INTERNATIONAL STANDARD

ISO 10767-1

Second edition
2015-10-01

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

Part 1: Method for determining source flow ripple and source impedance of pumps

Transmissions hydrauliques — Détermination des niveaux d'onde de pression engendrés dans les circuits et composants —

Partie 1: Méthode de détermination de l'onde de flux de la source et de l'impédance de la source des pompes

Reference number
ISO 10767-1:2015(E)

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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 131, *Fluid power systems*, Subcommittee SC 8, *Product testing*.

This second edition cancels and replaces the first edition (ISO 10767-1:1996), which has been technically revised.

ISO 10767 consists of the following parts, under the general title *Hydraulic fluid power — Determination of pressure ripple levels generated in systems and components*:

— *Part 1: Precision method for pumps*

— *Part 2: Simplified method for pumps*

— *Part 3: Method for motors*

Introduction

The first edition of ISO 10767-1, published in 1996, was developed with a view to provide means for measurement (experimental determination) of the set of two characteristic values consisting of source flow ripple Q_S and source impedance Z_S of hydraulic pumps giving rise to pressure ripple (fluid born vibration) in the hydraulic power circuit., measurement of these two values for a given ripple source is extremely important for design and development of low noise pumps and hydraulic power systems, and for this reason, there is a valid need for such an international standard to experimental measurement of source flow ripple Qs and source impedance Z_S.

However, as discussed in the paragraph below, the so-called “secondary source method” presented in the first edition requires a very complex test system as well as signal processing technique, making its implementation highly difficult; because of this, no country except for the UK, the proposer, has yet adopted ISO 10767-1 as a national standard.

The difficulty can be explained as follows.

To determine the two characteristic values of the source flow ripple, Q_S, and source impedance, Z_S, a secondary ripple source is located in the test circuit to generate wide range ripples in the test system. Frequency characteristics of Z_S, arising from the secondary source, are first determined, followed by measurement of Q_S of the test pump on the basis of the test pump itself. This means that measurement of the harmonics of the pressure ripple is made with both the test pump and the secondary source in operation. As the result, the measurement accuracy of the harmonic component of the test pump deteriorates significantly as we come close to harmonic frequency level, where differences between the harmonic frequency of the test pump ripple and that of the secondary source become small. To deal with the problem, very complicated signal processing such as compensation is performed, but its practical effect is quite limited. In addition, the standard specifies use of a rotary valve for the secondary source of wide range (50 Hz ~ 4k Hz) ripples, but there is no provision as to the design and frequency characteristics.

These problems arise from the requirement for the secondary source, whereas the method proposed by Weddfelt[2] and Kojima[3] allows measurement of delivery ripple characteristics (Q_S) and the internal source (Z_S) on the sole basis of pressure ripple generated by the test pump. This makes the test system quite simple and allows superior accuracy to be achieved without complex processing of signals. The method according to the approaches of Weddfelt and Kojima, respectively, is the same in principle, the only difference between the two being the arrangement of the piping. The present proposal represents the method according to Kojima,[3] while annexing that of Weddfelt[2] for the purpose of reference.

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

Part 1: Method for determining source flow ripple and source impedance of pumps

1 Scope

This part of ISO 10767 establishes a test procedure for measuring the source flow ripple and source impedance of positive-displacement hydraulic pumps. It is applicable to all types of positive-displacement pumps operating under steady-state conditions, irrespective of size, provided that the pumping frequency is in the range from 50 Hz to 400Hz.

Source flow ripple causes fluid borne vibration (pressure ripple) and then airborne noise from hydraulic systems. This procedure covers a frequency range and pressure range that have been found to cause many circuits to emit airborne noise which presents a major difficulty in design of hydraulic fluid power systems. Once the source flow ripple and source impedance of hydraulic fluid power pump are known, the pressure ripple generated by the pump in the fluid power system can be calculated by computer simulation using the known ripple propagation characteristics of the system components. As such, this part of ISO 10767 allows the design of low noise fluid power systems to be realized by establishing a uniform procedure for measuring and reporting the source flow ripple and the source impedance characteristics of hydraulic fluid power pumps.

In this part of ISO 10767, calculation is made for blocked acoustic pressure ripple as an example of the pressure ripple. An explanation of the methodology and theoretical basis for this test procedure is given in Annex B. The test procedure is referred to here as the *two pressures/two systems method*. Ratings are obtained as follows:

a) source flow ripple (in the standard "Norton" model) amplitude, in cubic meter per second[m^3/s], and phase, in degree, over 10 individual harmonics of pumping frequency;

b) source flow ripple (in the modified model) amplitude, in cubic meter per second [m^3/s], and phase, in degree, over 10 individual harmonics of pumping frequency; and its time history wave form,

c) source impedance amplitude, in Newton second per meter to the power of five [$(Ns)/m^5$]., and phase, in degree, over 10 individual harmonics of pumping frequency;

d) blocked acoustic pressure ripple, in MPa (1 MPa = 10^6 Pa) or in bar (1 bar = 10^5 Pa), over 10 individual harmonics of pumping frequency; and the RMS average of the pressure ripple harmonic f_1 to f_{10}.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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.

3.1
source flow ripple
fluctuating component of flow-rate generated within the pump, which is independent of the characteristics of the connected circuit

Note 1 to entry: Since there exist the following two definitions of the *pump* source flow ripple, it shall be used with distinct discrimination:

— source flow ripple in the standard "Norton" model, Q_S, is the source flow ripple implicitly assumed to be generated at the pump outlet, as shown in Figure 1 a);

— source flow ripple in the "modified" model, Q_S*, is the source flow ripple assumed to be generated at the inner end of the discharge flow line, as shown in Figure 1 b).

Note 2 to entry: The theoretical pump source flow ripple which is calculated from computer simulation using the dimensions and configuration of the pump, physical properties of the fluid and operating conditions corresponds to the pump *flow ripple* (3.2) in the modified model, Q_S*.

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

3.3
pressure ripple
fluctuating component of pressure in the hydraulic fluid, caused by interaction of the *source flow ripple* (3.1) with the system

3.4
blocked acoustic pressure ripple
pressure ripple (3.3) that would be generated at the pump discharge port when fluid is discharged into a circuit of infinite *impedance* (3.5)

3.5
impedance
complex ratio of the *pressure ripple* (3.3) to the *flow ripple* (3.2) occurring at a given point in a hydraulic system and at a given frequency

3.6
source impedance
impedance (3.5) of a pump at the discharge port in the standard "Norton" model

3.7
harmonic
sinusoidal component of the *pressure ripple* (3.3) or *flow ripple* (3.2) occurring at an integer multiple of the *pumping frequency* (3.8)

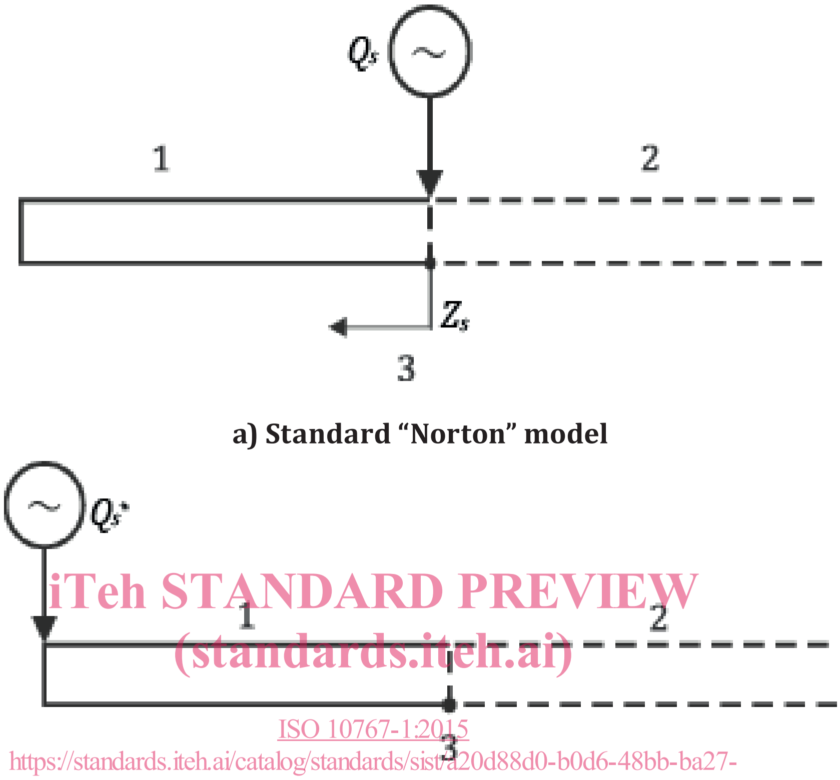
Note 1 to entry: A harmonic can be represented by its amplitude and phase, or, alternatively, by its real and imaginary components, provided that in this part of ISO 10767 the real and imaginary components are used in the arithmetic calculations.

3.8
pumping frequency
frequency given by the product of the *shaft rotational frequency* (3.9) and the number of pumping elements on that shaft

Note 1 to entry: It is expressed in hertz.

3.9
shaft rotational frequency
frequency (in hertz) given by the shaft rotational speed (in revolutions per minute) divided by 60

Note 1 to entry: Since the calculations in Clause 8 are all carried out using SI unit, all variables and constants shall be expressed in SI units, except for reporting of the end results.



a) Standard "Norton" model

b) Modified model

Key

1 discharge passageway

2 discharge line

3 pump exit

Figure 1 — Modelling of pump pulsation source

4 Instrumentation

4.1 Static measurements

The instruments used to measure

a) shaft rotational speed,

b) mean pressure,

c) mean discharge flow-rate, and

d) fluid temperature

shall have an accuracy throughout each test within the limits specified in Table 1.

NOTE The percentage limits are the of the value of the quantity being measured and not the maximum test values or the maximum reading of the instrument.

Table 1 — Permissible errors of static measurements

Shaft rotational frequency %	Mean flow %	Mean pressure %	Temperature °C
±0,5	±2,0	±2,0	±2,0

4.2 Dynamic measurements

The instruments used for measurement of pressure ripple shall have the following characteristics:

a) resonant frequency ≥ 30 kHz;

b) linearity ≤ ± 1 %.

The instruments need not respond to steady-state pressure. It can be advantageous to filter out any steady-state signal component by using a high-pass filter. This filter shall not introduce additional amplitude or phase error exceeding 1 % or 2°, respectively, at the pumping frequency.

4.3 Frequency analysis of pressure ripple

A suitable instrument shall be used to measure the harmonic amplitude and phase (or its real and imaginary components) of pressure ripple, for individual harmonics of the pumping frequency up to 3,5 kHz. The instrument shall be capable of measuring the pressure ripple from two pressure transducers simultaneously. The respective two pressure ripple signals of system 1 and system 2 shall be sampled in an instrument using external trigger signal obtained from a fixed reference on the pump shaft.

This instrument shall have the following accuracy and resolution for harmonic measurements over the frequency range from 50 Hz to 4 000 Hz:

a) amplitude within the range of ±1 %;

b) phase within the range of ±1°;

c) frequency within the range of ±0,5 %.

This can be achieved using a common type analysing recorder and then carrying out the spectral analyses by calculating discrete Fourier transforms (DFTs) of the time history data on a post processing digital computer. Annex B contains a tutorial explanation of this frequency analysis method.

NOTE In order to improve the accuracy of Fourier transformation, pump speed shall be adjusted minutely while observing the monitor of the analysing recorder so that the higher (e.g. 10th) harmonic amplitude peak appears nearly at the assigned higher (e.g. 10th) harmonic frequency (i.e. in case of f_1 being 225 Hz, f_{10} = 2,25 kHz) of the pumping frequency.

5 Pump installation

5.1 General

The pump shall be installed in the attitude recommended by the manufacture and mounted in such a manner that the response of the mounting-to-pump vibration is minimized.

5.2 Drive vibration

The electric motor and associated drive coupling shall not generate torsional vibration in the pump shaft. If necessary, the pump and the driving unit shall be isolated from each other to eliminate vibration generated by the electric motor.

5.3 Reference signal

A means of producing a reference signal relative to the pump shaft rotation shall be included, as one of essential elements in measurement according to this part of ISO 10767. The signal shall be an electrical pulse occurring once per revolution, with sharply defined rising and falling edges. This signal is used as an external trigger signal of analysing recorder, as well as for measurement of the shaft rotational speed. A magnetic gap detector (or a photo sensor) a satisfactory means of providing the required characteristics of reference signal mentioned above.

6 Test conditions and setting

6.1 General

Pump shaft speed, mean discharge pressure and fluid temperature are set to the values of required test conditions. These 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	±2,0 %
Mean pressure	±2,0 %
Shaft rotational speed	±0,5 %
Temperature	±2,0 °C

6.2 Mean flow

Mean flow is measured by the positive-displacement type flow meter installed on the outlet line of loading valve 2.

6.3 Mean discharge pressure

Mean discharge pressure shall be measured electrically using a piezoresistance type transducer or a strain gauge type transducer mounted in the adapter before loading valve 1.

A bourdon type pressure gauge shall not be used for measurement of the mean discharge pressure.

6.4 Pump shaft speed

Pump shaft speed is measured by the magnetic gap detector (or photo sensor) installed on the pump shaft. Shaft rotational frequency (Hz) is given by the shaft rotational speed (rev/min) divided by 60.

6.5 Fluid temperature

Temperature of the fluid shall be that measured at the pump inlet.

6.6 Fluid property

Density, viscosity and bulk modulus of the test fluid shall be known to an accuracy within the limits specified in Table 3.

NOTE The percentage limits are of the error of the estimated quantity to the real value

Table 3 — Required accuracy of fluid property data

Property	Required accuracy
Density	±2,0 %
Viscosity	±5,0 %
Bulk modulus	±5,0 %

7 Test rig

7.1 General

The test rig shall be installed as shown in Figure 2. The test rig shall include all fluid filters, fluid coolers, reservoir, loading valves and any ancillary pumps required to meet operating conditions of the hydraulic pump. Specific features are described in 7.2 to 7.10.

7.2 Test pump

The test pump shall be installed in the "as-delivered" condition.

7.3 Test fluid

Type of the test hydraulic fluid and the quality of filtration shall be in accordance with the pump manufacturer's recommendations.

7.4 Inlet line

Internal diameter of the inlet line to the pump shall be in accordance with the pump manufacturer's recommendations. Care shall be exercised when assembling the inlet line to prevent air leakage into the circuit. The supply pressure shall be in accordance with the pump manufacturer's recommendations and, if necessary, a boost pump shall be used. If a boost pump is used, the pressure and flow ripple of the boost pump shall be taken into account, so that they do not affect the test results.

7.5 Inlet pressure gauge (for static pressure)

The inlet pressure gauge of Bourdon tube type shall be mounted at the same height as the inlet fitting. Otherwise, the gauge shall be calibrated for any height difference therefrom.