International Standard 4391

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

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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Foreword

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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 and components*, and was circulated to the member bodies in January 1979.

It has 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 expressed disapproval of the document on technical grounds :

United Kingdom
USA

Printed in Switzerland

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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 introduction to ISO 31 — 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.*[1]

4 Definitions

For definitions of terms used, see ISO 5598.[1]

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, φ

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.

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 $V = \int_0^{2\pi} v \mathrm{d}\varphi$
7.1.16	Speed ratio	Z	1	Ratio of speed of two different units
7.1.17	Volume coefficient of thermal expansion	α	Θ^{-1}	—
7.1.18	Degree of irregularity for parameter X	δX	1	$\delta X = \frac{X_{max} - X_{min}}{X_{mi}}$, where X is any parameter

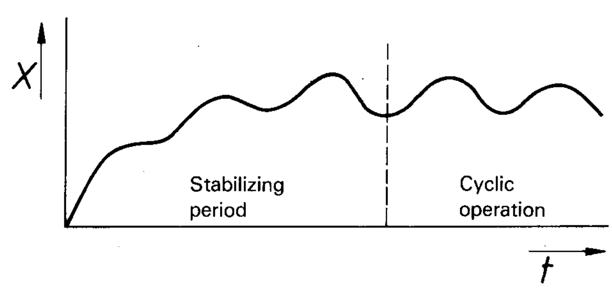
Reference	Description	Symbol	Dimension	Definition or explanation
7.1.19	Position of setting	ϵ	1	For variable units, the position of the control device is defined by the ratio between the theoretical swept volume V_i at a given adjustment and the maximum theoretical swept volume $V_{i,\,max}$ $\epsilon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

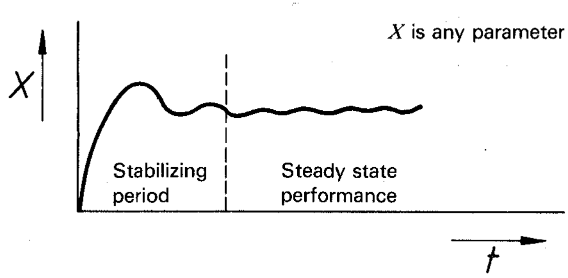
7.2 List of other symbols

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	$X_{ma} = \frac{X_1 + X_2 + \ldots + X_n}{n}$
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	Rotational angle	φ	—

8.2 List of other suffixes

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

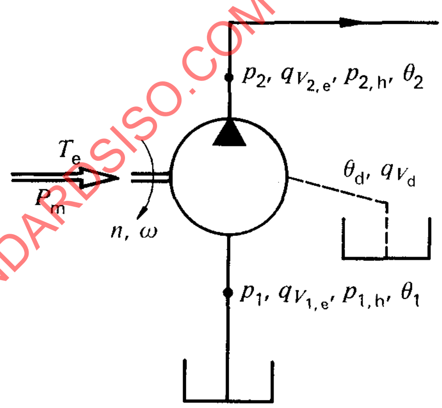
* Where the suffixes 0, 1 and 2 are not sufficient for specific description, identify inlets by odd numbers and outlets by even numbers.

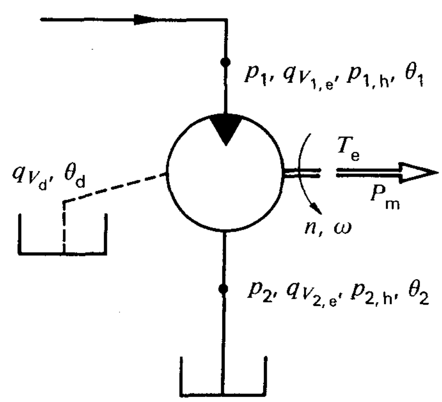
9 Examples for the use of symbols with suffix for general characteristics

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	$\Delta\theta$	Θ	*
9.7	Ambient temperature	θ_{am}	Θ	The temperature of the environment in which the apparatus is working
9.8	Fluid drainage temperature	$\theta_{d,f}$	Θ	Temperature of the fluid at an external drainage point
9.9	Fluid temperature	θ_f	Θ	The temperature of the fluid measured at a specified point
9.10	Fluid inlet temperature	$\theta_{1,f}$	Θ	Temperature of the fluid measured at the inlet of the unit
9.11	Fluid outlet temperature	$\theta_{2,f}$	Θ	Temperature of the fluid measured at the outlet of the unit
9.12	Local temperature	θ_{lc}	Θ	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 : $\Delta p = p_1 - p_2$

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

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

$$P_m = T_e \cdot \omega$$

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

* Δ is an indication of a differential value.

Reference	Description	Symbol	Dimension	Definition or explanation
	The above definition of hydraulic power is adopted because it is not possible to use the strain energy of the fluid in practice. **Definition :** 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. The differential pressure Δp 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 Δp to take account of this.			
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}	$P_m^M = T_e \cdot \omega$
10.13	Pump power	P_m^P	ML^2T^{-3}	$P_m^P = T_e \cdot \omega$
10.14	Differential pressure	Δp	$ML^{-1}T^{-2}$	$\Delta p^P = p_2 - p_1$ $\Delta p^M = p_1 - p_2$
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_p	$ML^{-1}T^{-2}$	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}	$q^P_{V_i} = V_i \cdot n; \quad q^M_{V_i} = V_i \cdot n$
10.20	Volumetric external losses	$q_{V_{s,ex}}$	L^3T^{-1}	$q^P_{V_{s,ex}}$: Loss of output due to external leakage $q^M_{V_{s,ex}}$: 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}	$q^P_{V_{s,in}}$: Loss of output due to internal leakage $q^M_{V_{s,in}}$: Increase of input to allow for internal leakage
10.23	Volumetric compressibility losses	$q_{V_{s,k}}$	L^3T^{-1}	$q^P_{V_{s,k}} = \left(q_{V_i} - q_{V_{s,in}} - q_{V_{s,ex}}\right)\dfrac{\Delta p}{K}$

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

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

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

Reference	Description	Symbol	Dimension	Definition or explanation
10.24	Adjusting torque	T_b	ML^2T^{-2}	—
10.25	Effective torque	T_e	ML^2T^{-2}	$T_e = \dfrac{P_m}{\omega}$
10.26	Theoretical torque	T_i	ML^2T^{-2}	$T_i = \dfrac{V_i \cdot \Delta p}{2\pi}$
10.27	Hydraulic-mechanical losses (torque losses)	T_s	ML^2T^{-2}	$T^P_s = T_e - T_i$ $T^M_s = T_i - T_e$
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	$V^P_e = \dfrac{q_{V_{2,e}}}{n}; \quad V^M_e = \dfrac{q_{V_{1,e}}}{n}$
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 $V^P_i = \left(\dfrac{\Delta q_{V_{2,e}}}{\Delta n}\right)_{\Delta p \to 0} = \left(\dfrac{\left(q_{V_{2,e}}\right)_{n_2} - \left(q_{V_{2,e}}\right)_{n_1}}{n_2 - n_1}\right)_{\Delta p \to 0}$ $V^M_i = \left(\dfrac{\Delta q_{V_{1,e}}}{\Delta n}\right)_{\Delta p \to 0} = \left(\dfrac{\left(q_{V_{1,e}}\right)_{n_2} - \left(q_{V_{1,e}}\right)_{n_1}}{n_2 - n_1}\right)_{\Delta p \to 0}$

Reference	Description	Symbol	Dimension	Definition or explanation
10.35	Overall efficiency	η_t	1	$\eta_t^P = \eta_v \cdot \eta_{hm} = \frac{q_{V_{2,e}}}{q_{V_i}} \cdot \frac{T_i}{T_e} = \frac{P_{2,h} - P_{1,h}}{P_m}$ $\eta_t^M = \eta_v \cdot \eta_{hm} = \frac{q_{V_i}}{q_{V_{1,e}}} \cdot \frac{T_e}{T_i} = \frac{P_m}{P_{1,h} - P_{2,h}}$
10.36	Volumetric efficiency	η_v	1	$\eta_v^P = \frac{q_{V_{2,e}}}{q_{V_i}}$; $\eta_v^M = \frac{q_{V_i}}{q_{V_{1,e}}}$
10.37	Hydraulic mechanical efficiency	η_{hm}	1	$\eta_{hm}^P = \frac{T_i}{T_e}$; $\eta_{hm}^M = \frac{T_e}{T_i}$
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			Combination of one or more hydraulic pumps and one or more motors forming a unit. During use, the functions of the pump and motor are determined by their actual function at a specified time. 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)
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	η_t	1	$\eta_t = \frac{P_m^M}{P_m^P} = \frac{T_e^M \cdot \omega^M}{T_e^P \cdot \omega^P}$