1)$$

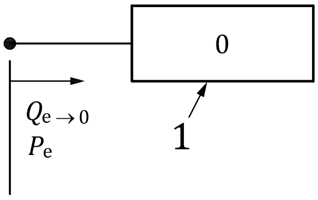
where

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

$Q_{e\rightarrow 0}$ 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 $Q_{e\rightarrow 0}$.

To enable a flow ripple 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

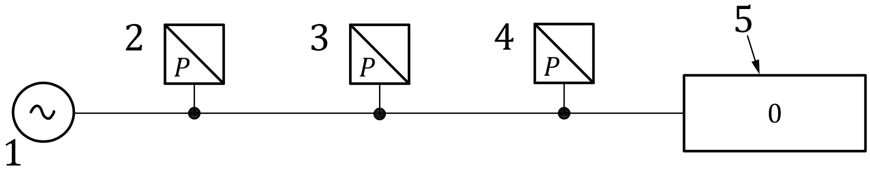
Figure 2 illustrates the principle for measuring the hydraulic impedance, Z_e, at the inlet of the single-port component (0).

NOTE 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. The diaphragms of the dynamic pressure sensors should be flush with the inner cylindrical surface of the measuring pipe.

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 and that the internal section of measuring pipes be constant between PT1 and PT3.

The speed of the sound in the measuring pipes is 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 pressure transducer PT1

3 pressure transducer PT2

4 pressure transducer PT3

5 component 0

NOTE Only the dynamic part of the pressure signal is required for PT1, PT2 and PT3.

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 $Q_{3\rightarrow 0}$.

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 Formulae (2) to (5) are obtained.

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

$$Q_{\mathrm{e}\rightarrow 0} = -\frac{A_\mathrm{e} Q_{3\rightarrow 0}}{B_\mathrm{e}} + \frac{\left(A_\mathrm{e}^2 - B_\mathrm{e}^2\right)}{B_\mathrm{e}} P_3 \tag{3}$$

$$P_\mathrm{e} = \frac{Q_{3\rightarrow 0}}{B_\mathrm{e}} - \frac{A_\mathrm{e} P_3}{B_\mathrm{e}} \tag{4}$$

$$\begin{aligned} Z_{\mathrm{e}\rightarrow 0} &= \frac{P_\mathrm{e}}{Q_{\mathrm{e}\rightarrow 0}} \\ &= \frac{Q_{3\rightarrow 0} - A_\mathrm{e} P_3}{\left(A_\mathrm{e}^2 - B_\mathrm{e}^2\right) P_3 - A_\mathrm{e} Q_{3\rightarrow 0}} \\ &= \frac{-\left(A_x P_3 + B_x P_x\right) - A_\mathrm{e} P_3}{\left(A_\mathrm{e}^2 - B_\mathrm{e}^2\right) P_3 + A_\mathrm{e}\left(A_x P_3 + B_x P_x\right)} \end{aligned} \tag{5}$$

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

$$Z_{\mathrm{e}\rightarrow 0} = \frac{-A_x - A_\mathrm{e} - B_x \dfrac{P_x}{P_3}}{A_\mathrm{e}^2 - B_\mathrm{e}^2 + A_\mathrm{e} A_x + A_\mathrm{e} B_x \dfrac{P_x}{P_3}} \tag{6}$$

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

The transfer function, P_x/P_3, can be directly measured by a suitable frequency-response analyser, but due account shall be taken of the pressure-transducer calibration (see 6.3.3).

6.3 Factors influencing the accuracy of the impedance measurement

6.3.1 General

The various factors influencing the accuracy of the impedance measurement and the precautions to take as a result are described in 6.3.2.

6.3.2 Pulse generator

It is necessary to have a device that is capable of producing a strong pressure ripple with a frequency and an amplitude that remain stable over the required frequency range. Suitable devices are:

a) a piston pump or other pump with a broad-band pressure ripple;