

Methods for determining the performance of pumps and motors for hydraulic fluid power transmission

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Contents

	Page
Cooperating organizations	Inside front cover
Foreword	ii
0 Introduction	1
1 Scope	1
2 Definitions	1
3 Symbols and units	2
4 Test installations	3
5 Test procedures	4
6 Test report	6
Appendix A Energy balance in a hydraulic unit	15
Appendix B Use of practical units	18
Appendix C Errors and classes of measurement	19
Appendix D Pretest check list	20
Figure 1 — Test circuit for pump unit (open circuit)	8
Figure 2 — Test circuit for pump unit (closed circuit)	9
Figure 3 — Test circuit for motor unit	10
Figure 4 — Pump performance against outlet pressure	11
Figure 5 — Pump performance against rotational frequency	12
Figure 6 — Motor performance against rotational frequency	13
Figure 7 — Integral transmission performance	14
Table 1 — Symbols and units	3
Table 2 — Subscripts	3
Table 3 — Permissible variation in indicated fluid temperature	4
Table 4 — Limits of permissible variation of mean indicated values of controlled parameters	6
Table 5 — Practical units	18
Table 6 — Permissible systematic errors of measuring instruments as determined during calibration	20
Publications referred to	Inside back cover

Foreword

This revised British Standard, prepared under the direction of the Mechanical Engineering Standards Committee, deals with the testing of hydraulic pumps and hydraulic motors for fluid power transmission, and supersedes BS 4617:1970, which is withdrawn. It also corresponds to the methods in the latest proposals (ISO/DIS 4409¹⁾) under consideration by Technical Committee ISO/TC 131 of the International Organization for Standardization (ISO).

Three classes of accuracy, A, B and C, are associated with these methods and are related as detailed in Appendix C. The class of accuracy should be agreed between manufacturer and user. It is expected that the methods of measurement used for testing the majority of units will be those included in class C. The methods of measurement in class B may be employed where a higher degree of accuracy is required. Class A methods of measurement will necessitate laboratory conditions, and may be employed exceptionally on tests where the attainment of high accuracy is held to justify the greatly increased time and cost expended.

It is hoped that the standard will unify testing methods and enable the performance of different units to be compared.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people, for whom it has been prepared.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 20, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ In course of preparation.

0 Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. Pumps are components that convert rotary mechanical power into hydraulic fluid power. Motors are components that convert hydraulic fluid power into rotary mechanical power.

Integral transmissions (e.g. hydraulic drive units) are a combination of one or more hydraulic pumps and motors and appropriate controls, forming a component.

With very few exceptions, all hydraulic fluid power pumps and motors are of the positive displacement type, i.e. they have internal sealing means making them capable of maintaining a relatively constant ratio between rotational speed and fluid flow over wide pressure ranges. They generally utilize gears, vanes, or pistons. Non-positive displacement components, such as centrifugal or turbine types, are seldom associated with hydraulic fluid power systems.

Pumps and motors are available either as “fixed” or “variable” displacement types. Fixed displacement units have pre-selected internal geometries that maintain a relatively constant volume of liquid passing through the component per revolution of the component’s shaft. Variable displacement components have means for changing the internal geometries so that the volume of liquid passing through the component per revolution of the component’s shaft can be changed.

1 Scope

This British Standard describes methods for determining the performance and efficiency of hydraulic fluid power positive displacement pumps, motors and integral transmissions. It applies to components having continuously rotating shafts.

The standard specifies requirements for test installations, test procedures (under steady state conditions) and the presentation of test results. It does not establish how closely production unit performance complies with specification requirements, nor which performance characteristics should be checked during a production test.

Appendix A provides a simple analysis of the energy balance in a hydraulic unit, and guidance in the use of practical units for the presentation of results is given in Appendix B.

Accuracy of measurement is divided into three classes, A, B, and C, which are explained in Appendix C, and Appendix D provides a pretest checklist of those items where agreement is necessary between the parties concerned.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this standard, the following definitions, together with those given in BS 5775 for quantities and units, apply.

2.1 Efficiency

2.1.1

pump overall efficiency (η_t)

the ratio of the power transferred to the liquid at its passage through the pump, to the mechanical input power, i.e.

$$\eta_t = \frac{p_{2e}Q_{2e} - p_{1e}Q_{1e}}{2\pi nT}$$

2.1.2

motor overall efficiency (η_t)

the ratio of the mechanical output power to the power transferred from the liquid at its passage through the motor, i.e.

$$\eta_t = \frac{2\pi nT}{p_{1e}Q_{1e} - p_{2e}Q_{2e}}$$

2.1.3

integral transmission overall efficiency (η_t)

the ratio of the output mechanical power to the input mechanical power, i.e.

$$\eta_t = \frac{n_2 T_2}{n_1 T_1}$$

2.2 Flow

2.2.1

flow (Q)

the measured flow volume per unit of time

2.2.2

drainage flow (Q_d)

the volume rate of flow from the casing of a component

2.2.3 effective outlet flow of a pump (Q_{2e})

the outlet volume rate of flow of a pump relating to the temperature θ_{2e} and pressure p_{2e} at the outlet of the pump. Where the flow is measured downstream of the pump at temperature θ and pressure p , that flow is corrected as follows to give the effective outlet value:

$$Q_{2e} = Q \left\{ 1 - \left(\frac{p_{2e} - p}{B_T} \right) + \gamma (\theta_{2e} - \theta) \right\}$$

2.2.4 effective inlet flow of a motor (Q_{1e})

the inlet volume rate of flow of a motor relating to the temperature θ_{1e} and pressure p_{1e} at the inlet to the motor. Where the flow is measured downstream of the motor outlet at temperature θ and pressure p , that flow is corrected as follows to give the effective inlet value:

$$Q_{1e} = Q \left\{ 1 - \left(\frac{p_{1e} - p}{B_T} \right) + \gamma (\theta_{1e} - \theta) \right\}$$

Where the motor has an external drainage, the drainage flow Q_d is corrected to refer to the inlet condition used in the computation of Q_{1e} , i.e.

$$Q_{1e} = Q \left\{ 1 - \left(\frac{p_{1e} - p}{B_T} \right) + \gamma (\theta_{1e} - \theta) \right\} + Q_d \left\{ 1 - \left(\frac{p_{1e} - p_d}{B_T} \right) + \gamma (\theta_{1e} - \theta_d) \right\}$$

2.3 Power

2.3.1 mechanical power (P_m)

the product of the torque and rotational frequency at a shaft of a pump or motor, i.e.

$$P_m = 2\pi nT$$

2.3.2 hydraulic power (P_h)

the product of the pressure and flow at any point, i.e.

$$P_h = pQ$$

2.3.3 effective outlet hydraulic power of a pump (P_{2h})

the total outlet hydraulic power of a pump, i.e.

$$P_{2h} = p_{2e}Q_{2e}$$

2.3.4 effective inlet hydraulic power of a motor (P_{1h})

the total inlet hydraulic power of a motor, i.e.

$$P_{1h} = p_{1e}Q_{1e}$$

NOTE to 2.3.3 and 2.3.4. The total energy of a hydraulic fluid is the sum of the various energies contained in the fluid. In 2.3.3 and 2.3.4, the kinetic, positional and strain energies of the fluid are neglected and the power is calculated using the static pressure only. Where these other energies have a significant effect on the test results, take due account of them. (See Appendix A.)

2.4 Pressure

2.4.1 effective pressure (p_e)

the fluid pressure, relative to atmospheric pressure, having a value

- positive, if the fluid pressure is greater than atmospheric pressure; or
- negative, if the fluid pressure is less than atmospheric pressure.

2.4.2 drainage pressure (p_d)

the pressure, relative to atmospheric pressure, measured at the outlet of a drainage connection on a component casing

2.5 rotational frequency (n)

the number of rotations per unit time, the direction of rotation (clockwise or counter-clockwise) being specified (by diagram, if necessary) by reference to the view looking at the shaft end

2.6 torque (T)

the measured value of the turning moment in the shaft of the component

3 Symbols and units

The symbols and units used in this standard are as given in Table 1. The letters and figures used as subscripts to the symbols in Table 1 are given in Table 2.

Table 1 — Symbols and units

Quantity	Symbol	Dimension ^a	Unit ^b
bulk modulus (secant isothermal)	B_T	$ML^{-1}T^{-2}$	Pa ^c
coefficient of thermal expansion (cubic)	γ	Θ^{-1}	K ⁻¹
efficiency	η	dimensionless	—
flow	Q^d	L^3T^{-1}	m ³ /s
inside diameter of pipe	d	L	m
kinematic viscosity	ν	L^2T^{-1}	m ² /s
mass density	ρ	ML^{-3}	kg/m ³
power	P	ML^2T^{-3}	W
pressure	p	$ML^{-1}T^{-2}$	Pa
rotational frequency	n	T^{-1}	r/s
temperature	θ	Θ	K or °C
torque	T	ML^2T^{-2}	N m
<i>The following additional symbols are used in Appendix A only</i>			
bulk modulus (secant isentropic)	B_s	$ML^{-1}T^{-2}$	Pa
bulk modulus (tangent isentropic)	K_s	$ML^{-1}T^{-2}$	Pa
bulk modulus (tangent isothermal)	K_T	$ML^{-1}T^{-2}$	Pa
energy	E	ML^2T^{-2}	kg m ² /s ²
fluid velocity	v	LT^{-1}	m/s
height	h	L	m
local acceleration due to gravity	g_n	LT^{-2}	m/s ²
volume	V	L^3	m ³
NOTE Symbols prefixed by Δ indicate the difference between two values of the quantity to which the symbol applies.			
^a M denotes mass, L denotes length, T denotes time, Θ denotes temperature.			
^b The practical units that may be used for the presentation of results are described in Appendix B.			
^c 1 Pa = 1 N/m ² .			
^d A less preferred symbol for flow is q_v .			

Table 2 — Subscripts

Subscript	Meaning
1	inlet
2	outlet
d	drainage
e	effective (measured)
h	hydraulic
m	mechanical
t	total
<i>The following additional subscripts are used in Appendix A only</i>	
O	atmospheric
k	kinetic
p	potential
S	strain

4 Test installations

NOTE 1 Figure 1, Figure 2, and Figure 3 are basic circuits that do not incorporate all the safety devices necessary to protect against damage in the event of any component failure. It is important that those responsible for conducting the test give consideration to safeguarding personnel and equipment.

NOTE 2 The graphical symbols used in Figure 1, Figure 2 and Figure 3 are in accordance with BS 2917.

4.1 Pump test circuit

4.1.1 Use an open test circuit similar to that shown in Figure 1. Where a pressurized inlet condition is required, provide a suitable means to maintain the inlet pressure within the specified limits (see 5.2.1).

4.1.2 Where a closed test circuit alternative to Figure 1 is desired, use a test circuit similar to that shown in Figure 2. In this circuit the boost pump provides a flow slightly in excess of the total circuit losses; a greater flow may be provided for cooling purposes.

4.2 Motor test circuit. Use a test circuit employing a controlled fluid supply similar to that shown in Figure 3.

4.3 General requirements

4.3.1 Design the installation to prevent air entrainment and take precautions to remove all free air from the system before testing.

4.3.2 Install and operate the component in the test circuit in accordance with the manufacturer's operating instructions.

4.3.3 Conduct the tests in still air and record the ambient temperature. Record any variation from still air conditions.

4.4 Filtration

4.4.1 Install a filter that provides a standard of filtration approved by the pump or motor manufacturer.

4.4.2 Record the position, number and specific description of each filter used in the test circuit.

4.5 Positioning of pressure and temperature tapping points

4.5.1 Where pressure measurements are made within a pipe, position the pressure tapping point not less than two and not more than four times the internal pipe diameter from the component port face.

NOTE Greater distances may be used provided consideration is given to the effect of pipe losses.

4.5.2 Where temperature measurements are made within a pipe, position the temperature tapping point between two and four times the internal pipe diameter from the pressure tapping point and further distant from the component.

5 Test procedures

5.1 General procedures

5.1.1 Pretest condition. Before the tests are carried out, "run in" the component in accordance with the manufacturer's recommendations.

5.1.2 Test fluids

5.1.2.1 Since the performance of a component may vary considerably with the viscosity of the fluid, use and record a stated fluid approved by the manufacturer of the component when conducting the tests.

5.1.2.2 Record the kinematic viscosity ν and the mass density of the fluid ρ for the controlled temperature used during the test.

5.1.2.3 Record the values for the isothermal secant bulk modulus B_T and for the coefficient of cubic thermal expansion γ .

5.1.3 Temperatures

5.1.3.1 Controlled temperature. Carry out the tests at a stated fluid temperature measured at the inlet to a pump or motor within the range recommended by the component manufacturer, the indicated temperature being controlled within the limits given in Table 3.

5.1.3.2 Other temperatures. Record the following temperature measurements:

- at the outlet of a pump or motor;
- at the point of measurement of flow;
- drainage fluid temperature (if applicable);
- ambient temperature.

NOTE For an integral transmission, it may not be possible to measure some of the above. Note this on the test report.

Table 3 — Permissible variation in indicated fluid temperature

Class of measurement (see Appendix C)	Maximum variation in temperature indication
	K
A	± 1.0
B	± 2.0
C	± 4.0

5.1.4 Atmospheric pressure. When it is significant to the test, record the absolute ambient atmospheric pressure during the tests.

5.1.5 Casing pressure. Where the fluid pressure within the casing of a component may affect its performance, record its value during the tests.

5.1.6 Steady state conditions

5.1.6.1 When steady state test conditions are reached for a specific test condition, take only one set of readings of individual quantities over concurrent equal time periods. Record each reading as the mean value of each quantity being measured.

5.1.6.2 Record each set of readings when the values of controlled parameters are within the tolerances given in Table 4.

5.1.7 Test measurements. Select the number of sets of readings to be taken and their disposition over the range in order to give a representative indication of the performance of the component over the full range of the quantity being varied.

5.2 Pump tests

5.2.1 Inlet pressure

5.2.1.1 During each test, maintain the inlet pressure constant (see Table 4) at a stated value within the permissible range of inlet pressures specified by the manufacturer.

5.2.1.2 Carry out the tests at different inlet pressures, if required.