FINAL DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 5352-1

ISO/TC **131**

Secretariat: **ANSI**

Voting begins on:
2023-04-13

Voting terminates on:
2023-06-08

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

Reference number
ISO/FDIS 5352-1:2023(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

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.

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	$J·mol^{-1}·°C^{-1}$
Duration of the dynamic phase	t	s
Time constant for heat exchange	τ	s
NOTE All pressures are expressed in relative terms.		

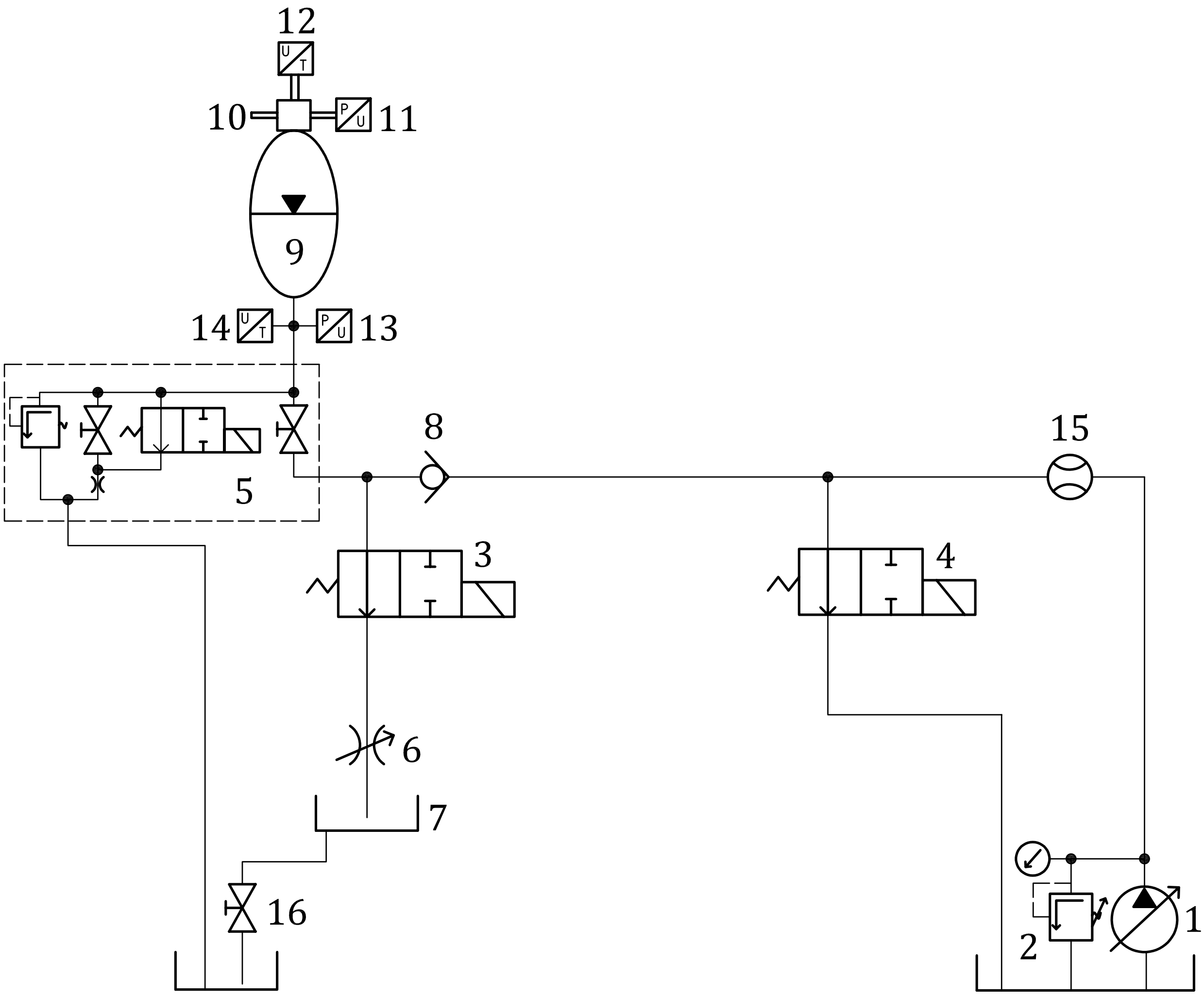
Table 1 *(continued)*

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

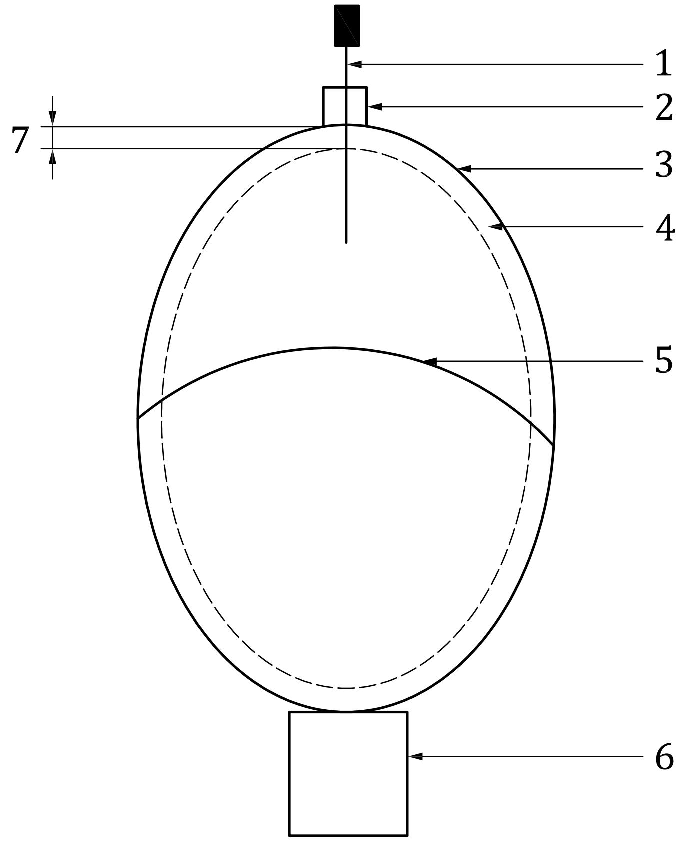
As a general rule, in order to obtain accurate results, it is advisable to use sensors and acquisition systems that allow a measurement accuracy of ±0,5 % of the measured value for pressures, and ±0,8 °C for temperatures.

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

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:

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

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 ☐ Draining 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.

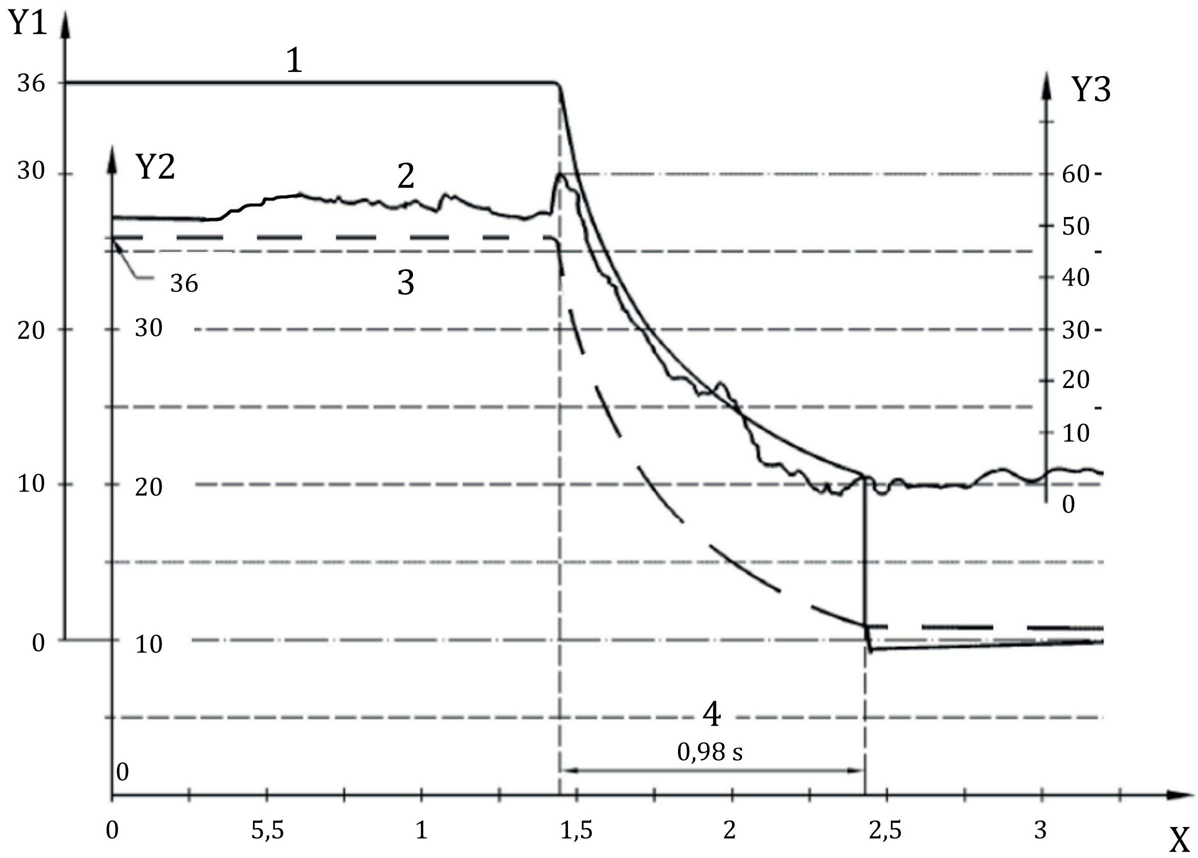
Table 3 — Minimum items to be included in determining mean discharge flow rate test report

Determining mean discharge flow rate			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			
Duration of the dynamic phase (discharging between p_1 and p_2) t			s
Measured hydraulic fluid volume after discharging V_m			l
Mean discharge flow rate q_m (calculated: $q_m = V_m . 60/t$)			l/min

Annex A
(informative)

Example of data recording to determine the mean flow rate of a gas-loaded bladder accumulator

Figure A.1 gives an example recording that allows the determination of the mean flow rate.



Key

X	time scale [s]	1	hydraulic fluid pressure
Y_1	hydraulic fluid pressure scale [MPa]	2	gas temperature
Y_2	gas pressure scale [MPa]	3	gas pressure
Y_3	temperature scale [°C]	4	discharging time

NOTE The curve temperature shapes depend on the technology of the accumulator.

Figure A.1 — Example recording

Annex B
(informative)

Example of analysis to determine the mean flow rate of a gas-loaded bladder accumulator

Table B.1 shows the data analysis of the recording given Figure A.1 in order to determine the mean flow rate.

Table B.1 — Parameters recorded and calculated for each measurement

Parameter	Symbol	Value	Unit	Observation
Initial pre-charging pressure	p_0	12,0	MPa	
Initial pre-charging temperature	T_0	24	°C	
Theoretical volume (manufacturer data)	V_0	12,0	l	
$Z_0 = Z(p_0,T_0)$	Z_0	1,010		Property of nitrogen according to the National Institute of Standards and Technology (NIST)
New p_0 before charging (depends on whether previous tests have been performed and whether gas temperature has changed)	p_{p0}	12,6	MPa	
Temperature corresponding to p_{p0}	T_{p0}	33	°C	
$Z_{p0} = Z(p_{p0},T_{p0})$	Z_{p0}	1,018		Property of nitrogen according to the National Institute of Standards and Technology (NIST)
New V_0 before charging	V_{p0}	11,87	l	$V_{p0} = p_0 . V_0 . Z_{p0} . (273{,}15+T_{p0}) / (Z_0 . p_{p0} . (273{,}15+T_0))$
Charging pressure	p_2	36,0	MPa	
Temperature just before discharging	T_2	60	°C	
$Z_2 = Z(p_2,T_2)$	Z_2	1,208		Property of nitrogen according to the National Institute of Standards and Technology (NIST)
Calculation of theoretical discharged hydraulic fluid volume	V_{th}	6,76	l	$V_{th} = V_0 - [p_0 . V_0 . Z_2 . (273{,}15+T_2) / (Z_0 . p_2 . (273{,}15+T_0))]$
New p_0 after discharging	p_{p0}'	13,0	MPa	
Temperature corresponding to p_{p0}'	T_{p0}'	32	°C	
$Z_{p0}' = Z(p_{p0}',T_{p0}')$	Z_{p0}'	1,024		Property of nitrogen according to the National Institute of Standards and Technology (NIST)
New V_0 after discharging	V_{p0}'	11,53	l	$V_{p0}' = p_{p0} . V_{p0} . Z_{p0}' . (273{,}15+T_{p0}') / (Z_{p0} . p_{p0}' . (273{,}15+T_{p0}))$
Calculation of the discharged hydraulic fluid volume	V_c	6,29	l	$V_c = V_{th} - (V_0 - V_{p0}')$
Measurement of discharged hydraulic fluid volume	V_m	6,10	l	
Discharging time	t	0,98	s	
Mean discharge flow rate	q_m	373,47	l/min	$q_m = V_m . 60 / t$

NOTE p_{p0}, T_{p0} and Z_{p0} correspond to an intermediate state between p_0 and p_2.

NOTE Based on Figure 1, if the accumulator 9 is in a vertical position, with its fluid port downwards, and is above the reservoir 7, the residual volume can be extracted and measured by depressurizing the gas side.

The different tests conducted show the following.

— In gas-loaded piston accumulators, there is no residual hydraulic fluid volume after complete discharging of the accumulator.

— In gas-loaded bladder accumulators, there is a “residual” volume to be taken into account. This hydraulic fluid volume remains trapped inside the accumulator after discharging, which means that discharging is not complete.

— The residual volume can be estimated to approximately 8 % of the actual V_0 of the accumulator, for vertically-mounted accumulators with the fluid port pointing downwards. This value is valid as long as discharging proceeds without untimely closing of the anti-extrusion device (poppet valve).

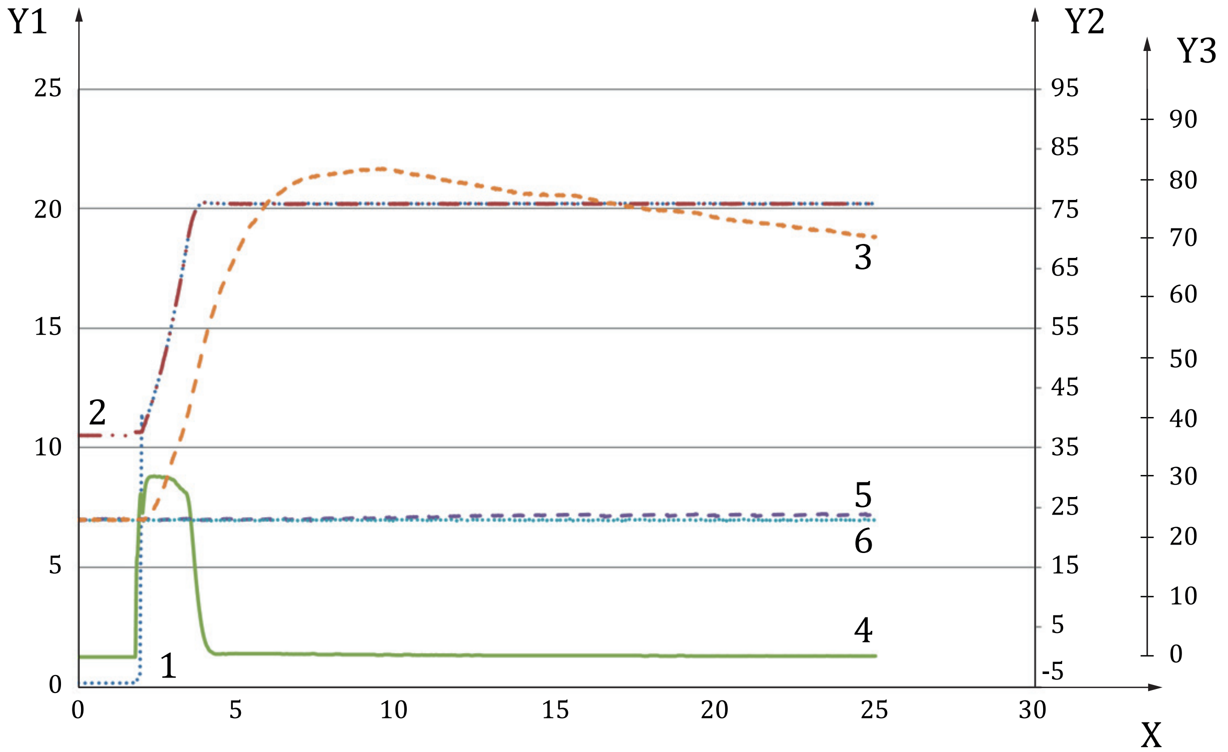
— If such untimely closing of the anti-extrusion device occurs, the value of the residual volume estimated to 8 % can even be higher.

— Diaphragm accumulators discharge all the fluid they contain, provided that the velocity of the fluid at the fluid port does not exceed 6 m/s (at higher velocities, a diaphragm accumulator can retain up to 15 % of its V_0 capacity, due to pressure drop in its connector Such conditions are not a normal use case and eventually lead to the destruction of the separator).

Annex C
(informative)

Example of data recording to determine the thermal losses of the test accumulator

When thermal losses of the test accumulator need to be determined during storage phase after charging, Figure C.1 presents all the necessary parameters to be recorded.

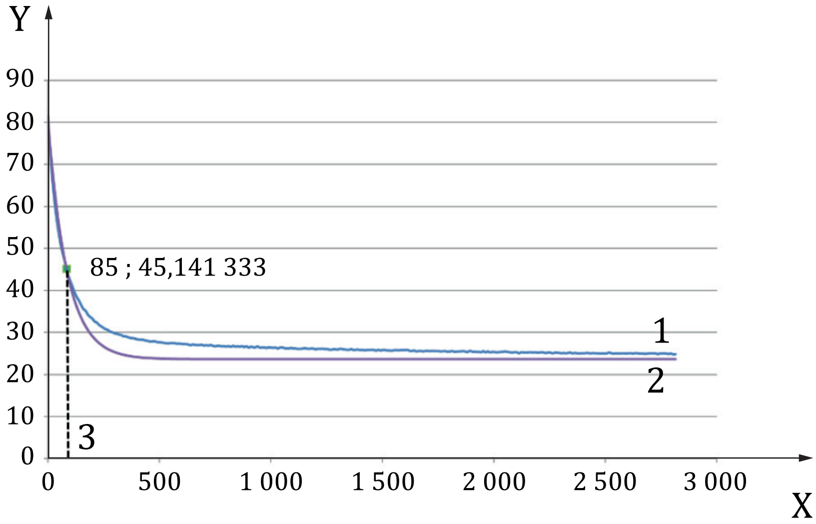


Key

X	time scale [s]	2	gas pressure
Y_1	gas pressure and hydraulic pressure scale [MPa]	3	gas temperature
Y_2	gas temperature, ambient temperature and hydraulic fluid temperature scales [°C]	4	hydraulic fluid flow rate
Y_3	hydraulic fluid flow rate scale [l/min]	5	hydraulic fluid temperature
1	hydraulic fluid pressure	6	ambient temperature

Figure C.1 — Example of accumulator charging

Figure C.2 and C.3 give recorded examples that allow the determination of the thermal losses of the test accumulator during a storage phase after charging, coming from gas temperature or gas pressure changes. Formulae are given in Annex D.



Key

X time scale [s]

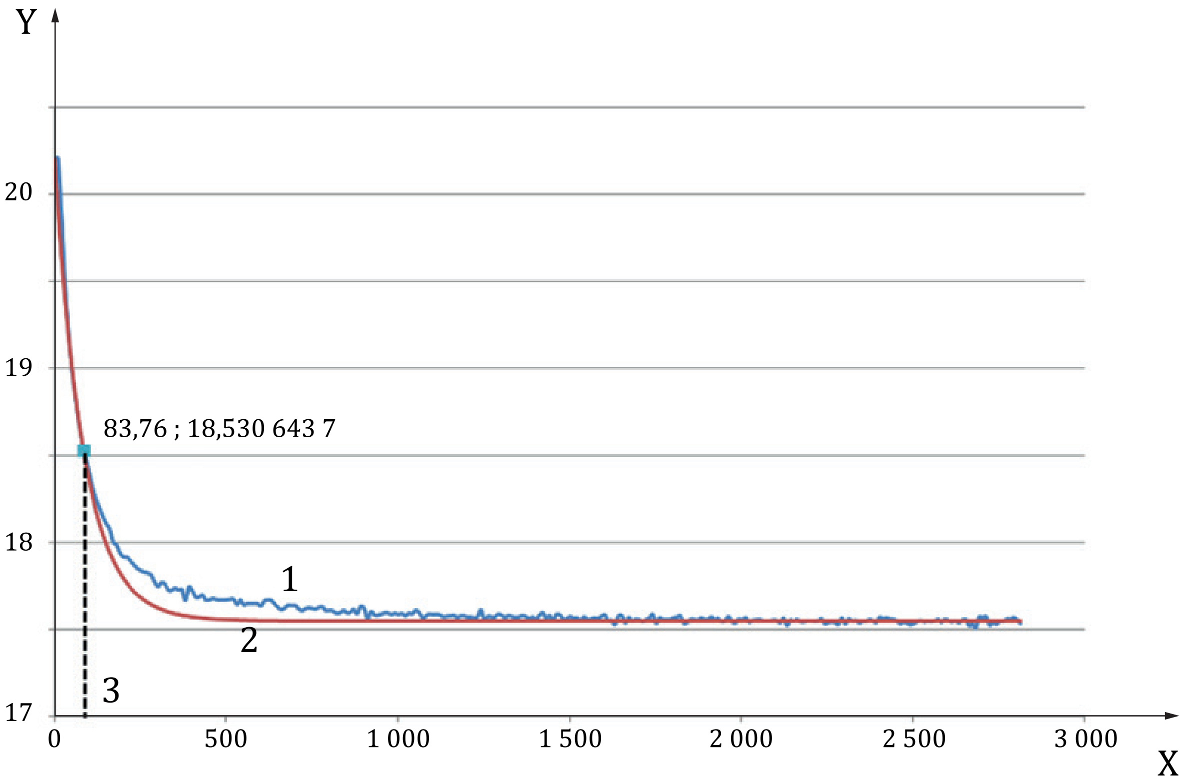
Y gas temperature scale [°C]

1 gas temperature

2 gas temperature evolution model

3 time constant for heat exchange τ_T defined using the gas temperature measurement [s]

Figure C.2 — Example of gas temperature evolution during isochoric storage after an accumulator charging (measured and model)



Key

X time scale [s]

Y gas pressure scale [MPa]

1 gas pressure

2 gas pressure evolution model

3 time constant for heat exchange τ_P defined using the gas pressure measurement [s]

Figure C.3 — Example of gas pressure evolution during isochoric storage after an accumulator charging (measured and model)

Annex D
(informative)

Example of analysis to determine the thermal losses of the test accumulator

Measuring the mean temperature in the gas-loaded accumulator is difficult because the gas temperature inside the accumulator is not homogeneous.

This Annex provides an example in which the heat transfer to the accumulator shell is not part of the calculation model

The gas temperature evolution model plotted on Figure C.2 is given by the Formula (D.1):

$$\frac{dT}{dt} = \frac{(T_{ext} - T)}{\tau} - \frac{1\,000.R_s.(273{,}15 + T)}{C_v\, V} \frac{dV}{dt} \tag{D.1}$$

with

$$\tau = \frac{m\, C_v}{h\, A}$$

where

- T_{ext} is the ambient temperature (°C);
- T is the gas temperature (°C);
- m is the gas mass (kg);
- R_s is the specific gas constant (J/kg/°C);
- C_v is the gas specific heat capacity (J/kg/°C);
- V is the gas volume (l);
- τ is the time constant for heat exchange (s);
- h is the coefficient of heat exchange with the exterior environment (W/m^2/°C);
- A is the heat exchange surface area (m^2), supposed to be constant;
- t is the time.

Given that the gas volume remains constant while the hydraulic fluid is stored inside the test accumulator, Formula (D.1) becomes:

$$T(t) = (T_i - T_{ext})e^{-\frac{t}{\tau}} + T_{ext} \tag{D.2}$$

where T_i is the gas temperature at the beginning of the isochoric storage (at $t = t_0$) (°C).

Similarly, the gas pressure evolution model plotted on Figure C.2 is as follows during the isochoric phases:

$$p(t)=(p_i-p_f)e^{-\frac{t}{\tau}}+p_f \quad \text{(D.3)}$$

where

p_i is the gas pressure at the beginning of the isochoric storage (at $t = t_0$);

p_f is the gas pressure after thermal equilibrium with the exterior environment is reached.

The time constant τ is determined using Formulae (D.4) and (D.5):

$$T(t_0+\tau_T)=T_i-[(T_i-T_{ext}).0,63] \quad \text{(D.4)}$$

$$p(t_0+\tau_p)=p_i-[(p_i-p_f).0,63] \quad \text{(D.5)}$$

Table D.1 shows the data analysis of the recording either for the gas pressure measurement or the gas temperature measurement.

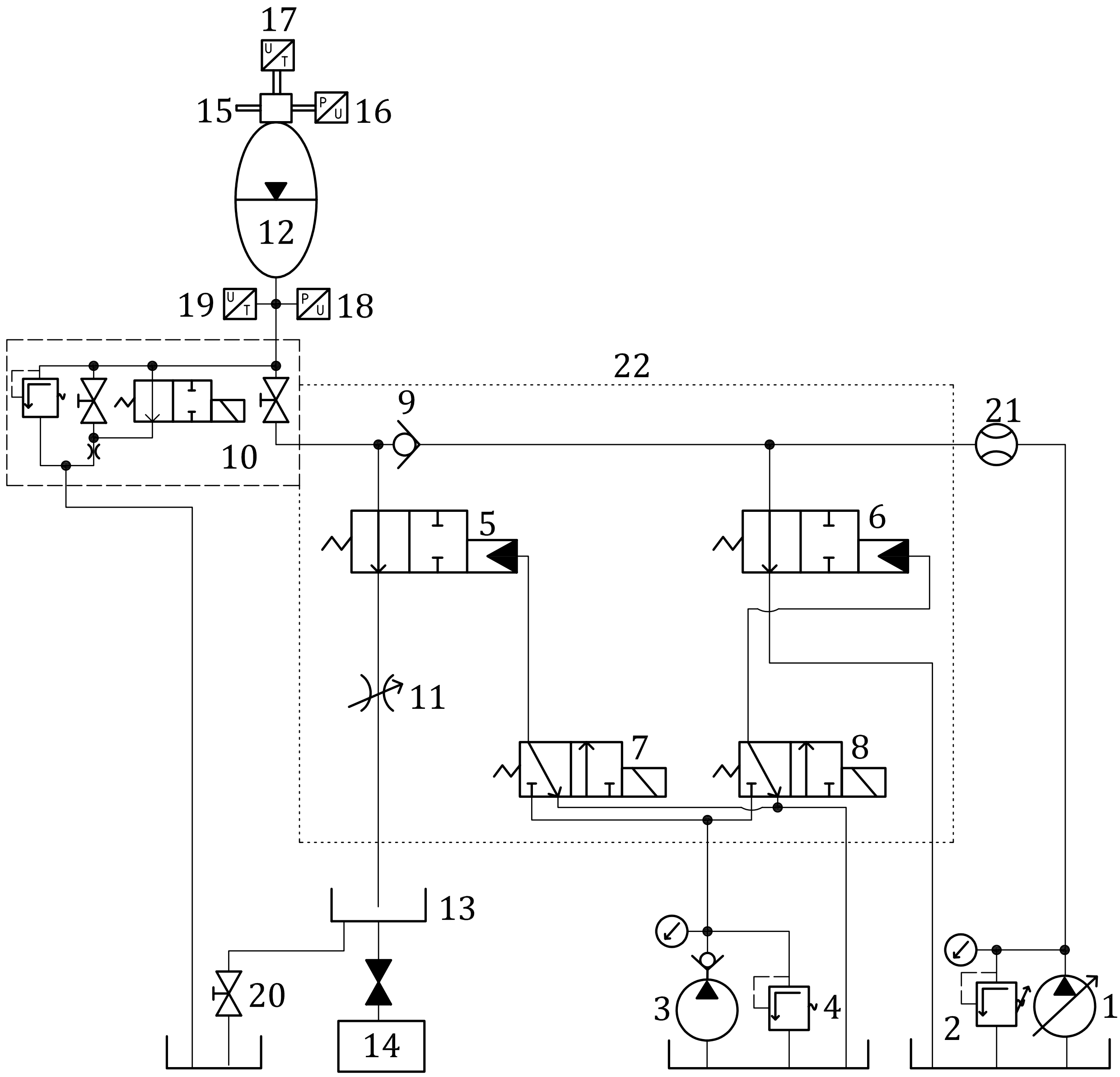
Table D.1 — Parameters recorded and calculated for each measurement

Parameter	Symbol	Value	Unit
Gas temperature at the beginning of the isochoric storage	T_i	81,72	°C
Minimum ambient temperature of the test room during isochoric storage	T_{ext_min}	22,73	°C
Maximum ambient temperature of the test room during isochoric storage	T_{ext_max}	23,90	°C
Mean ambient temperature of the test room during isochoric storage	T_{ext_mean}	23,13	°C
Time constant for heat exchange defined using the gas temperature measurement during isochoric storage	τ_T	85,00	s
Gas pressure at the beginning of the isochoric storage	p_i	20,202	MPa
Gas pressure at the end of the isochoric storage (minimum on the last 100 points)	p_{f_min}	17,525	MPa
Gas pressure at the end of the isochoric storage (maximum on the last 100 points)	p_{f_max}	17,576	MPa
Gas pressure at the end of the isochoric storage (mean on the last 100 points)	p_{f_mean}	17,549	MPa
Time constant for heat exchange defined using the gas pressure measurement during isochoric storage	τ_p	83,76	s

Annex E
(informative)

Example of test bench used for test accumulators whose volume *V* is between 1 l and 20 l

Figure E.1 provides an example of test bench used for test accumulator whose volume V is between 1 l and 20 l.



Key

1	fluid power supply	13	reservoir
2	pressure relief valve	14	weighing system
3	hydraulic pilot unit	15	gas filling system
4	pilot pressure relief valve	16	gas pressure sensor
5	valve with hydraulic pilot	17	gas temperature sensor
6	valve with hydraulic pilot	18	hydraulic fluid pressure sensor
7	solenoid valve	19	hydraulic fluid temperature sensor
8	solenoid valve	20	drain valve
9	check valve	21	flowmeter
10	distribution and mounting block	22	control block
11	adjustable flow-control valve		
12	test accumulator		

Figure E.1 — Example of hydraulic schematic diagram of an accumulator test bench

Components (5), (6), (7), (8), (9) and (11) are mounted on a control block (22) in order to reduce dead volumes and pressures losses of the distribution. Cartridge valve technology is used for components (5) and (6).

With this hydraulic circuit as designed, using the components (3), (4), (5), (6), (7) and (8), it is possible to obtain short response times to charge or discharge the test accumulator. Even with valves (5) and (6) sized for a maximum flowrate of 900 l/min, short response times are obtained by using hydraulic pilot valves (5) and (6). Given the volume of the test accumulators, response times of approximately 0,05 s were ensured by this test bench.

The whole distribution system and the piping are sized in order to perform charging and discharging operations with minimum pressure losses. For the maximum considered instantaneous flowrate (900 l/min), pressure losses of the valves (5) and (6) are approximately 0,25 MPa and pressures losses of the pipes are approximately 0,2 MPa (which corresponds to a pipe internal diameter of 50 mm).

Annex F
(informative)

Example of test report

Table F.1 is an example of test report showing requested items as a minimum with optional elements.

Table F.1 — Example of test report

Product description				Unit
Name of manufacturer				
Address of manufacturer[a]				
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 test		**Determining thermal losses**	**Determining mean discharge flow rate**	
Type of phase test		☐ Charging and isochoric storage ☐ Draining 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
Measured hydraulic fluid volume after discharging V_m				l
Mean discharge flow rate q_m (calculated: $q_m = V_m . 60/_t$)				l/min

[a] Optional element.

[b] 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.

Table F.1 *(continued)*

Product description				Unit
Gas pressure evolution during isochoric phase[b]	Graph	[Graph]	[redacted]	MPa
	Time constant for heat exchange		[redacted]	s
Gas temperature evolution during isochoric phase[b]	Graph	[Graph]	[redacted]	°C
	Time constant for heat exchange		[redacted]	s
Approving				
Signature[a]				
Name[a]				
Position[a]				
Date[a]				
Company stamp[a]				

[a] Optional element.

[b] 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.

ICS 23.100.01
Price based on 21 pages