INTERNATIONAL STANDARD

ISO 8528-5

First edition
1993-04-15

Reciprocating internal combustion engine driven alternating current generating sets —

Part 5:
Generating sets

Groupes électrogènes à courant alternatif entraînés par moteurs alternatifs à combustion interne —
Partie 5: Groupes électrogènes

Reference number
ISO 8528-5:1993(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 8528-5 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*

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

— *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 5:
Generating sets

1 Scope

This part of ISO 8528 defines terms and specifies design criteria arising out of the combination of a reciprocating internal combustion (RIC) engine and an alternating current (a.c.) generator when operating as a unit.

It applies to a.c. generating sets driven by RIC engines 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.

For generating sets driven by 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 3046-4:1978, *Reciprocating internal combustion engines — Performance — Part 4: Speed governing.*

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

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

ISO 8528-2:1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 2: Engines.*

ISO 8528-3:1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 3: Alternating current generators for generating sets.*

IEC 34-1:1983, *Rotating electrical machines — Part 1: Rating and performance.*

3 Symbols

NOTE 1 For indications of technical data for electrical equipment, IEC uses the term "rated" and the subscript "N". For indications of technical data for mechanical equipment, ISO uses the term "declared" and the subscript "r". Therefore, in this part of ISO 8528, the term "rated" is applied only to electrical items. Otherwise, the term "declared" is used throughout.

f_{d}	Dynamic frequency (frequency deviation)
$f_{\mathrm{d,max}}$	Maximum transient frequency rise
$f_{\mathrm{d,min}}$	Maximum transient frequency drop
f_{do}	Operating frequency of overfrequency limiting device
f_{ds}	Setting frequency of overfrequency limiting device
f_{i}	No-load frequency
$f_{\mathrm{i,r}}$	Rated no-load frequency
f_{max}	Maximum permissible frequency
f_{r}	Declared frequency (rated frequency)
$f_{\mathrm{i,max}}$	Maximum no-load frequency
$f_{\mathrm{i,min}}$	Minimum no-load frequency
f_{arb}	Frequency at actual power
f_{ov}	Overload frequency
$\overset{\wedge}{\underset{\vee}{f}}$	Width of frequency oscillation
I_{k}	Sustained short-circuit current
t	Time
t_{a}	Total stopping time
t_{b}	Load pick-up readiness time
t_{c}	Off-load run-on time
t_{d}	Run-down time
t_{e}	Load pick-up time
$t_{f,\mathrm{de}}$	Frequency recovery time after load decrease
$t_{f,\mathrm{in}}$	Frequency recovery time after load increase
t_{g}	Total run-up time
t_{h}	Run-up time
t_{i}	On-load run-on time
t_{p}	Start preparation time
t_{s}	Load switching time
t_{u}	Interruption time
t_{U}	Voltage recovery time
$t_{U,\mathrm{de}}$	Voltage recovery time after load decrease
$t_{U,\mathrm{in}}$	Voltage recovery time after load increase

t_v	Start delay time
t_z	Cranking time
t_0	Pre-lubricating time
v_f	Rate of change of frequency setting
v_U	Rate of change of voltage setting
$U_{s,do}$	Downward adjustable voltage
$U_{s,up}$	Upward adjustable voltage
U_r	Rated voltage
U_{rec}	Recovery voltage
U_s	Set voltage
$U_{st,max}$	Maximum steady-state voltage deviation
$U_{st,min}$	Minimum steady-state voltage deviation
U_0	No-load voltage
$U_{dyn,max}$	Maximum upward transient voltage on load decrease
$U_{dyn,min}$	Minimum downward transient voltage on load increase
$\hat{U}_{max,s}$	Maximum peak value of set voltage
$\hat{U}_{min,s}$	Minimum peak value of set voltage
$\hat{U}_{mean,s}$	Average value of the maximum and minimum peak value of set voltage
$\hat{U}_{mod,s}$	Voltage modulation
$\hat{U}_{mod,s,max}$	Maximum peak of voltage modulation
$\hat{U}_{mod,s,min}$	Minimum peak of voltage modulation
$\underset{\vee}{\hat{U}}$	Width of voltage oscillation
Δf_{neg}	Downward frequency deviation from linear curve
Δf_{pos}	Upward frequency deviation from linear curve
Δf	Steady-state frequency tolerance band
Δf_c	Frequency deviation from a linear curve
Δf_s	Range of frequency setting
$\Delta f_{s,do}$	Downward range of frequency setting
$\Delta f_{s,up}$	Upward range of frequency setting
ΔU	Steady-state voltage tolerance band
ΔU_s	Range of voltage setting
$\Delta U_{s,do}$	Downward range of voltage setting
$\Delta U_{s,up}$	Upward range of voltage setting
$\Delta \delta f_{st}$	Frequency/power characteristic deviation
α_U	Related steady-state voltage tolerance band

α_f	Related frequency tolerance band
β_f	Steady-state frequency band
δf_d	Transient frequency difference (from initial frequency) [see 5.3.3]
δU_{dyn}	Transient voltage deviation
δf_{dyn}	Transient frequency deviation (from rated frequency) [see 5.3.4]
δf_s	Related range of frequency setting
$\delta f_{s,do}$	Related downward range of frequency setting
$\delta f_{s,up}$	Related upward range of frequency setting
δf_{st}	Frequency droop
δ_{QCC}	Grade of quadrature-current compensation droop
δ_s	Cyclic irregularity
δf_{lim}	Overfrequency setting ratio
δU_{st}	Steady-state voltage deviation
δU_s	Related range of voltage setting
$\delta U_{s,do}$	Related downward range of voltage setting
$\delta U_{s,up}$	Related upward range of voltage setting
$\delta U_{2,0}$	Voltage unbalance

4 Other regulations and additional requirements

4.1 For 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 a.c. generating sets 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 Frequency characteristics

The steady-state frequency characteristics depend mainly on the performance of the engine speed governor.

The dynamic frequency characteristics, i.e. the response to load changes, depend on the combined behaviour of all the system components (for example on the engine torque characteristics, including type of turbocharging system, the characteristics of the load, the inertias, the damping, etc.; see 5.3) and thus on the individual design of all the relevant components. The dynamic frequency behaviour of the generating set may be related directly to the generator speed.

Terms, symbols and definitions for frequency characteristics are given in 5.1 to 5.3.

5.1 Steady-state frequency behaviour

No.	Term	Symbol	Definition
5.1.1	Frequency droop	δf_{st}	Frequency difference between rated no-load frequency and the rated frequency f_r at declared power expressed as a percentage of rated frequency at fixed frequency setting (see figure 1): $$\delta f_{st} = \frac{f_{i,r} - f_r}{f_r} \times 100$$
5.1.2	Frequency/power characteristic curve	—	Curve of steady-state frequencies in the power range between no-load and declared power, plotted against active power of the generating set (see figure 2).
5.1.3	Frequency/power characteristic deviation	$\Delta\delta f_{st}$	Maximum deviation from a linear frequency/power characteristic curve in the power range between no-load and declared power, expressed as a percentage of rated frequency (see figure 2): $$\Delta\delta f_{st} = \frac{\Delta f}{f_r} \times 100$$
5.1.4	Steady-state frequency band	β_f	Envelope width oscillation $\hat{\check{f}}$ of generating set frequency at constant power around a mean value, expressed as a percentage of rated frequency: $$\beta_f = \frac{\hat{\check{f}}}{f_r} \times 100$$ The maximum value of β_f occurring in the range between 20 % power and declared power shall be stated. For powers below 20 %, the steady-state frequency band may show higher values (see figure 3), but should allow synchronization.

5.2 Frequency-setting parameters

No.	Term	Symbol	Definition
5.2.1	Range of frequency setting	Δf_s	The range between the highest and lowest adjustable no-load frequencies (see figure 1): $$\Delta f_s = f_{i,max} - f_{i,min}$$
	Related range of frequency setting	δf_s	Range of frequency setting, expressed as a percentage of rated frequency: $$\delta f_s = \frac{f_{i,max} - f_{i,min}}{f_r} \times 100$$

No.	Term	Symbol	Definition
5.2.1.1	Downward range of frequency setting	$\Delta f_{s,do}$	Range between the declared no-load frequency and the lowest adjustable no-load frequency (see figure 1): $\Delta f_{s,do} = f_{i,r} - f_{i,min}$
	Related downward range of frequency setting	$\delta f_{s,do}$	Range of downward frequency setting expressed as a percentage of the rated frequency: $\delta f_{s,do} = \frac{f_{i,r} - f_{i,min}}{f_r} \times 100$
5.2.1.2	Upward range of frequency setting	$\Delta f_{s,up}$	Range between the highest adjustable no-load frequency and the declared no-load frequency (see figure 1): $\Delta f_{s,up} = f_{i,max} - f_{i,r}$
	Related upward range of frequency setting	$\delta f_{s,up}$	Range of upward frequency setting expressed as a percentage of the rated frequency: $\delta f_{s,up} = \frac{f_{i,max} - f_{i,r}}{f_r} \times 100$
5.2.2	Rate of change of frequency setting	v_f	Rate of change of frequency setting under remote control expressed as a percentage of related range of frequency setting per second: $v_f = \frac{(f_{i,max} - f_{i,min})/f_r}{t} \times 100$

5.3 Dynamic frequency behaviour (see figure 4)

No.	Term	Symbol	Definition
5.3.1	Maximum transient frequency rise (overshoot frequency)	$f_{d,max}$	Maximum frequency which occurs on sudden change from a higher to a lower power. NOTE — The symbol is different from that given in ISO 3046-4.
5.3.2	Maximum transient frequency drop (undershoot frequency)	$f_{d,min}$	Minimum frequency which occurs on sudden change from a lower to a higher power. NOTE — The symbol is different from that given in ISO 3046-4.
5.3.3	Transient frequency difference (from initial frequency) on load increase (−) and on load decrease (+), respectively	δf_d δf_d^- δf_d^+	Temporary frequency difference between undershoot (or overshoot) frequency and initial frequency during the governing process following a sudden load change, related to rated frequency, expressed as a percentage: $\delta f_d^- = \frac{f_{d,min} - f_{arb}}{f_r} \times 100$ $\delta f_d^+ = \frac{f_{d,max} - f_{arb}}{f_r} \times 100$ (A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.) NOTE — The operating limit values given in 16.6 and 16.7 are valid only for $f_{arb} = f_i$ in the case of increasing load, and for $f_{arb} = f_r$ in the case of decreasing load.

No.	Term	Symbol	Definition
5.3.4	Transient frequency deviation (from rated frequency) on load increase (−) and on load decrease (+), respectively	δf_{dyn} δf_{dyn}^{-} δf_{dyn}^{+}	Temporary frequency difference between undershoot (or overshoot) frequency and rated frequency during the governing process following a sudden load change, relative to rated frequency, expressed as a percentage: $\delta f_{dyn}^{-} = \frac{f_{d,min} - f_r}{f_r} \times 100$ $\delta f_{dyn}^{+} = \frac{f_{d,max} - f_r}{f_r} \times 100$ Transient frequency deviation shall therefore be in the allowable consumer frequency tolerance and shall be particularly stated. (A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.)
5.3.5	Frequency recovery time	$t_{f,in}$ $t_{f,de}$	The time interval between the departure from the steady-state frequency band after a sudden specified load change and the permanent re-entry of the frequency into the specified steady-state frequency tolerance band (see figure 4).
5.3.6	Steady-state frequency tolerance band	Δf	The agreed frequency band about the steady-state frequency which the frequency reaches within a given governing period after increase or decrease of the load.
	Related frequency tolerance band	α_f	This tolerance band usually is expressed as a percentage of the rated frequency: $\alpha_f = \frac{\Delta f}{f_r} \times 100$

6 Overfrequency characteristics

The terms, symbols and definitions for overfrequency characteristics are given in 6.1 to 6.4.

No.	Term	Symbol	Definition
6.1	Maximum permissible frequency[1)]	f_{max}	A frequency specified by the generating set manufacturer which lies a safe amount below the frequency limit (see also ISO 8528-2:1993, 6.5.1).
6.2	Setting frequency of overfrequency limiting device	f_{ds}	The frequency of the generating set, the exceeding of which activates the overfrequency limiting device. NOTE — In practice, instead of the value for the setting frequency, the value for the permissible overfrequency is stated (see also ISO 8528-2:1993, 6.5.2).
6.3	Overfrequency setting ratio	δf_{lim}	Difference between the setting frequency of the overfrequency limiting device and the rated frequency divided by the rated frequency, expressed as a percentage: $\delta f_{lim} = \frac{f_{ds} - f_r}{f_r} \times 100$
6.4	Operating frequency of overfrequency limiting device[2)]	f_{do}	The frequency at which, for a given setting frequency, the overfrequency limiting device starts to operate.

1) The frequency limit (see also ISO 8528-2:1993, figure 3) is the calculated frequency which the engine and generator of the generating set may sustain without risk of damage.

2) For a given generating set the operating frequency depends on the total inertia of the generating set and the design of the overfrequency protection system.

7 Voltage characteristics (see figure 5)

The generating set voltage characteristics are determined mainly by the inherent design of the a.c. generator and the performance of the automatic voltage regulator. Both the steady-state and the transient frequency characteristics may also influence the generator voltage.

The terms, symbols and definitions of voltage characteristics are given in 7.1 to 7.3.

7.1 Steady-state voltage behaviour

No.	Term	Symbol	Definition
7.1.1	Rated voltage	U_r	Line-to-line voltage at the terminals of the generator at rated frequency and at rated output. NOTE — Rated voltage is the voltage assigned by the manufacturer for operating and performance characteristics.
7.1.2	Set voltage	U_s	Line-to-line voltage for defined operation selected by adjustment.
7.1.3	No-load voltage	U_0	Line-to-line voltage at the terminals of the generator at rated frequency and no-load.
7.1.4	Steady-state voltage deviation	δU_{st}	Maximum deviation from the set voltage under steady-state conditions at rated frequency for all powers between no-load and rated output and at specified power factor, taking into account the influence of temperature rise. The steady-state voltage deviation is expressed as a percentage of the rated voltage: $\delta U_{st} = \pm \frac{U_{st,max} - U_{st,min}}{2 U_r} \times 100$
7.1.5	Voltage unbalance	$\delta U_{2,0}$	Ratio of the negative-sequence or the zero-sequence voltage components to the positive-sequence voltage components at no-load. Voltage unbalance is expressed as a percentage of rated voltage.

7.2 Voltage setting characteristics

No.	Term	Symbol	Definition
7.2.1	Range of voltage setting	ΔU_s	Range of maximum possible upward and downward adjustment of voltage at the generator terminals at rated frequency, for all loads between no-load and rated output and within the agreed range of power factor: $\Delta U_s = \Delta U_{s,up} + \Delta U_{s,do}$
	Related range of voltage setting	δU_s	Range of voltage setting expressed as a percentage of the rated voltage: $\delta U_s = \frac{\Delta U_{s,up} + \Delta U_{s,do}}{U_r} \times 100$