

International Standards and
Recommended Practices



Annex 16
to the Convention on
International Civil Aviation

Environmental Protection

Volume II
Aircraft Engine Emissions

This edition incorporates all amendments adopted by the Council prior to 8 March 2008 and supersedes, on 20 November 2008, all previous editions of Annex 16, Volume II.

For information regarding the applicability of the Standards and Recommended Practices, see Foreword.

Third Edition
July 2008

International Civil Aviation Organization



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AMENDMENTS

Amendments are announced in the supplements to the *Catalogue of ICAO Publications*; the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

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FOREWORD

Historical background

In 1972 the United Nations Conference on the Human Environment was held in Stockholm. The position of ICAO at this Conference was developed in Assembly Resolution A18-11 which contained the following clause among others:

- “2. in fulfilling this role ICAO is conscious of the adverse environmental impact that may be related to aircraft activity and its responsibility and that of its member States to achieve maximum compatibility between the safe and orderly development of civil aviation and the quality of the human environment;”

The 18th Assembly also adopted Resolution A18-12 relating to the environment which states:

“THE ASSEMBLY:

1. REQUESTS the Council, with the assistance and co-operation of other bodies of the Organization and other international organizations to continue with vigour the work related to the development of Standards, Recommended Practices and Procedures and/or guidance material dealing with the quality of the human environment;”

This resolution was followed up by the establishment of an ICAO Action Programme Regarding the Environment. As part of this Action Programme a Study Group was established to assist the Secretariat in certain tasks related to aircraft engine emissions. As a result of the work of this Study Group, an ICAO Circular entitled *Control of Aircraft Engine Emissions* (Circular 134) was published in 1977. This Circular contained guidance material in the form of a certification procedure for the control of vented fuel, smoke and certain gaseous emissions for new turbojet and turbofan engines intended for propulsion at subsonic speeds.

It was agreed by the Council that the subject of aircraft engine emissions was not one that was solely confined to objective technical issues but was one that needed consideration by experts in many fields and included the direct views of Member States. A Council committee, known as the Committee on Aircraft Engine Emissions (CAEE) was therefore established in 1977 to pursue a number of aspects of the subject.

At the second meeting of the Committee on Aircraft Engine Emissions, held in May 1980, proposals were made for material to be included in an ICAO Annex. After amendment following the usual consultation with Member States of the Organization, the proposed material was adopted by the Council to form the text of this document. The Council agreed that it was desirable to include all provisions relating to environmental aspects of aviation in one Annex. It therefore renamed Annex 16 as “Environmental Protection”, making the existing text of the Annex into “Volume I — Aircraft Noise”, the material contained in this document becoming “Volume II — Aircraft Engine Emissions”.

Applicability

Part I of Volume II of Annex 16 contains definitions and symbols and Part II contains Standards relating to vented fuel. Part III contains Standards relating to emissions certification applicable to the classes of aircraft engines specified in the individual chapters of the Part, where such engines are fitted to aircraft engaged in international civil aviation.

Action by Contracting States

Notification of differences. The attention of Contracting States is drawn to the obligation imposed by Article 38 of the Convention by which Contracting States are required to notify the Organization of any differences between their national regulations and practices and the International Standards contained in this Annex and any amendments thereto. Contracting States are invited to extend such notification to any differences from the Recommended Practices contained in this Annex, and any amendments thereto, when the notification of such differences is important for the safety of air navigation. Further, Contracting States are invited to keep the Organization currently informed of any differences which may subsequently occur, or of the withdrawal of any differences previously notified. A specific request for notification of differences will be sent to Contracting States immediately after the adoption of each amendment to this Annex.

The attention of States is also drawn to the provisions of Annex 15 related to the publication of differences between their national regulations and practices and the related ICAO Standards and Recommended Practices through the Aeronautical Information Service, in addition to the obligation of States under Article 38 of the Convention.

Use of the Annex text in national regulations. The Council, on 13 April 1948, adopted a resolution inviting the attention of Contracting States to the desirability of using in their own national regulations, as far as is practicable, the precise language of those ICAO Standards that are of a regulatory character and also of indicating departures from the Standards, including any additional national regulations that were important for the safety or regularity of international air navigation. Wherever possible, the provisions of this Annex have been written in such a way as to facilitate incorporation, without major textual changes, into national legislation.

Status of Annex components

An Annex is made up of the following component parts, not all of which, however, are necessarily found in every Annex; they have the status indicated.

1.— Material comprising the Annex proper:

- a) *Standards and Recommended Practices* adopted by the Council under the provisions of the Convention. They are defined as follows:

Standard: Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38.

Recommended Practice: Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention.

- b) *Appendices* comprising material grouped separately for convenience but forming part of the Standards and Recommended Practices adopted by the Council.
- c) *Provisions* governing the applicability of the Standards and Recommended Practices.
- d) *Definitions* of terms used in the Standards and Recommended Practices which are not self-explanatory in that they do not have accepted dictionary meanings. A definition does not have an independent status but is an essential part of each Standard and Recommended Practice in which the term is used, since a change in the meaning of the term would affect the specification.

- e) *Tables and Figures* which add to or illustrate a Standard or Recommended Practice and which are referred to therein, form part of the associated Standard or Recommended Practice and have the same status.

2.— Material approved by the Council for publication in association with the Standards and Recommended Practices:

- a) *Forewords* comprising historical and explanatory material based on the action of the Council and including an explanation of the obligations of States with regard to the application of the Standards and Recommended Practices ensuing from the Convention and the Resolution of Adoption.
- b) *Introductions* comprising explanatory material introduced at the beginning of parts, chapters or sections of the Annex to assist in the understanding of the application of the text.
- c) *Notes* included in the text, where appropriate, to give factual information or references bearing on the Standards or Recommended Practices in question, but not constituting part of the Standards or Recommended Practices.
- d) *Attachments* comprising material supplementary to the Standards and Recommended Practices, or included as a guide to their application.

Disclaimer regarding patents

Attention is drawn to the possibility that certain elements of Standards and Recommended Practices in this Annex may be the subject of patents or other intellectual property rights. ICAO shall not be responsible or liable for not identifying any or all such rights. ICAO takes no position regarding the existence, validity, scope or applicability of any claimed patents or other intellectual property rights, and accepts no responsibility or liability therefore or relating thereto.

Selection of language

This Annex has been adopted in four languages — English, French, Russian and Spanish. Each Contracting State is requested to select one of those texts for the purpose of national implementation and for other effects provided for in the Convention, either through direct use or through translation into its own national language, and to notify the Organization accordingly.

Editorial practices

The following practice has been adhered to in order to indicate at a glance the status of each statement: *Standards* have been printed in light face roman; *Recommended Practices* have been printed in light face italics, the status being indicated by the prefix Recommendation; *Notes* have been printed in light face italics, the status being indicated by the prefix *Note*.

It is to be noted that in the English text the following practice has been adhered to when writing the specifications: Standards employ the operative verb “shall” while Recommended Practices employ the operative verb “should”.

The units of measurement used in this document are in accordance with the International System of Units (SI) as specified in Annex 5 to the Convention on International Civil Aviation. Where Annex 5 permits the use of non-SI alternative units, these are shown in parentheses following the basic units. Where two sets of units are quoted it must not be assumed that the pairs of values are equal and interchangeable. It may, however, be inferred that an equivalent level of safety is achieved when either set of units is used exclusively.

Any reference to a portion of this document which is identified by a number includes all subdivisions of that portion.

Table A. Amendments to Annex 16

<i>Amendment</i>	<i>Source(s)</i>	<i>Subject(s)</i>	<i>Adopted Effective Applicable</i>
1st Edition	Special Meeting on Aircraft Noise in the Vicinity of Aerodromes (1969)		2 April 1971 2 August 1971 6 January 1972
1	First Meeting of the Committee on Aircraft Noise	Noise certification of future production and derived versions of subsonic jet aeroplanes and updating of terminology used to describe aircraft weight.	6 December 1972 6 April 1973 16 August 1973
2	Third Meeting of the Committee on Aircraft Noise	Noise certification of light propeller-driven aeroplanes and subsonic jet aeroplanes of 5 700 kg and less maximum certificated takeoff weight and guidance on discharge of functions by States in the cases of lease, charter and interchange of aircraft.	3 April 1974 3 August 1974 27 February 1975
3 (2nd Edition)	Fourth Meeting of the Committee on Aircraft Noise	Noise certification standards for future subsonic jet aeroplanes and propeller-driven aeroplanes, other than STOL aeroplanes, and guidelines for noise certification of future supersonic aeroplanes, propeller-driven STOL aeroplanes and installed APU and associated aircraft systems when operating on the ground.	21 June 1976 21 October 1976 6 October 1977
4 (3rd Edition)	Fifth Meeting of the Committee on Aircraft Noise	Introduction of a new parameter, viz. number of engines in the noise certification standards for subsonic jet aeroplanes, improvements in detailed test procedures to ensure that the same level of technology is applied to all types of aircraft, and editorial changes to simplify the language and eliminate inconsistencies.	6 March 1978 6 July 1978 10 August 1978
5 (Annex 16, Volume I — 1st Edition)	Sixth Meeting of the Committee on Aircraft Noise	<ol style="list-style-type: none"> Annex retitled <i>Environmental Protection</i> and to be issued in two volumes as follows: Volume I — <i>Aircraft Noise</i> (incorporating provisions in the third edition of Annex 16 as amended by Amendment 5) and Volume II — <i>Aircraft Engine Emissions</i>. Introduction in Volume I of noise certification Standards for helicopters and for future production of existing SST aeroplanes, updating of guidelines for noise certification of installed APU and associated aircraft systems and editorial amendments including changes to units of measurement to bring the Annex in line with Annex 5 provisions. 	11 May 1981 11 September 1981 26 November 1981
6 (Annex 16, Volume II — 1st Edition)	Second Meeting of the Committee on Aircraft Engine Emissions	Introduction of Volume II containing Standards relating to the control of fuel venting, smoke and gaseous emissions from newly manufactured turbojet and turbofan engines intended for subsonic and supersonic propulsion.	30 June 1981 30 October 1981 18 February 1982
1	First Meeting of the Committee on Aviation Environmental Protection	Changes in test fuel specifications, Appendix 4.	4 March 1988 31 July 1988 17 November 1988
2 (2nd Edition)	Second Meeting of the Committee on Aviation Environmental Protection	<ol style="list-style-type: none"> increased stringency of NOx emissions limits; improvements in the smoke and gaseous emissions certification procedure. 	24 March 1993 26 July 1993 11 November 1993

<i>Amendment</i>	<i>Source(s)</i>	<i>Subject(s)</i>	<i>Adopted Effective Applicable</i>
3	Third Meeting of the Committee on Aviation Environmental Protection	Amendment of the criteria on calibration and test gases in Appendices 3 and 5.	20 March 1997 20 March 1997
4	Fourth Meeting of the Committee on Aviation Environmental Protection	Increased stringency of NO _x emissions limits.	26 February 1999 19 July 1999 4 November 1999
5	Sixth Meeting of the Committee on Aviation Environmental Protection	Increase in stringency of the NO _x emissions Standards.	23 February 2005 11 July 2005 24 November 2005
6 (3rd Edition)	Seventh meeting of the Committee on Aviation Environmental Protection	a) clarification of applicable corrections to reference day and reference engine conditions and of the humidity terminology used; b) amendments allowing the use of test fuels outside those specified with certificating authority approval; c) standardization of terminology relating to thrust setting; d) clarification of the appropriate value of fuel flow to be used at each LTO point; and e) amendments to the requirements specifying the materials that may be used in sampling rates.	7 March 2008 20 July 2008 20 November 2008
7	Eighth meeting of the Committee on Aviation Environmental Protection (CAEP/8).	a) increase in stringency of the NO _x emissions Standards; b) an update to the references to the <i>Environmental Technical Manual</i> (Doc 9501), Volume II — <i>Procedures for the Emissions Certification of Aircraft Engines</i> ; c) updates to the text to replace “variations in procedures” by “equivalent procedures”, in order to improve consistency and harmonization within Annex 16, Volume II and with the <i>Environmental Technical Manual</i> (Doc 9501), Volume II — <i>Procedures for the Emissions Certification of Aircraft Engines</i> ; d) the format of applicability dates in 2.3.2 made consistent with the convention used in Annex 6 and Annex 16, Volume I; e) improved readability by moving some paragraphs to more appropriate places; and f) minor editorial changes.	4 March 2011 18 July 2011 17 November 2011
8	Ninth meeting of the Committee on Aviation Environmental Protection (CAEP/9)	a) amendments to Attachment A to Appendix 3 to update the hydrocarbon (HC) analyser oven temperature range; b) amendments to allow the use of modern instruments for humidity measurement and to update the location of the humidity instrument during emissions certification tests; and c) minor editorial changes associated with terminology, document numbering and typographical changes.	3 March 2014 14 July 2014 1 January 2015

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

PART I. DEFINITIONS AND SYMBOLS

CHAPTER 1. DEFINITIONS

Where the following expressions are used in Volume II of this Annex, they have the meanings ascribed to them below:

Afterburning. A mode of engine operation wherein a combustion system fed (in whole or part) by vitiated air is used.

Approach phase. The operating phase defined by the time during which the engine is operated in the approach operating mode.

Climb phase. The operating phase defined by the time during which the engine is operated in the climb operating mode.

Date of manufacture. The date of issue of the document attesting that the individual aircraft or engine as appropriate conforms to the requirements of the type or the date of an analogous document.

Derivative version. An aircraft gas turbine engine of the same generic family as an originally type-certificated engine and having features which retain the basic core engine and combustor design of the original model and for which other factors, as judged by the certifying authority, have not changed.

Note.— Attention is drawn to the difference between the definition of Aderived version of an aeroplane@ in Volume I of Annex 16 and the definition of Aderivative version@ in this Volume.

Exhaust nozzle. In the exhaust emissions sampling of gas turbine engines where the jet effluxes are not mixed (as in some turbofan engines for example) the nozzle considered is that for the gas generator (core) flow only. Where, however, the jet efflux is mixed the nozzle considered is the total exit nozzle.

Oxides of nitrogen. The sum of the amounts of the nitric oxide and nitrogen dioxide contained in a gas sample calculated as if the nitric oxide were in the form of nitrogen dioxide.

Rated thrust. For engine emissions purposes, the maximum take-off thrust approved by the certifying authority for use under normal operating conditions at ISA sea level static conditions, and without the use of water injection. Thrust is expressed in kilonewtons.

Reference pressure ratio. The ratio of the mean total pressure at the last compressor discharge plane of the compressor to the mean total pressure at the compressor entry plane when the engine is developing take-off thrust rating in ISA sea level static conditions.

Note.— Methods of measuring reference pressure ratio are given in Appendix 1.

Smoke. The carbonaceous materials in exhaust emissions which obscure the transmission of light.

Smoke Number. The dimensionless term quantifying smoke emissions (*see* 3 of Appendix 2).

Take-off phase. The operating phase defined by the time during which the engine is operated at the rated thrust.

Taxi/ground idle. The operating phases involving taxi and idle between the initial starting of the propulsion engine(s) and the initiation of the take-off roll and between the time of runway turn-off and final shutdown of all propulsion engine(s).

Unburned hydrocarbons. The total of hydrocarbon compounds of all classes and molecular weights contained in a gas sample, calculated as if they were in the form of methane.

CHAPTER 2. SYMBOLS

Where the following symbols are used in Volume II of this Annex, they have the meanings ascribed to them below:

CO	Carbon monoxide
Dp	The mass of any gaseous pollutant emitted during the reference emissions landing and take-off cycle
F_n	Thrust in International Standard Atmosphere (ISA), sea level conditions, for the given operating mode
F_{oo}	Rated thrust
F^*_{oo}	Rated thrust with afterburning applied
HC	Unburned hydrocarbons (<i>see</i> definition)
NO	Nitric oxide
NO ₂	Nitrogen dioxide
NO _x	Oxides of nitrogen (<i>see</i> definition)
SN	Smoke Number (<i>see</i> definition)
π_{oo}	Reference pressure ratio (<i>see</i> definition)

PART II. VENTED FUEL

CHAPTER 1. ADMINISTRATION

1.1 The provision of this Part shall apply to all turbine engine powered aircraft intended for operation in international air navigation manufactured after 18 February 1982.

1.2 Certification related to the prevention of intentional fuel venting shall be granted by the certifying authority on the basis of satisfactory evidence that either the aircraft or the aircraft engines comply with requirements of Chapter 2.

Note.— The document attesting certification relating to fuel venting may take the form of a separate fuel venting certificate or a suitable statement contained in another document approved by the certifying authority.

1.3 Contracting States shall recognize as valid a certification relating to fuel venting granted by the certifying authority of another Contracting State provided the requirements under which such certification was granted are not less stringent than the provision of Volume II of this Annex.



CHAPTER 2. PREVENTION OF INTENTIONAL FUEL VENTING

Aircraft shall be so designed and constructed as to prevent the intentional discharge into the atmosphere of liquid fuel from the fuel nozzle manifolds resulting from the process of engine shutdown following normal flight or ground operations.



PART III. EMISSIONS CERTIFICATION

CHAPTER 1. ADMINISTRATION

1.1 The provisions of 1.2 to 1.4 shall apply to all engines included in the classifications defined for emission certification purposes in Chapters 2 and 3 where such engines are fitted to aircraft engaged in international air navigation.

1.2 Emissions certification shall be granted by the certifying authority on the basis of satisfactory evidence that the engine complies with requirements which are at least equal to the stringency of the provisions of Volume II of this Annex. Compliance with the emissions levels of Chapters 2 and 3 shall be demonstrated using the procedure described in Appendix 6.

Note.— The document attesting emissions certification may take the form of a separate emissions certificate or a suitable statement contained in another document approved by the certifying authority.

1.3 The document attesting emissions certification for each individual engine shall include at least the following information which is applicable to the engine type:

- a) name of certifying authority;
- b) manufacturer's type and model designation;
- c) statement of any additional modifications incorporated for the purpose of compliance with the applicable emissions certification requirements;
- d) rated thrust;
- e) reference pressure ratio;
- f) a statement indicating compliance with Smoke Number requirements;
- g) a statement indicating compliance with gaseous pollutant requirements.

1.4 Contracting States shall recognize as valid emissions certification granted by the certifying authority of another Contracting State provided that the requirements under which such certification was granted are not less stringent than the provisions of Volume II of this Annex.

1.5 Contracting States shall recognize as valid engine exemptions for an engine production cut-off requirement granted by a certifying authority of another Contracting State provided that the exemptions are granted in accordance with the process and criteria defined in the *Environmental Technical Manual* (Doc 9501), Volume II — *Procedures for the Emissions Certification of Aircraft Engines*.

CHAPTER 2. TURBOJET AND TURBOFAN ENGINES INTENDED FOR PROPULSION ONLY AT SUBSONIC SPEEDS

2.1 General

2.1.1 Applicability

2.1.1.1 The provisions of this chapter shall apply to all turbojet and turbofan engines, as further specified in 2.2 and 2.3, intended for propulsion only at subsonic speeds, except when certificating authorities make exemptions for:

- a) specific engine types and derivative versions of such engines for which the type certificate of the first basic type was issued or other equivalent prescribed procedure was carried out before 1 January 1965; and
- b) a limited number of engines over a specific period of time beyond the dates of applicability specified in 2.2 and 2.3 for the manufacture of the individual engine.

2.1.1.2 In such cases, an exemption document shall be issued by the certificating authority, the identification plates on the engines shall be marked “EXEMPT NEW” or “EXEMPT SPARE” and the grant of exemption shall be noted in the permanent engine record. Exemptions shall be reported by engine serial number and made available via an official public register.

2.1.1.3 The provisions of this chapter shall also apply to engines designed for applications that otherwise would have been fulfilled by turbojet and turbofan engines.

Note.— In considering exemptions, certificating authorities should take into account the probable numbers of such engines that will be produced and their impact on the environment. When such an exemption is granted, the certificating authority should consider imposing a time limit on the production of such engines for installation on new aircraft. Further guidance on issuing exemptions is provided in the Environmental Technical Manual (Doc 9501), Volume II — Procedures for the Emissions Certification of Aircraft Engines.

2.1.2 Emissions involved

The following emissions shall be controlled for certification of aircraft engines:

Smoke
Gaseous emissions
 Unburned hydrocarbons (HC);
 Carbon monoxide (CO); and
 Oxides of nitrogen (NO_x).

2.1.3 Units of measurement

2.1.3.1 The smoke emission shall be measured and reported in terms of Smoke Number (SN).

2.1.3.2 The mass (D_p) of the gaseous pollutant HC, CO, or NO_x emitted during the reference emissions landing and take-off (LTO) cycle, defined in 2.1.4.2 and 2.1.4.3, shall be measured and reported in grams.

2.1.4 Reference conditions

2.1.4.1 Atmospheric conditions

The reference atmospheric conditions shall be ISA at sea level except that the reference absolute humidity shall be 0.00634 kg water/kg dry air.

2.1.4.2 Thrust settings

The engine shall be tested at sufficient thrust settings to define the gaseous and smoke emissions of the engine so that mass emission rates and Smoke Numbers can be determined at the following specific percentages of rated thrust as agreed by the certificating authority:

<i>LTO operating mode</i>	<i>Thrust setting</i>
Take-off	100 per cent F_{oo}
Climb	85 per cent F_{oo}
Approach	30 per cent F_{oo}
Taxi/ground idle	7 per cent F_{oo}

2.1.4.3 Reference emissions landing and take-off (LTO) cycle

The reference emissions LTO cycle for the calculation and reporting of gaseous emissions shall be represented by the following time in each operating mode.

<i>Phase</i>	<i>Time in operating mode, minutes</i>
Take-off	0.7
Climb	2.2
Approach	4.0
Taxi/ground idle	26.0

2.1.4.4 Fuel specifications

The fuel used during tests shall meet the specifications of Appendix 4.

2.1.5 Test conditions

2.1.5.1 The tests shall be made with the engine on its test bed.

2.1.5.2 The engine shall be representative of the certificated configuration (*see* Appendix 6); off-take bleeds and accessory loads other than those necessary for the engine's basic operation shall not be simulated.

2.1.5.3 When test conditions differ from the reference atmospheric conditions in 2.1.4.1, the gaseous emissions test results shall be corrected to the reference atmospheric conditions by the methods given in Appendix 3.

2.2 Smoke

2.2.1 Applicability

The provisions of 2.2.2 shall apply to engines whose date of manufacture is on or after 1 January 1983.

2.2.2 Regulatory Smoke Number

The Smoke Number at any of the four LTO operating mode thrust settings when measured and computed in accordance with the procedures of Appendix 2, or equivalent procedures as agreed by the certificating authority, and converted to a characteristic level by the procedures of Appendix 6 shall not exceed the level determined from the following formula:

$$\text{Regulatory Smoke Number} = 83.6 (F_{oo})^{-0.274}$$

or a value of 50, whichever is lower

Note.— Guidance material on the definition and the use of equivalent procedures is provided in the Environmental Technical Manual (Doc 9501), Volume II — Procedures for the Emissions Certification of Aircraft Engines.

2.3 Gaseous emissions

2.3.1 Applicability

The provisions of 2.3.2 shall apply to engines whose rated thrust is greater than 26.7 kN and whose date of manufacture is on or after 1 January 1986 and as further specified for oxides of nitrogen.

2.3.2 Regulatory levels

Gaseous emission levels when measured and computed in accordance with the procedures of Appendix 3 and converted to characteristic levels by the procedures of Appendix 6, or equivalent procedures as agreed by the certificating authority, shall not exceed the regulatory levels determined from the following formulas:

$$\text{Hydrocarbons (HC): } D_p/F_{oo} = 19.6$$

$$\text{Carbon monoxide (CO): } D_p/F_{oo} = 118$$

Oxides of nitrogen (NO_x):

- a) for engines of a type or model for which the date of manufacture of the first individual production model was before 1 January 1996 and for which the date of manufacture of the individual engine was before 1 January 2000.

$$D_p/F_{oo} = 40 + 2\pi_{oo}$$

- b) for engines of a type or model for which the date of manufacture of the first individual production model was on or after 1 January 1996 or for which the date of manufacture of the individual engine was on or after 1 January 2000.

$$D_p/F_{oo} = 32 + 1.6\pi_{oo}$$

- c) for engines of a type or model for which the date of manufacture of the first individual production model was on or after 1 January 2004:

- 1) for engines with a pressure ratio of 30 or less:

- i) for engines with a maximum rated thrust of more than 89.0 kN:

$$D_p / F_{oo} = 19 + 1.6\pi_{oo}$$

- ii) for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p / F_{oo} = 37.572 + 1.6\pi_{oo} - 0.2087F_{oo}$$

- 2) for engines with a pressure ratio of more than 30 but less than 62.5:

- i) for engines with a maximum rated thrust of more than 89.0 kN:

$$D_p / F_{oo} = 7 + 2.0\pi_{oo}$$

- ii) for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p / F_{oo} = 42.71 + 1.4286\pi_{oo} - 0.4013F_{oo} + 0.00642\pi_{oo} \times F_{oo}$$

- 3) for engines with a pressure ratio of 62.5 or more:

$$D_p / F_{oo} = 32 + 1.6\pi_{oo}$$

- d) for engines of a type or model for which the date of manufacture of the first individual production model was on or after 1 January 2008 or for which the date of manufacture of the individual engine was on or after 1 January 2013:

- 1) for engines with a pressure ratio of 30 or less:

- i) for engines with a maximum rated thrust of more than 89.0 kN:

$$D_p / F_{oo} = 16.72 + 1.4080\pi_{oo}$$

- ii) for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p / F_{oo} = 38.5486 + 1.6823\pi_{oo} - 0.2453F_{oo} - 0.00308\pi_{oo}F_{oo}$$

- 2) for engines with a pressure ratio of more than 30 but less than 82.6:

- i) for engines with a maximum rated thrust of more than 89.0 kN:

$$D_p / F_{oo} = -1.04 + 2.0\pi_{oo}$$

- ii) for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p / F_{oo} = 46.1600 + 1.4286\pi_{oo} - 0.5303F_{oo} + 0.00642\pi_{oo}F_{oo}$$

- 3) for engines with a pressure ratio of 82.6 or more:

$$D_p / F_{oo} = 32 + 1.6\pi_{oo}$$

- e) for engines of a type or model for which the date of manufacture of the first individual production model was on or after 1 January 2014:

- 1) for engines with a pressure ratio of 30 or less:

- i) for engines with a maximum rated thrust of more than 89.0 kN:

$$D_p / F_{oo} = 7.88 + 1.4080\pi_{oo}$$

- ii) for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p / F_{oo} = 40.052 + 1.5681\pi_{oo} - 0.3615F_{oo} - 0.0018\pi_{oo}F_{oo}$$

- 2) for engines with a pressure ratio of more than 30 but less than 104.7:

- i) for engines with a maximum rated thrust of more than 89.0 kN:

$$D_p / F_{oo} = -9.88 + 2.0\pi_{oo}$$

- ii) for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p / F_{oo} = 41.9435 + 1.505\pi_{oo} - 0.5823F_{oo} + 0.005562\pi_{oo} F_{oo}$$

- 3) for engines with a pressure ratio of 104.7 or more:

$$D_p / F_{oo} = 32 + 1.6\pi_{oo}$$

Note.— Guidance material on the definition and the use of equivalent procedures is provided in the Environmental Technical Manual (Doc 9501), Volume II — Procedures for the Emissions Certification of Aircraft Engines.

2.4 Information required

Note.— The information required is divided into three groups: 1) general information to identify the engine characteristics, the fuel used and the method of data analysis; 2) the data obtained from the engine test(s); and 3) the results derived from the test data.

2.4.1 General information

The following information shall be provided for each engine type for which emissions certification is sought:

- a) engine identification;
- b) rated thrust (in kilonewtons);
- c) reference pressure ratio;
- d) fuel specification reference;
- e) fuel hydrogen/carbon ratio;

- f) the methods of data acquisition;
- g) the method of making corrections for ambient conditions; and
- h) the method of data analysis.

2.4.2 Test information

The following information shall be provided for each engine tested for certification purposes at each of the thrust settings specified in 2.1.4.2. The information shall be provided after correction to the reference ambient conditions where applicable:

- a) fuel flow (kilograms/second);
- b) emission index (grams/kilogram) for each gaseous pollutant; and
- c) measured Smoke Number.

2.4.3 Derived information

2.4.3.1 The following derived information shall be provided for each engine tested for certification purposes:

- a) emission rate, i.e. emission index $\times$ fuel flow, (grams/second) for each gaseous pollutant;
- b) total gross emission of each gaseous pollutant measured over the LTO cycle (grams);
- c) values of D_p/F_{oo} for each gaseous pollutant (grams/kilonewton); and
- d) maximum Smoke Number.

2.4.3.2 The characteristic Smoke Number and gaseous pollutant emission levels shall be provided for each engine type for which emissions certification is sought.

CHAPTER 3. TURBOJET AND TURBOFAN ENGINES INTENDED FOR PROPULSION AT SUPERSONIC SPEEDS

3.1 General

3.1.1 Applicability

The provisions of this chapter shall apply to all turbojet and turbofan engines intended for propulsion at supersonic speeds whose date of manufacture is on or after 18 February 1982.

3.1.2 Emissions involved

The following emissions shall be controlled for certification of aircraft engines:

Smoke

Gaseous emissions

Unburned hydrocarbons (HC);

Carbon monoxide (CO); and

Oxides of nitrogen (NO_x).

3.1.3 Units of measurement

3.1.3.1 The smoke emission shall be measured and reported in terms of Smoke Number (SN).

3.1.3.2 The mass (D_p) of the gaseous pollutants HC, CO, or NO_x emitted during the reference emissions landing and take-off (LTO) cycle, defined in 3.1.5.2 and 3.1.5.3 shall be measured and reported in grams.

3.1.4 Nomenclature

Throughout this chapter, where the expression F_{oo}^* is used, it shall be replaced by F_{oo} for engines which do not employ afterburning. For taxi/ground idle thrust setting, F_{oo} shall be used in all cases.

3.1.5 Reference conditions

3.1.5.1 Atmospheric conditions

The reference atmospheric conditions shall be ISA at sea level except that the reference absolute humidity shall be 0.00634 kg water/kg dry air.