Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”
Mazdoor Kisan Shakti Sangathan
“The Right to Information, The Right to Live”

“पुराने को छोड़ नये के तरफ”
Jawaharlal Nehru
“Step Out From the Old to the New”


“ज्ञान से एक नये भारत का निर्माण”
Satyanarayan Gangaram Pitroda
“Invent a New India Using Knowledge”

“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”
Bhartrhari—Nitisatakam
“Knowledge is such a treasure which cannot be stolen”
Indian Standard

RECIPROCATING INTERNAL COMBUSTION ENGINE DRIVEN ALTERNATING CURRENT GENERATING SETS

PART 2 ENGINES

ICS 27.020; 29.160.40
NATIONAL FOREWORD

This Indian Standard (Part 2) which is identical with ISO 8528-2 : 2005 ‘Reciprocating internal combustion engine driven alternating current generating sets — Part 2: Engines’ issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Automotive Primemovers Transmission and Steering Systems and Internal Combustion Engines Sectional Committee and approval of the Transport Engineering Division Council.

The text of ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words ‘International Standard’ appear referring to this standard, they should be read as ‘Indian Standard’.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

This standard also makes a reference to the BIS Certification Marking. Details of which are given in National Annex A.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

<table>
<thead>
<tr>
<th>International Standard</th>
<th>Corresponding Indian Standard</th>
<th>Degree of Equivalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 3046-1</td>
<td>IS 10000 (Part 4) : 1980 Methods of test for internal combustion engines: Part 4 Declarations of power, efficiency, fuel consumption and lubricating oil consumption</td>
<td>Technically Equivalent</td>
</tr>
</tbody>
</table>

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

<table>
<thead>
<tr>
<th>International Standard</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 3046-4</td>
<td>Reciprocating internal combustion engines — Performance — Part 4: Speed governing</td>
</tr>
</tbody>
</table>

(Continued on third cover)
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 (e.g. essential hospital supplies, high rise buildings), supplementary requirements may be necessary. The provisions of this part of ISO 8528 should be regarded as the basis for establishing any supplementary requirements.

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

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

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3046-1, 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

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

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

ISO 8528-1\(^2\), Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance

ISO 8528-5\(^2\), Reciprocating internal combustion engine driven alternating current generating sets — Part 5: Generating sets

\(^2\) ISO 8528-1 and ISO 8528-5 are under revision.
## 3 Symbols, terms and definitions

An explanation of the symbols and abbreviations used in this International Standard is shown in Table 1.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Term</th>
<th>Unit</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n )</td>
<td>Engine speed</td>
<td>( \text{min}^{-1} )</td>
<td>Engine speed at declared power corresponding to the rated frequency of the generating set.</td>
</tr>
<tr>
<td>( n_r )</td>
<td>Declared speed</td>
<td>( \text{min}^{-1} )</td>
<td>Engine speed at declared power corresponding to the rated frequency of the generating set.</td>
</tr>
<tr>
<td>( n_{sf} )</td>
<td>Firing speed</td>
<td>( \text{min}^{-1} )</td>
<td>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.</td>
</tr>
<tr>
<td>( n_{\text{max}} )</td>
<td>Maximum permissible speed</td>
<td>( \text{min}^{-1} )</td>
<td>Speed of the engine specified by the RIC engine manufacturer which lies a safe amount below the speed limit (see Note 1 and Figure 3).</td>
</tr>
<tr>
<td>( n_a )</td>
<td>Partial-load speed</td>
<td>( \text{min}^{-1} )</td>
<td>Steady-state engine speed of an engine running at ( a % ) of the declared power given by: [ a = 100 \times \frac{P_a}{P_r} ] EXAMPLE: at 45 % power, ( a = 45 ) (see Figure 2) For ( a = 45 ) [ n_a = n_{lf} - \frac{P_a}{P_r} (n_{lf} - n_r) ] [ = n_{lf} - 0.45 (n_{lf} - n_r) ] Corresponding values of declared speed and partial-load speed are based on an unchanged speed setting.</td>
</tr>
<tr>
<td>( n_{lf} )</td>
<td>Declared no-load speed</td>
<td>( \text{min}^{-1} )</td>
<td>Steady-state engine speed without load at the same speed setting as for the declared speed ( n_r ).</td>
</tr>
<tr>
<td>( n_{\text{min}} )</td>
<td>Lowest adjustable no-load speed</td>
<td>( \text{min}^{-1} )</td>
<td>Lowest steady-state engine speed without load obtainable on the governor speed setting device.</td>
</tr>
<tr>
<td>( n_{\text{max}} )</td>
<td>Highest adjustable no-load speed</td>
<td>( \text{min}^{-1} )</td>
<td>Highest steady-state engine speed without load obtainable on the governor speed setting device.</td>
</tr>
<tr>
<td>( n_{d,s} )</td>
<td>Setting speed of overspeed limiting device</td>
<td>( \text{min}^{-1} )</td>
<td>Speed of the engine, the exceeding of which activates the overspeed limiting device (see Figure 3).</td>
</tr>
<tr>
<td>( n_{d,o} )</td>
<td>Operating speed of overspeed limiting device</td>
<td>( \text{min}^{-1} )</td>
<td>Speed of the engine at which, for a given setting speed, the limiting device starts to operate (see Note 2 and Figure 3).</td>
</tr>
</tbody>
</table>
Table 1 (continued)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Term</th>
<th>Unit</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta n_s$</td>
<td>Speed setting related range</td>
<td>%</td>
<td>Range of speed setting, expressed as a percentage of the declared speed given by: $\delta n_s = \frac{n_{i,max} - n_{i,min}}{n_r} \times 100$</td>
</tr>
<tr>
<td>$\Delta n_s$</td>
<td>Speed setting range</td>
<td>min$^{-1}$</td>
<td>Range between the highest and lowest adjustable no-load speeds given by: $\Delta n_s = n_{i,max} - n_{i,min}$</td>
</tr>
<tr>
<td>$\Delta n_{s,do}$</td>
<td>Speed setting downward range</td>
<td>min$^{-1}$</td>
<td>Range between the declared no-load speed and the lowest adjustable no-load speed given by: $\Delta n_{s,do} = n_{i,r} - n_{i,min}$</td>
</tr>
<tr>
<td>$\delta n_{s,do}$</td>
<td>Speed setting related downward range</td>
<td>%</td>
<td>Downward range of speed setting, expressed as a percentage of the declared speed given by: $\delta n_{s,do} = \frac{n_{i,r} - n_{i,min}}{n_r} \times 100$</td>
</tr>
<tr>
<td>$\Delta n_{s,up}$</td>
<td>Speed setting upward range</td>
<td>min$^{-1}$</td>
<td>Range between the highest adjustable no-load speed and the declared no-load speed given by: $\Delta n_{s,up} = n_{i,max} - n_{i,r}$</td>
</tr>
<tr>
<td>$\delta n_{s,up}$</td>
<td>Speed setting related upward range</td>
<td>%</td>
<td>Upward range of speed setting, expressed as a percentage of the declared speed given by: $\delta n_{s,up} = \frac{n_{i,max} - n_{i,r}}{n_r} \times 100$</td>
</tr>
<tr>
<td>$\nu_n$</td>
<td>Speed setting rate of change</td>
<td>% s$^{-1}$</td>
<td>Rate of change of speed setting under remote control, expressed as a percentage of the related range of speed setting per second given by: $\nu_n = \frac{(n_{i,max} - n_{i,min})}{n_r} \times 100$</td>
</tr>
<tr>
<td>Adjustment range</td>
<td>min$^{-1}$</td>
<td>Speed range over which the overspeed limiting device may be adjusted.</td>
<td></td>
</tr>
<tr>
<td>$\delta n_{st}$</td>
<td>Speed droop</td>
<td>%</td>
<td>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 given by: $\delta n_{st} = \frac{n_{i,r} - n_r}{n_r} \times 100$</td>
</tr>
<tr>
<td>$\Delta \delta n_{st}$</td>
<td>Speed/power characteristic deviation</td>
<td>%</td>
<td>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).</td>
</tr>
<tr>
<td>Speed/power characteristic curve</td>
<td></td>
<td></td>
<td>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).</td>
</tr>
</tbody>
</table>
Table 1 (continued)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Term</th>
<th>Unit</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P$</td>
<td>Engine power</td>
<td>kW</td>
<td></td>
</tr>
<tr>
<td>$P_a$</td>
<td>Actual engine power</td>
<td>kW</td>
<td></td>
</tr>
<tr>
<td>$P_r$</td>
<td>Declared engine power</td>
<td>kW</td>
<td></td>
</tr>
<tr>
<td>$t_r$</td>
<td>Response time</td>
<td>s</td>
<td>Time between activation of the overspeed limiting device and commencement of its operation.</td>
</tr>
<tr>
<td>$p_{me}$</td>
<td>Brake mean effective pressure</td>
<td>kPa</td>
<td></td>
</tr>
<tr>
<td>$V_{st}$</td>
<td>Engine swept volume</td>
<td>l</td>
<td></td>
</tr>
</tbody>
</table>

NOTE 1 The speed limit is the maximum calculated speed which the engine may sustain without risk of damage.

NOTE 2 For a given engine, the operating speed depends on the total inertia of the generating set and the design of the overspeed protection system.

NOTE 3 100 kPa = 1 bar.
Key

\( P \)  engine power
\( n \)  engine speed

1  speed/power characteristic curve
2  power limit

a  Upward speed setting.
b  Downward speed setting range.
c  Range of speed setting.

Figure 1 — Speed/power characteristic, range of speed setting
Key

$P$  engine power

$n$  engine speed

1  linear Speed/Power characteristic curve

2  speed/Power characteristic curve

a  Speed/Power characteristic deviation.

Figure 2 — Speed/power characteristic deviation from the linear curve
4 Other regulations and additional requirements

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 name shall be stated by the customer prior to placing the order.

For engines operating in non-classified equipment, any additional requirements are subject to agreement between the manufacturer and customer.

If special requirements arising from regulations or a regulatory authority (e.g. inspecting and/or legislative authorities) have to be met, the authority name shall be stated by the customer prior to placing the order.

Any 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:

a) the electrical power required for the customer’s plant;

b) the electrical power required for the essential independent auxiliaries (see ISO 3046-1); and

c) the power loss in the a.c. generator itself.

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 the RIC engine and voltage characteristics of the a.c. generator.

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

5.1.2 ISO standard power

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

5.1.3 Service power

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

In order to ensure that a continuous supply of electrical power is available to the connected load, it is essential that the actual power output required from the RIC engine driving the a.c. generator is not more than the service power.

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 and shall include at least:

a) the power under ISO standard and service conditions;

b) the declared speed; and

c) the consumption of fuel and lubricating oil under ISO standard conditions.

This information enables the generating set manufacturer and customer to confirm that the main characteristics of the RIC engines available are suitable for the intended application.
In order to evaluate the generating set in service conditions (in particular, sudden-load acceptance), it is necessary to establish the Brake Mean Effective Pressure, $p_{me}$ (kPa), of the engine used, corresponding to the engine power when the generating set is operating at its declared power and rated frequency and is defined as follows:

$$p_{me} = \frac{KP}{V_{st} \times n_r}$$

where $K = 1.2 \times 10^5$ for a four-stroke engine and $K = 0.6 \times 10^5$ 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 RIC engine manufacturer shall provide the generating set manufacturer with data regarding 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, the RIC engine manufacturer shall specify the measures to be adopted and/or corrective procedures to be used to alleviate the problem.

### 6 Speed characteristics

#### 6.1 General

The choice of governing system fitted to the RIC engine 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.

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

The terms, symbols and definitions for speed characteristics are given in Clause 3.

#### 6.2 Types of speed governor used for generating sets

**6.2.1 Proportional (P) governor**

A speed governor which corrects the control signal in proportion to a load related speed change. The change in electrical load results in a change of the steady-state speed of the RIC engine.

**6.2.2 Proportional Integral (PI) governor**

A P governor which in addition proportionally corrects the control signal to the RIC engine when there is a load-related change in speed due to a change in the a.c. generator electrical load. It also corrects the change in speed with an integral action. If this governor type is used, a change in electrical load does not usually result in a change in speed. To make generating set parallel operation possible, and if no additional governing of the load sharing is provided, a PI governor shall also work as a P governor.

**6.2.3 Proportional Integral Differential (PID) governor**

A PI governor which in addition corrects the control signal as a function of the rate of speed change (differential action). If this governor type is used, a change in electrical load does not usually result in a change in speed. To make parallel generating set operation possible, and if no additional governing of the load sharing is provided, a PID governor shall also work as a P governor.
6.3 Use of speed governor

6.3.1 General

See 6.3 of ISO 8528-1.

6.3.2 Single operation

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

6.3.3 Parallel operation

6.3.3.1 Proportional (P) governor

A proportional governor shall be used for performance Classes G1 and G2 (see Clause 7 of ISO 8528-1:2005).

6.3.3.2 Proportional Integral (PI) governor

A proportional integral governor shall be used for performance Classes G1 to G4. If the governor is used in an isochronous mode, it requires an auxiliary device such as a load-sharing facility.

6.3.3.3 Proportional Integral Differential (PID) governor

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

7 RIC engine load acceptance

7.1 General

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

The generator set manufacturer should consider the actual load-acceptance behaviour of the RIC engine and a.c. generator to be used (see Figures 6 and 7 of ISO 8528-5).

7.2 Non-turbocharged RIC engines

These are RIC engines which are naturally aspirated or pressure-charged by a mechanically driven compressor (supercharged). For these engines, the maximum possible load step is equal to the service power.

7.3 Turbocharged RIC engines

These are RIC engines which are pressure charged by an exhaust gas-driven turbocharger. For these engines, the load steps which may be applied 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 shaft system of the generating set. Requirements relating to torsional vibrations of RIC engines are dealt with in ISO 3046-5.

The complete generating set has to be considered when calculating torsional vibrations (see ISO 8528-5).

The engine manufacturer shall supply the generating set manufacturer with the necessary information to enable him to ensure satisfactory operation of the engine/generator pair.

8.2 Linear vibration

The RIC engine produces linear vibrations which result in structural vibrations in the baseframe and foundation on which the RIC engine and a.c. generator are mounted. If requested, the engine manufacturer shall provide to the generating set manufacturer data related to the linear vibrations produced.

The complete generating set has to be considered when calculating linear vibrations (see ISO 8528-5).

8.3 Noise

If requested, the RIC engine manufacturer shall provide the generator set manufacturer with noise-related data (see ISO 8528-5).

9 Heat balance

The RIC engine manufacturer shall provide the generating set manufacturer with the on-site condition heat balance data which shall include but not be limited to:

a) the RIC engine cooling heat, flow rate and temperatures (coolant, oil, air);

b) the exhaust gas heat, flow rate and temperatures; and

c) the radiated heat dissipation.

10 Inlet and exhaust system

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

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

a) in the pipes, openings or filtering devices of the RIC engine air intake system; and

b) 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 under the specified conditions and details of any special starting aids required.
12 Fuel, lubricants and coolants

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.

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

The following fuel characteristics are of particular significance:

a) density (kg m\(^{-3}\));

b) viscosity (N s m\(^{-2}\));

c) calorific value (kJ);

d) cetane number;

e) vanadium, sodium, silica and aluminium oxide content (%);

f) in the case of heavy fuel, the sulphur content (%).

13 Governing system values

The governing system values are shown in Table 2.

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related downward speed setting range</td>
<td>( \delta n_{s,\text{inf}} )</td>
<td>%</td>
<td>(- (2.5 + \delta n_{s,t}))</td>
</tr>
<tr>
<td>Related upward speed setting range</td>
<td>( \delta n_{s,\text{sup}} )</td>
<td>%</td>
<td>+ 2.5</td>
</tr>
<tr>
<td>Rate of change of speed setting</td>
<td>( \nu_n )</td>
<td>% s(^{-1})</td>
<td>0.2 to 1</td>
</tr>
<tr>
<td>Speed droop</td>
<td>( \delta n_{st} )</td>
<td>%</td>
<td>( \leq 8 ) ( \leq 5 ) ( \leq 3 )</td>
</tr>
</tbody>
</table>

\( \text{AMC}^a \) = By agreement between the manufacturer and customer.
NATIONAL ANNEX A
(National Foreword)

A-1 BIS CERTIFICATION MARKING

RiC engine driven ac generating set may also be marked with the Standard Mark.

A-1.1 The use of the Standard Mark is governed by the provisions of the Bureau of Indian Standards Act, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.
For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (revised)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.
Bureau of Indian Standards

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of ‘BIS Catalogue’ and ‘Standards: Monthly Additions’.

This Indian Standard has been developed from Doc No.: TED 2 (774).

Amendments Issued Since Publication

<table>
<thead>
<tr>
<th>Amendment No.</th>
<th>Date of Issue</th>
<th>Text Affected</th>
</tr>
</thead>
</table>

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