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Reciprocating internal combustion engines — Performance —

Part 4: Speed governing

Moteurs alternatifs à combustion interne — Performances —

Partie 4: Régulation de la vitesse

Reference number
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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.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3046-4 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*.

This third edition cancels and replaces the second edition (ISO 3046-4:1997), which has been technically revised.

ISO 3046 consists of the following parts, under the general title *Reciprocating internal combustion engines — Performance*:

- *Part 1: Declarations of power, fuel and lubricating oil consumptions, and test methods — Additional requirements for engines for general use*

- *Part 3: Test measurements*

- *Part 4: Speed governing*

- *Part 5: Torsional vibrations*

- *Part 6: Overspeed protection*

Reciprocating internal combustion engines — Performance —

Part 4:
Speed governing

1 Scope

This part of ISO 3046 establishes a classification for the requirements and parameters of speed-governing systems and specifies terms and definitions of typical engine speeds for reciprocating internal combustion (RIC) engines. Where necessary, individual requirements are given for particular engine applications.

This part of ISO 3046 applies to RIC engines for land, rail-traction and marine use, excluding engines used to propel road-construction and earth-moving machines, agricultural and industrial types of tractors, road vehicles and aircraft. Also excluded are self-governing engines and those engines requiring only maximum speed or maximum fuel delivery limitation.

This part of ISO 3046 defines requirements for compression–ignition oil engines (diesel engines). For spark ignition engines and dual fuel engines, special requirements can apply.

NOTE 1 Performance and parameters for speed-governing systems applied to RIC engine driven generating sets are specified in ISO 8528-2 and ISO 8528-5.

NOTE 2 The terms and definitions of typical engine speeds in connection with overspeed protection devices are specified in ISO 3046-6.

2 Terms and definitions, symbols and subscripts

For the purposes of this document, the following terms and definitions, symbols and subscripts apply.

NOTE Terms and definitions related to overspeed devices are given in ISO 3046-6.

2.1 Speed-governing systems

2.1.1
engine speed governor
device which under specific engine operating conditions compares the actual speed and the setting speed and causes a modification of the fuel delivery into the engine in order to adjust the actual speed of the RIC engine towards the setting speed

NOTE 1 See ISO 7967-7:2005, 3.1.1.

NOTE 2 Speed governors can be classified according to:

a) the speed sensing and amplification of their output signal (see ISO 7967-7:2005, 3.3.1);

b) their dynamic behaviour (transfer function) (see ISO 7967-7:2005, 7.2);

c) their related engine application (see ISO 7967-7:2005, 3.3.3).

2.1.2

speed-setting device

device allowing adjustment of the set point of a speed governor, depending on the application or required kind of adjustment respectively

NOTE Adapted from ISO 7967-7:2005, definition 3.1.2.

2.1.3

torque control

modification of the maximum natural fuel delivery curve obtained from the fuel injection system at speeds below the engine **declared speed**

NOTE Adapted from ISO 7967-7:2005, definition 3.5.3.

2.2 Speed-governing parameters

2.2.1

declared speed droop

$\delta n_{\mathrm{st,r}}$

speed difference between the **declared no-load speed** and the **declared speed** at declared power, expressed as a percentage of the declared speed at a fixed speed setting, calculated using the following equation:

$$\delta n_{\mathrm{st,r}} = \frac{n_{\mathrm{i,r}} - n_{\mathrm{r}}}{n_{\mathrm{r}}} \times 100$$

where

n_{r} is the declared speed;

$n_{\mathrm{i,r}}$ is the declared no-load speed

NOTE See Table 1 and Figures 4 and 5.

2.2.2

load sharing at parallel operation

ΔP

difference between the proportion of power supplied by an individual engine and the proportion of the total declared power supplied by all engines, expressed as a percentage, calculated using the following equation:

$$\Delta P = \left[\frac{P_{\mathrm{a}}}{P_{\mathrm{r}}} - \frac{\sum P_{\mathrm{a}}}{\sum P_{\mathrm{r}}} \right] \times 100$$

where

P_{a} is the actual delivered power of an individual engine;

P_{r} is the declared (rated) power of an individual engine

2.2.3

maximum force

maximum value of the force at the output of the governor at any specified position of travel

[ISO 7967-7:2005, definition 3.4.1]

2.2.4

maximum torque

maximum value of the torque at the output shaft of the governor at any specified position of travel

[ISO 7967-7:2005, definition 3.4.2]

2.2.5
range of speed setting
Δn_s
difference between the **lowest adjustable no-load speed** and the highest adjustable no-load speed determined by the speed-setting device

NOTE See 2.3.7 and 2.3.10.

2.2.6
rate of change of speed setting
v_n
rate at which the speed setting can be changed within the **range of speed setting**, expressed as a percentage of the declared speed setting per second, calculated using the following equation:

$$v_n = \frac{n_\mathrm{i,max} - n_\mathrm{i,min}}{n_\mathrm{r} \times t} \times 100$$

where

n_i is the no-load speed;

n_r is the declared speed;

t is time

NOTE 1 See ISO 8528-2:2005, 6.3.4.

NOTE 2 For ship propulsion engines, the rate of change of speed setting will necessarily depend on the particular application, manufacturer and/or customer demand (e.g. different rate of change of speed setting for manoeuvring and normal acceleration/deceleration).

2.2.7
speed governor input signal
input signal to the governor, which is a measure of the instantaneous engine speed

NOTE Adapted from ISO 7967-7:2005, definition 3.2.1.

2.2.8
speed governor output signal
signal delivered by the speed governor that is used to adjust the fuel delivery

NOTE Adapted from ISO 7967-7:2005, definition 3.2.2.

2.2.9
steady-state speed band
βn
width of the envelope of oscillation, Δn, of speed at constant power around a mean value, expressed as a percentage of the declared speed, n_r, calculated using the following equation

$$\beta n = \frac{\Delta n}{n_\mathrm{r}} \times 100$$

NOTE 1 See Figure 6.

NOTE 2 The operating limiting values for the steady-state speed band over the whole operating range of an RIC engine depend on the power output and whether the engine is coupled to the driven machinery or not. These operating limiting values also depend on the declared speed of the RIC engine.

The following cases can be differentiated.

a) Engines coupled with driven machinery:

   1) $n < 0{,}5\, n_\mathrm{r}$;

   2) $n \geqslant 0{,}5 n_\mathrm{r}$ and $P \geqslant 0{,}25 P_\mathrm{r}$;

   3) $n \geqslant 0{,}5 n_\mathrm{r}$ and $P < 0{,}25 P_\mathrm{r}$.

b) Engines not coupled with driven machinery and running at lowest adjustable no-load speed.

The curves given in Figures 1 to 3 have been prepared on the basis of experience. These curves can also be expressed, as a percentage, using the following equation:

$$\beta n = c n_\mathrm{r}^{-m}$$

where the values of c and m are given in Table 1 for the cases specified in a) and b).

NOTE 3 The values of c and m depend on the inertia of the system, the capability of the speed governor and the power output of the engine over the whole speed range, and, in this context, are therefore only important for the end user.

2.2.10
work capacity

maximum work available from the governor as its output shaft or arm moves through its full available travel

2.3 Steady-state engine speeds

2.3.1
declared no-load speed

$n_\mathrm{i,r}$

high idling speed

steady-state **engine speed** without load at the same speed setting as for the **declared speed**

2.3.2
declared speed

n_r

speed at which the engine delivers the declared power

[ISO 2710-1:2000, definition 11.1.2]

2.3.3
engaging speed

n_c

engine speed at which the driven device is coupled to the engine

2.3.4
engine speed

n

number of crankshaft revolutions in a given period of time

[ISO 2710-1:2000, definition 11.1]

2.3.5
fast idling speed

$n_\mathrm{i,f}$

increased **lowest adjustable no-load speed**

NOTE This speed is often used for cold engine start and during engine warm-up. It can be achieved by either manual or automatic adjustment.

[ISO 7967-7:2005, definition 3.6.1.13]

2.3.6
firing speed

n_{sf}

speed to which an engine is accelerated from rest by the use of an external energy supply separate from the fuel feed system before it becomes self-sustaining

[ISO 2710-1:2000, definition 11.1.5]

NOTE The firing speed (and **starting speed**) depend upon the ambient and operating conditions of the engine during start and upon the type of starting system used.

2.3.7
highest adjustable no-load speed based on overload speed

$n_{\mathrm{i,ov}}$

highest steady-state engine speed without load at the same speed setting as for **overload speed**

NOTE For generating sets, this speed can be selected by the speed governor speed-setting device (see ISO 8528-5).

2.3.8
idling speed

steady-state **engine speed** without load

NOTE Adapted from ISO 2710-1:2000, definition 11.1.4.

2.3.9
lowest adjustable speed

$n_{\mathrm{p,min}}$

lowest steady-state **engine speed** which can be selected by the **speed-setting device** with the engine coupled and operating on the propeller curve or on another specified power curve

2.3.10
lowest adjustable no-load speed

$n_{\mathrm{i,min}}$

low idling speed

lowest steady-state **engine speed** without load at the same speed setting as for **lowest adjustable speed**

NOTE 1 For generating sets, this speed can be selected by the speed-setting device of the speed governor (see ISO 8528-5).

NOTE 2 Adapted from ISO 7967-7:2005, definition 3.6.1.8.

2.3.11
lowest continuous full-load speed

$n_{\mathrm{f,l}}$

steady-state lowest permissible **engine speed** at full load (fuel control rod for rated power)

2.3.12
lowest continuous speed at partial power

$n_{\mathrm{p,l}}$

steady-state lowest permissible continuous **engine speed** on the propeller curve or on another specified power curve

2.3.13
no-load speed

n_{i}

speed at maximum torque

n_{tq}

engine speed at **maximum torque** on maximum fuel position, including, if applicable, any additional torque fuel setting

2.3.14
no-load speed based on speed at partial power

$n_{\mathrm{i,p}}$

steady-state **engine speed** without load at the same speed setting as for **speed at partial power**

2.3.15
overload speed

n_{ov}

speed at which the engine delivers the overload power declared by the manufacturer

2.3.16
speed at partial power

n_{p}

steady-state **engine speed** between the **declared speed** and the lowest adjustable speed

2.3.17
starting speed

n_{s}

maximum speed to which the engine (together with the mechanically-coupled auxiliaries) can be accelerated by the starting system when the fuel rack is in the stop position

NOTE 1 The starting speed (and firing speed) depend upon the ambient and operating conditions of the engine during start and upon the type of starting system used.

NOTE 2 The starting speed can be influenced by the power requirements of the auxiliary equipment and will be higher than the firing speed.

2.4 Dynamic speed behaviour

2.4.1
overshoot speed

$n_{\mathrm{d,max}}$

maximum transient engine speed which occurs on change from a higher to a lower power or on change of speed setting from lower to higher speed

NOTE Adapted from ISO 7967-7:2005, definition 3.6.2.2.

2.4.2
speed recovery time on load increase

$t_{\mathrm{n,in}}$

speed recovery time on load decrease

$t_{\mathrm{n,de}}$

time interval between the departure from the steady-state speed band after a specified load change and the permanent re-entry of the speed into the specified steady-state speed band at the new speed

2.4.3
transient speed difference (from initial speed) on load increase (–) or on load decrease (+)

δn_{dyn}

temporary speed difference between undershoot (or overshoot) speed and initial speed during the governing process following load change

NOTE Transient speed difference is expressed as a percentage of initial speed where a negative sign relates to an undershoot after a load increase and a positive sign to an overshoot after a load decrease, calculated using the following equations respectively:

$$\delta n_{\mathrm{dyn}}^{-} = \frac{n_{\mathrm{d,min}} - n_{\mathrm{i,p}}}{n_{\mathrm{p}}} \times 100$$

$$\delta n_{\mathrm{dyn}}^{+} = \frac{n_{\mathrm{d,max}} - n_{\mathrm{i,p}}}{n_{\mathrm{p}}} \times 100$$

2.4.4

undershoot speed

$n_{\mathrm{d,min}}$

minimum transient engine speed which occurs on change from a lower to a higher power or on change of speed setting from higher to lower speed

NOTE Adapted from ISO 7967-7:2005, definition 3.6.2.1.

2.5 Symbols and subscripts

2.5.1 Symbols

c	constant to compute the steady-state speed band
m	constant for the exponents to compute the steady-state speed band
P_{a}	actual delivered power of an individual engine
P_{r}	declared (rated) power of an individual engine
Δn	width of the envelope of oscillation of speed at constant power around a mean value
$\sum P_{\mathrm{a}}$	sum of powers actually delivered by all engines operating in parallel
$\sum P_{\mathrm{r}}$	sum of the declared (rated) powers of all engines operating in parallel

2.5.2 Subscripts

a	actual
c	coupled
de	decrease
dyn	dynamic
f	full load
i	no load (idling)
in	increase
l	lowest
n	speed
ov	overload
p	partial-load power
r	declared (rated)
s	starting
sf	firing
st	static deviation (droop)
tq	torque

3 Classification of speed-governing systems

3.1 For the classification and assessment of speed-governing systems, the following characteristics or qualities are essential:

a) speed sensing and amplification of the output signal;

b) dynamic behaviour (transfer function);

c) function related to engine application.

In addition, it is important to know the type of speed-setting device used.

3.2 For examples of speed-governing systems relating to compression-ignition oil engines, see Figures 4 and 5. For an example of an RIC engine running at constant speed, see ISO 8528-2:2005, Figure 1.

4 Dynamic speed behaviour

The dynamic speed behaviour (see Figure 6) is dependent on:

a) whether a turbocharging system is installed on the RIC engine;

b) the brake mean effective pressure (p_{me}) of the RIC engine at declared power;

c) the speed governor behaviour;

d) the operating behaviour of the driven machinery;

e) the rotational inertia of the RIC engine and driven machinery;

f) the coupling between the RIC engine and driven machinery.

Since the operating behaviour of the driven machinery is unknown to the engine manufacturer, no specifications or values for transient engine behaviour can be stated.

5 Additional regulations and requirements

The following are additional to the requirements given in Clauses 6 to 8.

- For engines used on ships and offshore installations which have to comply with rules of a classification society, the additional requirements of the classification society shall be observed. The classification society shall be stated by the customer prior to placing of the order.

- For non-classed engines, such additional requirements are, in each case, subject to agreement between the manufacturer and customer.

If other special requirements are to be met, for example regulations imposed by an inspecting or legislative authority, then such authority shall be stated by the customer prior to placing the order.

Any further additional requirements shall be subject to agreement between the manufacturer and customer.

6 Technical requirements for speed-governing systems

The customer or the engine manufacturer shall specify the technical requirements for the operating limiting-values and the accuracy of the speed-governing system in accordance with Clause 8. The engine manufacturer usually selects the speed-governing system to meet these requirements.

The range of speed setting (Δn_s) shall be defined in agreement between the engine manufacturer and the customer depending on the engine application (see Figures 4 and 5).

In the case of parallel operation of all engines on one shaft, the engine load sharing depends on the speed droop and the accuracy of the governor speed-setting device. By using an automatic load-sharing device, the limited values may be reduced. When adjusting the speed governor and the speed-setting device, the limited values for the lowest engine power at the lowest adjustable speed and the declared power at declared speed shall be smaller. To keep the limited values when load sharing, the speed droop shall be within the limits given in Table 1.

7 Testing of speed-governing systems

The speed-governing system shall be tested either during the acceptance test or, if necessary, during the operating test of the engine coupled to the driven machinery agreed to in the contract (see ISO 3046-1). The limiting values shall be checked and recorded.

8 Classification of performance and steady-state limiting values for speed-governing systems

As the dynamic behaviour for the speed-governing system is dependent on the application and the driven machinery, only the steady-state limiting values are laid down in this part of ISO 3046 (see Table 1). The limiting values for generator sets are given in ISO 8528-5:2005, Clause 16.

The requirements for speed-governing accuracy are specified by the following four performance classes.

- M1: reduced requirements over a wide range of engine speed (see Figure 1).
- M2: normal requirements over a wide range of engine speed (see Figure 2).
- M3: high requirements over a wide range of engine speed (see Figure 3).
- M4: requirements shall be by agreement between the manufacturer and customer.

Customers should select the minimum performance class that will meet their requirements.

NOTE Accuracy of the speed governor operating behaviour can be affected by thermal drift in the speed governor and a load change of the RIC engine. Therefore, it is assumed that all measurements are made at steady-state temperature and constant load.

The engine manufacturer shall state the normal period of time required after engine start to establish controllability within the limiting values specified in Table 1.

When, depending on the engine application, a normal period of time is not required or must be reduced, the periods of time and technical measures to be taken shall be agreed between the engine manufacturer and the customer.

Table 1 — Operating limit values

Parameter	Symbol	Unit	Operating limit values for performance class[a]						
			M1[b]		M2[c]		M3		M4
Declared speed droop[d] (see 2.2.1)	$\delta n_{\mathrm{st,r}}$	%	$\leqslant 15$		$\leqslant 10$		$\leqslant 5$		AMC[e]
Steady-state speed band (see 2.2.9)	βn	%	See Figure 1		See Figure 2		See Figure 3		AMC[e]
Steady-state speed band with engine coupled to driven machinery where:	—	—	c	m	c	m	c	m	AMC[e]
$n < 0{,}5\ n_{\mathrm{r}}$	—	—	48	0,440	70	0,545	48	0,530	AMC[e]
$n \geqslant 0{,}5\ n_{\mathrm{r}}$ and $P \geqslant 0{,}25\ P_{\mathrm{r}}$ [f]	—	—	39	0,455	49	0,540	40	0,550	AMC[e]
$n \geqslant 0{,}5\ n_{\mathrm{r}}$ and $P < 0{,}25\ P_{\mathrm{r}}$ [f]	—	—	48	0,440	70	0,545	48	0,530	AMC[e]
Steady-state speed band with engine not coupled to driven machinery and running at lowest adjustable no-load speed	—	—	68	0,460	104	0,550	63	0,530	AMC[e]
Rate of change of speed setting (see 2.2.6)	v_n	%/s	AMC[e]		AMC[e]		AMC[e]		AMC[e]
Load sharing at parallel operation (several engines driving one shaft[e]) (see 2.2.2)	ΔP	%	$\leqslant 10$		$\leqslant 10$		$\leqslant 10$		AMC[e]

NOTE For propulsion systems with shaft driven generators, the required transient speed variations and load sharing (in the case of parallel operation with a generating set) shall be agreed between the manufacturer and customer.

[a] The values for classes A1 and A2 included in ISO 3046-4:1997 have been incorporated into ISO 8528-5 as performance classes G2 and G1 applied to RIC engine-driven generating sets.

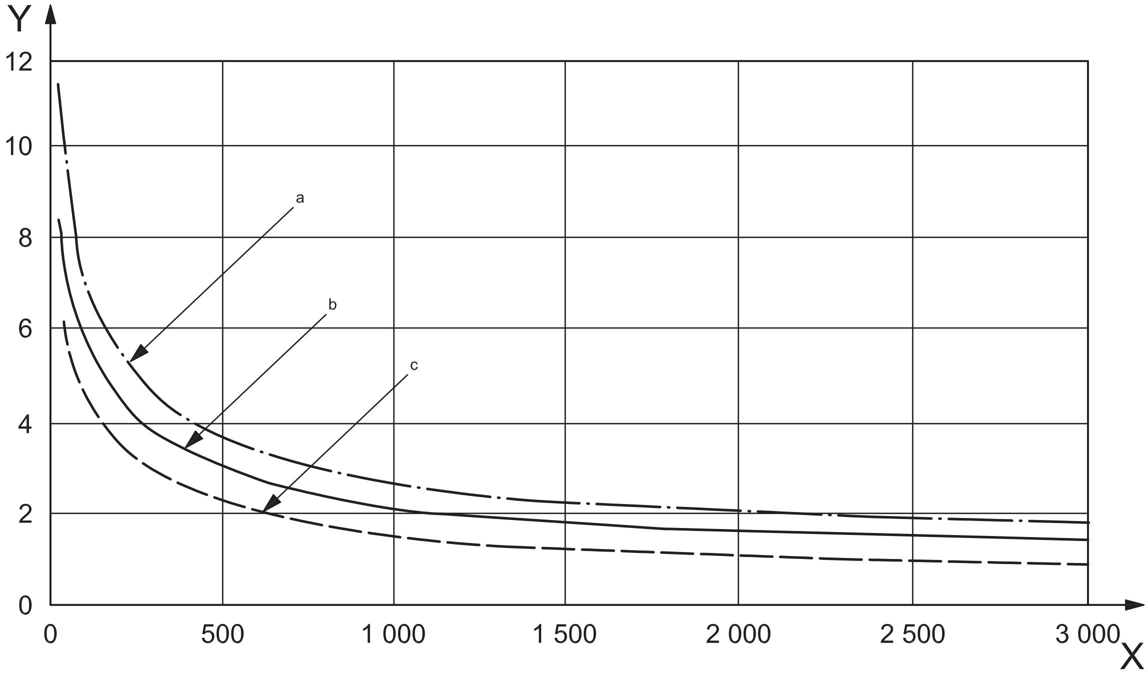
[b] Performance class M1 corresponds to class B2 of ISO 3046-4:1997.

[c] Performance class M2 corresponds to class B1 of ISO 3046-4:1997.

[d] For some applications there is no declared speed droop (i.e. isochronous control).

[e] Agreement between manufacturer and customer.

[f] As a result of technical conditions (e.g. parallel running of engines with different power outputs with speed control not having sufficiently adaptable characteristics), a higher value for ΔP may be specified by agreement between the manufacturer and customer. However, in such cases the permissible power output of the smaller engine corresponding to the relevant operating condition shall not be exceeded.



Key

X declared speed, n_r (min^{-1})

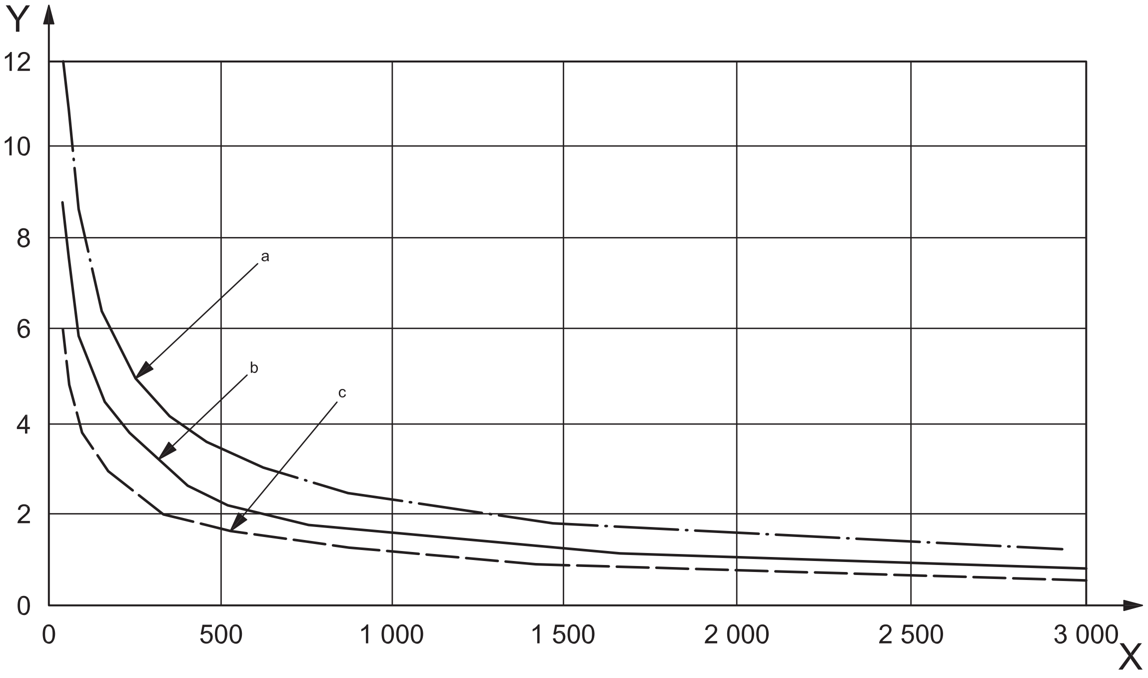
Y steady-state speed band, βn (%)

[a] Engine not coupled to driven machinery.

[b] $n < 0{,}5\ n_r$ or $n \geqslant 0{,}5\ n_r$ and $P < 0{,}25\ P_r$.

[c] $n \geqslant 0{,}5\ n_r$ and $P \geqslant 0{,}25\ P_r$.

Figure 1 — Operating limit values for performance class M1



Key

X declared speed, n_r (min^{-1})

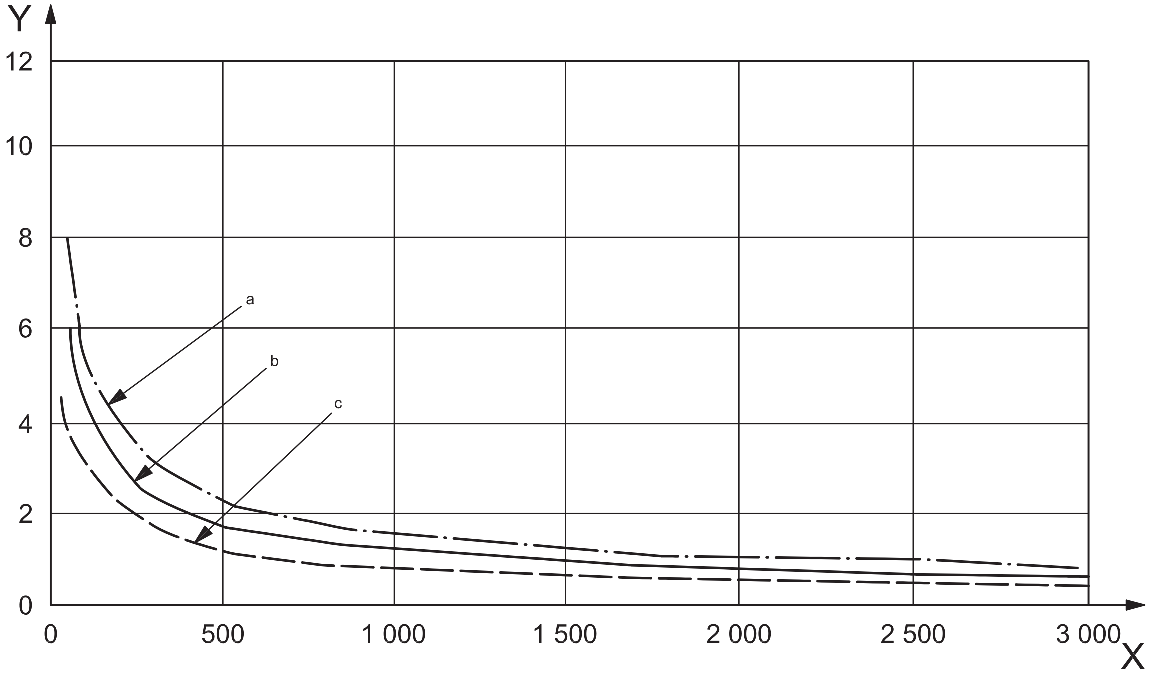
Y steady-state speed band, βn (%)

[a] Engine not coupled to driven machinery.

[b] $n < 0{,}5\ n_r$ or $n \geqslant 0{,}5\ n_r$ and $P < 0{,}25\ P_r$.

[c] $n \geqslant 0{,}5\ n_r$ and $P \geqslant 0{,}25\ P_r$.

Figure 2 — Operating limit values for performance class M2



Key

X declared speed, n_r (min^{-1})

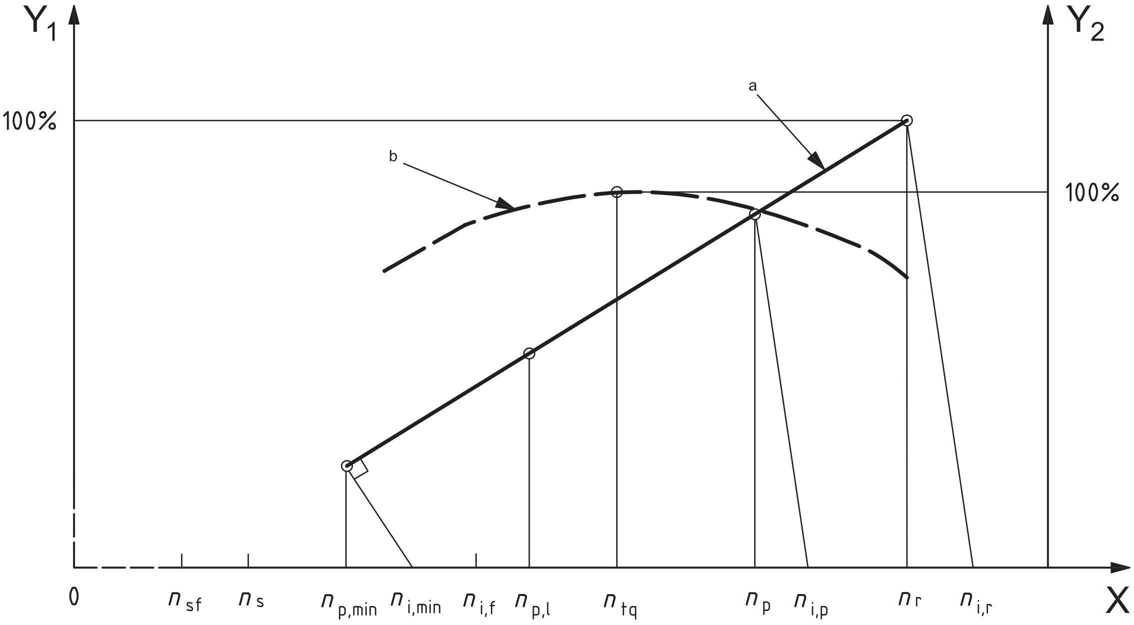
Y steady-state speed band, βn (%)

[a] Engine not coupled to driven machinery.

[b] $n < 0{,}5\ n_r$ or $n \geqslant 0{,}5\ n_r$ and $P < 0{,}25\ P_r$.

[c] $n \geqslant 0{,}5\ n_r$ and $P \geqslant 0{,}25\ P_r$.

Figure 3 — Operating limit values for performance class M3



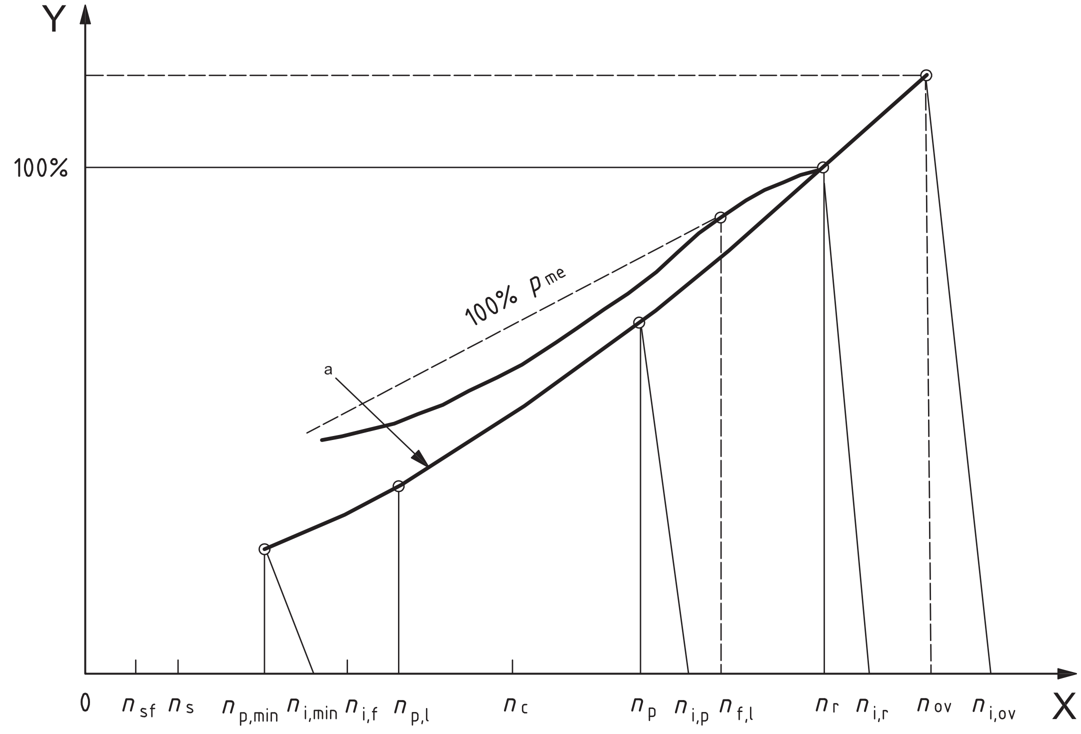
Key

X	engine speed, n (min^{-1})
Y_1	engine power
Y_2	engine torque

[a] Engine power curve.

[b] Engine torque curve.

Figure 4 — Compression ignition oil engine with defined control rod position



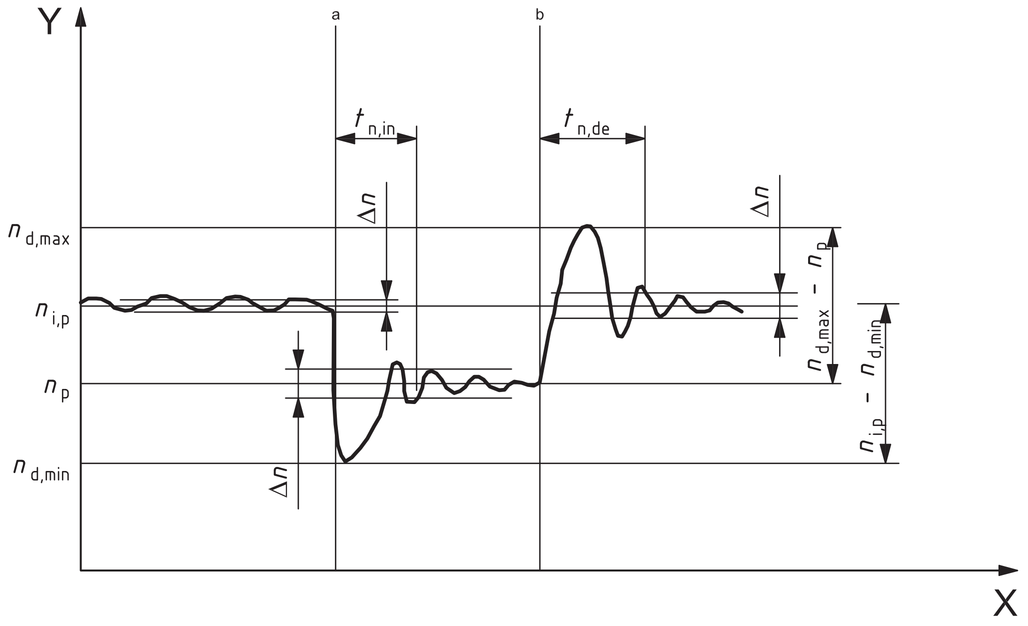
Key

X engine speed, n (min^{-1})

Y engine power

[a] Nominal propeller curve.

Figure 5 — Compression ignition oil engine for use with a fixed-pitch propeller



Key

X time, *t*
Y engine speed, *n* (min^{-1})

[a] Power increase.

[b] Power decrease.

Figure 6 — Dynamic speed behaviour

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