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Hydraulic fluid power — Determination of discharge flow rate and thermal losses of gas loaded accumulators —

Part 1: **Test method**

Transmissions hydrauliques — Détermination du débit de décharge et des pertes thermiques des accumulateurs hydro-pneumatiques —

Partie 1: Méthode d'essai

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Foreword

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This document was prepared by Technical Committee ISO/TC 131, *Fluid power systems*.

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Hydraulic fluid power — Determination of discharge flow rate and thermal losses of gas loaded accumulators —

Part 1: Test method

1 Scope

This document defines a test method which enables the determination of the characteristic values of discharge flow rate and thermal losses of gas-loaded accumulators with separators used in fluid power systems.

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598 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/

4 Symbols and units

For the purposes of this document, the symbols and units listed in Table 1 apply.

Table 1 — Symbols and units

Description	Symbol	unit
Hydraulic fluid mass	m	kg
Gas pressure at T	p	MPa
Maximum working pressure	p_s	MPa
Pre-charging pressure, i.e. the gas pressure in the accumulator when the hydraulic circuit is not under pressure (initial state) at a temperature of 20 °C ± 5 °C	p_0	MPa
Minimum working pressure of the hydraulic circuit	p_1	MPa
Maximum working pressure of the hydraulic circuit	p_2	MPa
Gas constant	R	$J \cdot mol^{-1} \cdot °C^{-1}$
Duration of the dynamic phase	t	s
Time constant for heat exchange	τ	s
NOTE All pressures are expressed in relative terms.		

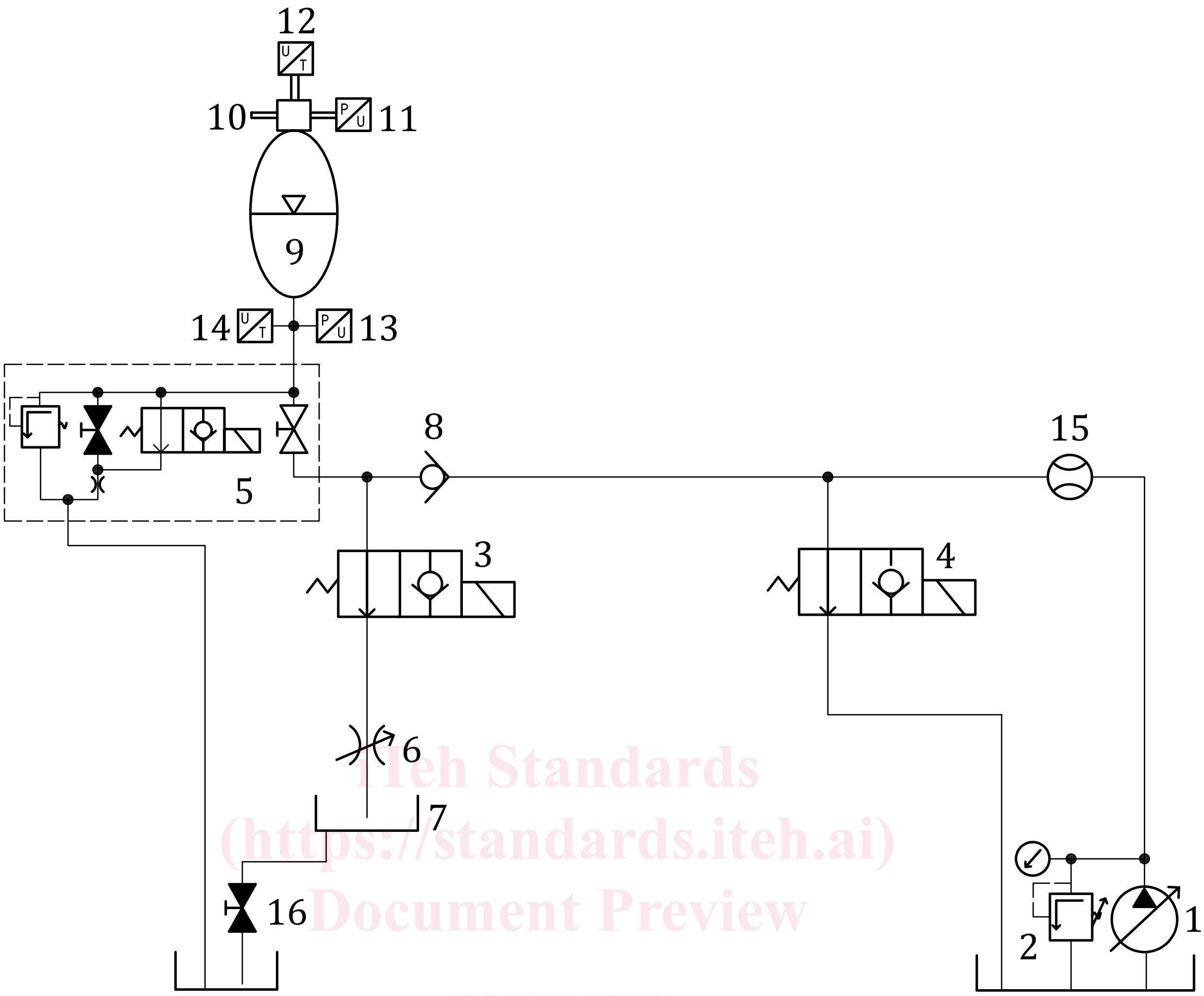
Table 1 *(continued)*

Description	Symbol	unit
Gas temperature	T	°C
Ambient temperature	T_{ext}	°C
Minimum range temperature	TS_{min}	°C
Maximum range temperature	TS_{max}	°C
Mean discharge flow rate	q_m	l/min
Gas molar volume	v	$m^3 \cdot mol^{-1}$
Internal volume of the gas chamber	V	l
Gas volume at pressure p_0	V_0	l
Volumes occupied by the gas contained in the accumulator and any additional gas bottles at pressures p_1 and p_2 respectively	V_1, V_2	l
Measured hydraulic fluid volume	V_m	l
NOTE All pressures are expressed in relative terms.		

5 Test bench

5.1 Appropriate characteristics

A suitable test bench ensuring the scope of this document shall present the appropriate characteristics, as shown in Figure 1.



Key

1 fluid power supply
2 pressure relief valve
3 normally open valve
4 normally open valve
5 distribution and mounting block
6 adjustable flow-control valve
7 reservoir
8 check valve
9 test accumulator
10 gas filling system
11 gas pressure sensor
12 gas temperature sensor
13 hydraulic fluid pressure sensor
14 hydraulic fluid temperature sensor
15 flowmeter
16 drain valve

NOTE 1 The actuation of the valves 3 and 4 can be electric or hydraulic.

NOTE 2 The safety valve (drawing inside the distribution block, key 5) can be placed on the hydraulic part or on the gas part.

NOTE 3 The flowmeter (15) is required only when the hydraulic fluid filling conditions for the test accumulator need to be known.

Figure 1 — Hydraulic schematic diagram of the gas-loaded accumulator test bench

5.2 Operating principle

Refer to Figure 1 for the devices included in this subclause.

In case of hydraulic actuation, hydraulic parts for actuation shall be installed on the test bench.

The test accumulator (9), charged with inert gas (using the filling device (10)), is installed in its testing position and orientation on the distribution block (5).

NOTE The position and the orientation of the gas-loaded accumulator during the test (vertical, horizontal, or even inclined) are important and can have an impact on the measurements. See Clause 6 for the elements to be included in the test report.

In order to charge the test accumulator (9), the valves (3 and 4) shall be closed. The accumulator is charged up to a value *p* which was previously set by adjusting the pressure relief valve (2) of the fluid power supply (1).

The charge within the test accumulator (9) is maintained by the check valve (8). At that time, it is possible to by-pass the fluid power supply (1) again by opening the valve (4).

The test accumulator (9) is discharged by opening the valve (3). The discharge rate can be adjusted with the adjustable flow-control valve (6).

The gas and hydraulic fluid pressures and temperatures (11, 12, 13, 14) are recorded during the test.

The hydraulic fluid stored inside the test accumulator (9) during the charging operation is collected in a reservoir (7) placed below the distribution block (5). Depending on the tests to be conducted, the test accumulator (9) may be completely or partially discharged.

A drain valve (16), located below the reservoir (7), is used to drain the reservoir before the next test.

5.3 Design and dimensioning

Refer to Figure 1 for the devices included in this sub-clause.

The non-exhaustive list shown below gives appropriate requirements on how to design the test bench and conduct the tests in order to obtain high-quality results.

— The distribution components (3, 4, 5 and 8) shall be as tight (pressure-sealed) as possible to prevent any leak rate likely to alter the measurements during pressure stabilisation phases.

— The whole distribution system and the piping shall be generously sized in order to perform charging and discharging operations with minimum pressure losses, and therefore perform measurements with high flowrates. A maximum pressure loss of 0,5 MPa shall be ensured for the maximum instantaneous flowrate for which the test bench is designed (with adjustable flow-control valve (6) fully open). The pressure loss shall be determined by calculation (pressure loss in the valves and pressure loss in the pipes).

— Dead volumes shall be as small as possible in relation to the volumes which are to be measured; the cartridge valve technology may be used.

— The opening and closing times of the valves (3 and 4) shall be short in relation to the duration of the charging and the discharging operation, to prevent any effect on the characteristics of the accumulators. A maximum ratio of approximately 8 % between opening/closing times of the valves and duration of the charging/discharging operation shall be ensured;

  In order to perform tests with industrial valves, the opening and closing times of the valves shall not be less than 50 ms.

— the pressure losses of the distribution block (5) shall remain negligible in relation to the pressure losses of the coupling of the accumulator.

Two tests can be considered as comparable, provided that, as a minimum, ambient temperature and gas pressures measured are common during the charging phase or discharging phase.

5.4 Measuring requirements

Refer to Figure 1 for the devices included in this subclause.

The measuring requirements are as follows:

— the pressure sensor (11) to measure the gas pressure shall installed on an adapter connected to the gas interface of the test accumulator;

— the temperature sensor (12) to measure the gas temperature shall be installed on an adapter connected to the gas interface of the test accumulator;

— the pressure sensor (13) to measure the hydraulic fluid pressure shall be installed as close to the fluid port of the test accumulator as possible;

— the temperature sensor (14) to measure the hydraulic fluid temperature shall be installed as close to the fluid port of the test accumulator as possible.

Various systems for measuring the discharged hydraulic fluid volume may be considered. For example, a graduated reservoir can be used. Another possibility is the use of a weighting system. In this case, the discharged hydraulic fluid volume shall be calculated from measured mass, m, and hydraulic fluid density. However, irrespective of the selected technology, attention should be taken to ensure the repeatability of the measurements performed. This measuring system is only required for determining the mean flow rate characteristics.

5.5 Precautions to be taken when performing the tests

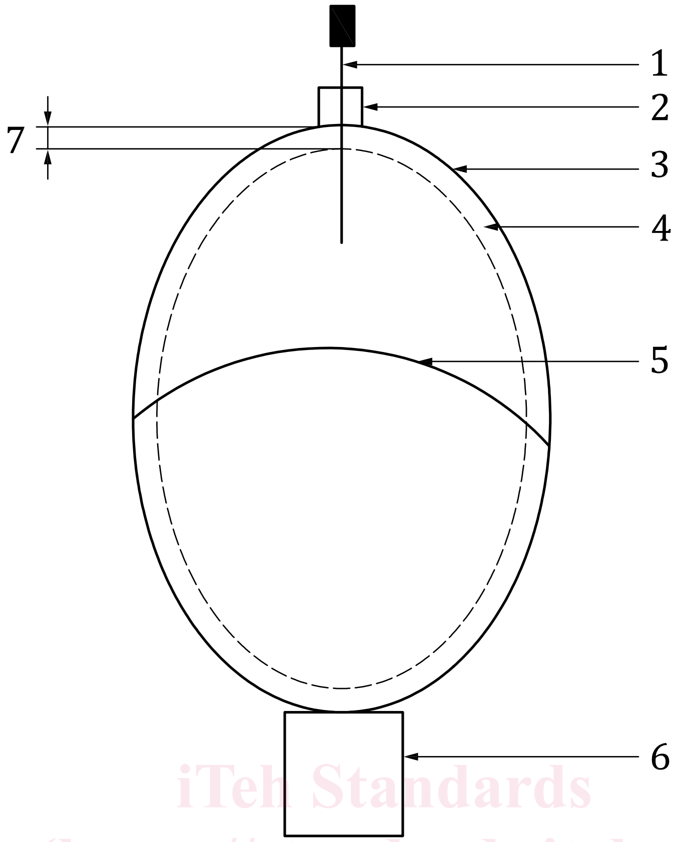
As a general rule, in order to obtain accurate results, it is advisable to use sensors and acquisition systems that allow a measurement accuracy of ±0,5 % of the measured value for pressures, and ±0,8 °C for temperatures.

To avoid distortion of the results, the temperature of the hydraulic fluid injected into the test accumulator shall be stable and measured. In most cases, the measurements will not be distorted if the hydraulic fluid temperature changes are less than 3 °C.

In order to calculate the mean discharge flow rate of the test accumulator (see example in Annexes A and B), the discharging time is measured based on the recorded hydraulic fluid pressure signal. This discharging time shall be determined accurately; for that purpose, a level of accuracy of ±1 % is advisable.

The thermal losses of the test accumulator are determined based on the gas pressure and temperature signals (see example in Annexes C and D). Rapid temperature changes due to gas compression and expansion require a temperature sensor with a short response time. It is advisable to use a gas temperature sensor with a minimum response time of 0,1 s. This response time is defined as the time taken by the sensor to provide 90 % of the final value following a change in the value to be measured.

Installing the gas temperature sensor inside the gas part of the test accumulator may have a significant impact on the gas temperature measurement. It is important to measure the gas temperature and that this measurement is not influenced by the position of the temperature sensor. In particular, this sensor shall be installed outside of the boundary layer of the test accumulator wall, which means, in most cases, at a minimum distance of 30 mm (see Figure 2). Indeed, in the boundary layer close to the internal accumulator wall, the gas temperature corresponds to an almost linear temperature gradient between the gas temperature in the middle of the gas part and the wall temperature of the accumulator. Positioning the gas temperature sensor in this boundary layer area is therefore not representative of the real gas temperature in most of the gas part of the accumulator.



Key

1 gas temperature sensor
2 gas port
3 gas-loaded accumulator wall
4 boundary layer
5 separator
6 hydraulic fluid port
7 minimum distance of 30 mm

NOTE This figure is not representative of a particular technology of gas-loaded accumulator but is applicable to any accumulator technology with separator.

Figure 2 — Boundary layer position

Similar to the calculation of the mean discharge flow rate, determining the thermal losses of the test accumulator during the charging or discharging phases requires a high measurement acquisition frequency in order to properly measure pressure and temperature variations during these dynamic phases. Data acquisition frequency shall be selected to capture all variations during the dynamic phase.

NOTE A minimum of 100 data acquisition points during the dynamic phase is considered to be sufficient.

However, such a high measurement acquisition frequency is not necessary to determine the thermal losses of the test accumulator during the constant-volume (isochoric) phases (storage of hydraulic fluid or absence of hydraulic fluid in the test accumulator).

To accurately determine the thermal losses of the test accumulator, the ambient temperature within the test room shall be stable and measured. In most cases, the measurements are not distorted if the ambient temperature changes are less than 3 °C.

When a gas-loaded bladder accumulator is tested, should an untimely closing of the anti-extrusion device occur, discharging will not be complete; as a result, a certain quantity of hydraulic fluid will remain entrapped and will change the initial gas volume (V_0) of the accumulator. Consequently, it is advisable to check between each test that the changes in the pre-charging pressure p_0 and the initial temperature T_0 are compatible with the initial volume of the accumulator V_0. For that purpose, Formula (1) is used:

$$10^6 . p . v = Z(p, T) . R . (273{,}15 + T) \qquad (1)$$

where Z is the coefficient which depends on p, T and the properties of the gas.

6 Information to be included in the test report

The test results shall be documented in a test report. Tables 2 and 3 give an overview of the elements which are requested as a minimum for thermal losses and for mean discharge flow rate, respectively. An example of test report is given in Annex F.

Table 2 — Minimum items to be included in determining thermal losses test report

Determining thermal losses			Unit
Product description			
Name of manufacturer			
Model number			
Serial number			
Month and year of manufacture			
Internal volume of gas chamber V			l
Maximum working pressure p_s			MPa
Allowable temperature range TS_{min} - TS_{max}			°C
Test conditions			
Test accumulator orientation			
Pre-charging pressure p_0			MPa
Gas pressure at the beginning of the test			MPa
Gas temperature at the beginning of the test			°C
Ambient temperature at the beginning of the test			°C
Hydraulic fluid temperature at the beginning of the test			°C
Hydraulic test fluid designation			
Test results			
Type of phase test		☐ Charging and isochoric storage ☐ Discharging and isochoric phase	
Gas pressure evolution during dynamic phase (charging or discharging between p_1 and p_2)		[Graph]	MPa
Duration of the dynamic phase (charging or discharging between p_1 and p_2) t			s
Gas pressure evolution during isochoric phase[a]	[Graph]		MPa
	Time constant for heat exchange		s
Gas temperature evolution during isochoric phase[a]	[Graph]		°C
	Time constant for heat exchange		s

[a] For the gas pressure evolution and the gas temperature evolution, the graph is only needed if a value is not given for the time constant for heat exchange. The time constant for heat exchange is determined from the formulae given in Annex D.