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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

Hydrauliska anläggningar – Bestämning av egenskaper hos vätskeburet ljud i komponenter och system – Del 2: Mätning av ljudets hastighet i vätska

The International Standard ISO 15086-2:2000 has the status of a Swedish Standard. This document contains the official English version of ISO 15086-2:2000.

Swedish Standards corresponding to documents referred to in this Standard are listed in ”Catalogue of Swedish Standards”, issued by SIS. The Catalogue lists, with reference number and year of Swedish approval, International and European Standards approved as Swedish Standards as well as other Swedish Standards.

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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.

Attention is drawn to the possibility that some of the elements of this part of ISO 15086 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15086-2 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 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*

Annexes A, B and C form a normative part of this part of ISO 15086. Annexes D and E are for information only

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 fluctuations 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 part of ISO 15086, is based upon the application of plane wave transmission line theory to the analysis of pressure fluctuations in rigid pipes [1].

Two different measurement approaches are presented, namely the use of:

— three pressure transducers in a pipe,

— 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.

The antiresonance method should be used 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 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 part of ISO 15086 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 part of ISO 15086 is applicable to all types of hydraulic circuit operating under steady state conditions, irrespective of size, for pressure pulsations over a frequency range from 25 Hz to 2 500 Hz.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 15086. 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 15086 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 1000:1992, *SI units and recommendations for the use of their multiples and of certain other units.*

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 15086, the terms and definitions given in ISO 5598 and the following apply.

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 source within the system

3.3
fundamental frequency
lowest frequency of pressure ripple measured by the frequency-analysis instrument

3.4
harmonic
sinusoidal component of the pressure ripple or flow ripple occurring at an integer multiple of the fundamental frequency

NOTE 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 and consequently pressure ripple in the circuit

3.6
measurement pipe
pipe in which the pressure transducers are mounted

3.7
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

3.8
entry impedance.
impedance at the entry of a pipe or piping system

3.9
first acoustic antiresonance frequency
lowest frequency at which the magnitude of the entry impedance of the measurement pipe is at a minimum

4 Symbols and subscripts

4.1 Symbols

A, A', a, B, B', b Frequency-dependent wave propagation coefficients (complex numbers)

c Acoustic velocity in the fluid

d Internal diameter of pipe

f Frequency of the wave pulsation harmonic

$\mathbf{f}_i$ Vector of frequencies at which measurements are conducted

f_0 First acoustic antiresonance frequency (in hertz)

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 $\sqrt{-1}$

L Distance between transducers 1 and 2 (Method 1)

L' Distance between transducers 2 and 3 (Method 1)

l	Distance between pressure transducers (Method 2)
P_1	Pressure ripple of transducer PT1 (complex number)
P_2	Pressure ripple of transducer PT2 (complex number)
P_3	Pressure ripple of transducer PT3 (complex number)
$Q_{1 \to 2}$	Flow ripple at location 1, from 1 to 2 (complex number)
$Q_{2 \to 1}$	Flow ripple at location 2, from 2 to 1 (complex number)
$\mathrm{Q}_{2 \to 3}$	Flow ripple at location 3, from 2 to 3 (complex number)
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
ν	Kinematic viscosity of fluid
ω	$2\pi f$

NOTE H, H', H^*, P_1, P_2, P_3, $Q_{1 \to 2}$, $Q_{2 \to 1}$, $Q_{2 \to 3}$ are all frequency-dependent terms and hence are designated by upper-case letters.

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.

4.2 Subscripts

O	Index for old value
N	Index for new value

5 Instrumentation

5.1 Static measurements

The instruments used to measure

a) mean flow (Method 1 only);

b) mean fluid pressure;

c) fluid temperature;

shall meet the requirements for "industrial class" accuracy of measurement, i.e. class C as given in annex B.

5.2 Dynamic measurements

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

a) resonant frequency ⩾ 30 kHz;

b) linearity ⩾ ± 1 %;

c) preferably include acceleration compensation.

The instruments need not respond to steady-state pressure. 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 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.

The instrument shall be capable of measuring the pressure ripple from the pressure transducers such that, for a particular harmonic, the measurements from each transducer are performed simultaneously and synchronised in time with respect to each other.

The instrument shall have an accuracy and resolution for harmonic measurements of

a) amplitude within ± 0,5 %;

b) phase within ± 0,5°;

c) frequency within ± 0,5 %;

over the frequency range from 25 Hz to 2 500 Hz.

5.4 Uncertainty

Compliance with the above specification will result in an uncertainty in measurement of speed of sound of less than ± 3 %.

6 Hydraulic noise generator

6.1 General

Any type of hydraulic noise generator may be used, provided that sufficient pressure ripple is created at the pressure transducers to allow accurate measurements to be taken.

EXAMPLE Pumps and motors create a pressure ripple consisting essentially of many harmonics of the fundamental frequency. In these cases, the fundamental frequency is equal to the product of the shaft rotational frequency and the number of gear teeth, vanes or pistons, etc. (as appropriate to the machine employed).

Suitable alternatives include:

— an auxiliary valve with a rotating spool allowing flow to pass to the return line over part of its rotation;

— an electrohydraulic servo-valve driven by a frequency generator.

— The servo-valve may be operated with a white noise signal in order to obtain significant pressure ripple measurements at each frequency of interest.

6.2 Generator vibration

If necessary, the measurement pipe should be structurally isolated from the generator to minimize vibration.

7 Test conditions

7.1 General

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

7.2 Fluid temperature

The temperature of the fluid shall be that measured at the entry to the measurement pipe.

7.3 Fluid density and viscosity

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

7.4 Mean fluid pressure

The mean fluid pressure of the fluid shall be that measured at the entry to the measurement pipe.

7.5 Mean flow measurement

The mean flow shall be measured down-stream of the measurement pipe (Method 1 only).

Table 1 — Permissible variations in tests conditions

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

Table 2 — Required accuracy of fluid property data

Property	Required accuracy
Density	± 2 %
Viscosity	± 5 %

8 Test rig

8.1 General

If, at any test condition, the pressure ripple amplitudes are too small for satisfactory frequency-spectrum analysis to be performed, an alternative noise generator shall be selected.

The pressure transducers shall be mounted such that their diaphragms are flush, within ± 0,5 mm, with the inner wall of the pipe.

Two alternative specifications for the measurement pipe and transducer position are given, in accordance with the method employed.

