

JIS

JAPANESE INDUSTRIAL STANDARD

**General Rules for Test
Code of Reciprocating
Internal Combustion Engines**

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In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

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General Rules for Test Code of
Reciprocating Internal Combustion Engines

B 8002-1986

1. Scope

This Japanese Industrial Standard specifies the items common to the testing methods on performances of all of the reciprocating internal combustion engines excluding those for aircrafts, hereinafter referred to as the "engines".

Remarks 1. Standards for testing methods concerning engines having specific uses are separately specified in accordance with this standard, as appropriate. In carrying out the tests on engines for specific uses, those standards for respective uses shall be applied.

In the case where any appropriate standard for specific use is not available, these general rules for test code shall be applied.

2. The units and numerical values given in { } in this standard are in accordance with the customary units, and are appended for reference.

2. Terms

The terms specified in JIS B 0108, JIS B 0109 and JIS B 0110 shall generally be used in this standard.

3. Test Items

3.1 Classification of Tests Classification of tests shall be in accordance with the following:

- (1) Acceptance Test The acceptance test means the test for determining, at the time of delivery of products, whether the quality items concerning design and manufacture satisfy the requirements of the purchaser. However, regarding the engines of the same type as those which have been subjected to a type test, part of the test items may be omitted.

Applicable Standards, Corresponding International Standards and Reference Standards: See page 41

- (2) **Type Test** The type test means the test for determining whether the qualities of products satisfy all of the quality items given in design, as well as for confirming their reliability and durability, on the representative product of a certain type of engine.
- (3) **Special Test** The special test means the test carried out to supplement the acceptance test or the type test for determining whether an engine meets the specifications formulated by the competent authorities or by a similar organization or the requirements of a purchaser.

The test items of this test shall be determined by an agreement between the parties concerned with acceptance.

4. Test Conditions

4.1 **Standard Atmospheric Conditions** When the power and the specific fuel consumption of an engine are to be expressed by the ISO power and ISO specific fuel consumption, the following atmospheric conditions shall apply.

Atmospheric pressure (p_r) : 100 kPa {750 mmHg}
 Atmospheric temperature (T_r) : 298 K (25 °C)
 Relative humidity (ϕ_r) : 30 %
 Cooling water temperature of air cooler (T_{cr}) : 298 K (25 °C)

Remark: A relative humidity 30 % at an atmospheric temperature 298 K is equivalent to a steam pressure 1 kPa{7.5 mmHg}, and the dry air partial pressure of the air amounts to 99 kPa{742.5 mmHg}.

4.2 Auxiliaries

4.2.1 **Scope of Auxiliaries** As the condition for determining the power, distinction shall be made clearly of the auxiliaries influencing and not influencing the brake power of an engine, and of the auxiliaries necessary and unnecessary for continued or repeated operation. Among the apparatus mounted on the engine, the apparatus the absence of which makes the engine incapable of operating at a rated power shall not be considered to be auxiliaries, but be treated as engine components. What components are to be included in this kind of engine components shall be specified in accordance with the standards of testing methods for respective uses.

Remarks: Such apparatus as fuel-injection pump, turbocharger and air-cooler shall be treated as engine components.

4.2.2 **Classification of Auxiliaries** Classification of the auxiliaries shall be in accordance with the following:

- (1) Auxiliaries driven by part of the engine brake power
- (2) Auxiliaries driven by a source other than the engine brake power
- (3) Auxiliaries indispensable to the continued or repeated operation
- (4) Auxiliaries unnecessary for the continued or repeated operation

Examples of the auxiliaries to be fitted to the engines shall be given in Informative Reference 1.

4.3 Conditions for Operation

4.3.1 Prior to carrying out a test, the engine manufacturer shall conduct a running-in and preliminary test considered to be sufficient.

4.3.2 The test shall generally be carried out on the test bed of the engine manufacturer's plant. However, if any other method is to be employed, it shall be as agreed on between the parties concerned with acceptance.

4.3.3 The test shall be carried out with the engine equipped with auxiliaries necessary for the operation of the engine. If fulfillment of the test conditions given in a contract is anticipated, the accessory of the test bed as it stands may be used in the test. Any alteration on test apparatus that may affect the mechanical performances shall be subjected to an agreement between the parties concerned.

4.3.4 Only in the case of an engine in which speed change mechanism, fluid mechanism, reversing coupling or a generator is so perfectly integrated into the engine itself that separation of them from the engine makes its operation impossible, the test may be carried out with engine fitted with the speed change mechanism or with the generator.

Remark: In the case where an engine has been operated as it is mounted by the above devices in spite of the contruction that permits their separation, the engine power shall be corrected allowing for a power diminution caused by the coupling of them.

4.3.5 During the test, no adjustment of any kind shall be made on the engine except when an adjustment for maintaining the operational condition or for maintaining the normal operation indicated in the operational instruction manual is required.

4.3.6 Interruption of operation during the test shall only be permitted where it is indicated in the operational instruction manual as absolutely necessary for the normal maintenance of the engine.

In case of an interruption of operation due to the defects of engine components or auxiliaries, the advisability of a partial retest or a total retest shall be subject to the agreement between the parties concerned.

4.3.7 In the acceptance test or a type test, if it is impossible to observe as specified the atmospheric conditions and the nature of fuel, necessary corrections on the test results shall be determined by an agreement between the parties concerned.

Remark: In the case of a dual fuel engine, the acceptance test shall be conducted using liquid fuel.

In the case where the gaseous fuel, approximately of the same ignition characteristics as gaseous fuel used in the installation site, is available in the factory of the engine manufacturer, an additional test using the gaseous fuel may be conducted upon an agreement.

The acceptance test for a spark-ignition gas engine or pilot-injection gas engine may be performed at the engine manufacturer's works, provided that the composition and ignition characteristics of the gaseous fuel available in the works are approximately the same as those of the gaseous fuel used in the installation site.

If by agreement, an acceptance test has been carried out in the engine manufacturer's works using the gaseous fuel of which chemical composition and ignition characteristics are remarkably different from those of gaseous fuel at the installation site, tests shall be made on the rated power, rated r.p.m and the prescribed fuel consumption as determined by an agreement.

In the above case, a readjustment of the engine shall be required before using the gaseous fuel specified to be used at the installation site.

5. Classification and Expression of Powers

5.1 Classification of Powers Classification of powers as motive powers shall be as follows:

- (1) Indicated Power The total sum of motive powers generated in cylinders by the pressure of working gas acting on pistons.
- (2) Brake Power The total sum of powers at the motive force extracting shaft of an engine. It is classified into following two divisions:

Remark: In denoting the brake power for auxiliaries, 1. to 3. of Informative Reference 1 shall be complied with. Further, the actual numerical values shall be shown in indicating the powers required for driving the auxiliaries given in 2. or 3. of Informative Reference 1.

- (a) Gross Brake Power The brake power measured on an engine test bed, mounting only the standard auxiliaries which are required for the test operation of an engine and directly driven.
- (b) Net Brake Power The brake power in the case of fitting all of the auxiliaries which are necessary for the specific application of the engine, and which have an effect on the power.

5.2 Classification of Brake Powers Classification of powers as loads shall be in accordance with the following, although these are generally expressed by net brake powers.

- (1) Continuous Power The continuous power means the power that can be continuously generated, at the prescribed r.p.m and under the prescribed atmospheric conditions and maintenance conditions specified by the engine manufacturer, throughout the period of maintenance interval specified by the engine manufacturer.

- (2) **Overload Power** The overload power means the power allowed for immediately after continuous operation under the prescribed atmospheric conditions.

The permissible period and frequency depend on service conditions, and it is necessary to have allowance for the overload power as against the maximum limited value of fuel supply. The overload power shall be determined by its permissible period, frequency and r.p.m, and be expressed by a percentage ratio to the continuous power.

Unless particularly specified, within an operation for 12 h at an r.p.m corresponding to the service condition of an engine, an overload power of 110 % the continuous power is permissible for a total of 1 h continuously or intermittently.

- Remarks 1. Since the power of marine main engine is generally limited by the continuous power, overload power is not employed in actual working. However, in an exceptional case, overload power may be used.
2. Where no application of engine is specified, the engine manufacturer shall specify the overload power and the r.p.m.

- (3) **Limited Fuel Power** The limited fuel power means that power which can be generated with a limited fuel supply, by an engine corresponding to the work, under specified r.p.m and specified atmospheric conditions, and the engine power shall never exceed this power.

5.3 Designations of Brake Power

(1) ISO Power

- (1.1) **ISO Power** The ISO power means the power as confirmed on the operating bed of an engine manufacturer which has been corrected or adjusted to the standard atmospheric conditions given in 4.1.
- (1.2) **ISO Standard Power** The ISO standard power means the continuous net brake power which can be continuously generated under the following conditions throughout the period of the prescribed maintenance interval specified by an engine manufacturer.
- (a) Various conditions of the operating bed and the specified r.p.m formulated by the engine manufacturer.
 - (b) The power which has been corrected or adjusted to the standard atmospheric conditions given in 4.1.
 - (c) The maintenance conditions specified by the engine manufacturer.
- (2) **Service Power** The service power means the power which is to be determined under the atmospheric conditions and operational conditions where the engine is placed.

In determining the service power, it is necessary to take into consideration the following matters.

- (a) Atmospheric conditions specified by a public institutions or a similar organization or a user.

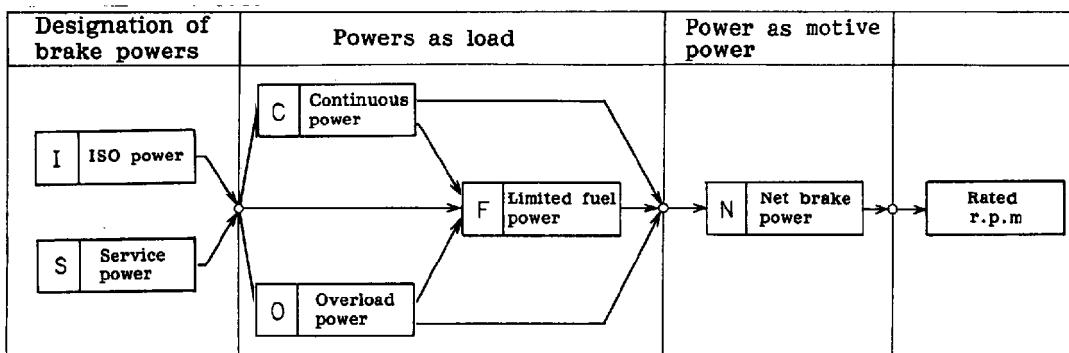
Remark: For example, for the main engines and auxiliary engines of ships applying the standards of the International Association of Classification Societies (IACS), the following atmospheric conditions are used if no limitation is provided for sea route.

Atmospheric pressure	100 kPa {750 mmHg}
Atmospheric temperature	318 K (45 °C)
Relative humidity	60 %
Sea water temperature	305 K (32 °C)
(Cooling water temperature of air cooler)	

- (b) General loading conditions of engine
- (c) Prescribed period of maintenance interval
- (d) Various conditions required for the control of engine
- (e) All information related to the operation of the engine during service

Remark: Tolerances on prescribed power in relation to the application of engine and manufacturing method may be established. Formulation of these tolerances and their values is up to the engine manufacturer.

5.4 Method of Indication for Powers by Graphical Symbols Indication of graphical power symbols corresponding to the designation of brake powers shall be as given in the following:



Example: ICN 1000 kW/425 min⁻¹

6. Denotation of Fuel Consumption and Standard Calorific Values

6.1 Denotation of Fuel Consumption Denotation of fuel consumption shall be as given in the following:

- (1) Fuel Consumption The amount of fuel consumed by an engine per unit time at certain brake power. This shall be expressed in mass unit (kg or g) or energy unit (J){kcal} for the liquid fuel, and in energy unit (J){kcal} for the gaseous fuel.
- (2) Specific Fuel Consumption Fuel consumption per unit power.
- (3) ISO Specific Fuel Consumption Specific fuel consumption under the ISO power.

Unless particularly designated by the engine manufacturer, the ISO specific fuel consumption shall be given.

6.2 Standard Calorific Value The standard calorific value of the fuel shall be given as follows:

- (1) The specific fuel consumption of an engine using the liquid fuel shall be expressed by the value of the low calorific value of the used fuel converted to the standard calorific value 42000 kJ/kg(10030 kcal/kg).
- (2) The specific fuel consumption of an engine using gaseous fuel shall be expressed by the low calorific value of used fuel as a basis of calculation.

7. Denotation of Lubricating Oil Consumption

Denotation of the lubricating oil consumption shall be given as follows:

- (1) Lubricating Oil Consumption The amount of lubricating oil consumed by an engine per unit time. This value, to be used as an informative value, shall be expressed by the nominal power and g or kg per unit time under the r.p.m at that time.

Further, the time measured then shall be noted.

- (2) As the nominal value, consumption after the necessary running-in shall be employed.
- (3) The amount discarded in an oil exchange shall be excluded.

8. Correction of Powers and Adjustments of Power and Specific Fuel Consumption

8.1 The power and specific fuel consumption at the time of the change of atmospheric conditions shall be obtained using one of the methods specified in 8.2 and 8.3 according to the degrees of change.

Remark: Definitions

- (1) power correction A method of calculation by which an engine power established under certain atmospheric conditions is changed into the power under other atmospheric conditions without carrying out any adjustment on the engine, in the case where the degree of change of atmospheric conditions is comparatively small.

- (2) power adjustment A method of calculation by which an engine power under certain atmospheric conditions is changed into the power under other atmospheric conditions, in the case where the degree of change in atmospheric conditions is comparatively large.

The adjustment of power shall be carried out by the adjustment of the engine.

- (3) engine adjustment A method of adjusting an engine, for the purpose of adapting it to different atmospheric conditions.

For example, methods of adjustment by moving the limiting device of the fuel injection pump, by changing the matching of the exhaust turbosupercharger, by changing the injection timing of the fuel injection pump, or by other mechanical alterations.

8.2 Method to Obtain Power by Power Correction In correcting a power to the power under the standard atmospheric conditions which are different from the test conditions, the following methods shall be employed:

(1) Power Correction Formula

$$P_r = kP \quad \dots\dots\dots (1)$$

where P_r : correction power (power under the standard atmospheric conditions) kW{PS}

P : actually measured power kW{PS}

k : correction factor (k_a or k_d)

(2) Determination of Correction Factor

(2.1) Spark Ignition Engine

$$k_a = \left(\frac{p_r - a\phi_r p_{sr}}{p_x - a\phi_x p_{sx}} \right)^{1.2} \left(\frac{T}{T_r} \right)^{0.6} \quad \dots\dots\dots (2)$$

where $T(t)$: temperature at suction inlet of engine K (°C)

p_s : partial pressure of saturated steam
kPa {mmHg}

p : atmospheric pressure kPa {mmHg}

ϕ : relative humidity

Subscript "r" indicates the values under the standard atmospheric conditions and "x" indicates the values under an arbitrary atmospheric conditions.

Letter "a" means 1.

Hereinafter, the symbols given above shall be used extensively.

This formula shall be applied only to the case where k_a is within the range of 0.93 to 1.07 and the suction temperature at inlet of engine is $T_r \pm 10 \text{ K } (\pm 10^\circ \text{C})$, and the dry air pressure is within the range of 80 to 110 kPa. In the cases outside the range of the above, adjustment in accordance with the following 8.3 shall be carried out, recording the test conditions (temperature and pressure) in the test report.

The correction formula given above shall be applied to the nonsupercharged and supercharged engines.

Remark: In an engine of which suction temperature is automatically adjustable, where the engine manufacturer considers this system to be effective, the exponent of the temperature correction item shall be zero. The automatic control of temperature shall be deemed to be effective when the air temperature in the suction air system can be adjusted to $\pm 5 \text{ K } (\pm 5^\circ \text{C})$.

(2.2) Diesel Engine

$$k_d = f_a f_m \dots\dots\dots (3)$$

where f_a : atmospheric factor

f_m : air-fuel ratio factor

(2.2.1) f_a : Atmospheric Factor This factor is subject to the influence of the conditions of suction air (pressure, temperature and humidity) of the engine, and so shall be expressed by the following formula according to the classification of engine.

(a) Nonsupercharged and Mechanically Supercharged Engines

$$f_a = \left(\frac{p_r - a\phi_r p_{sr}}{p_x - a\phi_x p_{sx}} \right) \left(\frac{T_x}{T_r} \right)^{0.7} \dots\dots\dots (4)$$

(b) Turbosupercharged Engines without and with Air-cooler

$$f_a = \left(\frac{p_r - a\phi_r p_{sr}}{p_x - a\phi_x p_{sx}} \right)^{0.7} \left(\frac{T_x}{T_r} \right)^{1.5} \dots\dots\dots (5)$$

(2.2.2) f_m : Air-fuel Ratio Factor The factor f_m shall be expressed by the following formula as a function of q_c , in relation to the air-fuel ratio.

$$f_m = 0.036 q_c - 1.14 \dots\dots\dots (6)$$

$$q_c = q/\pi$$

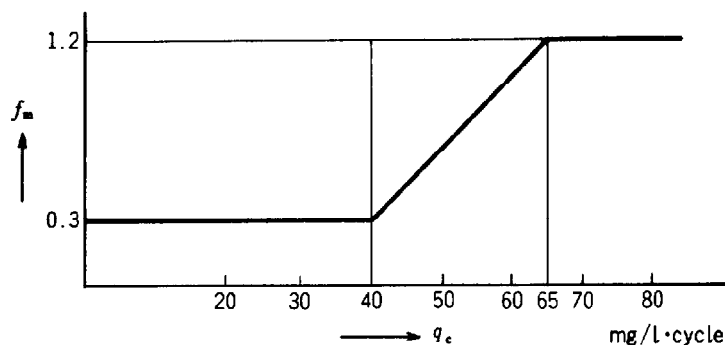
where q : amount of fuel supply per 1 l of gross stroke capacity and per 1 cycle mg/l · cycle

π : pressure ratio at outlet and inlet of super-charger (in the case of nonsupercharged engine $\pi=1$)

This formula shall be applied to the case where the value of q_c is in the range of 40 to 65 mg/l · cycle. Where q_c is less than 40 mg/l · cycle, f_m becomes constant at 0.3, and where f_m is larger than 65 mg/l · cycle, it becomes constant at 1.2 (Fig. 1).

Furthermore, this formula shall be applied only where k_a is in the range of 0.9 to 1.1, the suction temperature of engine is $T_s \pm 15 \text{ K}$ ($\pm 15^\circ \text{C}$) and where dry air pressure is in the range of 80 to 110 kPa. In the case outside the above ranges, mention to that effect shall be made in the test report, and adjustment in accordance with 8.3 shall be carried out.

Fig. 1. Relation between q_c and f_m



8.3 Methods of Obtaining Power and Specific Fuel Consumption by Power Adjustment

Methods of obtaining the power and specific fuel consumption shall be as follows:

- (1) **Method of Obtaining Power** In the case where operational conditions are remarkably different from the standard conditions due to the circumstances of installation site and the like, adjustment shall be performed to change the power under the standard conditions to that at the installation site using the following formula.

Furthermore, this calculating method may be employed inversely in the calculation of adjustment to change power under the conditions different from standard atmospheric conditions to the power under the standard atmospheric conditions.

The calculating formulas for power adjustment

$$P_x = \alpha P_r \quad \dots\dots\dots (7)$$

$$\alpha = K - 0.7 (1 - K) \cdot \left(\frac{1}{\eta_m} - 1 \right) \quad \dots\dots\dots (8)$$

$$K = \left(\frac{p_x - \alpha \phi_x p_{sx}}{p_r - \alpha \phi_r p_{sr}} \right)^m \left(\frac{T_r}{T_x} \right)^n \left(\frac{T_{cr}}{T_{cx}} \right)^q \quad \dots\dots\dots (9)$$

In case the r.p.m of a turbocharger and the temperature at exhaust turbine inlet do not reach the limited values at the time of the nominal power under the standard atmospheric conditions, establish substitute atmospheric conditions under which these are to reach the limited values, and the calculation from these conditions to arbitrary atmospheric conditions or vice versa shall be carried out. In this case, the following formulas shall be used instead of the formula (9).

$$K = \left(\frac{p_x}{p_{ra}} \right)^m \left(\frac{T_{ra}}{T_x} \right)^n \left(\frac{T_{cr}}{T_{cx}} \right)^q \dots\dots\dots (10)$$

$$p_{ra} = p_r \frac{\pi_r}{\pi_{max}} \dots\dots\dots (11)$$

- where P_r : brake power under standard atmospheric conditions kW{PS}
- p_r : standard atmospheric pressure kPa{mmHg}
- p_{sr} : partial pressure of saturated steam under standard atmospheric conditions kPa{mmHg}
- ϕ_r : relative humidity under standard atmospheric conditions
- $T_r(t_r)$: atmospheric temperature under standard atmospheric conditions K (°C)
- $T_{cr}(t_{cr})$: cooling water temperature of air-cooler under standard atmospheric conditions K (°C)
- p_{ra} : substitute atmospheric pressure given in formula (11) kPa{mmHg} (see 2. of Informative Reference 5)
- $T_{ra}(t_{ra})$: substitute atmospheric temperature given by manufacturer K (°C) (see 2. of Informative Reference 5)
- π_r : ratio of charging pressure when operated by nominal power under standard atmospheric conditions to atmospheric pressure (given by manufacturer)
- π_{max} : permissible maximum ratio of charging pressure to atmospheric pressure (given by manufacturer)
- α : power adjustment factor
- K : ratio of indicated power
- η_m : mechanical efficiency
- P_x : brake power under arbitrary conditions kW{PS}
- p_x : atmospheric pressure under arbitrary conditions kPa{mmHg}

p_{sx} : partial pressure of saturated steam under arbitrary atmospheric conditions kPa{mmHg}

ϕ_x : relative humidity under arbitrary atmospheric conditions

$T_x (t_x)$: atmospheric temperature under arbitrary atmospheric conditions K (°C)

$T_{cx} (t_{cx})$: cooling water temperature of air-cooler under arbitrary conditions K (°C)

For factor a , indexes m , n and q , the values given in Table 1 shall be used.

- Remarks 1. The relation between the altitude and the atmospheric pressure is given in Informative Reference 2, the relation between the atmospheric temperature and the saturated steam pressure is given in Informative Reference 3, the examples of calculation for power corrections are given in 1. and 2. of Informative Reference 4 and the examples of calculation for adjustments of power and specific fuel consumption are given in 1. and 2. of Informative Reference 5.
2. Where the atmospheric conditions are more advantageous than those of the standard atmospheric conditions, the nominal power under those atmospheric conditions may sometimes be limited by the manufacturer to the nominal power under the standard atmospheric conditions.
 3. In the case where relative humidity is not known, relative humidity in the correction systems A, E and G in Table 1 shall be assumed to be 30 %.
 4. The mechanical efficiency shall be presented by manufacturer. If it is not presented, however, η_m shall be estimated to be 80 %.
 5. In the case where ISO power is to be designated, the engine manufacturer shall clearly state the adjusting system in Table 1 he has selected.

Table 1. Exponents of Calculation Formulas
for Power Adjustment

Classification of engines	Conditions of engine		System of adjustment	Factor Exponents			
				<i>a</i>	<i>m</i>	<i>n</i>	<i>q</i>
Diesel and dual fuel engines using liquid or gaseous fuel	Nonsupercharged engines	Power limited by excessive air	A	1	1	0.75	0
		Power limited by thermal load	B	0	1	1	0
	Turbosupercharged engine without air-cooler	Low-speed and medium speed four-stroke cycle engines	C	0	0.7	2.0	0
	Turbosupercharged engine with air-cooler		D	0	0.7	1.2	1
Spark ignition engines using gaseous fuel	Nonsupercharged engine	Low speed and medium speed four-stroke cycle engines	E	1	0.86	0.55	0
	Turbosupercharged engine with air-cooler		F	0	0.57	0.55	1.75
Spark ignition engine using liquid fuel	Nonsupercharged engine		G	1	1	0.5	0

Remark: In the system of adjustment D, for an engine of which charging air is cooled with the cooling water of the engine body, *q* may be assumed to be equal to 0.

- (2) Method of Obtaining Specific Fuel Consumption The specific fuel consumption measured under atmospheric conditions different from the standard atmospheric conditions shall be adjusted to the value under the standard atmospheric conditions using the following formula.

Furthermore, the same formula shall also be used in the case of converting the specific fuel consumption under the standard atmospheric conditions to the value under arbitrary atmospheric conditions.

$$g_{tx} = \beta g_{tr} \quad \dots \dots \dots (12)$$

where $\beta = K/\alpha$

g_r: specific fuel consumption g/kWh {g/PS · h} or J/kWh

α: power adjustment factor

β: specific fuel consumption adjustment factor

K: ratio of indicated power

Subscript "r" gives the value under the standard atmospheric conditions and "x" gives the value under arbitrary atmospheric conditions.

- Remarks 1.** The power and specific fuel consumption shall be adjusted according to this item only when the values given in 8.2 are exceeded by the correction factor due to the discrepancy between the atmospheric conditions at the time of operation of an engine and the standard atmospheric conditions, as well as by temperature and by pressure.

2. In the case where the system of adjustment is not given in Table 1, the system of adjustment shall be made through written agreement between the parties concerned in respect to the method of obtaining the power and specific fuel consumption.
3. In a supercharged engine, at the rated power and under the standard atmospheric conditions, when the turbosupercharger has not reached the permissible r.p.m, or the exhaust gas temperature at the turbine inlet has not exceeded the permissible temperature, the engine manufacturer shall present substitute atmospheric conditions for power adjustment.
4. In adjusting to the power at the installation site on a test bed, in the case, for example, where the maximum pressure in the cylinder exceeds the permissible value, the test shall be carried out within a range not exceeding the maximum pressure considered to be safe by the engine manufacturer.
5. Instead of carrying out the adjustment of the engine power and specific fuel consumption by calculation, a test may be conducted under the atmospheric conditions artificially formed to meet the atmospheric conditions of the installation site of the engine.

Furthermore, the following methods shall be used as expediences for artificial formation of conditions of installation site.

- (1) At the same time with contraction of the suction air inlet (exhaust turbosupercharger inlet) of the engine, reduce the pressure of exhaust outlet to the same value.
- (2) Adjust the suction air temperature of the engine by heating or cooling.
- (3) Adjust the cooling liquid or air temperature at the inlet of the air-cooler.

9. Performance Tests

9.1 Designation of Power

9.1.1 The brake power which can be generated by an engine under given conditions shall be designated by the engine manufacturer. Hereinafter, this nominal power may also be referred to as the "rated power".

9.1.2 The power designated in accordance with 9.1.1 shall of necessity be substantiated by measurement to be actually generated under the same conditions or within appropriate permissible values under different conditions.