CIVIL AVIATION REQUIREMENTS

SECTION 6 – DESIGN STANDARDS AND TYPE CERTIFICATION SERIES ‘C’ PART II

AIRCRFAT ENGINE EMISSIONS CERTIFICATION – STANDARDS AND PROCEDURES

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Director General of Civil Aviation
OFFICE OF THE DIRECTOR GENERAL OF CIVIL AVIATION
TECHNICAL CENTRE, OPP. SAFDARJUNG AIRPORT, NEW DEL

RECORD OF REVISION

This CAR has been issued to formulate regulations towards engine emissions certification based on International Civil Aviation Organization's International Standards and Recommended Practices (SARPs) as contained in Annex-16, Environmental Protection, Volume-II "Aircraft Engine Emissions". The CAR was initially developed and issued on 10th January' 2011 and becomes effective forthwith. Thereafter, the CAR has undergone revisions due to amendments from the recommendations of the meeting of the Committee on Aviation Environmental Protection (CAEP). The Record of Revisions to the aforesaid CAR is as follows:

Sl. No.	Issue Number	Revision Number	Date	Remarks
1.	Issue - I	Revision - 0	10/01/2011	Initial issue of CAR to adopt engine emissions standards as contained in Annex-16, Volume-II including Amendment 6.
2.	Issue - I	Revision – 1	December 2011	Revisions due to Amendment 7.
3.	Issue - I	Revision - 2	October 2014	Revisions due to Amendment 8.
4.	Issue - II	Revision - 0	July 2017	Rewritten due to revisions due to Amendment 9.

INTRODUCTION

Rule 49 of the Aircraft Rules, 1937 stipulates requirements for a Type Certificate (TC) in respect of a new type of aeronautical products such as aircraft, engine and propeller or change in type design in case of its derived version, designed and manufactured in India. The Type Certificate Data Sheet (TCDS), which forms the part of the Type Certificate, contains the certification basis in respect of that aircraft and the applicable certification basis as mentioned in CAR 21.17 and environmental protection requirements as mentioned in CAR 21.18. With the objective of compliance with the above mentioned rules, CAR, Section-6, Series-C, Part-II has been developed based on the International Standards and Recommended Practices (SARPs) contained in ICAO Annex-16, Volume-II.

This CAR is issued under the provisions of Rule 133A of the Aircraft Rules, 1937, for information, guidance and compliance by all such organizations who intend to design and develop aeronautical products including Auxiliary Power Unit (APU) in India for which a Type Certificate is to be issued by DGCA under the provisions mentioned in CAR 21

The requirements contained in this CAR are in-line with the requirements as mentioned in ICAO Annex-16, Volume-II. It prescribes applicability, measurement of reference pressure ratio, smoke emission evaluation, measurement points, Instrumentation and measurement techniques for gaseous emissions, specification for HC analyser, CO and CO_2 analysers, NOx analyser, calibration and test gases, calculation of the emissions parameters, specifications for additional data, specification for fuel to be used in aircraft turbine engine emission testing, Instrumentation and measurement techniques for gaseous emissions from afterburning gas turbine engines, and compliance procedure for gaseous emissions and smoke along with relevant calculations for different category of engines fitted on aeroplanes for demonstrating compliance to the above requirements.

This CAR Issue-II supersedes earlier issued CAR, Issue-I, Revision-3 October, 2014.

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ENGINE EMISSIONS CERTIFICATION PROCEDURES FOR AIRCRAFT

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SUBPART – A: PREVENTION OF INTENTIONAL FUEL VENTING.

1. APPLICABILITY:

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1.1 The provision of this CAR shall apply to all turbine engine powered aircraft intended for operation in India manufactured after 18 February, 1982.

2. GENERAL REQUIREMENTS:

2.1 Certification related to the prevention of intentional fuel venting shall be granted by DGCA on the basis of satisfactory evidence that either the aircraft or the aircraft engines comply with requirements of paragraph 2.5 of this subpart.

2.2 The certification document relating to fuel venting may be issued by DGCA as a separate fuel venting certificate, if required.

2.3 DGCA shall recognize fuel venting certificate issued/granted by the certificating authority of another State provided the requirements towards the certification are equivalent to the provision of this Subpart.

2.4 All civil aeroplanes, operating in India for which a type certificate is to be issued by DGCA or imported through validation or type acceptance, shall have a valid emissions certificate for the engine installed in the aeroplane in accordance with the provisions contained in CAR 21.16 (A).

2.5 Aircraft shall be so designed and constructed so 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.

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SUBPART – B: EMISSIONS CERTIFICATION.

1. APPLICABILITY:

1.1 The provisions of 1.2 to 1.5 of this subpart shall apply to all engines and their derivative versions included in the classifications defined for emission certification purposes in subparts C, D and E where such engines are fitted to aircraft engaged in operations.

1.2 Emissions certification shall be granted by DGCA on the basis of satisfactory evidence that the engine complies with requirements of this subpart. Compliance with the emissions levels of subparts C, D and E of this CAR shall be demonstrated using the procedure described in Appendix-6 of ICAO Annex-16, Volume-II.

1.3 The document relating to emissions certification may be issued by DGCA as a separate emissions certificate, if required.

1.4 The emissions certification document for each individual engine shall include the following information:

a) Name of certificating 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.

1.5 DGCA shall recognize emissions certificate issued/granted by the certificating authority of another State provided that the requirements towards the certification are equivalent to the provisions of this subpart.

1.6 DGCA shall recognize an engine exemptions granted by certificating authority of another State, for an engine production cut-off requirement. However, the exemptions granted shall be 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.

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SUBPART – C: TURBOJET AND TURBOFAN ENGINES INTENDED FOR PROPULSION ONLY AT SUBSONIC SPEEDS

1. APPLICABILITY:

1.1 The provisions specified in paragraph 5 and 6 of this subpart shall apply to all turbojet and turbofan engines, intended for propulsion only at subsonic speeds, except in the case where exemptions have been issued by DGCA for the following:

a) Specific engine types and derivative versions of such engines for which the type certificate of the first basic type was issued before 1st January, 1965; and

b) A limited number of engines for the manufacturing of the individual engine, over a specific period of time beyond the dates of applicability.

1.2 In case, an exemption certificate is issued by DGCA, the identification plates on the engines shall be marked **"Exempt New"** or **"Exempt Spare"**. Such exemptions shall be reported by engine serial number and noted in the engine record.

1.3 The provisions of this subpart shall also apply to all those engines which are designed for applications that otherwise would have been fulfilled by turbojet and turbofan engines.

1.4 While granting exemptions, DGCA shall take into account the numbers of such engines to be produced under such exemptions and their impact on the environment. However, DGCA may impose a time limit on the production of such engines for installation on new aircraft. Further guidance on issuing such exemptions is provided in the Environmental Technical Manual (Doc 9501), Volume II — Procedures for the Emissions Certification of Aircraft Engines.

2. Emissions involved:

2.1 The following emissions shall be considered for certification of aircraft engines:

a) **Smoke,**
b) **Gaseous emissions,**
i) Unburned hydrocarbons (HC),
ii) Carbon monoxide (CO), and
iii) Oxides of nitrogen (NOx).

3. Units of measurement:

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

3.2 The mass (Dp) of the gaseous pollutant HC, CO, or NOx emitted during the reference emissions landing and take-off (LTO) cycle, defined in paragraph 4.2 and 4.3 of this subpart, shall be measured and reported in grams.

4. Reference Conditions:

4.1 **Atmospheric conditions:** The reference atmospheric conditions for engine performance shall be ISA at sea level or the reference absolute humidity shall be 0.00634 kg water/kg dry air.

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 DGCA:

LTO operating mode	**Thrust setting**
Take-off	100 per cent F_{∞}
Climb	85 per cent F_{∞}
Approach	30 per cent F_{∞}
Taxi/ground	idle 7 per cent F_{∞}

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:

LTO operating mode	**Time in operating mode, minutes**
Take-off	0.7
Climb	2.2
Approach	4.0
Taxi/ground idle	26.0

4.4 **Fuel specifications:** The fuel used during tests shall meet the following specifications unless a deviation and any necessary corrections have been agreed upon by DGCA. The fuel shall not contain any additives for smoke suppression (such as organometallic compounds, etc):

Property	**Allowable range of values**
Density kg/m3 at 15°C	780 – 820

Distillation temperature, °C	
10% boiling point	155 – 201
Final boiling point	235 – 285
Net heat of combustion, MJ/kg	42.86 – 43.50
Aromatics, volume %	15 – 23
Naphthalenes, volume %	1.0 – 3.5
Smoke point, mm	20 – 28
Hydrogen, mass %	13.4 – 14.3
Sulphur, mass %	less than 0.3%
Kinematic viscosity at –20°C, mm2/s	2.5 – 6.5

4.5 **Test conditions:**

a) The tests shall be made with the engine on its test bed.
b) The engine shall be representative of the certificated configuration off-take bleeds and accessory loads other than those necessary for the engine's basic operation shall not be simulated.
c) When test conditions differ from the reference atmospheric conditions as mentioned at paragraph 4.1 of this subpart, the gaseous emissions test results shall be corrected to the reference atmospheric conditions by the methods given in Appendix-3 of ICAO Annex-16, Volume-II.

5. Smoke:

5.1 **Applicability:**

5.1.1 The provisions of paragraph 5.2 of this subpart shall apply to engines whose date of manufacture is on or after 1st January, 1983.

5.2 **Regulatory Smoke Number:**

5.2.1 The Smoke Number shall be measured and computed in accordance with the procedures given at Appendix-2 of ICAO Annex-16, Volume-II and converted to a characteristic level by the procedures of Appendix-6 of ICAO Annex-16, Volume-II. However, the Smoke Number at any of the four LTO operating mode thrust settings shall not exceed the level determined from the following formula:

Regulatory Smoke Number = 83.6 (F_∞) – 0.274 or a value of 50, whichever is lower.

6. Gaseous emissions:

6.1 Applicability:

6.1.1 The provisions of paragraph 6.2 of this subpart shall apply to engines whose rated thrust is greater than 26.7 kN and whose date of manufacture is on or after 1st January, 1986 and as specified for oxides of nitrogen.

6.2 Regulatory Levels:

6.2.1 Gaseous emission levels shall be measured and computed in accordance with the procedures of Appendix-3 of ICAO Annex-16, Volume-II and converted to characteristic levels by the procedures of Appendix-6 of ICAO Annex-16, Volume-II. However, gaseous emission levels shall not exceed the regulatory levels determined from the following formulas:

Hydrocarbons (HC): $Dp/F_{\infty} = 19.6$
Carbon monoxide (CO): $Dp/F_{\infty} = 118$
Oxides of nitrogen (NOx):

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.

$$Dp/F_{\infty} = 40 + 2\pi_{\infty}$$

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.

$$Dp/F_{\infty} = 32 + 1.6\pi_{\infty}$$

c) For engines of a type or model for which the date of manufacture of the first individual production model was on or after 1st 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:
$Dp/F_{\infty} = 19 + 1.6\pi_{\infty}$

ii) For engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:
$Dp/F_{\infty} = 37.572 + 1.6\pi_{\infty} - 0.2087F_{\infty}$

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:
$Dp / F_{\infty} = 7 + 2.0\pi_{\infty}$

ii) For engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:
$Dp / F_{\infty} = 42.71 + 1.4286\pi_{\infty} – 0.4013F_{\infty} + 0.00642\pi_{\infty} \times F_{\infty}$

3) For engines with a pressure ratio of 62.5 or more:
$Dp / F_{\infty} = 32 + 1.6\pi_{\infty}$

d) For engines of a type or model for which the date of manufacture of the first individual production model was on or after 1st January, 2008 or for which the date of manufacture of the individual engine was on or after 1st 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:
$Dp / F_{\infty} = 16.72 + 1.4080\pi_{\infty}$

ii) For engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:
$Dp / F_{\infty} = 38.5486 + 1.6823\pi_{\infty} – 0.2453F_{\infty} – 0.00308\pi_{\infty}F_{\infty}$

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:
$Dp / F_{\infty} = –1.04 + 2.0\pi_{\infty}$

ii) For engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:
$Dp / F_{\infty} = 46.1600 + 1.4286\pi_{\infty} – 0.5303F_{\infty} + 0.00642\pi_{\infty} F_{\infty}$

3) For engines with a pressure ratio of 82.6 or more:
$Dp / F_{\infty} = 32 + 1.6\pi_{\infty}$

e) For engines of a type or model for which the date of manufacture of the first individual production model was on or after 1st 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:
$Dp / F_{\infty} = 7.88 + 1.4080\pi_{\infty}$

ii) For engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:
$Dp/F_{\infty} = 40.052 + 1.5681\pi_{\infty} - 0.3615F_{\infty} - 0.0018\pi_{\infty} F_{\infty}$

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:
$Dp/F_{\infty} = -9.88 + 2.0\pi_{\infty}$

ii) For engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:
$Dp/F_{\infty} = 41.9435 + 1.505\pi_{\infty} - 0.5823F_{\infty} + 0.005562\pi_{\infty} F_{\infty}$

3) For engines with a pressure ratio of 104.7 or more:
$Dp/F_{\infty} = 32 + 1.6\pi_{\infty}$

7. Information required:

7.1 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.

7.2 **General information:**

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

a) Engine identification,
b) Rated thrust (in kilo-newton),
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.

7.3 **Test information:**

7.3.1 The following information shall be provided for each engine tested for certification purposes at each of the thrust settings specified in paragraph 4.2 of this subpart. 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.

7.4 **Derived information:**

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

a) Emission rate, i.e. emission index X 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 Dp/F_{∞} for each gaseous pollutant (grams/kilo newton), and

d) Maximum Smoke Number.

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

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SUBPART – D: TURBOJET AND TURBOFAN ENGINES INTENDED FOR PROPULSION AT SUPERSONIC SPEEDS

RESERVED.

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SUBPART – E: PARTICULATE MATTER EMISSIONS

1. APPLICABILITY:

1.1 The provisions of this subpart shall apply to all aircraft engines, intended for propulsion only at subsonic speeds, for which an application for type certification is submitted to DGCA. Specific provisions for the relevant engine categories shall apply as detailed in paragraph 4.2 of this subpart.

1.2 **Emissions involved:** The purpose of this section is to control non-volatile particulate matter mass ($nvPM_{mass}$) emissions.

1.3 **Units of measurement:** The concentration of nvPM mass ($nvPM_{mass}$) shall be reported in µg/m3.

2. Reference conditions:

2.1 **Atmospheric conditions:** The reference atmospheric conditions for the reference standard engine shall be ISA at sea level or the reference absolute humidity shall be 0.00634 kg water/kg dry air.

2.2 **Reference emissions landing and take-off (LTO) cycle:** The engine shall be tested at sufficient thrust settings to define the nvPM emissions of the engine so that nvPM mass emission indices (EI_{mass}) and nvPM number emission indices (EI_{num}) can be determined at the following specific percentages of rated thrust and at thrusts producing maximum $nvPM_{mass}$ concentration, maximum EI_{mass} and maximum EI_{num} as agreed by DGCA:

LTO operating mode	Thrust setting
Take-off	100 per cent F_∞
Climb	85 per cent F_∞
Approach	30 per cent F_∞
Taxi/ground	idle 7 per cent F_∞

2.3 **Fuel Specifications:** The fuel used during tests shall meet the specifications as specified at paragraph 4.4 of Subpart-C of this CAR.

3. Test conditions:

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

3.2 The engine shall be representative of the certificated configuration, off take bleeds and accessory loads other than those necessary for the engine's basic operation shall not be simulated.

3.3 When test conditions differ from the reference atmospheric conditions as mentioned in paragraph 2.1 of this Subpart, EI_{mass} and EI_{num} shall be corrected to the engine combustor inlet temperature under the reference atmospheric conditions by the method given in Appendix-7 of ICAO Annex-16, Volume-II.

3.4 The maximum $nvPM_{mass}$ concentration and EI_{mass} and EI_{num} shall be corrected for thermophoretic losses in the Collection Part of the sampling system by the method given in Appendix-7 of ICAO Annex-16, Volume-II.

4. Non-Volatile Particulate Matter Emissions

4.1 Applicability:

4.1.1 The provision further specified in paragraphs 4.2 and 4.3 of this subpart shall apply to all turbofan and turbojet engines of a type or model, and their derivative versions, with a rated thrust greater than 26.7 kN and whose date of manufacture of the individual engine is on or after 1 January 2020.

4.2 Regulatory Levels:

4.2.1 The maximum $nvPM_{mass}$ concentration measured in µg/m3 obtained from measurement at sufficient thrust settings, in such a way that the mission maximum can be determined, and computed in accordance with the procedures of Appendix 7 of ICAO Annex-16, Volume-II and converted to characteristic levels by the procedures of Appendix 6 of ICAO Annex-16, Volume-II, or equivalent procedures as agreed by DGCA shall not exceed the level determined from the following formula:

Regulatory limit concentration of $nvPM_{mass} = 10\ (3 + 2.9\ F_{\infty}^{\ -0.274})$

4.3 Reporting Requirement:

4.3.1 The manufacturer shall report the following values of nvPM emissions measured and computed in accordance with the procedures of Appendix-7 of ICAO Annex-16, Volume-II, or any equivalent procedures as agreed by DGCA:

a) Characteristic level for the maximum $nvPM_{mass}$ concentration (µg/m3),

b) Fuel flow (kg/s) at each thrust setting of the LTO cycle,

c) EI_{mass} (mg/kg of fuel) at each thrust setting of the LTO cycle,

d) EI_{num} (particles/kg of fuel) at each thrust setting of the LTO cycle,

e) Maximum EI_{mass} (mg/kg of fuel),

f) Maximum EI_{num} (particles/kg of fuel),

5. Information required:

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.

5.1 General information:

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

a) Engine identification,

b) Rated output (in kN),

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 thermophoretic losses in the Collection Part of the sampling system, and

h) The method of data analysis.

5.2 Test information:

5.2.1 For each test the following information shall be reported:

a) Net heat of combustion (MJ/kg),

b) Fuel hydrogen content (mass %),

c) Fuel total aromatics content (volume %),

d) Fuel naphthalene (volume %), and

e) Fuel sulphur (mass %).

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SUBPART – F: NON-VOLATILE PARTICULATE MATTER ASSESSMENT FOR INVENTORY PURPOSES

1. The purpose of this subpart is to provide guidance on how to calculate the nvPM mass and number correction factors for the nvPM system losses other than the Collection Part thermophoretic losses. The nvPM system, the Collection Part and the thermophoretic losses calculation are described in Appendix 7 of ICAO Annex-16, Volume-II.

2. The nvPM mass and number system loss correction factors permit an estimation of the concentration of the nvPM mass and number at the exhaust of the aircraft engine from the nvPM mass and number concentration obtained following the procedures described in Appendix 7 of ICAO Annex-16, Volume-II.

3. For inventory and modelling purposes, the turbine engine manufacturers should determine the nvPM mass and nvPM number system loss correction factors (k_{SLmass} and k_{SL_num}) using the methodology described in Appendix 8 of ICAO Annex-16, Volume-II and should report these factors to DGCA.

4. For inventory and modelling purposes, the nvPM mass and number concentration obtained following the procedures described in Appendix 7 of ICAO Annex-16, Volume-II should be corrected for system losses using the methodology described in Appendix 8 of ICAO Annex-16, Volume-II.

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Director General of Civil Aviation

APPENDIX -I

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

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

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

4. **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.

5. **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 certificating authority, have not changed.

6. **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.

7. **Gas concentration**: The volume fraction of the component of interest in the gas mixture — expressed as volume percentage or as parts per million.

8. **Non-Volatile Particulate Matter (nvPM):** Emitted particles that exists at gas turbine engine exhaust nozzele exit plane that do not volatilise when heated to a temperature of 350 °C.

9. **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.

10. **Parts per million (ppm):** The unit volume gas concentration of a gas per million unit volume of the gas mixture of which it is a part.

11. **Parts per million carbon (ppmC):** The mole fraction of hydrocarbon multiplied by 106 measured on a methane-equivalence basis. Thus, 1 ppm of methane is indicated as 1 ppmC. To convert ppm concentration of any hydrocarbon to an equivalent ppmC value, multiply ppm gas concentration by the number of carbon atoms per molecule of the gas. For example, 1 ppm propane translates as 3 ppmC hydrocarbon; 1 ppm hexane as 6 ppmC hydrocarbon.

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

13. **Reference gas:** A mixture of gases of specified and known composition used as the basis for interpreting instrument response in terms of the gas concentration of the gas to which the instrument is responding.

14. **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.

15. **Response:** The change in instrument output signal that occurs with change in sample gas concentration.

16. **Type Certificate:** A document issued by a Contracting State to define the design of an aircraft, engine or propeller type and to certify that this design meets the appropriate airworthiness requirements of that State.

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

18. **Smoke Number:** The dimensionless term quantifying smoke emissions.

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

20. **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).

21. **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.

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APPENDIX -II

NOMENCLATURE: SYMBOLS AND UNITS

Following is the list of definitions and symbols used in this CAR. Many of the following definitions and symbols are specific to aircraft noise certification. Some of the definitions and symbols may also apply to purposes beyond aircraft noise certification.

CO	Carbon monoxide
Dp	The mass of any gaseous pollutant emitted during the reference emissions landing and take-off cycle
EI_{mass}	nvPM mass emission index corrected for thermophoretic losses, in mg/kg fuel
EI_{num}	nvPM number emission index corrected for thermophoretic losses, in number/kg fuel
Fn	Thrust in International Standard Atmosphere (ISA), sea level conditions, for the given operating mode
F_{∞}	Rated thrust
F^*_{∞}	Rated thrust with afterburning applied
HC	Unburned hydrocarbons
k_{SL}mass	nvPM mass system loss correction factor
k_{SL}num	nvPM number system loss correction factor
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen
nvPM	Non-volatile particulate matter
nvPM mass	nvPM mass concentration at instrument STP condition, corrected for dilution and thermophoretic losses in the collection section of the sampling system in µg/m3
SN	Smoke Number
Π_{∞}	Reference pressure ratio

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