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# International Standard



# 4391

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INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

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## Hydraulic fluid power — Pumps, motors and integral transmissions — Parameter definitions and letter symbols

*Transmissions hydrauliques — Pompes, moteurs et variateurs — Définitions des grandeurs et lettres utilisées comme symboles*

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**Descriptors** : fluid power, hydraulic fluid power, hydraulic equipment, pumps, hydraulic motors, hydraulic variable speed drive units, definitions, symbols, letters (symbols).

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing international Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4391 was developed by Technical Committee ISO/TC 131, *Fluid power systems*.

This second edition was submitted directly to the ISO Council, in accordance with clause 6.11.2 of part 1 of the Directives for the technical work of ISO. It cancels and replaces the first edition (i.e. ISO 4391-1982), which had been approved by the member bodies of the following countries :

Australia	Finland	Netherlands
Austria	France	Norway
Belgium	Germany, F.R.	Poland
Bulgaria	India	Romania
Canada	Italy	Spain
Chile	Japan	Sweden
Czechoslovakia	Libyan Arab Jamahiriya	USSR

The member bodies of the following countries had expressed disapproval of the document on technical grounds :

United Kingdom  
USA

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# Hydraulic fluid power — Pumps, motors and integral transmissions — Parameter definitions and letter symbols

## 0 Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. Pumps are components which convert rotary mechanical power into fluid power. Motors are components which convert fluid power into rotary mechanical power. Transmissions convert a unidirectional variable speed shaft input to a unidirectional or bidirectional variable speed output.

## 1 Scope

This International Standard describes and systematically defines the principal technical characteristics of hydraulic pumps, motors and integral transmissions.

It allots letter symbols to these characteristics, and indicates how they can be more clearly defined by suffixes corresponding to particular cases. It also lists an analysis of parameter dimensions.

## 2 Field of application

The determination of exact descriptions with letter symbols, dimensions and definitions should create a single and unambiguous terminology for hydraulic pumps, motors and integral transmissions.

It is not yet possible to define a terminology absolutely valid in all cases concerning life, material fatigue or wear with respect to conditions of operation. This field is to be treated with reserve and should undergo precise study in each particular case.

## 3 References

ISO 31/0, *General principles concerning quantities, units and symbols.*

ISO 31/1, *Quantities and units of space and time.*

ISO 31/2, *Quantities and units of periodic and related phenomena.*

ISO 31/3, *Quantities and units of mechanics.*

ISO 31/4, *Quantities and units of heat.*

ISO 1219, *Fluid power systems and components — Graphic symbols.*

ISO 5598, *Fluid power systems and components — Vocabulary.*<sup>1)</sup>

## 4 Definitions

For definitions of terms used, see ISO 5598.

## 5 Guidelines for the use of letter symbols and suffixes

### 5.1 Letter symbols

See clause 7 for letter symbols.

### 5.2 Suffixes for letter symbols

See clause 8 for suffixes for letter symbols.

### 5.3 Letter symbols and suffixes

The use of symbols is self-explanatory but in combination with suffixes a large variety of possibilities can be developed. Therefore, the following guidelines are required to avoid the creation of too many different symbol-suffix combinations for the same subject.

5.3.1 Only if necessary for clarification are letters to be placed at the top of the symbols (P, M, T) to indicate the unit to be used, i.e. when equations are to be developed and compared for pumps, motors and transmissions.

5.3.2 If two or more suffixes are required, use a comma between them.

5.3.3 First priority : 0, 1, 2

5.3.4 Second priority : 3, b, d, e, g, h, hm, i, m, s, t, v,  $\phi$

5.3.5 Third priority : c, dry, ex, f, fi, in, k, p, n

5.3.6 Fourth priority : am, aux, lc, r, st

1) At present at the stage of draft.

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5.3.7 Last priority : a, ma, mi, max, min

5.3.8 See clauses 8, 9 and 10 for examples of the use of symbols with suffixes.

#### 5.4 Terms without symbols

See clause 12 for definition of terms without symbols.

#### 6 Identification statement (Reference to this International Standard)

Use the following statement in test reports, catalogues and sales literature when electing to comply with this International Standard :

"Parameter definitions and letter symbols in accordance with ISO 4391, *Hydraulic fluid power — Pumps, motors and integral transmissions — Parameter definitions and letter symbols.*"

### 7 Letter symbols for characteristics

#### 7.1 Alphabetical sequence of Latin and Greek letters for symbols

Reference	Description	Symbol	Dimension	Definition or explanation
7.1.1	Bulk modulus	$K$	$ML^{-1}T^{-2}$	The relationship of applied stress and volumetric strain produced when stress is applied uniformly to all sides of a body. It is the reciprocal of compressibility.
7.1.2	Force	$F$	$MLT^{-2}$	—
7.1.3	Frequency	$f$	$T^{-1}$	—
7.1.4	Moment of inertia	$I$	$ML^2$	Value calculated from the moments of inertia of the moving parts
7.1.5	Mass	$m$	M	—
7.1.6	Rotational frequency (speed)	$n$	$T^{-1}$	The number of revolutions of the drive shaft in unit time
7.1.7	Power	$P$	$ML^2T^{-3}$	—
7.1.8	Pressure	$p$	$ML^{-1}T^{-1}$	Static pressure at a stated point
7.1.9	Mass flow rate	$q_m$	$MT^{-1}$	The mass of a fluid crossing the transverse plane of a flow path per unit time
7.1.10	Volume flow rate	$q_v$	$L^3T^{-1}$	The volume of a fluid crossing the transverse plane of a flow path per unit time
7.1.11	Stiffness	$S$	$ML^2T^{-2}$	Ratio of the variation of torque applied to a shaft and the variation of the angular position of the shaft
7.1.12	Torque	$T$	$ML^2T^{-2}$	—
7.1.13	Time	$t$	T	—
7.1.14	Instantaneous displacement	$v$	$L^3$	Swept volume at a given shaft position
7.1.15	Swept volume	$V$	$L^3$	The volume of a theoretically incompressible fluid that would be displaced by a complete stroke, cycle or revolution $V = \int_0^{2\pi} v d\phi$
7.1.16	Speed ratio	$Z$	1	Ratio of speed of two different units
7.1.17	Volume coefficient of thermal expansion	$\alpha$	$\Theta^{-1}$	—
7.1.18	Degree of irregularity for parameter $X$	$\delta X$	1	$\delta X = \frac{X_{max} - X_{min}}{X_{mi}}$ , where $X$ is any parameter

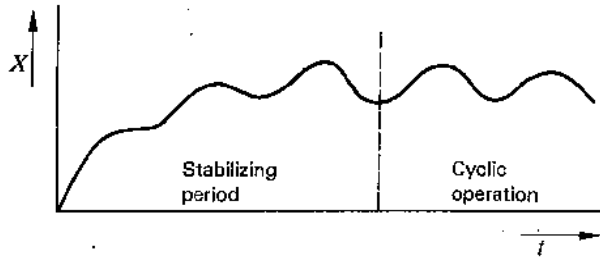
Reference	Description	Symbol	Dimension	Definition or explanation
7.1.19	Position of setting	$\epsilon$	1	For variable units, the position of the control device is defined by the ratio between the theoretical swept volume $V_i$ at a given adjustment and the maximum theoretical swept volume $V_{i,max}$ $\epsilon = \frac{V_i}{V_{i,max}}$
7.1.20	Efficiency	$\eta$	1	—
7.1.21	Temperature	$\theta$	$\Theta$	—
7.1.22	Angular velocity	$\omega$	$T^{-1}$	The number of radians of a shaft in unit time $\omega = 2\pi n$

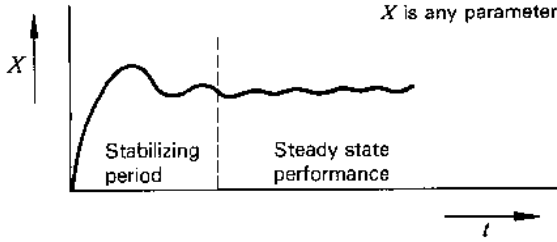
## 7.2 List of other symbols

Reference	Description	Symbol	Dimension	Definition or explanation
7.2.1	Direction of rotation : — clockwise — anti-clockwise	R L	1 1	From the point of view of an observer looking at the end of the shaft

## 8 Suffixes for symbols for characteristics

### 8.1 Alphabetical sequence of Latin and Greek letters for suffixes

Reference	Description	Suffix	Definition or explanation and examples
8.1.1	Acceptable conditions	a	Conditions which permit a tolerable standard of performance and life
8.1.2	Ambient	am	Surrounding
8.1.3	Auxiliary	aux	—
8.1.4	Adjustment	b	—
8.1.5	Cyclic stabilized conditions	c	Conditions in which the relevant parameters vary in a repetitive manner, similar conditions repeating at regular intervals 
8.1.6	Drainage	d	—
8.1.7	Indication of dry	dry	For values for which the fluid impact is not to be considered
8.1.8	Measured value	e	Obtained by direct measurement or by calculation based on measurements
8.1.9	External	ex	—
8.1.10	Fluid	f	—
8.1.11	Filling	fi	Indicating values due to imperfect filling of pump

Reference	Description	Suffix	Definition or explanation and examples
8.1.12	Geometric	g	Calculated on the basis of the geometric dimensions
8.1.13	Hydraulic	h	—
8.1.14	Hydraulic mechanical	hm	—
8.1.15	Theoretical	i	—
8.1.16	Internal	in	—
8.1.17	Compressibility related	k	—
8.1.18	Local	lc	—
8.1.19	Mechanical	m	—
8.1.20	Arithmetic mean	ma	$X_{ma} = \frac{X_1 + X_2 + \dots + X_n}{n}$
8.1.21	Integral mean	mi	Mean value obtained by integration with respect to time. Mean value in the course of one revolution in time $t_1$ $X_{mi} = \frac{1}{t_1} \int_0^{t_1} X dt$
8.1.22	Limiting conditions of operation	min max	These are characterized by the extreme (minimum or maximum) values which each parameter can take; the other parameters being stated
8.1.23	Rated conditions	n	Steady state conditions for which a component or system is recommended as a result of specified testing. The "rated characteristics" are in general shown in catalogues
8.1.24	Peak duty related	p	A peak duty is an impulse during which the quantity exceeds the permitted maximum value. A peak duty is defined by a value which for a short period exceeds average value
8.1.25	Discontinuous conditions of operation	r	Conditions in which the relevant parameters do not attain stabilization as defined in either 8.1.5 or 8.1.27
8.1.26	Losses	s	—
8.1.27	Steady state conditions of operation	st	Conditions in which relevant parameters do not change appreciably after a period for stabilization  
8.1.28	Total value	t	Total value of a parameter where other values are also used
8.1.29	Volumetric value	v	—
8.1.30	Rotational angle	$\varphi$	—

8.2 List of other suffixes

Reference	Description	Suffix	Definition or explanation and examples
8.2.1	Position in unit	0	Neutral condition Inlet or input Outlet or output
8.2.2		1	
8.2.3		2	
8.2.4	Type of unit	P	Pump Motor Integral transmission
8.2.5		M	
8.2.6		T	

} Placed at the top of the symbols

\* Where the suffixes 0, 1 and 2 are not sufficient for specific description, identify inlets by odd numbers and outlets by even numbers.

## 9 Examples for the use of symbols with suffix for general characteristics

Reference	Description	Symbol	Dimension	Definition or explanation
9.1	Dry mass	$m_{dry}$	M	Mass of unit without fluid
9.2	Fluid mass	$m_f$	M	Mass of fluid contained in unit when ready to operate
9.3	Total (working) mass	$m_t$	M	Mass of unit ready to operate $m_t = m_{dry} + m_f$
9.4	Volumetric loss	$q_{V_s}$	$L^3T^{-1}$	—
9.5	Torque loss	$T_s$	$ML^2T^{-2}$	$T_s^P = T_e - T_i$ or $T_s^M = T_i - T_e$
9.6	Differential temperature	$\Delta\theta$	$\ominus$	*
9.7	Ambient temperature	$\theta_{am}$	$\ominus$	The temperature of the environment in which the apparatus is working
9.8	Fluid drainage temperature	$\theta_{d,t}$	$\ominus$	Temperature of the fluid at an external drainage point
9.9	Fluid temperature	$\theta_f$	$\ominus$	The temperature of the fluid measured at a specified point
9.10	Fluid inlet temperature	$\theta_{1,t}$	$\ominus$	Temperature of the fluid measured at the inlet of the unit
9.11	Fluid outlet temperature	$\theta_{2,t}$	$\ominus$	Temperature of the fluid measured at the outlet of the unit
9.12	Local temperature	$\theta_{lc}$	$\ominus$	Temperature of the equipment at a defined point

## 10 Examples for the use of symbols with suffix for pumps and motors

Reference	Description	Symbol	Dimension	Definition or explanation
10.1	Transformation of energy	—	—	General

Pump :  $\Delta p = p_2 - p_1$

$P_{1,h} = p_1 \cdot q_{V_{1,e}}$

$P_{2,h} = p_2 \cdot q_{V_{2,e}}$

$P_m = T_e \cdot \omega$

$\eta_t = \frac{P_{2,h} - P_{1,h}}{P_m} = \frac{P_{2,h} - P_{1,h}}{T_e \cdot \omega}$

Motor :  $\Delta p = p_1 - p_2$

$P_{1,h} = p_1 \cdot q_{V_{1,e}}$

$P_{2,h} = p_2 \cdot q_{V_{2,e}}$

$P_m = T_e \cdot \omega$

$\eta_t = \frac{P_m}{P_{1,h} - P_{2,h}} = \frac{T_e \cdot \omega}{P_{1,h} - P_{2,h}}$

\*  $\Delta$  is an indication of a differential value.



Reference	Description	Symbol	Dimension	Definition or explanation
	<p>The definition of hydraulic power below is adopted because it is not possible to use the strain energy of the fluid in practice.</p> <p><b>Definition :</b></p> <p>The effective flow is the actual flow under conditions of pressure and temperature existing at the outlet of the pump or at the inlet of the motor. If the flow is measured under other conditions, corrections have to be applied to determine the effective flow.</p> <p>The differential pressure <math>\Delta p</math> is the difference between the static pressures at the outlet and the inlet of a pump or of a motor. If there is a difference of kinetic or potential energy between the inlet and the outlet, correct <math>\Delta p</math> to take account of this.</p>			
10.2	Hydraulic pumps	—	—	Units which transform rotary mechanical energy into hydraulic energy
10.3	Hydraulic motors	—	—	Units which transform hydraulic energy into rotary mechanical energy
10.4	Adjusting force	$F_b$	$MLT^{-2}$	Maximum force required for adjustment taking into account all conditions including friction, pressure, speed, direction and time of adjustment
10.5	Acceptable frequency of adjustment	$f_{b,a}$	$T^{-1}$	Frequency at which the equipment could be adjusted for the travel or angle of adjustment indicated
10.6	Dry moment of inertia	$I_{dry}$	$ML^2$	Moments of inertia of the mechanical parts
10.7	Moment of inertia of fluid	$I_f$	$ML^2$	—
10.8	Total moment of inertia	$I_t$	$ML^2$	Moments of inertia of all dynamic masses (mechanical and fluid) $I_t = I_{dry} + I_f$
10.9	Hydraulic power	$P_h$	$ML^2T^{-3}$	—
10.10	Theoretical power	$P_i$	$ML^2T^{-3}$	$P_i^P = q_{V_i} \cdot \Delta p = T_i \cdot \omega$ $P_i^M = q_{V_i} \cdot \Delta p = T_i \cdot \omega$
10.11	Nominal power	$P_n$	$ML^2T^{-3}$	Rated power of the driving prime mover
10.12	Motor power	$P_m^M$	$ML^2T^{-3}$	$P_m^M = T_o \cdot \omega$
10.13	Pump power	$P_m^P$	$ML^2T^{-3}$	$P_m^P = T_e \cdot \omega$
10.14	Differential pressure	$\Delta p$	$ML^{-1}T^{-2}$	$\Delta p^P = p_2 - p_1$ $\Delta p^M = p_1 - p_2$
10.15	Minimum (inlet/outlet) pressure	$p_{min}$	$ML^{-1}T^{-2}$	$p_{1,min}^P$ : Minimum acceptable pressure at the inlet of the pump $p_{2,min}^M$ : The minimum outlet pressure of the motor to ensure satisfactory operation
10.16	Maximum (outlet/inlet) pressure	$p_{max}$	$ML^{-1}T^{-2}$	$p_{2,max}^P$ : The maximum permitted outlet pressure of the pump in steady state conditions $p_{1,max}^M$ : The maximum permitted inlet pressure of the motor in steady state conditions For other conditions of operation, other values of the maximum pressure can be defined with other symbols
10.17	Peak pressure	$p_D$	$ML^{-1}T^{-2}$	A pressure which may exceed the permitted maximum pressure for a relatively short time
10.18	Effective flow	$q_{V_e}$	$L^3T^{-1}$	$q_{V_{2,e}}^P$ : Actual flow at pump outlet $q_{V_{1,e}}^M$ : Actual flow at motor inlet Actual flow measured at the temperature and pressure present at that point

Reference	Description	Symbol	Dimension	Definition or explanation
10.19	Theoretical flow	$q_{V_i}$	$L^3T^{-1}$	$q_{V_i}^P = V_i \cdot n$ ; $q_{V_i}^M = V_i \cdot n$
10.20	Volumetric external losses	$q_{V_{s,ex}}$	$L^3T^{-1}$	$q_{V_{s,ex}}^P$ : Loss of output due to external leakage $q_{V_{s,ex}}^M$ : Increase of input to allow for external leakage
10.21	Volumetric filling losses	$q_{V_{s,fi}}$	$L^3T^{-1}$	Loss of output due to imperfect filling of the pump
10.22	Volumetric internal losses	$q_{V_{s,in}}$	$L^3T^{-1}$	$q_{V_{s,in}}^P$ : Loss of output due to internal leakage $q_{V_{s,in}}^M$ : Increase of input to allow for internal leakage
10.23	Volumetric compressibility losses	$q_{V_{s,k}}$	$L^3T^{-1}$	$q_{V_{s,k}}^P = \left( q_{V_i} - q_{V_{s,in}} - q_{V_{s,ex}} \right) \frac{\Delta p}{K}$

If the elasticity and the play of the mechanical parts are neglected, as well as changes in volume of the fluid due to physical/chemical characteristics or to the presence of air in the fluid, then

$$q_{V_{2,e}}^P = q_{V_i} - \left( q_{V_{s,in}} + q_{V_{s,ex}} \right) - q_{V_{s,k}}$$

$$q_{V_{1,e}}^M = q_{V_i} + q_{V_{s,in}} + q_{V_{s,ex}} + q_{V_{s,k}}$$

10.24	Adjusting torque	$T_b$	$ML^2T^{-2}$	—
10.25	Effective torque	$T_e$	$ML^2T^{-2}$	$T_e = \frac{P_m}{\omega}$
10.26	Theoretical torque	$T_i$	$ML^2T^{-2}$	$T_i = \frac{V_i \cdot \Delta p}{2\pi}$
10.27	Hydraulic-mechanical losses (torque losses)	$T_s$	$ML^2T^{-2}$	$T_s^P = T_e - T_i$ $T_s^M = T_i - T_e$
10.28	Starting torque	$T_0$	$ML^2T^{-2}$	The minimum torque available at the motor shaft when starting from rest for a given pressure differential under specified conditions
10.29	Time of adjustment	$t_b$	T	Time required for adjustment
10.30	Shortest time of adjustment	$t_{b,min}$	T	The shortest possible time required for the angle of adjustment indicated
10.31	Total time of adjustment	$t_{b,t}$	T	Time required for adjustment taking into account the travel and angle of the total adjustment
10.32	Effective swept volume	$V_e$	$L^3$	$V_e^P = \frac{q_{V_{2,e}}}{n}$ ; $V_e^M = \frac{q_{V_{1,e}}}{n}$
10.33	Geometric swept volume	$V_g$	$L^3$	Volume displaced, calculated geometrically without reference to tolerances, clearances or deformation
10.34	Derived swept volume	$V_i$	$L^3$	The volume displaced (pump), or volume absorbed (motor) at defined minimum working pressure, obtained from measurements at two different speeds $V_i^P = \left( \frac{\Delta q_{V_{2,e}}}{\Delta n} \right)_{\Delta p=0} = \left( \frac{(q_{V_{2,e}})_{n_2} - (q_{V_{2,e}})_{n_1}}{n_2 - n_1} \right)_{\Delta p=0}$ $V_i^M = \left( \frac{\Delta q_{V_{1,e}}}{\Delta n} \right)_{\Delta p=0} = \left( \frac{(q_{V_{1,e}})_{n_2} - (q_{V_{1,e}})_{n_1}}{n_2 - n_1} \right)_{\Delta p=0}$

Reference	Description	Symbol	Dimension	Definition or explanation
10.35	Overall efficiency	$\eta_t$	1	$\eta_t^P = \eta_v \cdot \eta_{hm} = \frac{q_{V2,e}}{q_{V1}} \cdot \frac{T_i}{T_e} = \frac{P_{2,h} - P_{1,h}}{P_m}$ $\eta_t^M = \eta_v \cdot \eta_{hm} = \frac{q_{V1}}{q_{V1,e}} \cdot \frac{T_e}{T_i} = \frac{P_m}{P_{1,h} - P_{2,h}}$
10.36	Volumetric efficiency	$\eta_v$	1	$\eta_v^P = \frac{q_{V2,e}}{q_{V1}}; \quad \eta_v^M = \frac{q_{V1}}{q_{V1,e}}$
10.37	Hydraulic mechanical efficiency	$\eta_{hm}$	1	$\eta_{hm}^P = \frac{T_i}{T_e}; \quad \eta_{hm}^M = \frac{T_e}{T_i}$
10.38	Zero position	$\epsilon = 0$	1	Corresponds to zero swept volume ( $\epsilon = 0$ )

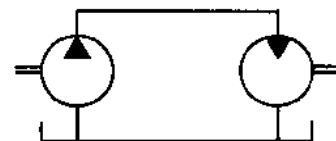
## 11 Examples for the use of symbols with suffix for integral transmissions

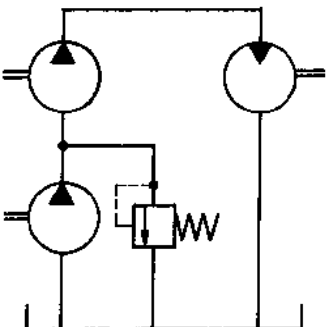
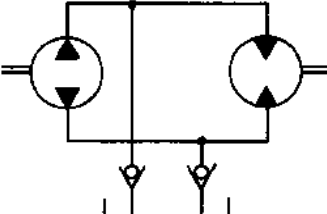
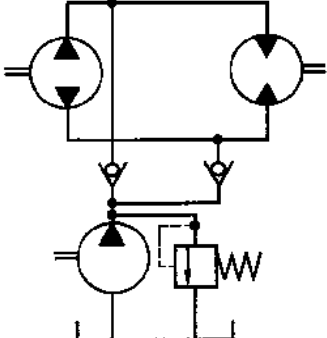
Reference	Description	Symbol	Dimension	Definition or explanation
11.1	Integral transmission			<p>Combination of one or more hydraulic pumps and one or more motors forming a unit.</p> <p>During use, the functions of the pump and motor are determined by their actual function at a specified time.</p> <p>The input shaft is connected to the source of energy; the output shaft is connected to the load and is driven by the motor(s)</p>
11.2	Output shaft speed	$n^M$	$T^{-1}$	Number of revolutions per unit time of the output shaft
11.3	Theoretical output speed	$n_i^M$	$T^{-1}$	$n_i^M = n^P \cdot Z_i = n^P \cdot \frac{V_i^P}{V_i^M}$
11.4	Input shaft speed	$n^P$	$T^{-1}$	Number of revolutions per unit time of the input shaft
11.5	Moment of inertia of moving mechanical parts connected to the motor shaft	$I_m^M$	$ML^2$	Moment of inertia of all the mechanical parts connected to the motor shaft
11.6	Moment of inertia of moving mechanical parts connected to the pump shaft	$I_M^P$	$ML^2$	Moment of inertia of all the mechanical parts connected to the pump shaft, relative to the pump shaft
11.7	Power input to auxiliary drive	$P_{aux}$	$ML^2T^{-3}$	Sum of the mechanical power inputs which are necessary in order to drive the boost pump and cooling system
11.8	Auxiliary drive input torques	$T_{aux}$	$ML^2T^{-2}$	Sum of the input torques which are necessary in order to drive the auxiliary units (boost pump and cooling system)
11.9	Theoretical output torque	$T_i^M$	$ML^2T^{-2}$	$T_i^M = \frac{T_i^P}{Z_i} = T_i^P \cdot \frac{V_i^M}{V_i^P}$
11.10	Input torque	$T^P$	$ML^2T^{-2}$	Sum of all input torques to the transmission
11.11	Theoretical speed ratio	$Z_i$	1	$Z_i = \frac{V_i^P}{V_i^M}$
11.12	Overall efficiency	$\eta_t$	1	$\eta_t = \frac{P_m^M}{P_m^P} = \frac{T_e^M \cdot \omega^M}{T_e^P \cdot \omega^P}$

Reference	Description	Symbol	Dimension	Definition or explanation
11.13	Setting parameters			
11.13.1	Position of setting	$\epsilon^P$ $\epsilon^M$	1	For the units attached to the pump shaft and the motor shaft, respectively
11.13.2	Zero position	$\epsilon^P = 0$	1	Pump in zero swept volume position
11.13.3	Maximum swept volume position	$\epsilon^P = 1$ $\epsilon^M = 1$	1	Pump and motor in the maximum swept volume position
11.13.4	Maximum speed position	$\epsilon^P = 1$ $\epsilon^M = \text{min}$	1	Pump in maximum position; motor in minimum position Output speed = maximum speed
11.13.5	Neutral position	$\epsilon^M = 0$	1	Motor adjusted to zero swept volume position (the function of the neutral position can be achieved in certain designs by opening a bypass valve)
11.13.6	Free position	$\epsilon^P = 0$ $\epsilon^M = 0$	1	Pump and motor are both in zero swept volume position

## 12 Definition of terms without symbols

Reference	Description	Definition or explanation
12.1	Open loop control	The swept volume setting is determined by an independent parameter
12.2	Closed loop control	The swept volume setting is determined by a dependent parameter such as flow, pressure and power
12.3	Constant pressure control	The control setting varies so as to maintain the pressure constant within limits
12.4	Power control	The control setting varies so as to follow a predetermined power characteristic
12.5	Output flow control	The control setting varies so as to follow a predetermined flow characteristic
12.6	Power regulator	Regulated adjustment to give a given characteristic power curve
12.7	Torque regulator	Regulated adjustment to give a characteristic torque curve
12.8	Speed regulation	Regulated adjustment to give a characteristic speed curve
		<p>The term "open loop control" is used here where the input parameters (<math>\epsilon</math>, <math>n</math>, ...) act upon the output parameter or parameters (<math>V</math>, <math>q_v</math>, <math>p</math>, ...) according to a relationship applicable to the system and without being affected by these output parameters.</p> <p>All the elements which so operate are termed the control loop and the last link is the output control member.</p> <p>The term "closed loop control" or "regulating control" is used where the output parameters are within the control loop and are compared with one or more selected quantities to which they must be made equal by the control mechanism. This equalisation is effected by the "output member" at the end of the control loop.</p> <p>In the present case, the output control member is that part of the pump which changes the swept volume. The output parameters are the flow and the output pressure.</p>
12.9	Circuit	Path of hydraulic fluid in the transmission
12.10	Open circuit	Circuit in which return fluid is directed to the reservoir before re-circulation
12.11	Open circuit without boost pump	Open circuit in which the pump takes its entire supply directly from the reservoir



Reference	Description	Definition or explanation
12.12	Open circuit with boost pump	Open circuit in which the pump takes its entire supply by means of the boost pump 
12.13	Closed circuit	Circuit in which return fluid is directed to the pump inlet
12.14	Closed circuit without boost pump	Circuit in which the pump takes the major part of its fluid supply from the hydraulic motor and the rest direct from the reservoir 
12.15	Closed circuit with boost pump	Circuit in which the pump takes the major part of its fluid supply from the hydraulic motor and the rest from an auxiliary boost pump 
12.16	Adjustment	Change of setting
12.17	Individual adjustment	Adjustment of pump and motor by a separate actuator
12.18	Combined adjustment	Adjustment of pump and motor by a common actuator
12.19	Simultaneous adjustment	Pump and motor are adjusted simultaneously by means of a common actuator
12.20	Sequential adjustment	Pump and motor are adjusted one after the other by a common actuator
12.21	Controlled adjustment	Change of setting independent of speed and torque
12.22	Regulated adjustment	Change of setting dependent on speed and/or torque
12.23	Power transmission	Manner in which the power is transmitted between the input and output shaft(s)
12.24	Simple power transmission	The power is transmitted hydraulically from a pump to a motor
12.25	Multiple power transmission	The power is transmitted hydraulically from a pump or several pumps to one or more motors
12.26	Split power transmission	Only part of the power is transmitted hydraulically from the input shaft to the output shaft