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SURFACE VEHICLE STANDARD

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RECIPROCATING INTERNAL COMBUSTION ENGINES—PERFORMANCE— PART 1: STANDARD REFERENCE CONDITIONS, DECLARATIONS OF POWER, FUEL AND LUBRICATING OIL CONSUMPTIONS, AND TEST METHODS

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Foreword—ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and nongovernmental, 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 3046-1 was prepared by Technical Committee ISO/TC 70, Internal combustion engines, Subcommittee SC 2, Performance and tests.

This fourth edition cancels and replaces the third edition (ISO 3046-1:1986), ISO 3046-2:1987, and ISO 3046-1:1986/Amd. 1:1987. A method of power correction (see clause 14) has been added.

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

Part 1: Standard reference conditions, declarations of power, fuel and lubricating oil consumptions, and test methods
Part 3: Test measurements
Part 4: Speed governing
Part 5: Torsional vibrations
Part 6: Overspeed protection
Part 7: Codes for engine power

Appendices A, B, C, D, E, and F of this part of ISO 3046 are for information only.

The standard reference conditions defined in this edition of ISO 3046-1 were first introduced in the third edition (ISO 3046-1:1986). The 5-year transition period, which permitted the use of ISO 3046-1:1981 conditions, expired at the end of 1991. Users of this part of ISO 3046 are therefore now required to adopt the values quoted in clause 6.

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1. ***Scope—***This part of ISO 3046 specifies standard reference conditions and methods of declaring the power, fuel consumption, lubricating oil consumption, and test methods for reciprocating internal combustion (RIC) engines in commercial production using liquid or gaseous fuels. Where necessary, individual requirements are given for particular engine applications.

This part of ISO 3046 covers RIC engines for land, rail-traction, and marine use, excluding engines used to propel agricultural tractors, road vehicles, and aircraft.

This part of ISO 3046 may be applied to engines used to propel road construction and earthmoving machines, industrial trucks, and for other applications where no suitable International Standard for these engines exists.

This part of ISO 3046 may be applied to tests on a test bed at the manufacturer's works and to tests on site (see 15.4.4).

2. ***References***

2.1 **Applicable Publications—**The following publications form a part of this specification to the extent specified herein. The latest issue of the publications shall apply.

2.1.1 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 1204—Reciprocating internal combustion engines—Designation of the direction of rotation and of cylinders and valves in cylinder heads, and definition of right-hand and left-hand in-line engines and locations on an engine
ISO 1585—Road Vehicles—Engine test code—Net power
ISO 2710:1978—Reciprocating internal combustion engines—Vocabulary
ISO 2710/Add. 1—Addendum 1: Symbols
ISO 3046-3—Reciprocating internal combustion engines—Performance—Part 3: Test measurements
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 3046-6—Reciprocating internal combustion engines—Performance—Part 6: Overspeed protection
ISO 3046-7—Reciprocating internal combustion engines—Performance—Part 7: Codes for engine power
ISO 7876-1:1990—Fuel injection equipment—Vocabulary—Part 1: Fuel injection pumps
ISO 8528-1—Reciprocating internal combustion engine driven alternating current generating sets—Part 1: Application, ratings and performance

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3. Definitions—For the purposes of this part of ISO 3046, the following definitions apply. For the convenience of users of this part of ISO 3046, some definitions are quoted from ISO 2710 and ISO 7876-1.

3.1 Auxiliary

3.1.1 DEPENDENT AUXILIARY—Item of equipment, the presence or absence of which affects the final shaft output of the engine.

3.1.2 INDEPENDENT AUXILIARY—Item of equipment which uses power supplied from a source other than the engine.

3.1.3 ESSENTIAL AUXILIARY—Item of equipment which is essential for the continued or repeated operation of the engine.

3.1.4 NONESSENTIAL AUXILIARY—Item of equipment which is not essential for the continued or repeated operation of the engine.

3.2 Engine

3.2.1 ENGINE ADJUSTMENT—Physical procedure of modifying an engine for the purpose of adapting it to a different set of ambient conditions, such as by moving limiting fuel stop, rematching the turbocharger, changing the fuel injection timing or other mechanical changes. In that case the engine is an adjusted engine (see 3.3.11).

3.2.2 NONADJUSTED ENGINE—Engine which is preset so that no physical procedure of modifying the engine for the purpose of adapting it to a different set of ambient conditions is carried out.

3.2.3 ENGINE SPEED—The number of revolutions of the crankshaft in a given period of time. [ISO 2710:1978, 10.2.1]

3.2.4 DECLARED ENGINE SPEED—The engine speed corresponding to the declared power.

NOTE 1—In some applications, the declared engine speed is named "rated speed."

3.3 Power and Load

3.3.1 DECLARED POWER—The value of the power, declared by the manufacturer, which an engine will deliver under a given set of circumstances.

NOTE 2—In some applications, the declared power is named "rated power."

3.3.2 INDICATED POWER—The total power developed in the working cylinders as a result of the pressure of the working medium acting on the pistons. [ISO 2710:1978, 10.3.1]

3.3.3 BRAKE POWER—The power or the sum of the powers measured at the driving shaft or shafts. [ISO 2710:1978, 10.3.2]

3.3.4 CONTINUOUS POWER—The power which an engine is capable of delivering continuously, between the normal maintenance intervals stated by the manufacturer, at the stated speed and under stated ambient conditions, the maintenance prescribed by the manufacturer being carried out.

3.3.5 OVERLOAD POWER—The power which an engine may be permitted to deliver, with a duration and frequency of use depending on the service application, at stated ambient conditions, immediately after operating at the continuous power.

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3.3.6 FUEL STOP POWER—The power which an engine is capable of delivering during a stated period corresponding to its application, and stated speed and under stated ambient conditions, with the fuel limited so that this power cannot be exceeded.

3.3.7 ISO POWER—The power determined under the operating conditions of the manufacturer's test bed and adjusted or corrected as determined by the manufacturer to the standard reference conditions specified in Section 6.

3.3.8 ISO STANDARD POWER—The continuous brake power which the engine manufacturer declares that an engine is capable of delivering using only the essential dependent auxiliaries, between the normal maintenance intervals stated by the manufacturer, and under the following conditions.

a. At a stated speed at the operating conditions of the engine manufacturer's test bed
b. With the declared power adjusted or corrected as determined by the manufacturer to the standard reference conditions specified in Section 6
c. With the maintenance prescribed by the engine manufacturer being carried out

3.3.9 SERVICE POWER—The power delivered under the ambient and operating conditions of an engine application.

3.3.10 SERVICE STANDARD POWER—The name given to the continuous brake power which the engine manufacturer declares that an engine is capable of delivering, using only the essential dependent auxiliaries, between the normal maintenance intervals stated by the manufacturer and under the following conditions:

a. At a stated speed at the ambient and operating conditions of the engine application
b. With the declared power adjusted or corrected as determined by the manufacturer to the stated ambient and operating conditions of the engine application
c. With the maintenance prescribed by the engine manufacturer being carried out

3.3.11 POWER ADJUSTMENT—Calculation procedure by which a power value under one set of ambient conditions is modified to represent the power value expected under another set of ambient conditions, to maintain approximately constant thermal and/or mechanical load in critical engine components (see Section 13).

3.3.12 POWER CORRECTION—Calculation procedure by which a power value determined under engine test conditions is modified so that it represents the power value expected under other operating or reference conditions without any engine adjustment. In that case, the power and performance parameters may vary as a function of ambient conditions (see Section 14).

3.3.13 LOAD—A general term describing the magnitude of the "power" or "torque" demanded from the engine by its driven machinery and usually expressed relative to a declared power or torque.

NOTE 3—For quantitative purposes, the terms "power" or "torque" should be used, instead of "load," together with a statement of speed.

[ISO 2710:1978, 10.3.4]

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3.4 Consumption and Delivery

3.4.1 FUEL CONSUMPTION—The quantity of fuel consumed by an engine per unit of time at a stated power and under stated ambient conditions.

3.4.2 SPECIFIC FUEL CONSUMPTION—The quantity of fuel consumed by an engine per unit of power and time.

3.4.3 ISO SPECIFIC FUEL CONSUMPTION—The name given to the specific fuel consumption at the ISO standard power.

3.4.4 FUEL DELIVERY—Metered volume (mass) of fuel delivered by a fuel injection system during one working cycle.

[ISO 7876-1:1990, 10.24]

3.4.5 SPECIFIC FUEL DELIVERY—Metered volume (mass) of fuel delivered by a fuel-injection system during one working cycle per liter of engine swept volume.

3.4.6 LUBRICATING OIL CONSUMPTION—The quantity of lubricating oil consumed by an engine per unit of time.

[ISO 2710:1978, 10.4.3]

3.5 Tests

3.5.1 ACCEPTANCE TEST—Test carried out as an overall check on the manufacturing quality, and to establish that the contractual commitments have been fulfilled.

3.5.2 TYPE TEST—Test carried out on a representative engine of a certain engine type to establish the main performance data of the engine and, as far as possible, to enable their reliability and durability in service to be assessed.

3.5.3 SPECIAL TEST—Test additional to acceptance or type tests carried out to meet the requirements of inspecting and legislative authorities, classification societies, or customers.

4. Symbols—The symbols used in this part of ISO 3046 are given in Table 1. Subscripts are given in Table 2.

5. Other Regulations and Additional Requirements

5.1 For engines 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 the order.

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TABLE 1—SYMBOLS

Symbols Common Use	Symbols EDP[1] Representation	Definition	Unit
a	A	Humidity factor	dimensionless
b_r	BR	Specific fuel consumption under standard reference conditions	kg/(kW·h)
b_x	BX	Specific fuel consumption under site ambient conditions	kg/(kW·h)
b_y	BY	Specific fuel consumption under test ambient conditions	kg/(kW·h)
f_a	FA	Atmospheric factor	dimensionless
f_m	FM	Engine factor (characteristic parameter for each type of engine)	dimensionless
k	K	Ratio of indicated power	dimensionless
m	M	Exponent of the dry air pressure ratio or total barometric pressure ratio	dimensionless
n	N	Exponent of the ambient air thermodynamic temperature ratio	dimensionless
p_r	PR	Standard reference total barometric pressure	kPa
p_{ra}	PRA	Substitute reference total barometric pressure	kPa
p_{sr}	PSR	Standard reference saturated water vapor pressure	kPa
p_{sx}	PSX	Ambient saturated water vapor pressure on site	kPa
p_{sy}	PSY	Ambient saturated water vapor pressure during test	kPa
p_x	PX	Ambient total barometric pressure on site	kPa
p_y	PY	Ambient total barometric pressure during test	kPa
P_r	PPR	Brake power or net brake power under standard reference conditions	kW
P_{ra}	PPRA	Brake power or net brake power under substitute reference conditions	kW
P_x	PPX	Brake power or net brake power under ambient conditions on site	kW
P_y	PPY	Brake power or net brake power under ambient conditions during test	kW
q	Q	Fuel mass per cycle per liter of engine swept volume	mg/(cycle-l)
q_c	QC	Fuel mass per cycle per liter of air available for combustion	mg/(cycle-l)
r	R	Boost pressure ratio (ratio of absolute air pressure at the compressor outlet to that at the compressor inlet)	dimensionless
r_r	RR	Boost pressure ratio under standard reference conditions	dimensionless
$T_{r,\,max}$	RRMAX	Maximum allowable boost pressure ratio under standard reference conditions	dimensionless
s	S	Exponent of the charge air coolant thermodynamic temperature ratio	dimensionless
t_{cr}	TCR	Standard reference charge air coolant temperature	°C
t_{cx}	TCX	Ambient charge air coolant temperature on site	°C
t_r	TR	Standard reference ambient air temperature	°C
t_x	TX	Ambient air temperature on site	°C
T_{cr}	TTCR	Standard reference charge air coolant thermodynamic temperature	K
T_{cra}	TTCRA	Substitute reference charge air coolant thermodynamic temperature	K
T_{cx}	TTCX	Ambient charge air coolant thermodynamic temperature on site	K
T_{cy}	TTCY	Ambient charge air coolant thermodynamic temperature during test	K
T_r	TTR	Standard reference ambient air thermodynamic temperature	K
T_{ra}	TTRA	Substitute reference ambient air thermodynamic temperature	K
T_x	TTX	Ambient air thermodynamic temperature on site	K
T_y	TTY	Ambient air thermodynamic temperature during test	K
α	ALP	Power adjustment factor	dimensionless
α_a	ALPA	Power correction factor for spark-ignition engines	dimensionless
α_c	ALPC	Power correction factor for compression-ignition engines	dimensionless
β	BET	Fuel consumption recalculation factor	dimensionless
η_m	ETAM	Mechanical efficiency	dimensionless
ϕ_r	PPHIR	Standard reference relative humidity	%
ϕ_x	PPHIX	Ambient relative humidity on site	%
ϕ_y	PPHIY	Ambient relative humidity during test	%

1. EDP = Electronic data processing if using uppercase letters only

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TABLE 2—SUBSCRIPTS

Subscript	Meaning
a	Atmospheric
c	Compression ignition engine(1)
	Coolant(1)
	Corrected(1)
m	Mechanical
max	Maximum
r	Standard reference conditions
ra	Substitute reference conditions
s	Saturated
x	Site conditions
y	Test conditions

1. Depending on the application.

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

5.2 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 the order.

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

***6. Standard Reference Conditions*—**For the purpose of determining the power and fuel consumption of engines, the following standard reference conditions shall be used.

a. Total barometric pressure—p_r = 100 kPa
b. Air temperature—T_r = 298 K (tr = 25 °C)
c. Relative humidity—ϕr = 30%
d. Charge air coolant temperature—T_{cr} = 298 K (t_{cr} = 25 °C)

NOTE 4—Relative humidity of 30% at a temperature of 298 K corresponds to a water-vapor pressure of 1 kPa. Hence the corresponding dry barometric pressure is 99 kPa.

***7. Auxiliaries*—**In order to show clearly the conditions under which the power output is determined, it is necessary to distinguish those auxiliaries which affect the final shaft output of the engine and also those which are necessary for the continuous or repeated use of the engine. For examples, see Appendix A.

Items of equipment fitted to the engine and without which the engine could not under any circumstances operate at its declared power are considered to be engine components and are not, therefore, classed as auxiliaries.

NOTE—Items such as fuel injection pump, exhaust turbocharger and charge air cooler are in this category of engine components.

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8. *Declarations of Power*

8.1 General

8.1.1 PURPOSE OF STATEMENT OF POWER—Statements of power are required for two main purposes, as follows.

a. The declaration of the value of the power
b. The verification by measurement that the engine delivers the power which has been declared in (a), under the same set of circumstances or after proper allowance has been made for any difference in circumstances.

To specify the set of circumstances under which the declared value of a power would be achieved, the declaration shall state:

a. The type of statement of power (see 8.4, standard or service power) and, if necessary, the ambient and operating conditions (see 8.4)
b. The type of power application (see 8.3, continuous power with overload power and/or fuel stop power)
c. The type of power (see 8.2, indicated or brake power)
d. The declared engine speed (see 3.2.4)

For the methodology of expressing the engine power according to a, b, and c, see Figure 1. For appropriate codes, where necessary, refer to ISO 3046-7.

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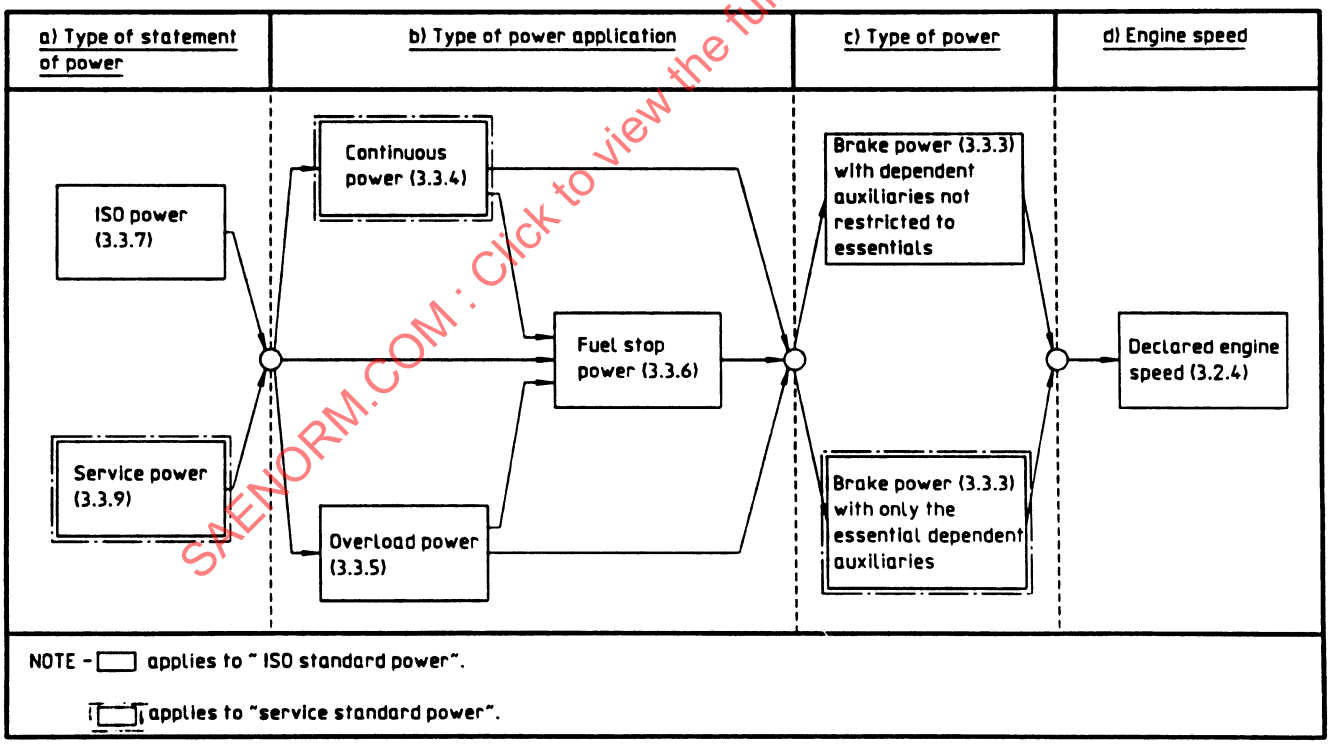

FIGURE 1—DIAGRAM SHOWING THE METHODOLOGY TO BE USED IN POWER STATEMENTS

NOTE 6—The terms used in a to c may be combined, for example, continuous brake fuel stop power.

NOTE 7—Where appropriate to the engine application and the method of manufacture, the power achieved may be subject to a tolerance on the declared power. The existence of such a tolerance and its magnitude should be stated by the manufacturer.

8.1.2 POWER AND TORQUE—For engines delivering power by a shaft or shafts, for the purposes of this part of ISO 3046, any power is a quantity proportional to the mean torque, calculated or measured, and to the mean rotational speed of the shaft or shafts transmitting this torque.

For engines delivering power other than by a shaft or shafts, reference shall be made to the appropriate International Standard for the driven machine.

8.1.3 ENGINE WITH INTEGRAL GEARING—When stating the power of an engine fitted with an integral (built-in) speed increasing or reducing device, the speed of the driving-shaft extremity shall also be given at the declared engine speed.

8.2 Types of Power

8.2.1 Indicated power and brake power are types of power.

8.2.2 Except in the cases of ISO standard power and service standard power, any statement of brake power shall be supported by the following list of auxiliaries:

a. Essential dependent auxiliaries as defined in 3.1.1 and 3.1.3
b. Essential independent auxiliaries as defined in 3.1.2 and 3.1.3
c. Nonessential dependent auxiliaries as defined in 3.1.1 and 3.1.4

The power absorbed by the auxiliaries listed in b and c may be significant. In such cases, their power requirement shall be declared.

NOTE 8—Examples of typical auxiliaries are listed in Appendix A for guidance purposes.

8.3 Types of Power Application—Continuous power, overload power, and fuel stop power are types of power application.

The duration and frequency of use of the overload power which is permitted will depend on the service application, but adequate allowance shall be made in setting the engine fuel stop to permit the overload power to be delivered satisfactorily. The overload power shall be expressed as a percentage of the continuous power, together with the duration and frequency permitted and the appropriate engine speed.

Unless otherwise stated, an overload power of 110% of the continuous power at a speed corresponding to the engine application is permitted for a period of 1 h, with or without interruptions, within a period of 12 h of operation. This period also applies to any overload power up to 110% of the continuous power.

NOTE 9—The power of marine main-propulsion engines is normally limited to the continuous power, so that the overload power cannot be given in service. However, for special applications, marine main-propulsion engines may develop overload power in service.

For engines for electrical power generation, the specifications given in ISO 8528-1 apply.

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8.4 Types of Statement of Power—ISO power and service power are types of statement of power.

To establish service power, the following conditions shall be taken into account:

a. The ambient conditions, or any nominal ambient conditions according to the special requirements of inspecting and/or legislative authorities and/or classification societies, as specified by the customer (see Section 11).

NOTE 10—For example, the following nominal ambient conditions apply to main and auxiliary RIC engines on ships for International Association of Classification Societies (IACS) unrestricted service:

Total barometric pressure: p_x = 100 kPa
Air temperature: T_x = 318 K (t_x = 45 °C)
Relative humidity: ϕ_x = 60%
Sea or raw temperature (change air coolant inlet): T_{cx} = 305 K (t_{cx} = 32 °C)

b. The normal duty of the engine
c. The expected interval between maintenance periods
d. The nature and amount of supervision required
e. Any information relevant to the operation of the engine in service (see Sections 11 and 12)

9. Declarations of Fuel Consumption

9.1 Fuel Consumption—The quantity of liquid fuels shall be expressed in mass units (kg) or in energy units (J).

The quantity of gaseous fuels shall be expressed in energy units (J).

If not otherwise specified by the manufacturer, a declared specific fuel consumption shall be considered to be the ISO specific fuel consumption.

9.2 Calorific Value of Fuels

9.2.1 LIQUID-FUEL ENGINES—Where a distillate type of fuel is specified, any declared specific fuel consumption of a liquid-fuel engine given in mass units shall be related to a lower calorific value of 42 700 kJ/kg.

Where any other type of fuel is specified, the declared specific fuel consumption shall either be expressed in energy units, or both the specific fuel consumption in mass units and the associated lower calorific value shall be stated.

9.2.2 GAS ENGINES—Any declared specific fuel consumption of a gas engine shall be related to a stated lower calorific value of the gas. The type of gas shall be declared.

9.3 Specific Fuel Consumption Declarations—The specific fuel consumption of an engine shall be declared at:

a. The ISO standard power
b. (If required by special agreement) any other declared power and at specified engine speeds appropriate to the particular engine application

Unless otherwise stated, a deviation of +5% is permitted for the specific fuel consumption for the declared power.

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10. Declarations of Lubricating Oil Consumption

10.1 The value of the lubricating oil consumption is used for guidance. It shall be expressed in liters or kilograms per engine operating hour at the declared power and engine speed.

10.2 The lubricating oil consumption after a stated period of running-in shall be declared.

10.3 The oil discarded during an engine oil change shall not be included in the lubricating oil consumption declaration.

10.4 The lubricating oil used shall be declared.

11. Information to be Supplied by the Customer—The customer shall supply the following information.

a. The application and the power required from the engine and details arising from these
b. The expected frequency and duration of the required powers and the corresponding engine speeds, preferably as a load profile
c. Site conditions

1. Site barometric pressure: highest and lowest readings available; if no pressure data are available, the altitude above sea level
2. The monthly mean minimum and maximum ambient air temperatures on site during the hottest and coldest months of the year
3. The highest and lowest ambient air temperatures on site around the engine
4. The relative air humidity (or alternatively, the water vapor pressure or the wet and dry bulb temperature) at the maximum ambient air temperature on site
5. The maximum and minimum temperatures of the cooling water available

d. The specification and lower calorific value of the fuel available
e. Whether the engine is to comply with the requirements of any classification society or with special requirements
f. Characteristics of the essential dependent auxiliaries supplied by the customer
g. Any other information appropriate to the particular engine application

12. Information to be Supplied by the Engine Manufacturer—The engine manufacturer shall supply the following information.

a. The declared brake powers and, where appropriate, their tolerances

b. The corresponding engine speed

NOTE 11—For certain applications of variable-speed engines, it is common practice to supply a power speed diagram covering the ranges of power over which the engine may be used in continuous and in short-period operation.

A typical example for a marine main-propulsion engine with a fixed-pitch propeller is given in Figure 2. For the preparation of such a diagram, the customer should supply the required information according to Section 11.

c. The direction of rotation (see ISO 1204).

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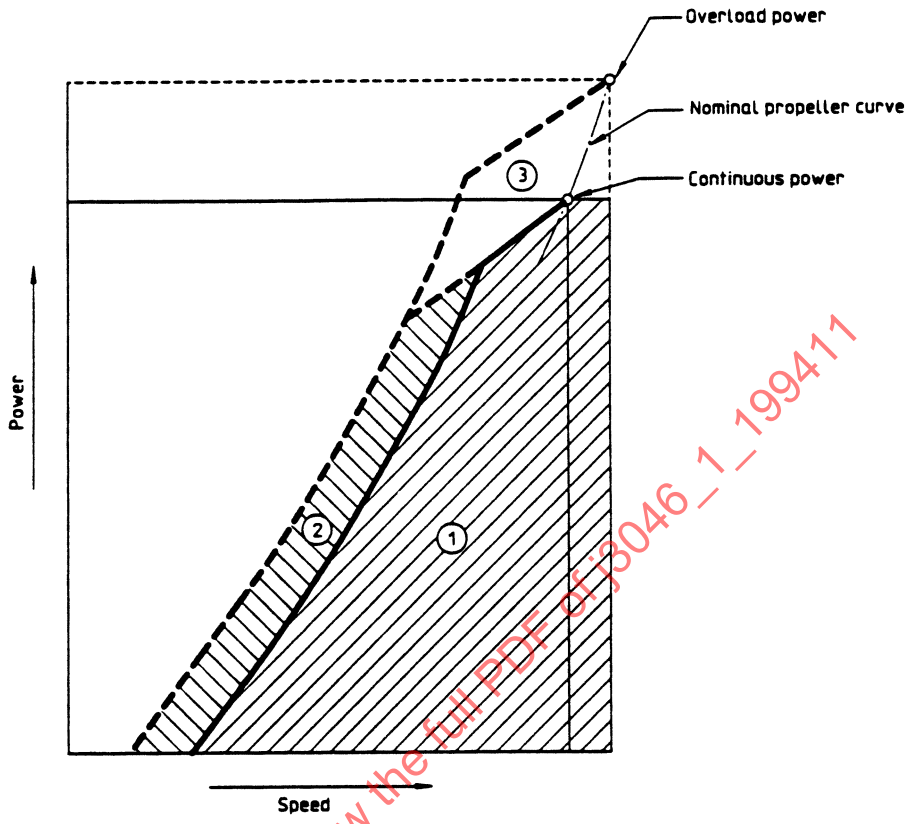

1 Range of continuous power

2 Range of intermittent operation

3 Range of short-time overload operation for special applications

FIGURE 2—EXAMPLE OF A POWER/SPEED DIAGRAM

d. The number and arrangement of cylinders (see ISO 1204).

e. Whether the engine is two-stroke or four-stroke, naturally aspirated, mechanically pressure-charged or turbocharged, and whether with or without a charge air cooler.

f. The air flow required for the operation of the engine for:

1. Combustion and scavenging
2. Cooling and ventilation

g. The method of starting apparatus supplied and additional apparatus required

h. The type and grade of lubricating oil recommended

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i. The type of governing, with speed droop if required (see ISO 3046-4 and ISO 3046-6)
For variable speed duties, the working engine speed range and the idling speed
If necessary, the critical engine speed range shall be indicated

j. The method of cooling and the capacity of the cooling system with the rates of circulation of the cooling fluids

k. Whether hot air discharge ducting can be fitted (for air-cooled engines only)

l. A schedule of recommended maintenance and overhaul periods

m. Specifications and lower calorific values of fuels recommended

n. Engine fuel supply temperature and/or viscosity

o. Maximum permissible back-pressure in the exhaust system and the maximum permissible air-intake depression

p. Characteristics of the essential independent auxiliaries supplied by the manufacturer

q. Any other information appropriate to the particular engine application

13. Methods of Power Adjustment and Specific Fuel Consumption Recalculation

13.1 General—The engine manufacturer shall indicate the amounts by which the test or site ambient conditions may differ from the standard reference conditions without having to adjust the power and recalculate the specific fuel consumption.

13.2 Application—The procedures given in this part of ISO 3046 shall be applied to calculate:

a. The expected power and specific fuel consumption for site ambient conditions from values known for standard reference conditions (see 13.3 and 13.4)
b. Whether the values of power and fuel consumption attained under engine test ambient conditions correspond to the declared values (see 13.3 and 13.4)

13.3 Adjustment of Power for Ambient Conditions

13.3.1 When it is required that the engine be operated under conditions different from the standard reference conditions given in Section 6 and if it is required that the power output shall be adjusted to or from the standard reference conditions, Equations 1 to 3 shall be used if other methods are not stated by the manufacturer (see Note 12 in 13.3.2 and also 13.3.4).

$$P_x = \alpha P_r \qquad \text{(Eq. 1)}$$

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where the power adjustment factor, α, is given by:

$$\alpha = k - 0.7(1-k)\left(\frac{1}{\eta_m} - 1\right) \quad \text{(Eq. 2)}$$

(see Note 13 in 13.3.2)

where the ratio of indicated power is:

$$k = \left(\frac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r p_{sr}}\right)^m \left(\frac{T_r}{T_x}\right)^n \left(\frac{T_{cr}}{T_{cx}}\right)^s \quad \text{(Eq. 3)}$$

For examples, see C.1, D.3 and Appendix E.

13.3.2 In the case of turbocharged engines in which the limits of turbocharger speed, turbocharger turbine inlet temperature and maximum combustion pressure have not been reached at the declared power under standard reference conditions, the manufacturer may declare substitute reference conditions to or from which power adjustment shall be made. (For an example, see C.2.)

In this case:

$$P_x = \alpha P_{ra} \quad \text{(Eq. 4)}$$

Equations 5 and 6 shall then be used instead of Equation 3.

Replacing the dry air pressure ratio in Equation 3 by the total barometric pressure ratio, the ratio of the indicated power is given by

$$k = \left(\frac{p_x}{p_{ra}}\right)^m \left(\frac{T_{ra}}{T_x}\right)^n \left(\frac{T_{cra}}{T_{cx}}\right)^s \quad \text{(Eq. 5)}$$

where the substitute reference total barometric pressure is

$$p_{ra} = p_r\left(\frac{r_r}{r_{r,max}}\right) \quad \text{(Eq. 6)}$$

The factor a and exponents m, n and s have the numerical values given in Table 3 (see 13.3.4).

NOTE 12—See also the tables in Appendix B, and the numerical examples in Appendices C, D, and E.

NOTE 13—When the test or site ambient conditions are more favorable than the standard reference conditions or substitute reference conditions (see 13.3.2), the declared power under the test or site ambient conditions may be limited by the manufacturer to the declared power under the standard reference conditions or substitute reference conditions.

NOTE 14—If the relative humidity is not known, a value of 30% should be assumed in formula references A, E, and G in Table 3.

For all other formula references, the power adjustment is independent of humidity (a = 0).

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13.3.3 The value of the mechanical efficiency shall be stated by the engine manufacturer. In the absence of any such statement, the value of $\eta m = 0.80$ shall be assumed.

13.3.4 When declaring the ISO standard power, the engine manufacturer shall state which of the formula references in Table 3 is applicable.

TABLE 3—NUMERICAL VALUES FOR POWER ADJUSTMENT

Engine Type	Conditions	Conditions	Formula Reference	Factor a	Exponent m	Exponent n	Exponent s
Compression-ignition oil engines and dual-fuel engines	Nonturbocharged	Power limited by air excess	A	1	1	0.75	0
Compression-ignition oil engines and dual-fuel engines	Nonturbocharged	Power limited by therma reasons	B	0	1	1	0
Compression-ignition oil engines and dual-fuel engines	Turbocharged without charge air cooling	Low and medium speed four-stroke engines	C	0	0.7	2	0
Compression-ignition oil engines and dual-fuel engines	Turbocharged with charge air cooling	Low and medium speed four-stroke engines	D	0	0.7	1.2	1
Spark-ignition engines using gaseous fuel	Nonturbocharged		E	1	0.86	0.55	0
Spark-ignition engines using gaseous fuel	Turbocharged with charge air cooling	Low and medium speed four-stroke engines	F	0	0.57	0.55	1.75
Spark-ignition engines using liquid fuel	Naturally aspirated		G	1	1	0.5	0

1 The formula references and the exponents have been derived by CIMAC (CIMAC = International Council on Combustion Engines).
2 The factors and exponents have been established by tests on a number of engines to be generally representative and shall be used if not otherwise stated by the manufacturer; for example in formula reference D, for an engine with the charge air cooled by engine jacket water, the value for exponents could be zero. At present, they apply only to the types of engine specified, but the table will be extended to include other types when sufficient data area available. For these engines, the power adjustment shall be stated by the engine manufacturer.
3 The formula references A, B, C, ..G are applied in examples given in Appendices C, D, and E.

13.4 Recalculation of Fuel Consumption for Test or Site Ambient Conditions for Adjusted Engines—When it is required that the engine be operated under test or site ambient conditions different from the standard reference conditions given in Section 6, the specific fuel consumption will differ from that declared for the standard reference conditions and shall be recalculated for or from the standard reference conditions.

The following equation shall be used if other methods are not declared by the manufacturer:

$$b_x = \beta b_r \qquad \text{(Eq. 7)}$$

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where:

$$\beta = \frac{k}{\alpha} \quad \text{(Eq. 8)}$$

NOTE 15—See also the tables in Appendix B and the numerical example in C.1.

14. Method of Power Correction—This power correction method, which is similar to the method given in ISO 1585, has been verified by tests on a representative number of preset engines with engine speeds of 2 000 min^{-1} and above. Manufacturers may extend this method to other engines as considered appropriate, or restrict it, if justified by experience.

This power correction method shall be applied to determine by calculation the power corrected to the standard reference conditions specified in Section 6 from the power observed (determined) under test ambient conditions.

For the purpose of power correction, the observed (determined) power shall be multiplied by a factor a as follows in Equations 9 and 10:

for spark-ignition engines:

$$P_r = \alpha_a \times P_y \quad \text{(Eq. 9)}$$

or, for compression-ignition engines:

$$P_r = \alpha_c \times P_y \quad \text{(Eq. 10)}$$

NOTE 16—In Equations 9 and 10, the mathematical approach is the inverse of that of Equation 1 in 13.3.

NOTE 17—Examples illustrating how correction factors are applied when testing preset engines are given in Appendix D.

14.1 Correction Factor α_a for Naturally Aspirated and Pressure-Charged Spark-Ignition Engines—The correction factor α_a is calculated from Equation 11:

$$\alpha_a = \left(\frac{p_r - \phi_r p_{sr}}{p_y - \phi_y p_{sy}}\right)^{1.2} \left(\frac{T_y}{T_r}\right)^{0.6} \quad \text{(Eq. 11)}$$

Equation 11 applies to engines with carburetors and to other engines where the fuel management system is designed to maintain a relatively constant fuel/air ratio as ambient conditions change. For other engine types, see 14.3.

Equation 11 is only applicable if the correction factor α_a is between 0.93 and 1.07, the ambient temperature at the air inlet to the engine is T_r ± 10 K (t_r ± 10 °C) and the dry barometric pressure is 80 kPa to 110 kPa. If these limits are exceeded, the corrected value obtained shall be given, and the test ambient conditions (temperature and pressure) precisely stated in the test report.

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14.2 Correction Factor α_c for Compression-Ignition Engines—The power correction factor ac for compression-ignition engines with preset fuel settings is calculated from Equation 12:

$$\alpha_c = (f_a)^{f_m} \quad \text{(Eq. 12)}$$

Correction Equation 12 is only applicable where the correction factor α_c is between 0.9 and 1.1, the ambient temperature of the air inlet of the engine is $T_r \pm 15$ K ($t_r \pm 15$ °C) and the dry barometric pressure is 80 kPa to 110 kPa. If these limits are exceeded, the corrected value obtained shall be given and test ambient conditions (temperature and pressure) precisely stated in the test report.

14.2.1 ATMOSPHERIC FACTOR, f_a—Factor fa indicates the effect of environmental conditions (pressure, temperature, and humidity) on the air drawn in by the engine. The atmospheric factor differs according to the type of engine and is calculated from the following equations.

a. For naturally aspirated engines, mechanically pressure-charged engines, and turbocharged engines with waste-gates operating:

$$f_a = \left(\frac{p_r - \phi_r p_{sr}}{p_y - \phi_y p_{sy}}\right)\left(\frac{T_y}{T_r}\right)^{0.7} \quad \text{(Eq. 13)}$$

b. For turbocharged engines without charge air cooling or with charge cooling by air/air cooler:

$$f_a = \left(\frac{p_r - \phi_r p_{sr}}{p_y - \phi_y p_{sy}}\right)^{0.7}\left(\frac{T_y}{T_r}\right)^{1.2} \quad \text{(Eq. 14)}$$

c. For turbocharged engines with charge air cooling by engine coolant:

$$f_a = \left(\frac{p_r - \phi_r p_{sr}}{p_y - \phi_y p_{sy}}\right)^{0.7}\left(\frac{T_y}{T_r}\right)^{0.7} \quad \text{(Eq. 15)}$$

14.2.2 ENGINE FACTOR, f_m—Factor f_m is dependent on the type of engine and the trapped air/fuel ratio corresponding to the fuel setting.

The engine factor f_m is a function of the corrected specific fuel delivery q_c, as follows:

$$f_m = 0.036 q_c - 1.14 \quad \text{(Eq. 16)}$$

in which

$$q_c = \frac{q}{r_r} \quad \text{(Eq. 17)}$$

NOTE 18—For two-stage turbocharging, r_r is the overall pressure ratio ($r_r = 1$ for naturally aspirated engines).

Equation 16 is valid for the following range of q_c, in milligrams per cycle per liter of air available for combustion:

$$37.2 \le q_c \le 65$$

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For q_c values lower than 37.2, a constant value of f_m equal to 0.2 shall be taken. For q_c values higher than 65, a constant value of f_m equal to 1.2 shall be taken (see Figure 3).

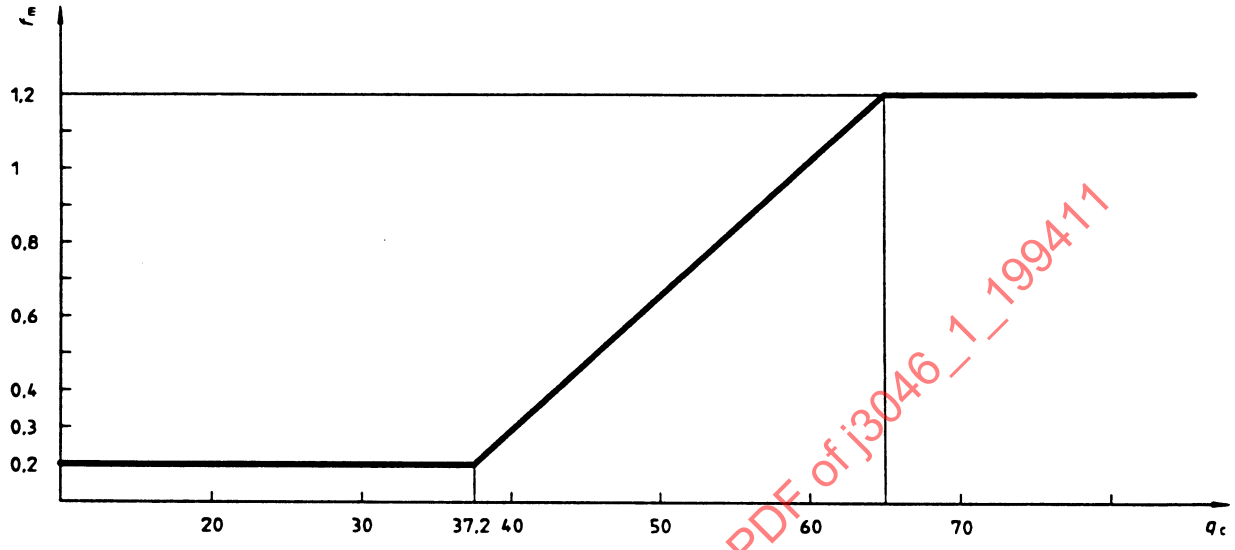

FIGURE 3—ENGINE FACTOR, f_m, AS A FUNCTION OF CORRECTED SPECIFIC FUEL DELIVERY, q_c

14.3 Other Types of Engine—For engines not covered by 14.1 and 14.2, a correction factor equal to 1 shall be applied when the ambient air density does not vary by more than ±2% from the density under standard reference conditions. When the ambient air density is beyond these limits, no correction shall be applied, but the test conditions shall be stated in the test report.

15. Test Methods—Acceptance tests, if required, shall be included in the contract. Type tests and/or special tests are subject to agreement between the manufacturer and customer.

15.1 Designation of Tests—This part of ISO 3046 gives two test categories; reference may be made to the relevant category of test as follows.

a. For acceptance tests (see 3.5.1)—ISO 3046-1 - A
b. For type tests (see 3.5.2)—ISO 3046-1 - T

15.2 Extent of Tests

15.2.1 The program of acceptance and type tests shall be established by the manufacturer.

15.2.2 It is the responsibility of the manufacturer to define the extent of measurements, which shall be agreed with the customer. Table 4 may be taken as a guide for selecting the engine groups appropriate to the test measurements given in list A (see Table 5).

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TABLE 4—ENGINE GROUPS FOR SELECTION OF TEST MEASUREMENTS

Engine Group Number	Typical Characteristics of Engine Group
1	Engines whose operating conditions are not measured in service; usually with maximum design engine speeds of more than 1800 min^{-1}.
2	Naturally aspirated engines with maximum design engine speeds of approximately 1500 min^{-1} and above.
3	Pressure-charged engines with maximum design engine speeds of approximately 1500 min^{-1} and above.
4	Engines with maximum design engine speeds of approximately 250 min-1 to 1500 min^{-1}.
5	Engines with maximum design engine speeds up to 250 min^{-1}.

15.2.3 For mass-produced engines not all tested on load, an adequate inspection procedure may be used instead of a full acceptance test.

15.2.4 Dependent on the test categories and the engine group number, five lists of recommended test measurements, calculated values and functional checks (lists A, B, C, D, E) are given in 15.5.

The following requirements are not included in the content of purchase and are subject to agreement between the manufacturer and the customer.

a. Additional measurements or tests requested during the test procedure by the customer or his representative.
b. The source and date of provision of data necessary for additional calculations, if required.

15.2.5 Whether some or all of the results from previous tests shall be recognized as a part of the acceptance test is subject to agreement between the manufacturer and customer.

15.3 Measurement Techniques

15.3.1 For the methods of measurement to be used during acceptance and type tests, symbols for parameters under measurement, units, etc., refer to ISO 3046-3.

15.3.2 If printing or memory-type measuring instruments are used, the printed and/or stored data shall be displayed during the test.

15.4 Test Conditions

15.4.1 Before an engine test, the manufacturer shall submit the necessary technical documentation concerning the engine type and application, when mutually agreed between the manufacturer and customer.

15.4.2 A period of running-in and preliminary tests considered adequate by the manufacturer shall precede the acceptance or type test.

15.4.3 Measurements for an acceptance or type test shall be carried out only when the engine has reached stable operating conditions as specified by the manufacturer.

15.4.4 Unless otherwise agreed between the manufacturer and customer, tests shall be carried out on a test bed at the manufacturer's works.

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TABLE 5—LIST A—TEST MEASUREMENTS

No.	Parameter to be Measured	Engine Group Number (see Table 4) 1	Engine Group Number (see Table 4) 2	Engine Group Number (see Table 4) 3	Engine Group Number (see Table 4) 4	Engine Group Number (see Table 4) 5
A1	Barometric pressure, humidity, and ambient temperature	x	x	x	x	x
A2	Engine speed or cycle frequency	x	x	x	x	x
A3	Engine-brake torque and/or fuel pump or governor or throttle control rod setting	x	x	x	x	x
A4	Engine-brake torque and/or fuel pump or governor or throttle control rod setting	x	x	x	x	x
A5	Fuel consumption		x	x	x	x
A6	Lubricating oil pressure		x	x	x	x
A7	Temperature and pressure of exhaust gas leaving the engine		x	x	x	x
A8	Air intake pressure and temperature at the engine or pressure charger inlet		x	x	x	x
A9	Exhaust-gas temperature at the turbine inlet			x	x	x
A10	Boost pressure in the air manifold			x	x	x
A11	Turbocharger speed			x	x	x
A12	Coolant mean temperature in and out of the cylinder block			x	x	x
A13	Lubricating oil temperature at the engine inlet and outlet			x	x	x
A14	Boost pressure drop through the charge air cooler			x	x	x
A15	Boost pressure after each charge air cooler			x	x	x
A16	Charge air temperature after each charge air cooler			x	x	x
A17	Coolant mean temperature at the inlet and outlet of the charge air cooler			x	x	x
A18	Maximum cylinder pressure				x	x
A19	Exhaust-gas pressure at the turbine inlet			x	x	x
A20	Exhaust-gas temperature of each cylinder				x	x
A21	Individual coolant circuit temperature and pressures				x	x
A22	Lubricating-oil pressure in individual circuits, e.g., turbocharger, piston cooling, etc.				x	x
A23	Lubricating-oil pressure before and after filters and coolers				x	x
A24	Secondary coolant and lubricating-oil temperatures in and out of heat exchangers				x	x
A25	Fuel supply pressure and temperature				x	x
A26	Compression pressure					x

Note—Additional items may be included by agreement between the manufacturer and customer.

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15.4.4.1 If the acceptance test is carried out on site, testing shall take place after the engine is in operating condition and at a time agreed upon by the customer and engine manufacturer. The presence of the engine manufacturer or his representative and their authority during acceptance testing, if required, should be included in the purchase agreement. The engine manufacturer or his representative shall be given the opportunity to instruct sufficiently all on-site personnel in operating the engine set and in the application of the measuring equipment.

15.4.4.2 If the acceptance test is carried out on site, the customer shall provide sufficient fuel, lubricants and coolants, as well as auxiliary personnel, unless otherwise agreed with the engine manufacturer.

15.4.4.3 On engine-related machinery not supplied by the engine manufacturer, any points of measurement necessary shall be located by the customer on instructions by the engine manufacturer.

15.4.5 Tests shall be carried out on the engine equipped with dependent auxiliaries necessary for its operation, either supplied with the engine or belonging to the test-bed equipment.

15.4.6 Test-bed equipment (e.g., air-inlet system, exhaust system; also independent auxiliaries such as water pumps, oil filters, heat exchangers, etc.) may be used, provided that the contractual requirements are fulfilled.

15.4.7 Only those engines which are supplied with built-in transmission systems (for example, hydraulic mechanisms, reversing couplings) or electric generators, and which cannot be tested separately, need to be tested with the transmission systems or generator coupled to the engine.

If engines are tested with coupled-driven machinery or a transmission system which is separable, then any variation in power, due to these coupled items, shall be eliminated from the power declared in accordance with this part of ISO 3046.

15.4.8 If the acceptance test is carried out on site and the declared power at the corresponding speed cannot be verified or achieved, due to the special circumstances of the installation and/or situation of the installation, the manufacturer and the customer shall accept the test report of the test on the manufacturer's works test bed as valid, and verify only:

a. The declared speed at a power other than the declared power or
b. The declared power at an engine speed other than the declared speed

In either case, measurement of the fuel consumption shall be omitted.

15.4.9 During tests on the engine, no additional measures, other than those required to maintain the test conditions and those required for normal operation as given in the working manual, shall be made.

15.4.10 The only permitted interruptions in testing are those necessary for engine maintenance as given in the working manual. If an interruption should occur caused by some defect of parts of the engine or the test equipment, the decision on whether to repeat the tests partially or entirely shall be agreed between the manufacturer and customer.

15.4.11 The standard reference conditions and decelerations of power, fuel, and lubricating oil consumption shall be as specified in Sections 6, 8, 9, and 10.

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15.4.12 In cases where it is not possible to maintain the specified ambient conditions and the fuel or fluid properties for the acceptance or type test, the influence of the differing conditions and/or properties and the necessary correction of the test results shall be subject to agreement between the manufacturer and customer.

In dual-fuel engines, the acceptance test is carried out with liquid fuel. An additional acceptance test with gaseous fuel may be stipulated by agreement if gaseous fuel is available at the manufacturer's works with approximately the same ignition characteristics as the gaseous fuel available on site.

In the case of spark-ignition gas engines and pilot injection gas engines, the acceptance test may be carried out at the manufacturer's works only if the composition and ignition characteristics of the gaseous fuel available are approximately the same as those of the gaseous fuel used on site.

If the acceptance test must be carried out on the basis of a special agreement at the manufacturer's works with a gaseous fuel with chemical values and properties differing significantly from those on site, the test may be made at agreed values of declared power, declared speed, and fuel consumption by resetting the engine accordingly. In such a case, a readjustment of the engine is necessary for the engine operation with the contractually specified gaseous fuel which is used on site.

15.5 Test Procedures

15.5.1 ACCEPTANCE TESTS

15.5.1.1 Acceptance tests comprise a specified sequence of power settings with measurements and calculated values given in lists A (see Table 5) and B (see Table 6) and the functional checks given in list C (see Table 7).

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TABLE 6—LIST B—TEST RESULTS

No.	Parameter to be Calculated
B1	Brake power
B2	Specific fuel consumption

TABLE 7—LIST C—FUNCTIONAL CHECKS

No.	Function to be Verified
C1	The correct functioning of the overspeed limiting device in accordance with ISO 3046-6
C2	The correct functioning of the speed governing system in accordance with ISO 3046-4
C3	The ability of all malfunction protection and warning devices to respond correctly to the fault conditions in which they should operate (for example, low-lubricating oil pressure, high-lubricating oil temperatures, high-coolant temperatures, pressure rise in the engine crankcase, etc.)
C4	The correct functioning of all automatic pressure and temperature controls
C5	The ability of the starting system to perform prior to and/or after the acceptance test conditions of the engine are reached, subject to agreement between the manufacturer and customer
C6	The correct functioning of the reversing mechanism, built-in reverse reduction gear and couplings
C7	That the temperature of important components is satisfactory
C8	That the crank web deflection does not exceed the given limits
C9	Stability of the engine on its support
C10	The condition after test of one or more piston and cylinder assemblies and bearings, chosen randomly for inspection

Note—Additional checks may be included by agreement between the manufacturer and customer.

15.5.1.2 The duration of the total acceptance test depends on the engine power and applications.

15.5.1.3 Measurements in list A (see Table 5) normally shall be made according to the specified engine group for each operating condition wherever appropriate and where provision exists on the engine for doing so. Where measurements are carried out for the purpose of verifying the declaration of power, engine speed, and fuel consumption, valid measurements shall be carried out at least twice. A measurement shall be considered valid if the variations of the engine-brake torque and engine-speed values in relation to the settings of the operating values do not exceed ±2%. The variation of the power output during this period shall not exceed ±3%. This requirement shall not normally apply to spark-ignition engines with a brake power less than 50 kW.

Measurements in list A (see Table 5) are arranged in an ascending order of test measurement complexity and are presented for guidance when the contract is drawn up between the manufacturer and customer. Either party may, by agreement, add to or delete from the measurements in list A, to suit the particular type of engine involved. Where no provision exists on the engine for a particular measurement, this shall be stated by the manufacturer.

15.5.1.4 Where appropriate, the manufacturer shall supply the calculated values given in list B (see Table 6) on the basis of test measurements obtained from list A (see Table 5).

15.5.1.4.1 Measurement of the fuel consumption shall be carried out during the measurement of power.

15.5.1.4.2 For engines having a brake power of 200 kW and above, if the variation between the results of two fuel consumption measurements is more than 2%, the measurement shall be repeated for this operating condition.

15.5.1.4.3 Fuel fed to the engine which is surplus and not consumed shall be taken into account in the measurements.

15.5.1.5 List C (see Table 7) comprises functional checks which may additionally be carried out on engines in groups 2 to 5 in Table 4. Selection from list C shall be made by agreement between the manufacturer and customer.

15.5.2 TYPE TESTS

15.5.2.1 A type test comprises a specified sequence of power/engine speed combined values, reversals, and stop.

15.5.2.2 Type tests shall include, as far as applicable, all measurements, calculations, and functional checks in list A, engine group 5 (see Table 5), and lists B and C (see Tables 6 and 7), and in addition list D (see Table 8).

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TABLE 8—LIST D—ADDITIONAL TESTS

No.	Parameter/Measures
D1	Air consumption
D2	Lubricating-oil consumption
D3	Dismantling, inspection, and measuring of important parts subject to wear

15.5.3 SPECIAL TESTS—Special tests are any of those in list E (see Table 9) which may be required by inspecting authorities, classification societies, by legislation or by the customer.

TABLE 9—LIST E—SPECIAL TESTS (EXAMPLES)

No.	Parameter or Function
E1	Torsional vibration frequencies and amplitudes at prescribed power/engine speed combinations when the engine is tested coupled to its contract-driven machinery, in accordance with ISO 3046-5
E2	Engine-heat balance
E3	Sound level
E4	Exhaust-gas emission characteristics
E5	Tests in conjunction with contract-driven machinery
E6	Parallel running and other electrical tests of engine-driven generators
E7	Emergency reversal of marine engines
E8	Determination of minimum stable engine speed of marine engines
E9	Change-over on dual-fuel engines
E10	Ability to carry out maintenance tasks within the time stated by the manufacturer
E11	Ability to maneuver and provide a stated power when operating with specified malfunctions, for example with one or more turbochargers inoperative

15.6 Power Adjustment, Specific Fuel Consumption Recalculation, and Power Correction—The manufacturer shall specify which method (power adjustment or power correction) is applicable to the engine.

15.6.1 ADJUSTED ENGINES—The test power may be determined, using the equation in Section 13 where necessary, in one or more of the following ways.

a. By adjusting the ISO power from standard reference conditions to test ambient conditions
b. .By adjusting the declared service power from the site ambient conditions to the power under test ambient conditions
c. By making the test power equal to the declared service power and testing under conditions altered artificially in accordance with 15.6.1.4 to simulate the site ambient conditions
d. By testing under conditions simulating some of the site ambient conditions in accordance with 15.6.1.4 and adjusting the declared service power to allow for the remaining differences

NOTE 19—Power adjustment by using equation from 13.3 is only permissible if the turbocharging equipment or timing of the engine is not changed or modified for site ambient conditions.

15.6.1.1 When adjusting the power, the engine manufacturer shall state which of the equation references given in Table 3 shall be used.

If there is no suitable equation reference for power adjustment in Table 3, the method of adjustment shall be agreed in writing by the manufacturer and customer.

15.6.1.2 If a turbocharged engine at the declared power and under the standard reference conditions attains neither the turbocharger speed limit nor the exhaust-gas temperature limit at the turbine inlet, nor the maximum combustion pressure, the manufacturer may declare substitute reference conditions as specified in 13.3.2 for the power adjustment.

15.6.1.3 When adjusting the declared power on site for test ambient conditions, results may be attained where, for example, the maximum combustion pressure in the engine cylinder exceeds the permitted value. In this case, the engine test shall be carried out at such a power considered safe by the manufacturer, at which the permitted value is not exceeded.

The values of the engine parameters corresponding to the required power may be extrapolated from the measured values by a method agreed upon between the manufacturer and customer.

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15.6.1.4 Engine tests may be carried out under ambient conditions created artificially to simulate site ambient conditions by one of the following.

a. Altering the air temperature at the engine inlet by artificial heating
b. .Altering the coolant temperature at the inlet of the charge air cooler, etc.
c. Other appropriate methods considered safe by the manufacturer

15.6.2 NONADJUSTED ENGINES (PRESET ENGINES)—Where the test conditions differ from the standard reference conditions, the method given in Section 14 may be used for power correction of measured power to standard reference conditions (correction by calculation).

The test may be carried out in air-conditioned test rooms where the atmospheric conditions are controlled to equal the reference conditions.

Where an influencing parameter is controlled by an automatic device, no power correction for that parameter shall be applied, provided that the relevant parameter is within the relevant range of the device. This applies in particular to:

a. Automatic air temperature controls where the device is still operating at 25 °C
b. Automatic boost control when the atmospheric pressure is such that the boost control is working
c. Automatic fuel control where the governor adjusts the fuel delivery for constant power output (by compensating for the influence of ambient pressure and temperature)

However, in the case of 15.6.2.a, if the automatic air temperature device is fully closed at full load at 25 °C (no heated air added to the intake air), the test shall be carried out with the device fully closed, and the normal correction factor applied. In the case of 15.6.2.c, the fuel consumption for compression-ignition engines shall be corrected by the reciprocal of the power correction factor.

16. 16. Test Report

16.1 The manufacturer shall provide a test report.

Normally, acceptance test reports shall be provided only for engine groups numbers 3, 4, and 5 (see Table 4).

Type test reports shall be provided for all groups of engine.

16.2 The test report shall include engine identification and the following test information:

a. Reference to this part of ISO 3046, including the year of publication
b. Date, place, designation of test, and inspecting authority
c. Type of fuel and lubricating oil used during tests

NOTE 20—If the fuel used complies with the specification of a national or International Standard, the properties need be verified only by explicit agreement between the manufacturer and customer.

If the fuel does not comply with the specification of a national or International Standard, the properties and constituents should be stated as agreed between the manufacturer and customer.

The lower calorific value of the fuel and its method of determination should be stated.

d. Dependent auxiliaries, engine settings, and proprietary equipment
e. Table of values measured during the test

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f. Parameters calculated during the test
g. Results of functional checks
h. Results of additional tests and special tests, if required

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APPENDIX A

(INFORMATIVE)
EXAMPLES OF AUXILIARIES WHICH MAY BE FITTED—

These lists are given for guidance purposes only and are not necessarily complete.

A.1 List F—Essential Dependent Auxiliaries—(see 3.1.1 and 3.1.3)

a. Engine-driven lubricating oil pressure pump
b. Engine-driven lubricating oil scavenge pump for dry-sump engines
c. Engine-driven engine-cooling water pump
d. Engine-driven raw-water pump
e. Engine-driven radiator-cooling fan
f. Engine-driven engine-cooling fan for air-cooled engines
g. Engine-driven gaseous fuel compressor
h. Engine-driven fuel-feed pump
i. Engine-driven fuel-pressure pump for common rail or servo-injection system
j. Engine-driven scavenge-air blower and/or charge-air blower
k. .Engine-driven generator, air compressor, or hydraulic pump when supplying power to items in list G
l. Engine-driven cylinder lubricating pump
m. Air cleaner or air silencer (normal or special)
n. Exhaust silencer (normal or special)

A.2 List G—Essential Independent Auxiliaries—(see 3.1.2 and 3.1.3)

a. Separately driven lubricating oil pressure pump
b. Separately driven lubricating oil scavenge pump for dry-sump engines
c. Separately driven engine-cooling water pump
d. Separately driven raw-water pump
e. Separately driven radiator-cooling fan
f. Separately driven engine-cooling fan for air-cooled engines
g. Separately driven gaseous fuel compressor
h. Separately driven fuel-feed pump
i. Separately driven fuel-pressure pump for common-rail or servo-injection system
j. Separately driven scavenge-air blower and/or charge-air blower
k. Separately driven crankcase extractor fan
l. Separately driven cylinder-lubricating pump
m. Governing or control system using power from an external source

A.3 List H—Nonessential Dependent Auxiliaries—(see 3.1.1 and 3.1.4)

a. Engine-driven starting air compressor
b. Engine-driven generator, air compressor, or hydraulic pump when supplying power to items not in list G
c. Engine-driven bilge pump
d. Engine-driven fire pump
e. Engine-driven ventilation fan
f. Engine-driven fuel-transfer pump
g. Engine-integral thrust bearing

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APPENDIX B

(INFORMATIVE)
TABLES FOR DETERMINATION OF WATER VAPOR PRESSURE, RATIOS, AND FACTORS

B.1 Determination of Water Vapor Pressure—The water vapor pressure ($\phi_x p_{sx}$) values are given in Table B1, in kilopascals, for different values of the air temperature t_x, in degrees Celsius, and relative humidity ϕ_x.

TABLE B1—WATER VAPOR PRESURE VALUES

t_x °C	$\phi_x p_{sx}$, kPa ϕ_x 1.0	$\phi_x p_{sx}$, kPa ϕ_x 0.9	$\phi_x p_{sx}$, kPa ϕ_x 0.8	$\phi_x p_{sx}$, kPa ϕ_x 0.7	$\phi_x p_{sx}$, kPa ϕ_x 0.6	$\phi_x p_{sx}$, kPa ϕ_x 0.5	$\phi_x p_{sx}$, kPa ϕ_x 0.4	$\phi_x p_{sx}$, kPa ϕ_x 0.3	$\phi_x p_{sx}$, kPa ϕ_x 0.2
-10	0.30	0.27	0.24	0.21	0.18	0.15	0.12	0.09	0.06
-9	0.33	0.29	0.26	0.23	0.20	0.16	0.13	0.10	0.07
-8	0.35	0.32	0.28	0.25	0.21	0.18	0.14	0.11	0.07
-7	0.38	0.34	0.30	0.27	0.23	0.19	0.15	0.11	0.08
-6	0.41	0.36	0.32	0.28	0.24	0.20	0.16	0.12	0.08
-5	0.43	0.39	0.35	0.30	0.26	0.22	0.17	0.13	0.09
-4	0.46	0.41	0.37	0.32	0.28	0.23	0.18	0.14	0.09
-3	0.49	0.44	0.39	0.34	0.30	0.25	0.20	0.15	0.10
-2	0.53	0.47	0.42	0.37	0.32	0.26	0.21	0.16	0.10
-1	0.56	0.50	0.45	0.39	0.34	0.28	0.22	0.17	0.11
0	0.60	0.54	0.48	0.42	0.36	0.30	0.24	0.18	0.12
1	0.64	0.58	0.51	0.45	0.39	0.32	0.26	0.19	0.13
2	0.69	0.62	0.55	0.48	0.41	0.34	0.28	0.21	0.14
3	0.74	0.66	0.59	0.52	0.44	0.37	0.30	0.22	0.15
4	0.79	0.71	0.63	0.55	0.47	0.40	0.32	0.24	0.16
5	0.85	0.76	0.68	0.59	0.51	0.42	0.34	0.25	0.17
6	0.91	0.82	0.73	0.64	0.55	0.46	0.36	0.27	0.18
7	0.98	0.88	0.78	0.68	0.59	0.49	0.39	0.29	0.20
8	1.05	0.94	0.84	0.73	0.63	0.52	0.42	0.31	0.21
9	1.12	1.01	0.90	0.78	0.67	0.56	0.45	0.34	0.22
10	1.20	1.08	0.96	0.84	0.72	0.60	0.48	0.36	0.24
11	1.28	1.16	1.03	0.90	0.77	0.64	0.51	0.39	0.26
12	1.37	1.24	1.10	0.96	0.82	0.69	0.55	0.41	0.27
13	1.47	1.32	1.17	1.03	0.88	0.73	0.59	0.44	0.29
14	1.57	1.41	1.25	1.10	0.94	0.78	0.63	0.47	0.31
15	1.67	1.51	1.34	1.17	1.00	0.84	0.67	0.50	0.33
16	1.79	1.61	1.43	1.25	1.07	0.89	0.71	0.54	0.36
17	1.90	1.71	1.52	1.33	1.14	0.95	0.76	0.57	0.38
18	2.03	1.83	1.62	1.42	1.22	1.01	0.81	0.61	0.41
19	2.16	1.94	1.73	1.51	1.30	1.08	0.86	0.65	0.43
20	2.30	2.07	1.84	1.61	1.38	1.15	0.92	0.69	0.46
21	2.45	2.20	1.96	1.71	1.47	1.22	0.98	0.73	0.49
22	2.60	2.34	2.08	1.82	1.56	1.30	1.04	0.78	0.52
23	2.77	2.49	2.21	1.94	1.66	1.38	1.11	0.83	0.55
24	2.94	2.65	2.35	2.06	1.76	1.47	1.18	0.88	0.59
25	3.12	2.81	2.50	2.19	1.87	1.56	1.25	0.94	0.62
26	3.32	2.98	2.65	2.32	1.99	1.66	1.33	0.99	0.66
27	3.52	3.17	2.82	2.46	2.11	1.76	1.41	1.06	0.70
28	3.73	3.36	2.99	2.61	2.24	1.87	1.49	1.12	0.75

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TABLE B1—WATER VAPOR PRESURE VALUES (CONTINUED)

t_x °C	$\phi_x p_{sx}$, kPa ϕ_x 1.0	$\phi_x p_{sx}$, kPa ϕ_x 0.9	$\phi_x p_{sx}$, kPa ϕ_x 0.8	$\phi_x p_{sx}$, kPa ϕ_x 0.7	$\phi_x p_{sx}$, kPa ϕ_x 0.6	$\phi_x p_{sx}$, kPa ϕ_x 0.5	$\phi_x p_{sx}$, kPa ϕ_x 0.4	$\phi_x p_{sx}$, kPa ϕ_x 0.3	$\phi_x p_{sx}$, kPa ϕ_x 0.2
29	3.96	3.56	3.17	2.77	2.38	1.98	1.58	1.19	0.79
30	4.20	3.78	3.36	2.94	2.52	2.10	1.68	1.26	0.84
31	4.45	4.01	3.56	3.12	2.67	2.23	1.78	1.34	0.89
32	4.72	4.25	3.78	3.30	2.83	2.36	1.89	1.42	0.94
33	5.00	4.50	4.00	3.50	3.00	2.50	2.00	1.50	1.00
34	5.29	4.76	4.24	3.71	3.18	2.65	2.12	1.59	1.06
35	5.60	5.04	4.48	3.92	3.36	2.80	2.24	1.68	1.12
36	5.93	5.34	4.74	4.15	3.56	2.97	2.37	1.78	1.19
37	6.27	5.64	5.02	4.39	3.76	3.14	2.51	1.88	1.25
38	6.63	5.97	5.30	4.64	3.98	3.32	2.65	1.99	1.33
39	7.01	6.31	5.61	4.90	4.20	3.50	2.80	2.10	1.40
40	7.40	6.66	5.92	5.18	4.44	3.70	2.96	2.22	1.48
41	7.81	7.03	6.25	5.47	4.69	3.91	3.12	2.34	1.56
42	8.24	7.42	6.59	5.77	4.94	4.12	3.30	2.47	1.65
43	8.69	7.82	6.95	6.08	5.21	4.34	3.47	2.61	1.74
44	9.15	8.24	7.32	6.41	5.49	4.58	3.66	2.75	1.83
45	9.63	8.67	7.71	6.74	5.78	4.82	3.85	2.89	1.93
46	10.13	9.12	8.11	7.09	6.08	5.07	4.05	3.04	2.03
47	10.65	9.58	8.52	7.45	6.39	5.33	4.26	3.20	2.13
48	11.18	10.07	8.95	7.83	6.71	5.59	4.47	3.36	2.24
49	11.73	10.56	9.39	8.21	7.04	5.87	4.69	3.52	2.35
50	12.30	11.07	9.84	8.61	7.38	6.15	4.92	3.69	2.46

B.2 Determination of Dry Air Pressure Ratio—The dry air pressure ratio $\left(\frac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r p_{sr}}\right)$ used in Equation 3 is given in Table B2 for the value of a = 1 of formula references A, E, and G (see Table 3) and for different values of total barometric pressure (p_x) and water vapor pressure ($\phi_x p_{sx}$). If the water vapor pressure is not known, it can be obtained from the air temperature and relative humidity by the use of Table B1.

B.3 Determination of the Ratio of Indicated Power, k—Equation 3 or 5 can be written as:

$$k = (R_1)^{y_1}(R_2)^{y_2}(R_3)^{y_3} \qquad \text{(Eq. B1)}$$

where:

$R_1 = \frac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r p_{sr}}$ or $\frac{p_x}{p_{ra}}$

$R_2 = \frac{T_r}{T_x}$ or $\frac{T_{ra}}{T_x}$

$R_3 = \frac{T_{cr}}{T_{cx}}$ or $\frac{T_{cra}}{T_{cx}}$

and $y_1 = m$; $y_2 = n$; $y_3 = s$

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The value of

$$R = \frac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r P_{sr}} \qquad \text{(Eq. B2)}$$

can be obtained from Table B2 and other values of R can be calculated.

The values of m, n, and s are obtained from Table B3.

Table B3 then gives values of R^y for known ratios R and known factors y.

The value of k is then obtained by multiplying together the appropriate values of R^y.

B.4 Determination of the Fuel Consumption Recalculation Factor, b—Table B4 gives values of the fuel consumption recalculation factor, β (see Equation 8), for known values of the ratio of indicated power k and mechanical efficiency η_m.

The value of k can (see Equations 3 and 5) be determined for B.3.

The value of η_m is stated by the manufacturer (see 13.3.3).

B.5 Determination of the Power Adjustment Factor, a—Table B5 gives values of the power adjustment factor, α (see Equation 2), for known values of the ratio of indicated power k and mechanical efficiency η_m.

The value of k (see Equations 3 and 5) can be determined from B.3.

The value of η_m is stated by the manufacturer (see 13.3.3).

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TABLE B2—VALUES OF DRY AIR PRESSURE RATIO— $\frac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r p_{sr}}$

$\phi_x p_{sx}$, kPa

Altitude m	Total Barometric Pressure, p_x kPa	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0	101.3	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89
100	100.0	1.01	1.00	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87
200	98.9	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86
400	96.7	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84
600	94.4	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82
800	92.1	0.93	0.92	0.91	0.90	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.79
1000	89.9	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.77
1200	87.7	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75
1400	85.6	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75	0.74	0.73
1600	83.5	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.71
1800	81.5	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.71	0.70	0.69
2000	79.5	0.80	0.79	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67
2200	77.6	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.65
2400	75.6	0.76	0.75	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.65	0.64	0.63
2600	73.7	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.61
2800	71.9	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.59
3000	70.1	0.70	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.59	0.58	0.57
3200	68.4	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.58	0.57	0.56	0.55
3400	66.7	0.67	0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.55	0.54
3600	64.9	0.65	0.64	0.63	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.52
3800	63.2	0.63	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.50
4000	61.5	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.50	0.48
4200	60.1	0.60	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.50	0.49	0.48	0.47
4400	58.5	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.50	0.48	0.47	0.46	0.45
4600	56.9	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.44
4800	55.3	0.55	0.54	0.53	0.52	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.42
5000	54.1	0.54	0.53	0.52	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.41

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TABLE B3—VALUES OF R^y FOR DETERMINATION OF THE RATIO OF INDICATED POWER, k

R	R^y y 0.5	R^y y 0.55	R^y y 0.57	R^y y 0.7	R^y y 0.75	R^y y 0.86	R^y y 1.2	R^y y 1.75	R^y y 2.0
0.60	0.775	0.755	0.747	0.699	0.682	0.645	0.542	0.409	0.360
0.62	0.787	0.769	0.762	0.716	0.699	0.663	0.564	0.433	0.384
0.64	0.800	0.782	0.775	0.732	0.716	0.681	0.585	0.458	0.410
0.66	0.812	0.796	0.789	0.748	0.732	0.700	0.607	0.483	0.436
0.68	0.825	0.809	0.803	0.763	0.749	0.718	0.630	0.509	0.462
0.70	0.837	0.822	0.816	0.779	0.765	0.736	0.652	0.536	0.490
0.72	0.849	0.835	0.829	0.795	0.782	0.754	0.674	0.563	0.518
0.74	0.860	0.847	0.842	0.810	0.798	0.772	0.697	0.590	0.548
0.76	0.872	0.860	0.855	0.825	0.814	0.790	0.719	0.619	0.578
0.78	0.883	0.872	0.868	0.840	0.830	0.808	0.742	0.647	0.608
0.80	0.894	0.885	0.881	0.855	0.846	0.825	0.765	0.677	0.640
0.82	0.906	0.897	0.893	0.870	0.862	0.843	0.788	0.707	0.672
0.84	0.917	0.909	0.905	0.885	0.877	0.861	0.811	0.737	0.706
0.86	0.927	0.920	0.918	0.900	0.893	0.878	0.834	0.768	0.740
0.88	0.938	0.932	0.930	0.914	0.909	0.896	0.858	0.800	0.774
0.90	0.949	0.944	0.942	0.929	0.924	0.913	0.881	0.832	0.810
0.92	0.959	0.955	0.954	0.943	0.939	0.931	0.905	0.864	0.846
0.94	0.970	0.967	0.965	0.958	0.955	0.948	0.928	0.897	0.884
0.96	0.980	0.978	0.977	0.972	0.970	0.966	0.952	0.931	0.922
0.98	0.990	0.989	0.989	0.986	0.985	0.983	0.976	0.965	0.960
1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.02	1.010	1.011	1.011	1.014	1.015	1.017	1.024	1.035	1.040
1.04	1.020	1.022	1.023	1.028	1.030	1.034	1.048	1.071	1.082
1.06	1.030	1.033	1.034	1.042	1.045	1.051	1.072	1.107	1.124
1.08	1.038	1.043	1.045	1.055	1.059	1.068	1.097	1.144	1.166
1.10	1.049	1.054	1.056	1.069	1.074	1.085	1.121	1.182	1.210
1.12	1.058	1.064	1.067	1.083	1.089	1.102	1.146	1.219	1.254
1.14	1.068	1.075	1.078	1.096	1.103	1.119	1.170	1.258	1.300
1.16	1.077	1.085	1.088	1.110	1.118	1.136	1.195	1.297	1.346
1.18	1.086	1.095	1.099	1.123	1.132	1.153	1.220	1.336	1.392
1.20	1.095	1.106	1.110	1.135	1.147	1.170	1.245	1.376	1.440

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TABLE B4—FUEL CONSUMPTION RECALCULATION FACTOR, β, VALUES

k	β_{η_m} 0.70	β_{η_m} 0.75	β_{η_m} 0.80	β_{η_m} 0.85	β_{η_m} 0.90	β_{η_m} 0.95
0.50	1.429	1.304	1.212	1.141	1.084	1.038
0.52	1.383	1.275	1.193	1.129	1.077	1.035
0.54	1.343	1.248	1.175	1.118	1.071	1.032
0.56	1.308	1.225	1.159	1.108	1.065	1.030
0.58	1.278	1.203	1.145	1.098	1.060	1.027
0.60	1.250	1.184	1.132	1.090	1.055	1.025
0.62	1.225	1.167	1.120	1.082	1.050	1.023
0.64	1.203	1.151	1.109	1.075	1.046	1.021
0.66	1.183	1.137	1.099	1.068	1.042	1.019
0.68	1.164	1.123	1.090	1.062	1.038	1.018
0.70	1.148	1.111	1.081	1.056	1.035	1.016
0.72	1.132	1.100	1.073	1.051	1.031	1.015
0.74	1.118	1.089	1.066	1.045	1.028	1.013
0.76	1.105	1.080	1.059	1.041	1.025	1.012
0.78	1.092	1.070	1.052	1.036	1.022	1.011
0.80	1.081	1.062	1.046	1.032	1.020	1.009
0.82	1.071	1.054	1.040	1.028	1.017	1.008
0.84	1.061	1.047	1.035	1.024	1.015	1.007
0.86	1.051	1.040	1.029	1.021	1.013	1.006
0.88	1.043	1.033	1.024	1.017	1.011	1.005
0.90	1.035	1.027	1.020	1.014	1.009	1.004
0.92	1.027	1.021	1.016	1.011	1.007	1.003
0.94	1.020	1.015	1.011	1.008	1.005	1.002
0.96	1.013	1.010	1.007	1.005	1.003	1.002
0.98	1.006	1.005	1.004	1.003	1.002	1.001
1.00	1.000	1.000	1.000	1.000	1.000	1.000
1.02	0.994	0.995	0.997	0.998	0.999	0.999
1.04	0.989	0.991	0.993	0.995	0.997	0.999
1.06	0.983	0.987	0.990	0.993	0.996	0.998
1.08	0.978	0.983	0.987	0.991	0.994	0.997
1.10	0.974	0.979	0.984	0.989	0.993	0.997
1.12	0.969	0.976	0.982	0.987	0.992	0.996
1.14	0.965	0.972	0.979	0.985	0.991	0.996
1.16	0.960	0.969	0.976	0.983	0.989	0.995
1.18	0.956	0.966	0.974	0.982	0.988	0.994
1.20	0.952	0.963	0.972	0.980	0.987	0.994

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TABLE B5—VALUES OF THE POWER ADJUSTMENT FACTOR, α

k	α η_m 0.70	α η_m 0.75	α η_m 0.80	α η_m 0.85	α η_m 0.90	α η_m 0.95
0.50	0.350	0.383	0.413	0.438	0.461	0.482
0.52	0.376	0.408	0.436	0.461	0.483	0.502
0.54	0.402	0.433	0.460	0.483	0.504	0.523
0.56	0.428	0.457	0.483	0.506	0.526	0.544
0.58	0.454	0.482	0.507	0.528	0.547	0.565
0.60	0.480	0.507	0.530	0.551	0.569	0.585
0.62	0.506	0.531	0.554	0.573	0.590	0.606
0.64	0.532	0.556	0.577	0.596	0.612	0.627
0.66	0.558	0.581	0.601	0.618	0.634	0.648
0.68	0.584	0.605	0.624	0.641	0.655	0.668
0.70	0.610	0.630	0.648	0.663	0.677	0.689
0.72	0.636	0.655	0.671	0.685	0.698	0.710
0.74	0.662	0.679	0.695	0.708	0.720	0.730
0.76	0.688	0.704	0.718	0.730	0.741	0.751
0.78	0.714	0.729	0.742	0.753	0.763	0.772
0.80	0.740	0.753	0.765	0.775	0.784	0.793
0.82	0.766	0.778	0.789	0.798	0.806	0.813
0.84	0.792	0.803	0.812	0.820	0.828	0.834
0.86	0.818	0.827	0.836	0.843	0.849	0.855
0.88	0.844	0.852	0.859	0.865	0.871	0.876
0.90	0.870	0.877	0.883	0.888	0.892	0.896
0.92	0.896	0.901	0.906	0.910	0.914	0.917
0.94	0.922	0.926	0.930	0.933	0.935	0.938
0.96	0.948	0.951	0.953	0.955	0.957	0.959
0.98	0.974	0.975	0.977	0.978	0.978	0.979
1.00	1.000	1.000	1.000	1.000	1.000	1.000
1.02	1.026	1.025	1.024	1.023	1.022	1.021
1.04	1.052	1.049	1.047	1.045	1.043	1.042
1.06	1.078	1.074	1.071	1.067	1.065	1.062
1.08	1.104	1.099	1.094	1.090	1.086	1.083
1.10	1.130	1.123	1.118	1.112	1.108	1.104
1.12	1.156	1.148	1.141	1.135	1.129	1.124
1.14	1.182	1.173	1.165	1.157	1.151	1.145
1.16	1.208	1.197	1.188	1.180	1.172	1.166
1.18	1.234	1.222	1.212	1.202	1.194	1.187
1.20	1.260	1.247	1.235	1.225	1.216	1.207

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APPENDIX C

(INFORMATIVE)
EXAMPLES OF POWER ADJUSTMENT AND SPECIFIC FUEL CONSUMPTION RECALCULATION FROM STANDARD REFERENCE CONDITIONS OR SUBSTITUTE REFERENCE CONDITIONS TO SITE AMBIENT CONDITIONS

C.1 ***Example 1—***A nonturbocharged engine with its power limited by air excess has an ISO standard power of 500 kW with a mechanical efficiency of 85%, and an ISO specific fuel consumption of 220 g/(kW·h).

What is the expected service standard power and specific fuel consumption at a site with a total barometric pressure of 87 kPa, air temperature 45 °C, and relative humidity 80%?

Standard Reference Conditions	**Site Conditions**
p_r = 100 kPa	p_x = 87 kPa
T_r = 298 K	T_x = 318 K
ϕ_r = 0.3	ϕ_x = 0.8

and η_m = 0.85.

From B.1, at t_x = 45 °C and ϕ_x = 0.8:

$$\phi_x p_{sx} = 7.71 \text{ kPa} \qquad \text{(Eq. C1)}$$

From B.2, at p_x = 87 kPa and $\phi_x p_{sx}$ = 7.71 kPa, by interpolation:

$$\frac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r p_{sr}} = 0.801 \qquad \text{(Eq. C2)}$$

From B.3, at $\frac{T_r}{T_x} = \frac{298}{318} = 0.937$ and n = 0.75, by interpolation:

$$\left(\frac{T_r}{T_x}\right)^n = 0.952 \qquad \text{(Eq. C3)}$$

From Equation 3, k = 0.801 x 0.952 = 0.763.

From B.4, at k = 0.763 and η_m = 0.85, by interpolation β = 1.040.

From B.5, at k = 0.763 and η_m = 0.85, by interpolation α = 0.733 6.

Hence:

site continuous brake power = 500 x 0.733 6 = 366.8 kW
site specific fuel consumption = 220 x 1.040 = 228.8 g/(kW·h)

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