INTERNATIONAL STANDARD

ISO 8528-2

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Reciprocating internal combustion engine driven alternating current generating sets —

Part 2:
Engines

Groupes électrogènes à courant alternatif entraînés par moteurs alternatifs à combustion interne —

Partie 2: Moteurs

Reference number
ISO 8528-2:1993(E)

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.

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.

International Standard ISO 8528-2 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*, Sub-Committee SC 2, *Performance and tests.*

ISO 8528 consists of the following parts, under the general title *Reciprocating internal combustion engine driven alternating current generating sets*:

— *Part 1: Application, ratings and performance*

— *Part 2: Engines*

— *Part 3: Alternating current generators for generating sets*

— *Part 4: Controlgear and switchgear*

— *Part 5: Generating sets*

— *Part 6: Test methods*

— *Part 7: Technical declarations for specification and design*

— *Part 8: Low-power general-purpose generating sets*

— *Part 9: Measurement and evaluation of mechanical vibration*

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— *Part 10: Measurement of airborne noise — Enveloping surface method*

— *Part 11: Security generating sets with uninterruptible power systems*

Parts 7, 8, 9 and 10 are in course of preparation. Part 11 is at an early stage of preparation and may be split into two parts.

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Reciprocating internal combustion engine driven alternating current generating sets —

Part 2:
Engines

1 Scope

This part of ISO 8528 specifies the principal characteristics of a reciprocating internal combustion (RIC) engine when used for alternating current (a.c.) generating set applications.

It applies to RIC engines for a.c. generating sets for land and marine use, excluding generating sets used on aircraft or to propel land vehicles and locomotives.

For some specific applications (for example, essential hospital supplies, high rise buildings, etc.), supplementary requirements may be necessary. The provisions of this part of ISO 8528 should be regarded as a basis.

The terms which define the speed governing and the speed characteristics of RIC engines are listed and explained where they apply specifically to the use of the engine for driving generators.

For other reciprocating-type prime movers (e.g. sewage gas engines, steam engines), the provisions of this part of ISO 8528 should be used as a basis.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8528. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8528 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3046-1:1986, *Reciprocating internal combustion engines — Performance — Part 1: Standard reference conditions and declarations of power, fuel consumption and lubricating oil consumption.*

ISO 3046-4:1978, *Reciprocating internal combustion engines — Performance — Part 4: Speed governing.*

ISO 3046-5:1978, *Reciprocating internal combustion engines — Performance — Part 5: Torsional vibrations.*

ISO 3046-6:1990, *Reciprocating internal combustion engines — Performance — Part 6: Overspeed protection.*

ISO 8528-1:1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance.*

ISO 8528-5:1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 5: Generating sets.*

3 Symbols

n_r	Declared speed, in revolutions per minute
n_{sf}	Firing speed, in revolutions per minute
n_{max}	Maximum permissible speed, in revolutions per minute
n_a	Partial-load speed, in revolutions per minute
$n_{i,r}$	Declared no-load speed, in revolutions per minute

$n_{i,min}$	Lowest adjustable no-load speed, in revolutions per minute
$n_{i,max}$	Highest adjustable no-load speed, in revolutions per minute
$n_{d,s}$	Setting speed of overspeed limiting devices, in revolutions per minute
$n_{d,o}$	Operating speed of overspeed limiting devices, in revolutions per minute
δn_s	Related range of speed setting
Δn_s	Range of speed setting
$\Delta n_{s,do}$	Downward range of speed setting
$\delta n_{s,do}$	Related downward range of speed setting
$\Delta n_{s,up}$	Upward range of speed setting
$\delta n_{s,up}$	Related upward range of speed setting
v_n	Rate of change of speed setting
δn_{st}	Speed droop
$\Delta \delta n_{st}$	Speed/power characteristic deviation
P	Engine power, in kilowatts
P_a	Actual engine power, in kilowatts
P_r	Declared engine power, in kilowatts
t_r	Response time, in seconds
p_{me}	Brake mean effective pressure, in kilopascals
V_{st}	Swept volume of the engine, in cubic centimetres

4 Other regulations and additional requirements

4.1 For RIC engines driving a.c. generating sets used on board 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 engines operating in non-classed equipment, such additional requirements are in each case subject to agreement between the manufacturer and customer.

4.2 If special requirements from regulations of any other authority (e.g. inspecting and/or legislative authorities) have to be met, the authority shall be stated by the customer prior to placing of the order.

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

5 General characteristics

5.1 Power characteristics

5.1.1 General

The power output required at the RIC engine coupling (net brake power as defined in ISO 3046-1) shall take into account the required electrical power for the customer's plant, the electrical power required for the essential independent auxiliaries (see ISO 3046-1) and the power loss in the a.c. generator.

In addition to the steady-state power requirement, sudden power changes due to additional loads, e.g. caused by electric motor starting, shall be taken into account since they affect the power output characteristics of RIC engines and voltage characteristics of a.c. generators.

The generating set manufacturer shall therefore take due account of any particular characteristic of the connected electrical load and of any load acceptance conditions expected by the customer.

5.1.2 ISO standard power

The power shall be declared by the engine manufacturer in accordance with ISO 3046-1.

5.1.3 Service power

The RIC engine power (see ISO 8528-1) required for a particular application, under site conditions to drive the a.c. generator with any essential independent auxiliaries (see ISO 3046-1), and with the generating set developing rated electrical power, shall be determined in accordance with ISO 3046-1.

In order to ensure a continuous supply of electrical power to the connected load, it is essential that the actual power output required from the RIC engine driving the generator is not more than the service power. The RIC engine driving the generator shall provide additional power to meet any specified transient load requirements. Overload power, as defined in ISO 3046-1, is not available.

5.2 Main characteristics of the RIC engine

The main characteristics of the RIC engine to be used by the generating set manufacturer shall be given by the engine manufacturer, specifying

— the power under ISO standard and service conditions;

— the declared speed;

— the fuel and lubricating oil consumptions under ISO standard conditions.

These characteristics declared by the engine manufacturer enable the generating set manufacturer and customer to confirm that the main characteristics of the RIC engines available are suitable for the application.

In order to evaluate the generating set service conditions (in particular, sudden-load acceptance) it is necessary to establish the brake mean effective pressure, p_{me}, in kilopascals[1)], of the engine used, corresponding to the engine power when the generating set is operating at its declared power and rated frequency, and defined as follows:

$$p_{me} = \frac{K\,P}{V_{st}\,n_r}$$

where $K = 1{,}2 \times 10^5$ for a four-stroke engine and $0{,}6 \times 10^5$ for a two-stroke engine.

5.3 Low-load operation

The customer shall be made aware that extended running under low load may affect the reliability and life of the RIC engine. The onus is on the RIC engine manufacturer to provide the generating set manufacturer with data of the minimum load the RIC engine is capable of sustaining indefinitely without deterioration. If the generating set is to be operated at lower loads than this minimum load, the onus is on the RIC engine manufacturer to specify, and if necessary recommend, the measures to be adopted and/or corrective procedures to be used.

6 Speed characteristics

6.1 General

The choice of governing system shall be based upon the steady-state and transient speed performance requested by the customer. The generating set manufacturer shall ensure that a suitable governing system, approved by the RIC engine manufacturer, is selected to meet the application requirements.

NOTE 1 ISO 3046-4 establishes general requirements and parameters of speed governing systems. ISO 3046-6 establishes general requirements for overspeed protection devices.

The terms, symbols and definitions for speed characteristics are given in 6.2 to 6.5.

1) 100 kPa = 1 bar

6.2 General speed terms

No.	Term	Symbol	Definition
6.2.1	Declared speed	n_r	Engine speed at declared power corresponding to the rated frequency of the generating set.
6.2.2	Firing speed (starting speed)	n_{sf}	Engine speed to which an engine must be accelerated from rest by the use of an external supply of energy separate from the fuel feed system before the engine becomes self-sustaining.
6.2.3	Partial-load speed	n_a	Steady-state engine speed of an engine running at a % of the declared power: $a = 100 \times \frac{P_a}{P_r}$ EXAMPLE 45 % power: $a = 45$ (see figure 2) For $a = 45$ $n_a = n_{i,r} - \frac{P_a}{P_r}(n_{i,r} - n_r)$ $= n_{i,r} - 0{,}45\,(n_{i,r} - n_r)$ Corresponding values of declared speed and partial-load speed are based on an unchanged speed setting.
6.2.4	Delcared no-load speed	$n_{i,r}$	Steady-state engine speed without load at the same speed setting as for the declared speed n_r (it is a particular case of 6.2.3; see figure 1).

6.3 Speed setting terms of governor (see figure 1)

No.	Term	Symbol	Definition
6.3.1	Lowest adjustable no-load speed	$n_{i,min}$	Lowest steady-state engine speed without load obtainable on the governor speed setting device.
6.3.2	Highest adjustable no-load speed	$n_{i,max}$	Highest steady-state engine speed without load obtainable on the governor speed setting device.
6.3.3	Range of speed setting	Δn_s	Range between the highest and lowest adjustable no-load speeds: $\Delta n_s = n_{i,max} - n_{i,min}$
	Related range of speed setting	δn_s	Range of speed setting, expressed as a percentage of the declared speed: $\delta n_s = \frac{n_{i,max} - n_{i,min}}{n_r} \times 100$

No.	Term	Symbol	Definition
6.3.3.1	Downward range of speed setting	$\Delta n_{s,do}$	Range between the declared no-load speed and the lowest adjustable no-load speed: $$\Delta n_{s,do} = n_{i,r} - n_{i,min}$$
	Related downward range of speed setting	$\delta n_{s,do}$	Downward range of speed setting, expressed as a percentage of the declared speed: $$\delta n_{s,do} = \frac{n_{i,r} - n_{i,min}}{n_r} \times 100$$
6.3.3.2	Upward range of speed setting	$\Delta n_{s,up}$	Range between the highest adjustable no-load speed and the declared no-load speed: $$\Delta n_{s,up} = n_{i,max} - n_{i,r}$$
	Related upward range of speed setting	$\delta n_{s,up}$	Upward range of speed setting, expressed as a percentage of the declared speed: $$\delta n_{s,up} = \frac{n_{i,max} - n_{i,r}}{n_r} \times 100$$
6.3.4	Rate of change of speed setting	v_n	Rate of change of speed setting under remote control, expressed as a percentage of the related range of speed setting per second: $$v_n = \frac{(n_{i,max} - n_{i,min})/n_r}{t} \times 100$$

6.4 Steady-state speed terms of governor

No.	Term	Symbol	Definition
6.4.1	Speed droop	δn_{st}	Difference between the declared no-load speed and the declared speed at declared power, for a fixed speed setting (see figure 1). It is expressed as a percentage of the declared speed. $$\delta n_{st} = \frac{n_{i,r} - n_r}{n_r} \times 100$$
6.4.2	Speed/power characteristic curve	—	Curve of steady-state speeds in the power range between no-load and declared power plotted against RIC engine power (see figures 1 and 2).
6.4.3	Speed/power characteristic deviation	$\Delta\delta n_{st}$	Maximum deviation from a linear speed power characteristic curve in the power range between no-load and declared power, expressed as a percentage of the declared speed (see figure 2).

6.5 Overspeed terms

No.	Term	Symbol	Definition
6.5.1	Maximum permissible speed	n_{max}	Speed of the engine specified by the RIC engine manufacturer which lies a safe amount below the speed limit (see note 2 and figure 3).
6.5.2	Setting speed of overspeed limiting device	$n_{d,s}$	Speed of the engine, the exceeding of which activates the overspeed limiting device (see figure 3).

No.	Term	Symbol	Definition
6.5.3	Operating speed of overspeed limiting device	$n_{d,o}$	Speed of the engine, at which, for a given setting speed, the overspeed limiting device starts to operate (see note 3 and figure 3).
6.5.4	Response time	t_r	Time between activation of the overspeed limiting device and commencement of its operation.
6.5.5	Adjustment range	—	Speed range over which the overspeed limiting device may be adjusted.

NOTES

2 The speed limit is the maximum calculated speed which the engine may sustain without risk of damage.

3 For a given engine, the operating speed depends on the total inertia of the generating set and the design of the overspeed protection system.

6.6 Types of speed governors used for generating sets

6.6.1 A proportional governor (P) corrects the control signal proportionally to a load-related speed change. The change in load results in a change of the steady-state speed.

6.6.2 A proportional integral governor (PI) corrects the control signal proportionally when there is a load-related change in speed and also corrects the change in speed with an integral action. If this governor type is used, usually a change in load does not result in a change in speed.

To make parallel operation of generating sets possible, a PI governor shall also work as a P governor, if no additional governing of the load sharing is provided.

6.6.3 A proportional integral differential governor (PID) is a proportional integral governor which also corrects the control signal proportionally to the rate of speed change. If this governor type is used, usually a change in load does not result in a change in speed.

To make parallel operation of generating sets possible, a PID governor shall also work as a P governor, if no additional governing of the load sharing is provided.

6.7 Use of speed governor (see also ISO 8528-1:1993, 6.3)

6.7.1 Single operation

P, PI and PID governors may be used, depending on the governing performance required by the application.

6.7.2 Parallel operation

6.7.2.1 A proportional governor (P) shall be used for performance classes G1 and G2 (see ISO 8528-1:1993, clause 7).

6.7.2.2 A proportional integral governor (PI) shall be used for performance classes G1 to G4. If used in isochronous mode, it requires an auxiliary device such as a load-sharing facility.

6.7.2.3 A proportional integral differential governor (PID) shall be used for performance classes G1 to G4 and in the same way as a PI governor, but with improved transient performance. If used in isochronous mode, it requires an auxiliary device such as a load-sharing facility.

7 Load acceptance

The load-acceptance behaviour of an RIC engine depends mainly on the type of combustion air supply system (see ISO 8528-1:1993, 14.2).

The generator set manufacturer should consider the actual load-acceptance behaviour of the RIC engine and generator used (see ISO 8528-5:1993, 9.3 and figures 6 and 7).

7.1 Non-turbocharged

This means naturally aspirated or pressure-charged by a mechanically driven compressor.

In this case, the maximum possible load step is equal to the service power.

7.2 Turbocharged

In this case, the load steps which may be applied to the engine vary according to the brake mean effective pressure (p_{me}), corresponding to the service power.

8 Vibration and noise

8.1 Torsional vibration

The RIC engine produces torsional vibrations in the complete shaft system of the generating set. Requirements relating to torsional vibrations of RIC engines are dealt with in ISO 3046-5.

The engine manufacturer shall supply the generating set manufacturer with the necessary information to enable him to ensure satisfactory operation. The generating set as a whole has to be considered when calculating torsional vibrations (see ISO 8528-5).

8.2 Linear vibration

The RIC engine produces linear vibrations which act as structural vibrations on the baseframe, foundation, coupling and the a.c. generator.

The engine manufacturer shall provide data relating to linear vibrations to the generating set manufacturer if requested. The generating set as a whole has to be considered when calculating linear vibrations (see ISO 8528-5).

8.3 Noise

The RIC engine manufacturer shall provide the generator set manufacturer with data relating to noise if requested (see ISO 8528-5).

9 Heat balance

The RIC engine manufacturer shall provide the generating set manufacturer with the heat balance data (for on-site conditions), including

— the RIC engine cooling heat (water, oil, air);
— the exhaust gas heat;
— the radiated heat dissipation.

10 Inlet and exhaust system

The RIC engine manufacturer shall provide the generating set manufacturer with the necessary data on air aspiration and exhaust gas.

The generating set manufacturer shall take into account the pressure loss limitations specified by the RIC engine manufacturer:

— in the pipes, openings or filtering devices of the RIC engine air intake system;
— in the pipes, silencers, etc. for the RIC engine exhaust gases.

11 Starting ability

If the RIC engine is required to start under particular conditions specified by the generating set customer or manufacturer (for instance at low ambient temperature), the RIC engine manufacturer shall provide the generating set manufacturer with starting capability figures for the RIC engine under these conditions, and details of any special starting aids required.

12 Fuel, lubricants and coolant

If necessary, the generating set manufacturer shall provide the RIC engine manufacturer with details of the fuel, lubricating oil and coolant to be used in service for approval.

The RIC engine manufacturer should provide the generating set manufacturer with specifications of recommended fuel, lubricants and coolant.

The following fuel characteristics are of particular significance:

— density;
— viscosity;
— calorific value;
— cetane number;
— vanadium, sodium, silica and aluminium oxide content;
— in the case of heavy fuel, the sulfur content.

13 Values of terms for governing system

The values of terms for the governing system are given in 13.1 to 13.4.

<table>
<tr><th rowspan="3">No.</th><th rowspan="3">Term</th><th rowspan="3">Symbol</th><th rowspan="3">Unit</th><th rowspan="3">Reference</th><th colspan="4">Values</th></tr>
<tr><th colspan="4">Performance class</th></tr>
<tr><th>G1</th><th>G2</th><th>G3</th><th>G4</th></tr>
<tr><td>13.1</td><td>Related downward speed setting range</td><td>$\delta n_{s,do}$</td><td>%</td><td>6.3.3.1</td><td colspan="3">$-(2{,}5+\delta n_{s,t})$</td><td rowspan="4">AMC[1)]</td></tr>
<tr><td>13.2</td><td>Related upward speed setting range</td><td>$\delta n_{s,up}$</td><td>%</td><td>6.3.3.2</td><td colspan="3">$+2{,}5$</td></tr>
<tr><td>13.3</td><td>Rate of change of speed setting</td><td>v_n</td><td>$\% \ s^{-1}$</td><td>6.3.4</td><td colspan="3">0,2 to 1</td></tr>
<tr><td>13.4</td><td>Speed droop</td><td>δn_{st}</td><td>%</td><td>6.4.1</td><td>$\leqslant 8$</td><td>$\leqslant 5$</td><td>$\leqslant 3$</td></tr>
<tr><td colspan="9">1) AMC = by agreement between manufacturer and customer.</td></tr>
</table>