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GERMAN PROPOSAL
FOR AN
ISO STANDARD
POSITIVE DISPLACEMENT PUMPS
CODE FOR ACCEPTANCE TESTS

Specifications
Acceptance Test on Positive Displacement Pumps
General Testing Rules

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1. General rules

1.1 Scope

These rules apply to positive displacement pumps of the following designs:

Reciprocating positive displacement pumps with piston, plunger, bellows, diaphragm, hose, or similar elements serving as the reciprocating displacers,

Rotary positive displacement pumps with lobe, vane, screw, helical rotor, gear, or similar elements serving as the rotary displacers.

1.2 Objective

These rules determine bases of general validity for the preparation and performance of acceptance tests. They include further information on the conditions under which acceptance tests shall be performed.

The rules permit unambiguous and clear agreements between pump manufacturer and purchaser. Consequently, the rules should be acknowledged as binding by the parties to the contract. Deviations and supplements shall be subject to special agreement.

1.3 Purpose of acceptance tests

The purpose of the acceptance tests is to prove the values and data specified by the manufacturer, and the satisfactory operation of the pump.

The values and data specified by the manufacturer for the agreed operating point which is generally determined by pump head, speed, and inlet area pressure, are as follows:

a) Pump discharge
b) Power requirement of the pump and pumping plant, resp.

For pumps up to 2 kW power requirement and for all simplex and duplex reciprocating pumps, specification of the power requirement shall be subject to special agreement.

1.4 Supply contract

All agreements on the acceptance test must be made already when the pump is ordered, and laid down in the supply contract.

2. Terms, symbols, units

The terms, symbols, and units in Table 1 coincide with DIN 24 260, with the exception of those marked with a cross (+) or an asterisk (*).

Those of the legal units which form a coherent system rank in the first place. When they are used, no conversion factors are needed. Some commonly used, non-coherent units added in brackets require the use of conversion factors.

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Table 1

Terms	Symbols	Legal units (coherent)	Other units (preferred)
Volume discharge of pump	Q	m^3/s (l/s, cm^3/s)	m^3/hr, l/min., l/hr
Weight discharge of pump	G	-	kp/hr
Mass discharge of pump	m	kg/s (kg/hr)	-
* Leakage flow (The volume of liquid escaping in a unit of time from the liquid contact space to ambient through leaks at, for example, piston seals, piston rod seals, and shaft seals)	Q_L	m^3/s (cm^3/s)	cm^3/hr
Pump head	H	m	m
Pressure in outlet area (discharge port)	p_d	N/m^2 (bar)	kp/cm^2
+ Pressure in the pumping chamber of reciprocating positive displacement pumps (between suction and discharge valves)	p_A	N/m^2 (bar)	kp/cm^2
Vapour pressure	p_D	N/m^2 (bar)	kp/cm^2
Barometric pressure at pump location	p_b	N/m^2 (mbar)	kp/cm^2, Torr
+ Test pressure (Pressure to which the pressure space of the pump is subjected during the static pressure test)	p_p	N/m^2 (bar)	kp/cm^2
Net positive suction head of pump[1]	H_H	m	m
Temperature	T	K (°C)	°C
Mean velocity in the pump inlet area	v_s	m/s	m/s
Mean velocity in the pump outlet area	v_d	m/s	m/s
Delivered power	P_Q	W (kW)	kW
Power requirement of pump	P	W (kW)	kW
+ Driving motor power input (The power absorbed by the driving motor at the motor terminals)	P_M	W (kW)	kW

Pump efficiency	η	-	-
Efficiency of motor pump unit	η_{Gr}	-	-
Speed	n	1/s (1/min)	1/min
Elevation of pump inlet area	z_s	m	m
Elevation of pump outlet area	z_d	m	m

+ not included in DIN 24 260

* deviating from DIN 24 260

1) When referred to the pump centre-line, the net positive suction head of the pump corresponds to $NPSH_{req}$ as used in the USA. In previous literature, the static portion $\frac{p_s + p_b - p_D}{\varrho \cdot g}$ of the net positive suction head is frequently designated "net positive suction head". If continued at all to be used it should be calle "static net positive suction head".

3. Test conditions

3.1 Location and date of acceptance test

The acceptance test is performed in the pump manufacturer's works. The date of the test will be advised in due time to the purchaser or the purchaser's delegate.

3.2 Direction of acceptance test

The pump manufacturer appoints the chief of tests responsible for the entire test procedure.

3.3 Duration of acceptance test

The duration of the acceptance test must be chosen to allow all necessary measurements to be performed.

The readings are taken simultaneously after the steady-state condition is reached.

3.4 Test fluid

The test fluid is determined by the pump manufacturer. Water or mineral oils are preferred (for example, lubricating oil acc. to DIN 51 501 or hydraulic fluid HL68 acc. to VDMA 24 318).

3.5 Permissible deviations from the agreed operating point during the acceptance test

During the test, deviations from the agreed operating point can be accepted, subject to special agreement.

3.6 Test classes

The test class is to be chosen for the acceptance test in accordance with Table 2, thus defining the scope of the test.

Test Class I is to be preferred for pumps with up to 2 kW power requirement and for simplex and duplex reciprocating pumps.

Table 2. Test classes

Class	Quantities determined
I	Q, H
II	Q, H, P
III	Q, H, P, H_H

3.7 Test pressure

The test pressure is to be chosen acc. to Table 3 with due reference to the operating pressure.

Table 3. Test pressure

Operating pressure p_d bar	Test pressure p_p bar
≤ 160	$1.5\ p_d$
$> 160 \leq 400$	$1.3\ p_d$
> 400	p_p specified by pump manufacturer

3.8 Classes of measurement

Depending on the accuracy required, the tests are divided into two classes, 1 and 2, cf. Table 4.

Class 2 should be applied generally to all pumps. Class 1 may be chosen for pumps with driving motor output exceeding 100 kW for which, however, special agreement between the parties concerned is necessary.

Table 4. Classes of measurement

Quantity		Permissible measuring error Class 1 %	Class 2 %
p_d	fp_d	± 2	± 4
p_s	fp_s	± 2	± 4
p_A	fp_A	± 3.0	± 3
p_b	fp_b	± 1.0	± 1.5
Q	fQ	± 1.5	± 2.5
Q_L	fQ_L	± 10	± 10
P	fP	± 3	± 5
n	fn	± 1.0	± 2
P_M	fP_M	± 2	± 4
H_H	fH_H	± 25	± 25

3.9 Permissible inherent tolerances

The tolerances shown in Table 5 are acceptable as regards pump discharge and power requirement. The tolerence group must be laid down in the supply contract.

If no group is laid down, Tolerance Group II will be applicable. This group is foreseen for rotary displacement pumps in particular.

Table 5. Permissible inherent tolerances

Pump discharge Q l/hr	Permissible tolerance b_Q Group II %	Permissible tolerance b_Q Group I %
≤ 100	+ 20 − 10	± 10
> 100 ≤ 1000	± 10	± 5
> 1000	+ 10 − 5	± 5

Power requirement P kW	Permissible tolerance b_Q Group II %	Permissible tolerance b_Q Group I %
≤ 5	+ 25	
> 5 ≤ 10	+ 20	+ 15
> 10 ≤ 50	+ 15	+ 10
> 50	+ 10	+ 5

4. Measuring methods and instruments

4.1 Volume discharge, weight discharge, and mass discharge of pump

Measurements of the pump discharge by volume, weight, and mass may be performed either on the suction or on the discharge side. Volumetric vessels checked by the pump manufacturer are used for pump discharge measurements, providing for variations in liquid level of at least 200 mm and measuring cycles of at least 20 s.

For measuring pump discharge by mass and weight, resp., balances checked by the pump manufacturer are to be used providing for weight variation and measuring cycle to correspond with the measuring accuracy required. The measuring cycle should have a duration of at least 20 s.

Volumetric liquid meters operating on the displacement or other principles are acceptable provided they meet the accuracy requirements.

4.2 Leakage flow

The leakage losses are measured only in case of special agreement, basically as described in 4.1.

4.3 Pressures in the inlet and outlet areas (suction and discharge ports)

4.3.1 Choice of measuring point

The measuring point should be located preferably at pipe or vessel walls, vertically to the direction of flow. The measuring point should be designed and provided with the care required by the disturbance to be expected.

Any difference in level between measuring point (h_M) and measuring instruments (h_G) is to be corrected (ϱ_u density, γ_u specific gravity of the transmission fluid). The pressure correction Δ_p is

$$\Delta p = (h_M - h_G) \cdot \varrho_u \cdot g \quad \text{or} \quad \Delta p = (h_M - h_G) \cdot \gamma_u \qquad \text{Equation (1)}$$

4.3.2 Measuring instruments

The precision class of the various instruments should be in accordance with the accuracy required. Shop-tested spring pressure gauges of Precision Class 0.6 should be preferred while liquid pressure gauges are acceptable for low pressures. Suitable throttling elements (needle valves, capillary tubes) may be used or liquid-filled pressure meters applied for damping the pointer deflection which, however, must remain observable. When testing reciprocating positive displacement pumps it is recommended to provide for pulsation dampening down to a residual pressure pulsation of max. 15 % of the pump discharge pressure.

When testing simplex and duplex reciprocating pumps acc. to Test Class I operating at a speed of less than 200 strokes/min., the pointer may move acc. to the stroke by 60 % of the discharge pressure considering the widest pointer deflection as the highest discharge pressure.

4.4 Barometric pressure p_b

Mercury barometers should be preferred for measuring the barometric pressure.

4.5 Pressure in the pumping chamber

For measuring the pressure in the pumping chamber, suitable mechanical or electrical indicators are acceptable.

4.6 Net positive suction head ~~h_H~~ NPSH of the pump

The net positive suction head is determined for beginning cavitation which is agreed upon with reference to the following externally observable effects:

a) Reduction in pump discharge Q by at least 2 %, with the other conditions unchanged.

b) Pressure variation in the pump outlet area (p_d) by at least 4 % (throttling element on the pump discharge side), due to a reduction in pump discharge.

c) Noise

d) Reduction in power input by at least 2 %.

In the operation of reciprocating positive displacement pumps cavitation can be recognized conveniently from the pressure variation in the pumping chamber p_A, depending on piston travel (indicator diagram).

Due to the pulsation-induced varying pressure p_s (influence of the suction-side pipework) in the operation of reciprocating positive displacement pumps, it is difficult to determine for them the net positive suction head. Consequently, either the pressure p_s must be maintained constant for a period of time by adequate pulsation dampening or the variation of p_s with time must be allowed for by using a suitable measuring method.

A suitably designed pulsation dampener allows normally the pressure p_s to be measured in the damping space. ~~when for determining H_H acc. to DIN 24 260, v_s is taken as 0~~

Differences in level between pump inlet area and measuring point in the damping space must be allowed for.

For pumps with predominantly uniform discharge, the pressure in the pump inlet area p_s is determined as described in 4.3. For net positive suction head determination, accurate temperature measurement is of prime importance.

4.7 Temperature

4.7.1 Measuring point

The measuring point should be in a location providing for lowest disturbance in the temperature field. Consequently, optimum heat transfer and minimum heat dissipation are essential.

a) For temperature measurements in pipes and tubes, the thermometer should be mounted under a 45^{o} angle or in a bend, against the direction of flow.

b) Thermometer wells with minimum heat dissipation are recommended for pressure piping and pressure vessels. The heat transfer between meter and thermometer well can be improved by a heat conducting but non-vaporizing fluid. The immediate vicinity of the measuring point and the projecting portion of the thermometer well are to be provided with suitable thermal insulation. Attention must be given to uniform temperature distribution in the fluid.

c) For temperature measurements in unpressurized pipes and vessels, direct immersion of the thermometer into the fluid is recommended. Attention must be given to uniform temperature distribution in the fluid.

4.7.2 Measuring instruments

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Temperature measurements must be performed in accordance with ~~VDE/VDI 3511~~. Liquid or resistance thermometers, or thermocouples, shall be used. Mercury thermometers with 0.1 - 0.2°C graduation are recommended for accurate measurements. Liquid thermometers require column correction when the measuring instruments were calibrated with the column immersed.

4.8 Speed

Electrical or mechanical speed indicators, tachometers, or counters, are recommended. It is acceptable to count the number of pump strokes or shaft revolutions in a defined period of time.

The permissible inaccuracies in measurement depend on the requirements.

4.9 Power requirement of pump, or driving motor power input

Either of the following methods may be used:

a) Determination of the power requirement by measuring the torque at the pump shaft using a swivel-bearing motor or another torque meter.

b) Determination of the pump power requirement by measuring electrically the driving motor power input and using a known motor efficiency curve for conversion to the pump power requirement.

c) For designs with varying power requirements e.g. simplex and duplex reciprocating pumps, the necessary electric work is measured during an adequate period of time using a kilowatt-hour meter, for determining the average power requirement. It should be noted that the average power requirement of the pump can be used for determining the pump efficiency but not for motor sizing or selection.

5. Evaluation of test

5.1 Computation of test results

The measuring results required for comparison with the value specified are obtained from the measured values giving due consideration to all influences and disturbances. Also, the inaccuracies in measurement are determined for the measuring results.

5.2 Inaccuracies in measurement

The test results are computed from several measured quantities. According to the known analytical correlation

$$u = f(x, y, z) \qquad \text{Equation (2)}$$

The following applies to the mean square deviation:

$$u = \pm\sqrt{f_x^2 (\Delta x)^2 + f_y^2 (\Delta y)^2 + f_z^2 (\Delta z)^2} \qquad (3)$$

wherein:

f_x, f_y, f_z are the partial derivations of function f

$\Delta x, \Delta y, \Delta z$ are the mean errors of the quantities x, y, z which in themselves may be caused by a combination of errors

In the special case of a function $u = x^a \cdot y^b \cdot z^c$ in which a, b, and c represent positive or negative constants, the following equation applies:

$$\frac{\Delta u}{u} = \pm \sqrt{a^2 \cdot \left(\frac{\Delta x}{x}\right)^2 + b^2 \cdot \left(\frac{\Delta y}{y}\right) + c^2 \left(\frac{\Delta z}{z}\right)} \qquad (4)$$

Example:

Mean square deviation when determining the pump efficiency:

$$\eta = \frac{P_Q}{P} = \frac{\rho_s \cdot g \cdot Q \cdot H}{367 \cdot P} \quad \text{or} \quad \frac{\gamma_s \cdot Q \cdot H}{367 \cdot P}$$

$$\frac{\Delta \eta}{\eta} = \pm \sqrt{\left(\frac{\Delta \gamma_s}{\gamma_s}\right)^2 + \left(\frac{\Delta Q}{Q}\right)^2 + \left(\frac{\Delta H}{H}\right)^2 + \left(\frac{\Delta P}{P}\right)^2} \qquad (5)$$

The maximum relative error can be seen from the following equation:

$$\frac{\Delta u}{u} = f_x \cdot \frac{\Delta x}{u} + f_y \cdot \frac{\Delta y}{u} + f_z \cdot \frac{\Delta z}{u} \qquad (6)$$

For determining the propagation of errors, equation (3) is preferred.

5.3 Comparison of test results with the values specified

The values specified by the pump manufacturer for the agreed operating point are considered proved when the tolerance range (a, b, c, d - Fig. 1a) and the range of measurement inaccuracy (e, f, g, h - Fig. 1b) contact each other in at least one point.

6. <u>Final test report</u>

The final test report is to be prepared by the chief of tests. It shall contain in an easy-to-read fashion, all data with respect to the acceptance test and to the pump tested.

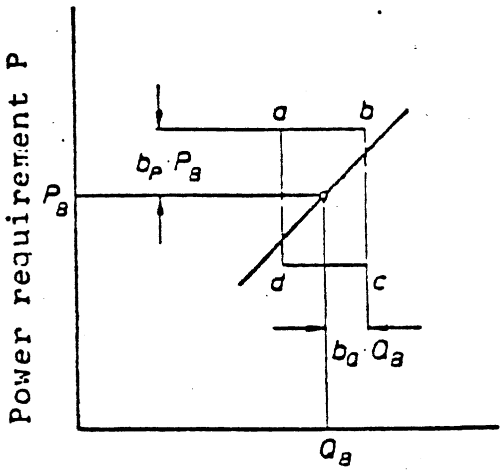
7. References

DIN 24 260 — Centrifugal pumps and centrifugal pump systems - Terms, symbols, units (issue June, 1971)

DIN 51 501 — Lubricants, lubricating oils N, minimum requirements (issue April, 1968)

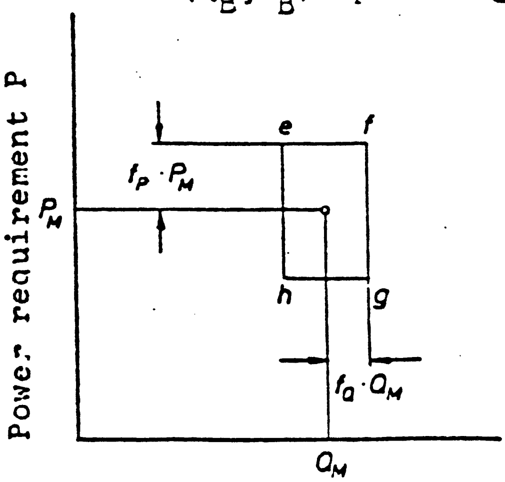
VDMA 24 318 — Oil-hydraulic systems, hydraulic fluids on mineral oil base, properties (issue June, 1968)

VDE/VDI 3511 — Technical temperature measurements (issue February, 1967)



Pump discharge Q

Fig. 1a. Inherent tolerance
(Q_B,P_B) Operating point



Pump discharge Q

Fig. 1b. Measuring cycle
(Q_M,P_M) Measuring point