



BSI Standards Publication

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

National foreword

This British Standard is the UK implementation of ISO 15086-2:2025. It supersedes BS ISO 15086-2:2000, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/18/-/8, Product testing.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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**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**

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

*Partie 2: Mesurage de la vitesse du son émis dans un fluide dans
une tuyauterie*

**Second edition
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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.

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 15086-2:2000), which has been technically revised.

The main changes are as follows:

- the frequency range of pressure ripples has been revised;
- the symbol units, the symbol B_e , subscript O and N have been added to [Table 1](#);
- the symbol f_0 (first acoustic antiresonance frequency) has been replaced by f_{a1} ;
- [Figures 3](#) and [C.1](#) have been added;
- [Figures 1](#), [2](#) and [4](#) have been corrected;
- [Formulae 1](#), [C.2](#), and [C.3](#) have been corrected;
- [Annex D](#) has been revised;
- 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 an enclosed circuit. During the process of converting mechanical power into hydraulic fluid power, flow and pressure ripple and structure-borne vibrations are generated.

Hydro-acoustical characteristics of hydraulic components can be measured with acceptable accuracy if the speed of sound in the fluid is precisely known.

The measurement technique for determining the speed of sound in a pipe, as described in this document, is based upon the application of plane wave transmission line theory to the analysis of pressure ripple in rigid pipes^[1].

Two different measurement approaches are presented, namely the use of

- three pressure transducers in a pipe, and
- acoustic antiresonance in a closed-end pipe system.

The three-pressure-transducer method should be used at any time when the speed of sound is to be measured under the effective working conditions in a system. This method can be performed simultaneously with the hydro-acoustical measurement methods specified in ISO 10767-1, ISO 10767-3 and ISO 15086-3, using the same equipment and measurements.

Either method is suitable to produce a table of speed-of-sound data as a function of mean pressure and temperature for a particular fluid.

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

1 Scope

This document describes the procedure for the determination of the speed of sound in a fluid enclosed in a pipe, by measurements from pressure transducers mounted in the pipe.

This document is applicable to all types of hydraulic circuit operating under steady state conditions, irrespective of size, for pressure pulsations 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 5598, *Fluid power systems and components — Vocabulary*

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

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 flowrate in a hydraulic fluid, caused by interaction with a flow ripple source within the system

3.2 pressure ripple

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

3.3 fundamental frequency

lowest frequency of *pressure ripple* (3.2) measured by the frequency-analysis instrument

3.4**harmonic**

sinusoidal component of the *pressure ripple* (3.2) or *flow ripple* (3.1) occurring at an integer multiple of the *fundamental frequency* (3.3)

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

3.5**hydraulic noise generator**

hydraulic component generating *flow ripple* (3.1) and consequently *pressure ripple* (3.2) in the circuit

3.6**measurement pipe**

pipe in which the pressure transducers are mounted

3.7**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

3.8**acoustic antiresonance frequency**

frequency at which the magnitude of the entry *impedance* (3.7) of the *measurement pipe* (3.6) is at a minimum.

4 Symbols**Table 1 — Symbols**

Symbol	Description	Unit
A, A', B, B'	Complex coefficients	$\text{m}^3 \cdot \text{s}^{-1} \cdot \text{Pa}^{-1}$
a, b	Frequency-dependent wave propagation coefficients	$\text{rad} \cdot \text{s}^{-1}$
B_e	Effective bulk modulus of elasticity	Pa
c	Speed of sound in the fluid	$\text{m} \cdot \text{s}^{-1}$
d	Internal diameter of measurement pipe	m
f	Frequency of the wave pulsation harmonic	Hz
f_i	i^{th} harmonic frequency	Hz
f_{ai}	i^{th} acoustic antiresonance frequency	Hz
H	Transfer function (complex number) between two pressure transducer signals after calibration correction	—
H'	Transfer function (complex number) between two pressure transducer signals under calibration	—
H^*	Transfer function (complex number) between two pressure transducer signals	—
j	Complex operator ($\sqrt{-1}$)	—
L	Distance between transducers 1 and 2 (Method 1)	m
L'	Distance between transducers 2 and 3 (Method 1)	m
l	Distance from PT_1 to the end of the tube (Method 2)	m
P_1	Pressure ripple of transducer PT_1 (complex number)	Pa
P_2	Pressure ripple of transducer PT_2 (complex number)	Pa
P_3	Pressure ripple of transducer PT_3 (complex number)	Pa
$Q_{1 \rightarrow 2}$	Flow ripple at location 1, from 1 to 2 (complex number)	$\text{m}^3 \cdot \text{s}^{-1}$
$Q_{2 \rightarrow 1}$	Flow ripple at location 2, from 2 to 1 (complex number)	$\text{m}^3 \cdot \text{s}^{-1}$

Table 1 (continued)

Symbol	Description	Unit
$Q_{2 \rightarrow 3}$	Flow ripple at location 2, from 2 to 3 (complex number)	$\text{m}^3 \cdot \text{s}^{-1}$
S_i	Coherence function corresponding to measurement frequencies, f_i	—
ε	Error (complex number)	—
$\bar{\varepsilon}$	Conjugate of complex number ε (complex number)	—
ε_x	Real part of ε	—
ε_y	Imaginary part of ε	—
ρ	Density of fluid	$\text{kg} \cdot \text{m}^{-3}$
ν	Kinematic viscosity of fluid	$\text{m}^2 \cdot \text{s}^{-1}$
ω	Angular frequency ($2\pi f$)	$\text{rad} \cdot \text{s}^{-1}$
Subscript O	Index for old value	—
Subscript N	Index for new value	—
NOTE $H, H', H^*, P_1, P_2, P_3, Q_{1 \rightarrow 2}, Q_{2 \rightarrow 1}, Q_{2 \rightarrow 3}$ are all frequency-dependent terms and hence are designated by upper-case letters.		

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

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

5 Instrumentation

5.1 Static measurements

The instruments used to measure

- mean flow (Method 1 only),
- mean fluid pressure, and
- fluid temperature

shall at least meet the requirements for "industrial class" accuracy of measurement, i.e. class C as given in [Annex A](#).

5.2 Dynamic measurements

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

- resonant frequency: ≥ 30 kHz,
- linearity: ± 1 %,
- preferably include acceleration compensation, and

shall at least meet the requirements for "industrial class" accuracy of measurement, i.e. class C as given in [Annex B](#).

The instruments need not respond to steady-state pressure. It can 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 0,5 % or 0,5° respectively of the current measurement.

5.3 Frequency analysis of pressure ripple

A suitable instrument shall be used to measure the amplitude and phase of the pressure ripple.