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SVENSK STANDARD SS-ISO 10767-2

Handläggande organ	Fastställd	Utgåva	Sida
SVENSK MATERIAL- & MEKANSTANDARD, SMS	1999-12-10	1	1 (1+23)

Hydraulic fluid power – Determination of pressure ripple levels generated in systems and components – Part 2: Simplified method for pumps

Hydrauliska anläggningar – Bestämning av tryckpulsationsnivåer alstrade i system och komponenter – Del 2: Förenklade metoder för pumpar

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ICS 23.100.10

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Telefon: 08 - 459 56 00. *Telefax*: 08 - 667 85 42
E-post: info@sms-standard.se
Prisgrupp P
Tryckt i januari 2000

Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

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.

International Standard ISO 10767-2 was prepared by Technical Committee ISO/TC 131, *Fluid power systems,* Subcommittee SC 8, *Product testing.*

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*

Annex A forms a normative part of this part of ISO 10767. Annexes B and C are for information only.

Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. Hydraulic pumps are devices which convert rotary mechanical power into fluid power. Pump flow has a large, steady component and a smaller, cyclical component superimposed upon it. It is this smaller, cyclical component of the pump flow that reacts with the fluid system of the pump and its circuit, that results in pressure ripple or fluid-borne noise. This fluid-borne noise can be transmitted through the liquid under pressure to other attached components and structures, and can result in unwanted noise and vibrations.

While the flow ripple is the cause of the pressure ripple, it is more difficult to measure. Therefore pressure ripple will be used in this procedure to characterize the fluid-borne noise generation potential of hydraulic fluid power pumps. Pressure ripple is a function of the pump design and the circuit in which it is measured. It is important, therefore, that the test circuit be controlled so as to provide uniform results when comparing the fluid-borne noise generation potential of different types of pumps. Pressure ripple determined in accordance with this part of ISO 10767 may be different to that measured in fluid power systems because of the high impedance of the test line.

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

Part 2:
Simplified method for pumps

1 Scope

This part of ISO 10767 specifies a procedure for measuring the fluid pressure ripple characteristics of hydraulic fluid power pumps with a maximum error of + 1 dB to – 3 B.

ISO 10767-1 can be used if pressure ripple measurements at lower pressure levels, lower frequencies, or at greater accuracy levels is required. This procedure covers a frequency and pressure range that has been found to excite many circuits to emit airborne noise that most concerns designers of hydraulic fluid power systems. It allows the pressure ripple data to be published with minimal calculations and processing of the measured data. This part of ISO 10767 promotes quieter fluid power systems by establishing a uniform procedure for measuring and reporting the fluid pressure ripple characteristics of hydraulic fluid power pumps. Annex B contains a tutorial explanation of the technical basis for this test procedure.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10767. 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 10767 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.*

ISO 9110-1:1990, *Hydraulic fluid power — Measurement techniques — Part 1: General measurement principles.*

ISO 10767-1:1996, *Hydraulic fluid power — Determination of pressure ripple levels generated in systems and components — Part 1: Precision method for pumps.*

3 Terms and definitions

For the purposes of this part of ISO 10767, the fluid power terms and definitions given in ISO 5598, the acoustical terms and definitions given in ISO 10767-1 and the following apply.

3.1
pump outlet port passage length
L_S
average length from the volume exchange cavities of the pump to the entrance of the test line in normal operation at the test conditions specified

3.2
pump outlet port passage diameter
D_S
average diameter of the discharge cavity from the volume exchange cavities of the pump to the entrance of the test line in normal operation at the test conditions specified

4 Symbols and units

4.1 For the purposes of this part of ISO 10767, the symbols given in Table 1 apply.

Table 1 — Symbols

Symbol	Quantity
B	bulk modulus of elasticity of the test fluid
c_0	reference speed of sound in test fluid not corrected for test line elasticity
D_L	inside diameter of test line
$D_{O,min}$	minimum line termination orifice diameter
$D_{O,max}$	maximum line termination orifice diameter
D_S	pump outlet port passage diameter
E	modulus of elasticity of test line material
f_1	fundamental pumping frequency
f_{max}	maximum frequency limit of test procedure
K	orifice flow coefficient, $K = \dfrac{4q}{\pi D_O^2 \sqrt{\Delta p}}$ (1)
L_L	test line length
L_S	pump outlet port passage length
Z	number of pumping chambers per revolution
n	harmonic number n = 1, 2, 3, ...
N	pump shaft speed
P_n	amplitude of n-th harmonic of pressure ripple (i.e. ½ of peak-to-peak)
p_{RMS}	the root mean square (RMS) average of the pressure ripple harmonics from f_1 to f_{max}
p_{max}	maximum pump outlet test pressure
p_{min}	minimum pump outlet test pressure
Δp	orifice pressure drop
q	average pump flow rate
ρ	mass density of test fluid
t	wall thickness of test line
V_S	pump outlet passage volume

4.2 Units used in this part of ISO 10767 are in accordance with ISO 1000.

4.3 Graphic symbols used in this part of ISO 10767 are in accordance with ISO 1219-1 unless otherwise stated.

5 Instrumentation

5.1 The instruments used to measure flow, pressure, drive speed, and oil temperature shall be in accordance with the recommendations in ISO 9110-1.

5.2 Pressure transducers for measuring pressure ripple shall be piezoelectric type transducers capable of accurate measurements from the pump drive shaft frequency up to 10 kHz minimum in accordance with ISO 9110-1.

5.3 The harmonic content of the pressure ripple shall be established as a function of frequency. This may be achieved using a Fast Fourier Transform (FFT) narrow-band spectrum analyzer. The analysis shall produce accurate measurements from drive shaft frequency up to 10 kHz minimum in accordance with ISO 9110-1.

6 General provisions

6.1 Control the average pressure, drive shaft speed, and fluid temperature to a class B accuracy level in accordance with ISO 9110-1.

6.2 Use the test fluid for which pressure ripple data is desired. Make sure that the test fluid is acceptable for use with the test pump.

6.3 Use extra care when installing pump inlet lines to maintain the inlet pressure within the manufacturer's rated conditions and to prevent air from leaking into the circuit.

6.4 "Run-in" the pump in accordance with the manufacturer's recommendations prior to running tests.

6.5 Run the pump to purge air from all lines and circuit components prior to running tests. All test conditions shall be stabilized within the limits specified in 6.1.

6.6 Use extra care to ensure that the operating pressure of the test lines, components, and the test pump does not exceed the manufacturer's ratings. Do not install any additional components to the test circuit because this can affect the accuracy of the measurements.

WARNING — Line pressure is determined by pump flow and the orifice size selected for the test circuit. Incorrect orifice size can result in extreme line pressure. Take the necessary safety precautions to protect both test equipment and personnel from extreme line pressure.

7 Determination of geometric parameters and speed of sound in the test fluid

7.1 Values for D_S and L_S can be obtained in any one of the following ways:

a) using the diameter of the pump outlet port as an approximation of D_S and calculating L_S from titration measurements of the pump outlet port volume V_S using the following equation:

$$L_S \approx \frac{4 V_S}{\pi D_S^2} \tag{2}$$

NOTE V_S includes all fittings up to the entrance of the test line.

b) from the manufacturer of the test pump;

c) by estimation from the results of a test procedure that measures the internal impedance of the test pump (e.g. ISO 10767-1).

7.2 Values for the speed of sound in the test fluid c_0 and the test fluid mass density ρ can be obtained from the manufacturer of the fluid. The speed of sound in the test fluid can be corrected for the elasticity of the test line using the following equation:

$$c = \sqrt{\frac{1}{\frac{1}{c_0^2} + \frac{(D_L + t)\rho}{E_t}}} \qquad (3)$$

7.3 If a value for the speed of sound in the test fluid c_0 is not available from the manufacturer of the fluid it may be estimated using the following equation:

$$c_0 = \sqrt{B/\rho} \qquad (4)$$

8 Valid frequency and pressure range

8.1 The fundamental pumping frequency is f_1. It is the lowest frequency of the pump pressure ripple that can be measured with this test procedure.

$$f_1 = \frac{ZN}{60} \qquad (5)$$

where N is expressed in rotations per minute in order to give f_1 in hertz.

8.2 The minimum pump outlet pressure that can be measured with this test procedure is p_{min}.

$$p_{min} = \frac{2\rho c q}{\pi D_S^2 \tan\left(\frac{2\pi f_1 L_S}{c}\right)} \qquad (6)$$

8.3 The highest frequency that can be measured with this test procedure is 2,5 kHz or f_{max}, whichever is the lower limit. The following equation is used to calculate f_{max}:

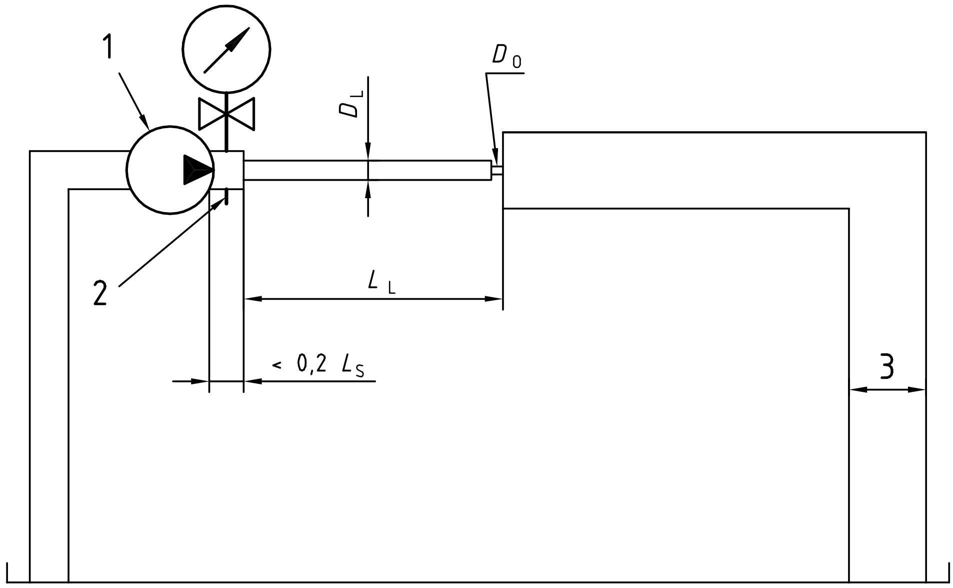
$$f_{max} = \left(\frac{c}{2 L_S}\right) - f_1 \qquad (7)$$

8.4 p_{max} is defined as the maximum pump outlet pressure where pressure ripple data is desired. p_{max} shall be less than the maximum pump outlet pressure allowed by the pump manufacturer and shall comply with the requirements of 6.6.

8.5 Acceptable pressure ripple measurements can be obtained with this test procedure at pump outlet pressures from p_{min} to p_{max} and over a frequency range from f_1 to f_{max} or 2,5 kHz whichever is the lower limit. If the value of p_{min} calculated in 8.2 is greater than p_{max}, valid pressure ripple measurements cannot be obtained using this test procedure.

9 Test circuit

9.1 A test circuit shall be constructed as shown in Figure 1. The test pump can be a single pump, as shown in Figure 1, a multiple stage pump, or may include a boost pump or supercharge pump.



Key

1 Text pump

2 Piezoelectric pressure transducer

3 Inside diameter > $5D_L$

NOTE Pipeline and orifice symbols are for illustrative purposes only and are not in accordance with ISO 1219-1.

Figure 1 — Schematic diagram of test circuit.

9.2 The transition from the pump outlet port to the entrance of the test line shall be completed within a distance of less than 20 % of the pump outlet port passage length L_S. Install the pressure transducer and pressure gauge between the pump outlet port and the entrance to the test line.

If the transition from outlet port to the entrance of the test line cannot be achieved within the distance specified, then this part of ISO 10767 does not apply. ISO 10767-1 may be a suitable alternative.

9.3 Mount the pressure transducer so that its sensing surface faces upward and is essentially tangential to the flow stream.

9.4 The outlet pressure gauge shall be shut off from the test circuit when making pressure ripple measurements. The gauge shut-off valve shall be located as close as possible to the test line to minimize branch circuit interactions.

9.5 The test line between the pump and the termination orifice shall be steel tubing with an inside diameter estimated using the following equation:

$$D_L = \sqrt{\frac{4\rho c q}{\pi(p_{max} + p_{min})}} \qquad (8)$$

A tubing inside diameter shall be chosen that is equal to D_L or the next smaller standard tubing size. The wall thickness of the tubing shall be chosen to comply with the operating pressure requirements given in 6.6.

9.6 The test line length L_L, as shown in Figure 1, shall be within the following limits:

$$0{,}9L_S \leqslant L_L \leqslant 1{,}1L_S \qquad (9)$$

9.7 Determine the maximum test line termination orifice diameter using the following equation:

$$D_{O,max} = \sqrt{\frac{4q}{\pi \ K \sqrt{p_{min}}}} \tag{10}$$

Testing with this orifice diameter will yield pump outlet pressure approximately equal to p_{min}

9.8 Determine the minimum test line termination orifice diameter using the following equation:

$$D_{O,min} = \sqrt{\frac{4q}{\pi \ K \sqrt{p_{max}}}} \tag{11}$$

Testing with this orifice diameter will yield pump outlet pressures approximately equal to p_{max}.

9.9 The termination orifice shall be located at the entrance to the fitting at the downstream end of the test line. Care should be taken not to create any significant oil volume cavities between the end of the test line and the entrance to the termination orifice.

9.10 The line downstream of the termination orifice shall have an inside diameter greater than $5D_L$.

10 Test procedure

10.1 Install the test line termination orifice with diameter $D_{O,max}$ as determined in 9.7.

10.2 With the pressure gauge shut-off valve opened, adjust the pump drive speed and inlet oil temperature to the desired test values.

10.3 Measure and record the actual average pump outlet port pressure.

10.4 Close the pressure gauge shut-off valve.

10.5 Measure the harmonic content of the pressure ripple. Record only the first 10 harmonics of pumping frequency. Establish the peak amplitude of each harmonic. Discard any harmonics above 2,5 kHz or f_{max}, whichever is the lower limit.

10.6 Shut down the test pump and install the test line termination orifice diameter $D_{O,min}$ as determined in 9.9 and repeat 10.2 to 10.5.

10.7 If pressure ripple data at an average pump outlet pressure between p_{min} and p_{max} is desired, choose as many intermediate test line termination orifice diameters as desired between $D_{O,max}$ and $D_{O,min}$ and repeat 10.2 to 10.5 with each orifice.

10.8 If pressure ripple data at other test conditions (i.e. drive speeds, pump displacements, oil temperatures, etc.) is required, calculate a new test line diameter according to 9.5 and termination orifice diameters according to 9.7 and 9.8 and repeat 10.2 to 10.7. The requirements of 8.2, 8.3 and 8.4 shall be met with each corresponding test line diameter, termination orifice, and operating condition.

11 Data presentation

11.1 Report the harmonics of pumping frequency obtained in 10.5 for each pump operating condition. This data shall be reported as the amplitude (i.e. 1/2 of the peak-to-peak value) of the pressure ripple.

11.2 Calculate the overall RMS average pressure ripple amplitude for the integral harmonics of pumping frequency from f_1 to f_{max} or 2,5 kHz (whichever is the lower) for each pump operating condition of 11.1. Do not include pressure ripple measurements above the tenth harmonic of pumping frequency. This can be calculated using the following equation:

$$p_{RMS} = \sqrt{\frac{P_1^2 + P_2^2 + P_3^2 + \ldots + P_n^2}{2}} \quad (12)$$

11.3 All pressure ripple measurements and test conditions shall be expressed in units in accordance with ISO 1000.

11.4 The test information and conditions shall be reported using the forms given in annex A.

12 Identification statement (Reference to this part of ISO 10767)

Use the following statement in test reports, catalogues and sales literature when electing to comply with this part of ISO 10767:

"Fluid borne noise characteristics of this pump were obtained and are presented in accordance with ISO 10767-2:1999, *Hydraulic fluid power — Determination of pressure ripple levels generated in systems and components — Part 2: Simplified method for pumps."*