International Standard 3046/1

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Reciprocating internal combustion engines — Performance — Part 1 : Standard reference conditions and declarations of power, fuel consumption and lubricating oil consumption

Moteurs alternatifs à combustion interne — Performances — Partie 1 : Conditions normales de référence et déclarations de la puissance et des consommations de combustible et d'huile de graissage

Third edition — 1986-08-15

UDC 621.432 : 621.43.018 **Ref. No. ISO 3046/1-1986 (E)**

Descriptors : internal combustion engines, reciprocating engines, specifications, standard atmosphere, power, consumption, fuels, lubricating oils.

ISO 3046/1-1986 (E)

Price based on 15 pages

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 3046/1 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines.*

This third edition cancels and replaces the second edition (ISO 3046/1-1981), the standard reference conditions in clause 5 of which have been changed. (See the Introduction.)

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Contents

Reciprocating internal combustion engines — Performance — Part 1 : Standard reference conditions and declarations of power, fuel consumption and lubricating oil consumption

0 Introduction

The standard reference conditions of clause 5 have been changed, but it is still permissible to use the old standard reference conditions for a period of five years from the publication of this third edition. Where this is done, the values shall be stated.

The standard reference conditions in the second edition (ISO 3046/1-1981) were as follows :

Total barometric pressure :	p_r = 100 kPa
Air temperature :	T_r = 300 K (27 °C)
Relative humidity :	ϕ_r = 60 %
Air coolant temperature :	T_{cr} = 300 K (27 °C)

1 Scope

This part of ISO 3046 specifies the standard reference conditions and the methods of declaring the power, fuel consumption and lubricating oil consumption for reciprocating internal combustion engines using liquid or gaseous fuels. Where necessary, individual requirements are given for particular engine applications.

2 Field of application

This part of ISO 3046 covers reciprocating internal combustion 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 earth-moving machines, industrial trucks and for other applications where no suitable International Standard for these engines exist.

3 References

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units.*

ISO 1204, *Reciprocating internal combustion engines — Designation of the direction of rotation.*

ISO 1205, *Reciprocating internal combustion engines — Designation of the cylinders.*

ISO 2710, *Reciprocating internal combustion engines — Vocabulary.*

ISO 3046/2, *Reciprocating internal combustion engines — Performance — Part 2 : Test methods.*

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

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

4 Units and terms

4.1 The units used are those of the International System of Units (SI Units) described in ISO 1000.

4.2 The general engine terms used are as defined in ISO 2710.

5 Standard reference conditions

For the purpose of determining the power and fuel consumption of engines, the following standard reference conditions shall be used :

Total barometric pressure :

p_r = 100 kPa

Air temperature :

T_r = 298 K (25 °C)

Relative humidity :

ϕ_r = 30 %

Charge air coolant temperature :

T_{cr} = 298 K (25 °C)

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

6 Auxiliaries

6.1 Introduction

In order to show clearly the conditions under which a power 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.

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

(Such items as fuel injection pump, exhaust turbocharger and charge air cooler are in this category of engine components.)

6.2 dependent auxiliary : Item of equipment, the presence or absence of which affects the final shaft output of the engine.

6.3 independent auxiliary : Item of equipment which uses power supplied from a source other than the engine.

6.4 essential auxiliary : Item of equipment which is essential for the continued or repeated operation of the engine.

6.5 non-essential auxiliary : Item of equipment which is not essential for the continued or repeated operation of the engine.

7 Declarations of power

7.1 Introduction

7.1.1 Purpose of statement of power

Statements of power are required for two main purposes, as follows.

a) The declaration by a manufacturer of the value of the power which his engine will deliver under a given set of circumstances. This declared value is known as the "rated 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 kind of statement of power (see 7.4) and if necessary, the ambient and operating conditions (see 7.4.2);

b) the kind of power output (see 7.3);

c) the kind of power (see 7.2);

d) the corresponding engine speed.

NOTES

1 The terms used in a) to c) may be combined, for example, continuous net brake fuel stop power.

2 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 shall be stated by the manufacturer.

3 Measurement of the powers referred to in this part of ISO 3046 shall be determined in accordance with ISO 3046/2.

7.1.2 Unit of power

Power shall be expressed in kilowatts (kW).

7.1.3 Power and torque

For engines delivering power by a shaft or shafts, any power in this International Standard 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.

7.1.4 Engine speed

The speed of an engine is the mean rotational speed of its crankshaft or crankshafts in revolutions per minute, except in the case of 'free piston' engines where the speed is the number of cycles per minute of the reciprocating components.

7.1.5 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.

7.2 Kinds of power

7.2.1 indicated power : The total power developed in the working cylinders as a result of the pressure of the working medium acting on the pistons.

7.2.2 brake power : The power or sum of the powers at the driving shaft or shafts.

7.2.2.1 Any statement of brake power shall be supported by the following list of auxiliaries :

a) essential dependent auxiliaries as defined in 6.2 and 6.4;

b) essential independent auxiliaries as defined in 6.3 and 6.4;

c) non-essential dependent auxiliaries as defined in 6.2 and 6.5.

The power absorbed by the essential independent and the non-essential dependent auxiliaries may be significant. In such cases, their power requirement shall be declared.

NOTE — Examples of typical auxiliaries are listed in annex A for guidance purposes. These lists are not necessarily complete.

7.2.3 Net brake power

Net brake power is the brake power measured when the engine is using only the auxiliaries listed in 7.2.2.1 a).

7.3 Kinds of power output

7.3.1 Continuous power

Continuous power is 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.

7.3.1.1 Overload power

Overload power is the power which an engine may be permitted to deliver, at stated ambient conditions, immediately after working at the continuous power.

The duration and frequency of use of 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.

NOTES

1 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.

2 If the engine application is not determined, the engine manufacturer shall specify the overload power and the corresponding engine speed.

7.3.2 Fuel stop power

Fuel stop power is the power which an engine is capable of delivering during a stated period corresponding to its application, and at stated speed and under stated ambient conditions, with the fuel limited so that the fuel stop power cannot be exceeded.

7.4 Kinds of statements of power

7.4.1 ISO powers

7.4.1.1 ISO power

ISO power is the power determined under the operating conditions of the manufacturer's test bed and adjusted to the standard reference conditions in clause 5.

7.4.1.2 ISO standard power

This is the name given to the continuous net brake power which the engine manufacturer declares that an engine is capable of delivering continuously, between the normal maintenance intervals stated by the manufacturer, and under the following conditions :

a) at a stated speed under the operating conditions of the engine manufacturer's test bed;

b) with the declared power adjusted to the standard reference conditions given in clause 5;

c) with the maintenance prescribed by the engine manufacturer being carried out.

7.4.2 Service power

Service power is the power determined under the ambient and operating conditions of an engine application.

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 clause 12);

NOTE — 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 (45 °C)

Relative humidity :

ϕ_x = 60 %

Sea water temperature (charge air coolant inlet) :

T_{cx} = 305 K (32 °C)

b) the normal duty of the engine;

c) the expected interval between maintenance periods;

d) the nature and amount of the supervision required;

e) all information relevant to the operation of the engine in service (see clauses 12 and 13).

8 Declarations of fuel consumption

8.1 Definitions

8.1.1 Fuel consumption

Fuel consumption is the quantity of fuel consumed by an engine per unit of time at a stated power and under stated ambient conditions.

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).

8.1.2 Specific fuel consumption

Specific fuel consumption is the fuel consumption per unit of power.

8.1.3 ISO specific fuel consumption

This is the name given to the specific fuel consumption at the ISO standard power.

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

8.2 Calorific value of fuels

8.2.1 Liquid fuel engines

Any declared specific fuel consumption of a liquid fuel engine shall be related to a reference distillate type fuel of lower calorific value of 42 000 kJ/kg (10 030 kcal/kg).

8.2.2 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.

8.3 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 powers 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.

9 Declarations of lubricating oil consumption

9.1 This is the quantity of lubricating oil consumed by an engine per unit of time. This quantity is used for guidance. It shall be expressed in litres or kilograms per engine operating hour at the declared power and engine speed.

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

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

9.4 The lubricating oil used shall be declared.

10 Adjustment of net brake power for ambient conditions

10.1 When it is required that the engine be operated under conditions different from the standard reference conditions given in clause 5, the net brake power output shall be adjusted to or from the standard reference conditions by the following formulae (see note 1) :

$$P_x = \alpha P_r \qquad \ldots (1)$$

$$\alpha = k - 0{,}7\,(1-k)\left(\frac{1}{\eta_m} - 1\right) \text{ (see note 2)} \qquad \ldots (2)$$

$$k = \left(\frac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r p_{sr}}\right)^m \left(\frac{T_r}{T_x}\right)^n \left(\frac{T_{cr}}{T_{cx}}\right)^q \qquad \ldots (3)$$

10.2 In the case of turbocharged engines in which the limits of turbocharger speed and turbocharger turbine inlet temperature 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 is to be made.

The following formulae (4) and (5) will then be used instead of formula (3) :

$$k = \left(\frac{p_x}{p_{ra}}\right)^m \left(\frac{T_{ra}}{T_x}\right)^n \left(\frac{T_{cra}}{T_{cx}}\right)^q \qquad \ldots (4)$$

$$p_{ra} = p_r \times \frac{\pi_r}{\pi_{max}} \qquad \ldots (5)$$

In formulae (1), (2), (3), (4) and (5)

P_r is the brake power under standard reference conditions;

p_r is the standard reference total barometric pressure;

p_{sr} is the saturation vapour pressure under standard reference conditions;

ϕ_r is the standard reference relative humidity;

T_r is the standard reference absolute air temperature;

T_{cr} is the standard reference absolute charge air coolant temperature;

p_{ra} is the substitute reference total barometric pressure given by formula (5);

T_{ra} is the substitute reference absolute air temperature to be stated by the manufacturer;

T_{cra} is the substitute reference absolute charge air coolant temperature to be stated by the manufacturer;

π_r is the boost pressure ratio at declared power under standard reference conditions to be stated by the manufacturer;

π_{max} is the maximum available boost pressure ratio to be stated by the manufacturer;

α is the power adjustment factor;

k is the ratio of indicated power;

η_m is the mechanical efficiency (see note 4);

P_x is the brake power under the conditions being considered;

p_x is the total barometric pressure condition being considered;

p_{sx} is the saturation vapour pressure under the conditions being considered;

ϕ_x is the relative humidity condition being considered;

T_x is the absolute air temperature being considered;

T_{cx} is the absolute charge air coolant temperature at the charge air cooler inlet being considered.

The factor a and exponents m, n and q have the numerical values given in table 1 (see note 5).

NOTES

1 For the convenience of users of these formulae, reference may be made to the tables in annexes B to F, and also to the numerical examples in annex G.

2 When the ambient conditions are more favourable than the standard reference conditions, the declared power under the ambient conditions may be limited by the manufacturer to the declared power at the standard reference conditions.

3 If the relative humidity is not known, a value of 30 % should be assumed in formulae references A, E and G in table 1.

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

4 The value of mechanical efficiency shall be stated by the engine manufacturer. In the absence of any such statement, the value of η_m = 0,80 will be assumed.

5 When declaring the ISO standard power, the engine manufacturer shall state which of the formulae references in table 1 is applicable.

Table 1 — Numerical values for power adjustment

Engine type	Condition		Formula reference	Factor	Exponents		
				a	m	n	q
Compression ignition oil engines and dual-fuel engines	Non-turbocharged	Power limited by air excess	A	1	1	0,75	0
		Power limited by thermal reasons	B	0	1	1	0
	Turbocharged without charge air cooling	Low and medium speed four-stroke engines	C	0	0,7	2	0
	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	Non-turbocharged		E	1	0,86	0,55	0
	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

NOTE — *The factors and exponents given in table 1 have been established by tests on a number of engines to be generally representative and shall be* used in the absence of any other specific information; for example in formula reference D, for an engine with the charge air cooled by engine jacket water, the value for exponent q could be zero. At present, they apply only to the types of engines specified but table 1 will be extended to include other types when sufficient data are available. For these engines, the power adjustment shall be stated by the engine manufacturer.

11 Adjustment of fuel consumption for ambient conditions

When it is required that the engine be operated under conditions different from the standard reference conditions given in clause 5, the fuel consumption will differ from that declared for the standard reference conditions and shall be adjusted to or from the standard reference conditions.

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

$$b_x = \beta b_r \qquad \ldots (6)$$

$$\text{where } \beta = \frac{k}{\alpha} \qquad \ldots (7)$$

where

b is the specific fuel consumption;

β is the fuel consumption adjustment factor;

α is the power adjustment factor (see 10.1 and 10.2);

k is the ratio of indicated power (see 10.1 and 10.2).

Subscript r corresponds to values under the standard reference conditions.

Subscript x corresponds to values under the conditions being considered.

NOTE — For the convenience of users of these formulae, reference may be made to the tables in annexes B to F, and also to the numerical examples in annex G.

12 Information to be supplied by the customer

The customer shall supply the following information concerning the required power :

a) The application and the power required from the engine and details arising therefrom.

b) The expected frequency and duration of the required powers and the corresponding engine speeds.

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 air temperatures during the hottest and coldest months of the year.

3) The highest and lowest ambient air temperatures around the engine.

4) The relative humidity (or alternatively the water vapour pressure or the wet and dry bulb temperature) ruling at the maximum temperature conditions.

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) The probable period for which the engine will be running continuously, and the duration of maximum and minimum load.

g) Any other information appropriate to the particular engine application.

13 Information to be supplied by the engine manufacturer

The engine manufacturer shall supply the following information :

a) The declared powers and where appropriate their tolerances.

b) The corresponding crankshaft and output shaft speeds.

NOTE — 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 can 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 the figure. For the preparation of such a diagram, the customer shall supply the required information according to clause 12.

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

d) The number and arrangement of cylinders (see ISO 1205).

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

f) The quantity of air 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(s) recommended.

i) The type of governing, with speed droop if required (see ISO 3046/4 and ISO 3046/6).

If for variable speed duties, the working speed range and the idling speed.

If necessary, the critical 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.

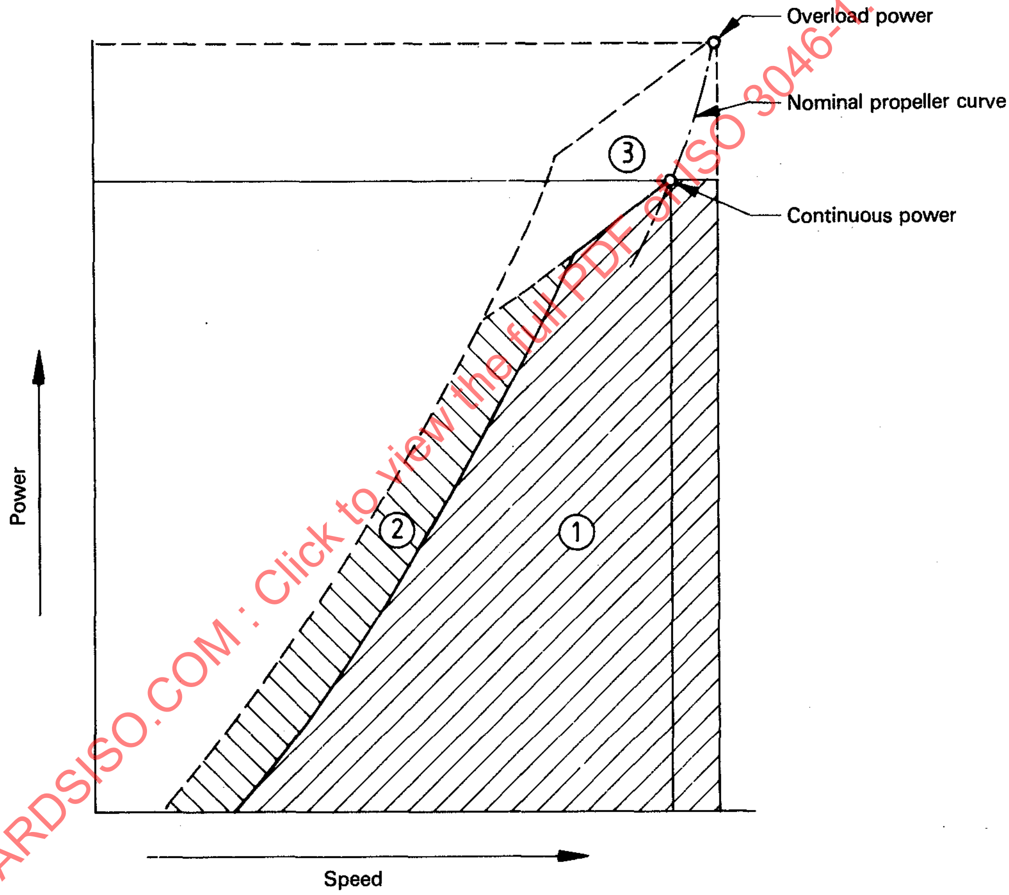
k) Whether hot air discharge ducting can be fitted (for air-cooled engines only).

l) A schedule of recommended maintenance and overhaul periods.

m) Specifications and lower calorific values of fuels recommended.

n) Maximum permissible back-pressure in the exhaust system and the maximum permissible intake depression.

o) Any other information appropriate to the particular engine application.



① Range of continuous power

② Range of intermittent operation

③ Range of short-time overload operation for special applications

Figure — Example for a power/speed diagram

Annex A

Examples of auxiliaries which may be fitted

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

LIST A — Essential dependent auxiliaries (see 6.2 and 6.4)

1) Engine-driven lubricating oil pressure pump.

2) Engine-driven lubricating oil scavenge pump for dry-sump engines.

3) Engine-driven engine cooling water pump.

4) Engine-driven raw water pump.

5) Engine-driven radiator cooling fan.

6) Engine-driven engine cooling fan for air-cooled engines.

7) Engine-driven gaseous fuel compressor.

8) Engine-driven fuel feed pump.

9) Engine-driven fuel pressure pump for common rail or servo-injection system.

10) Engine-driven scavenge air blower and/or charge air blower.

11) Engine-driven generator, air compressor or hydraulic pump when supplying power to items in list B.

12) Engine-driven cylinder lubricating pump.

13) Air cleaner or air silencer (normal or special).

14) Exhaust silencer (normal or special).

LIST B — Essential independent auxiliaries (see 6.3 and 6.4)

1) Separately driven lubricating oil pressure pump.

2) Separately driven lubricating oil scavenge pump for dry-sump engines.

3) Separately driven engine cooling water pump.

4) Separately driven raw water pump.

5) Separately driven radiator cooling fan.

6) Separately driven engine cooling fan for air-cooled engines.

7) Separately driven gaseous fuel compressor.

8) Separately driven fuel feed pump.

9) Separately driven fuel pressure pump for common rail or servo-injection system.

10) Separately driven scavenge air blower and/or charge air blower.

11) Separately driven crankcase extractor fan.

12) Separately driven cylinder lubricating pump.

13) Governing or control system using power from an external source.

LIST C — Non-essential dependent auxiliaries (see 6.2 and 6.5)

1) Engine-driven starting air compressor.

2) Engine-driven generator, air compressor or hydraulic pump when supplying power to items not in list B.

3) Engine-driven bilge pump.

4) Engine-driven fire pump.

5) Engine-driven ventilation fan.

6) Engine-driven fuel transfer pump.

7) Engine-integral thrust bearing.

Annex B

Determination of the power adjustment factor (α)

Table 2 gives values of the power adjustment factor (α) for known values of the ratio of indicated power (k) and mechanical efficiency (η_m).

The value of k can be determined from annex D.

The value of η_m is stated by the manufacturer (see clause 10, note 4).

Table 2 — Power adjustment factor (α) values

k	α					
	η_m					
	0,70	**0,75**	**0,80**	**0,85**	**0,90**	**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

Annex C

Determination of the fuel consumption adjustment factor (β)

Table 3 gives values of the fuel consumption adjustment factor (β) for known values of the ratio of indicated power (k) and mechanical efficiency (η_m).

The value of k can be determined from annex D.

The value of η_m is stated by the manufacturer (see clause 10, note 4).

Table 3 — Fuel consumption adjustment factor (β) values

k	β					
	η_m					
	0,70	0,75	0,80	0,85	0,90	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

Annex D

Determination of the ratio of indicated power (k)

Formula (3) or (4) can be written as : $k = (R_1)^{y_1} (R_2)^{y_2} (R_3)^{y_3}$

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

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

$R_3 = \dfrac{T_{cr}}{T_{cx}}$

and $y_1 = m$ $y_2 = n$ $y_3 = q$

The value of $R = \dfrac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r p_{sr}}$ can be obtained from annex E and other values of R can be calculated.

The values of m, n, q are obtained from table 1.

Table 4 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.

Table 4 — Values of R^y for determination of the ratio of indicated power (k)

R	R^y								
	y								
	0,5	0,55	0,57	0,7	0,75	0,86	1,2	1,75	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

Annex E

Determination of dry air pressure ratio

The dry air pressure ratio $\left(\dfrac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r p_{sr}}\right)$ used in formula (3) is given in table 5 for the value of $a = 1$ of formula references A, E and G, and for different values of total barometric pressure (p_x) and water vapour pressure ($\phi_x p_{sx}$). If the water vapour pressure is not known it can be obtained from the air temperature and relative humidity by the use of annex F.

Table 5 — Dry air pressure ratio values

Altitude	Total barometric pressure p_x	$\dfrac{p_x - a\phi_x p_{sx}}{p_r - a\phi_r p_{sr}}$													
		$\phi_x p_{sx}$ (kPa)													
m	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
1 000	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
1 200	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
1 400	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
1 600	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
1 800	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
2 000	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
2 200	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
2 400	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
2 600	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
2 800	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
3 000	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
3 200	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
3 400	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
3 600	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
3 800	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
4 000	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
4 200	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
4 400	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
4 600	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
4 800	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
5 000	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