



EUROPEAN CIVIL AVIATION CONFERENCE

CONFÉRENCE EUROPÉENNE DE L'AVIATION CIVILE

RECOMMENDATION ECAC/27-4

(Second¹ Edition)

NO_x EMISSION CLASSIFICATION SCHEME

Latest revision : 3 September 2011

1 Revision endorsed by ECAC Thirty-second Plenary Session (Special), 3 September 2011

Whereas

- a) Increasing air traffic and its impact upon the environment could lead to breaches of NO₂ limit values in European regulations designed to maintain local air quality and thus increase pressure upon regulators to introduce mitigation measures.
- b) ECAC, pursuant to its Environmental Policy Statement, is to "study the feasibility of stimulating the use of cleaner aircraft in European airspace through a system of environmental financial measures, and, if feasible and proved necessary, develop criteria for application of such measures by Member States, ensuring fair competition between equal technology".
- c) Some countries have already introduced different local systems for aircraft engine emission charges.
- d) The aviation industry expressed its interest for a single and harmonised European methodology.
- e) It is feasible to develop a single recommended methodology on how to classify aircraft according to their NO_x emissions for the potential purpose of emission charges and prevent the proliferation of local and individual solutions having regard to ICAO Resolution A33-7 and to ICAO Council Resolution (of 9 December 1996) on environmental charges and taxes (Doc9082/6).

Considering that

- a) The aim is to create a single recommended methodology on how to classify aircraft according to their NO_x emissions for the potential purpose of emission charges and prevent the proliferation of local and individual solutions. It is not a recommendation for the introduction of emission charging schemes or operational restrictions to aircraft operation.
- b) The recommended classification methodology is based upon the limits for local air quality stipulated in the EU legislation and on the availability of currently accepted aircraft engine emissions data. Nitrogen oxides (NO_x) are the prime pollutant used for this classification. Hydrocarbon (HC) emissions are also accounted for to cater for older engines that tend to have low NO_x emission values, but at the same time relatively high HC emissions. This is accomplished by applying a factor relating the actual HC value to the ICAO HC limit to the NO_x value. This overcomes the need to introduce HC as a separate pollutant whilst avoiding unduly favouring older engine technology.

- c) Two sets of data are used, one for those engines which are regulated by ICAO and the other for those which are not. Data for *regulated* jet engines of equal to, or more than, 26.7 kN thrust are based upon the standardised ICAO landing and take-off (LTO) cycle as set out in ICAO Annex 16, Volume II and published in Document 9646-AN/943 (1995) and amendments. Data for *unregulated* engines have been reported by their manufacturers to the Swedish Defence Research Institute (FOI) have reported data for unregulated engines. The Institute has produced a database that, with the manufacturers' consent, could be distributed to authorised parties.
- d) To ensure harmonisation and standardisation for all aircraft that are not regulated and for which no emission data are available, an aircraft emission value matrix has been developed¹.
- e) To ensure non-discrimination, all civil aircraft with a maximum take-off weight (MTOW) over 8,618 kg should be classified using the recommended methodology. Member States may classify emissions from other aircraft (e.g., aircraft not exceeding 8,618 kg MTOW that are powered by small turboprops and small turboprops or piston engines, and helicopters) at their discretion. The contribution to emissions of these aircraft is very small compared to those of heavier aircraft.
- f) By calculating the direct NO_x emission values of an individual aircraft engines exhaust the proposed methodology can be used as the basis for charging systems which implement the "polluter pays" principle.
- g) Economic aspects, including the monetary value that may be charged per unit of emissions, are not part of the methodology. These matters are left to the appropriate national or European authority. However, account should be taken of the international guidelines on aviation charges, and of the fact that the recommended approach is designed to implement the 'polluter pays' principle as described in Clause e) above.
- h) The references indicated (e.g. databases) are currently available but may change as a result of ongoing work. This fact should be considered and the situation checked when using them in future, for example to develop legislation.
- i) It should be recognised that some Member States have established policies, existing agreements, relevant legal obligations and laws which may influence the implementation of this Recommendation.

¹ Developed by Swiss FOCA on the base of small engines emission measurement and non-public manufacturer engines data

The Conference recommends

Member States to ensure that, if and when a landing charge system relating to NO_x emissions is introduced or changed at airports in their territories, the classification system and other elements of the attached Guidance Material are followed as a minimum requirement.



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NO_x EMISSION CLASSIFICATION SCHEME

GUIDANCE MATERIAL

Second Edition, 3 September

FOREWORD

This Guidance Material has been prepared to complement the ECAC Recommendation on an aircraft NO_x emission classification scheme for the potential purpose of emission charges. This document explains the calculation procedures and should be read in conjunction with that Recommendation.

This Guidance Material refers to data on the emission performance of individual engines. Users should be aware that not only they should ensure that they are considering the current version of this guidance, but also that they refer to the most up-to-date data available, as new engines or revised data may be added from time to time. References for sources of data and test methods are given as footnotes

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1. BACKGROUND

1. In November 2000 the Group of Experts on the Abatement of Nuisances Caused by Air Transport (ANCAT) of the European Civil Aviation Conference (ECAC) formed a Subgroup to conduct its Emissions Related Landing Charges Investigation (ERLIG)¹. The objective of this Subgroup was to recommend a common methodology for emissions classification, given ECAC Member States' need for one. The subgroup has produced a Recommendation on a NO_x classification scheme, and this document provides guidance to assist users in applying that recommendation.

2. This guidance, produced as part of the final report of the ERLIG Subgroup contains the recommended methodology for calculating the classification of aircraft for NO_x emissions as the potential purpose to use for charges and provides the necessary guidance about where to obtain the information on emission performance of aircraft. It was completed and updated on 3 September 2011, as recommended by ANCAT/78 meeting², which created an Ad hoc Group of ANCAT for that purpose.

2. ACRONYMS AND DEFINITIONS

3. Acronyms and definitions

ANCAT:	(ECAC) group of experts on the Abatement of Nuisances Caused by Air Transport
CAEP:	(ICAO) Committee on Aviation and Environmental Protection
CORINAIR:	Co-ordination Of Information On Air Emissions
ECAC:	European Civil Aviation Conference
EMCAL:	ANCAT (former) Subgroup on Emissions Calculations
ERLIG:	ANCAT (former) Subgroup on Emissions Related Landing Charges Investigation
ICAO:	International Civil Aviation Organisation
LTO:	Landing and Take-Off cycle: one LTO cycle comprising a landing plus a take-off
MTOW:	Maximum Take-Off Weight (if the term MTOM, Maximum Take-off Mass is being used, they shall mean the same).
Regulated Engines	Turbojet and turbofan engines of rated output > 26.7 kN covered by current ICAO certification standards.
Unregulated Engines	Other than regulated aircraft engines.

¹ Group of Experts on the Abatement of Nuisances Caused by Air Transport. 53rd meeting, Nice, 21-22 November 2000.

² Paris, 5-6 May 2010

4. Chemical Symbols :

CO	=	carbon monoxide
CO ₂	=	carbon dioxide
HC	=	unburned hydrocarbons
NO	=	nitric oxide
NO _x	=	nitrogen oxides - a collective term for both NO and NO ₂
NO ₂	=	nitrogen dioxide
PM	=	particulate matter

3. METHODOLOGY

3.1 Introduction

5. The basis on which the aircraft is classified for the potential purpose of an emission charge is the absolute mass of NO_x emissions of the aircraft within the LTO cycle and the ICAO, Annex 16, Volume II, HC limit for regulated engines. Every aircraft has to be considered individually by identifying the specific engine type and using the relevant data on the emissions performance together with the number of those engines fitted to the aircraft.

3.2 LTO-Cycle

6. Historically, ICAO developed standards for aircraft engine emissions based on a standardised landing and take-off cycle¹. The ICAO LTO cycle was originally designed only for the purpose of demonstrating compliance to the ICAO Engine Exhaust Emissions standards. In the daily aircraft operation thrust settings and time in each mode are very much dependent on the specific conditions like aircraft weight, outside temperature, wind, airport altitude, runway conditions and airline procedures. The standardised LTO-cycle will therefore not produce actual emissions levels, but approximate levels given the standardised cycle. For each mode, a representative time and thrust setting have been established.

7. Small turbofan engines < 26.7 kN rated output and turboprop engines are not regulated by the ICAO standards and recommendations. Thus, no ICAO emissions databank has been developed and published. Test data has however become available from the manufactures of the small engines.

¹ Movements below 3000 ft/ground (915 m), split in take-off, climbout, approach and taxi

Table 1: Times in mode and thrust settings for the LTO cycle for regulated engines and unregulated jet engines

Mode	Time in minutes	Thrust setting in kN
Take-Off	0.7	100%
Climb out	2.2	85%
Approach	4.0	30%
Taxi	26.0	7%

8. The data for turboprop engines is normally provided from tests without the propeller and the engine power output is measured in Shaft Horse Power. (SHP). However the thrust required to power the aircraft is mainly generated by the propeller, which is driven by the engine drive shaft via a gearbox, The ICAO standard LTO cycle is therefore not representative in terms of the relative (%) power settings in the lower power settings. The SHP required specifically in the taxi/idle mode and in some cases practically available due to throttle limiter is much less than the 7%. For turboprop engines a modified LTO cycle should be applied using the manufacturers recommended idle setting. Some manufacturers data include the practical idle settings with actual fuel flow and emissions index.

Table 2: Times in mode and power settings for the LTO cycle for turboprop engines

Mode	Time in minutes	Power setting in SHP
Take-Off	0.7	100%
Climbout	2.2	85%
Approach	4.0	30%
Taxi	26.0	Idle ¹

3.3 Calculation of the Emission Value for an Aircraft

3.3.1 NO_x-Calculation

9. The absolute amount of NO_x within the LTO cycle is calculated by using the ICAO measured values for all LTO-modes of the individual engine:

¹ Difference to standard ICAO LTO mode as shown in the study by the Swedish Defence Research Agency, FOI Memo 01-4245.

$$NO_{x\text{Aircraft}} = \text{Engines} * \sum_{LTO\text{-modes}} [(60 * \text{time} * \text{fuelflow} * NO_{x\text{-index}}) \div 1000] \text{ [in kg NO}_x\text{]}$$

where:

- Engines: number of engines fitted to the aircraft
Time: time in mode according to table 1 (in minutes)
Fuelflow: fuel flow per mode (in kg/sec)
NO_x-index: measured NO_x-emission index per mode (in g/kg fuel)

3.3.2 HC Considerations

10. ICAO has set standards using the LTO cycle for NO_x, CO, HC and visible smoke. Only the value for unburnt hydrocarbons (HC) is also being considered within the framework on a common emission related classification scheme. The current ICAO standard¹ requires that any regulated engine shall not exceed the characteristic HC D_p/F_{oo} of 19.6 g/kN rated output² during the LTO cycle test regime.

11. For non-regulated engines, hydrocarbons are not being considered as the total amount of hydrocarbons is very small and the term D_p/F_{oo} in g/kN is not applicable for unregulated engines.

3.3.3 Emission Value

12. All considered aircraft are set into a linear scale with the value:

$$Emission\ Value_{\text{Aircraft}} = a * NO_{x\text{Aircraft}} \quad \text{(no dimension)}$$

Where

A = 1 IF THE AVERAGE HC D_p/F_{oo} IS LESS OR EQUAL THAN THE CURRENT ICAO STANDARD OF 19.6 G/KN RATED OUTPUT OR FOR UNREGULATED ENGINES.

¹ ICAO, Annexe 16, Volume II: Aircraft Engine Emissions, 2nd edition, July 1993.

² D_p is the mass of any gaseous pollutant emitted during the reference emissions LTO cycle. F_{oo} is the rated output, which for engine emissions purposes, is the maximum power/thrust available for take-off under normal operating conditions at ISA sea level static conditions without the use of water injection as approved by the certifying authority.

A > 1 IF THE AVERAGE HC D_p/F_{00} IS LARGER THAN THE CURRENT ICAO STANDARD.

A = AVERAGE MEASURED HC D_p/F_{00} / 19.6, WITH A MAXIMUM VALUE FOR 'A' OF 4.0

4. MODEL APPLICATION

13. This aircraft emission classification model shall apply to aircraft with a MTOW over 8618 kg. The individual authority decides on how to treat aircraft with a MTOW not exceeding 8618 kg.

14. The same rules for calculating NO_x emissions apply to non-regulated engines as to regulated engines.

15. The charge should be continuous, based on the Emission Value_{Aircraft}.

5. DATA SOURCES

16. Emission factors for turbojet and turbofan engines of rated outputs > 26.7 kN are published in the ICAO Aircraft Exhaust Emissions Databank.¹

17. Small turbofan engines < 26.7 kN rated output and turboprop engines are not regulated by the ICAO standards and recommendations. Thus, no ICAO emissions data base has been developed and published. In the meantime, a set of data has been set up by the manufacturers for other purposes. This data should be used for calculation of the Emission Value of an aircraft until approved data is available.

18. The Swedish Defence Research Agency, FOI², collects and manages a database for unregulated engines and makes the data available to authorised users in a similar fashion as the ICAO database for regulated engines. This includes the recalculation of the emission values for the LTO mode 'idle' according to the procedures outlined in the FOI Memo 01-4245.

19. The emissions data supplied by engine manufacturers for the FOI database are not meant for public release and their release to any unauthorised third party will require approval by the engine manufacturers involved. In order to control access to the information contained in the database, the following process will be followed for the dissemination of database content:

- the database is contained on a secure website under the control of FOI;

¹ <http://www.caa.co.uk> → safety regulation → flight operation/ Human and environmental issues → ICAO Engine Emissions Databank , <http://www.caa.co.uk/default.aspx?catid=702&pagetype=90>

² <http://www.foi.se> → projects → Confidential database for turboprop engine emissions

- FOI issues data only to authorised recipients requiring the information for the classification of aircraft in accordance with the principles of this Guidance Material. (Such authorised users are considered to include Member State government departments or commercial entities operating under the direct control of such departments);
- FOI issues the data with the applied restriction that it is not to be further distributed; and
- FOI maintains a register of recipients of the data and provides the International Co-ordinating Council of Aerospace Industries Associations (ICCAIA) with regular reports on this register. In addition, FOI informs the ICCAIA of any requests for data originating from non-authorised organisations.

6. AIRCRAFT WITH PISTON ENGINES, HELICOPTER AND AIRCRAFT WITH ENGINES WITH NO EMISSION DATA

If an aircraft, equipped with

- piston engines,
- rotary wing engines,
- or any other engine,

has no emission data available neither in the ICAO nor in the FOI data base, then it is assigned an emission value derived from the following table (Aircraft Emission Value Matrix) and depending on the type, performance and number of engines fitted to the aircraft.

Aircraft Emission Value Matrix:

# Eng.	Piston: Turbo-diesel Micro-light	Piston: Conventional	Piston: Conventional	Piston: Conventional	Helicopter	Helicopter	Business Jets	Business Jets	Turbo-props	Turbo-props
		≤200 hp	>200 but ≤400 hp	>400 hp	<1000 shp	≥1000 shp	≤16 kN	>16 but < 26.7 kN	≤2000 shp	>2000 shp
1	0.1	0.2	0.4	0.5	0.2	0.7	0.5	1.0	0,4	0.8
2	0.2	0.4	0.8	1	0.4	1.4	1.0	2.0	0,8	1.6
3	-	0.6	1.2	1.5	-	2.1	1.5	3.0	1,2	2.4
4	-	0.8	1.6	2	-	2.8	-	-	1,6	3.2

Where the following definitions apply:

Eng.: number of engines fitted to the aircraft

Piston Turbodiesel / Microlight:	diesel piston engine powered aircraft and microlight piston engines
Piston Conventional:	piston engine powered aircraft with conventional air-cooled gasoline engine (Textron Lycoming / Teledyne Continental)
>200 but ≤ 400 hp:	conventional piston engine with more than and including 200 maximum break horse power, up to and including 400 maximum break horse power
< 1000 shp:	helicopter engine with less than 1000 maximum shaft horse power
≤ 16 kN:	business-jet engine up to and including 16 kilonewton maximum rated thrust
> 16 but < 26.7 kN:	business-jet engine above 16 kilonewton but below 26.7 kiloNewton maximum rated thrust.

7. PROPOSED DRAFT TEXT (SKTECH) FOR NATIONAL AERONAUTICAL INFORMATION PUBLICATION (AIP) OR SIMILAR

Preamble

The following text is meant to be used as a streamline for national AIP. The choice of weight limit or type of engine subject to the charge is taken by the competent authority and therefore the text could be adapted accordingly.

Art. (x) Emission-related landing charges

Art. (x.1) Principle

An emission related landing surcharge is applied to all aircraft equipped with a combustion engine and that are subject to a weight-based landing charge. The emission charge is based on the absolute emission characteristic of the engine as described in ECAC recommendation 27/4 [or a national reference document containing ECAC recommendation 27/4] *place holder - text to be defined*

Art. (x.2) Aircraft with turbofan, turbojet or turboprop engines with emission data available

Aircraft, equipped with turbofan, turbojet or turboprop engines that are:

- regulated under the ICAO Annex 16, Volume II, or
- not regulated, but have detailed emission data for the LTO cycle available from the FOI data base

are subject to the emission calculation as specified in ECAC Recommendation 27/4. Specifically, the following emission calculation formula applies:

$$\text{EmissionValue Aircraft} = a * \# \text{Engines} * \sum_{LTO\text{-modes}} (60 * \text{time} * \text{fuel flow} * \text{NOx}_{\text{Emissionfactor}} \div 1000)$$

where:

a = 1 if the characteristic certification LTO Hydrocarbon emissions per rated thrust (HC Dp/Foo) is less than or equal to the current ICAO standard of 19.6 g/kN rated thrust or for unregulated engines.

a > 1 if the characteristic certification LTO Hydrocarbon emissions per rated thrust (HC Dp/Foo) is greater than the current ICAO standard.

a = HC Dp/Foo /19.6, with a maximum value for 'a' of 4.0

LTO-Modes: ICAO Certification LTO Modes:

<u>Mode</u>	<u>Time</u> (in minutes)
Take-off	0.7
Climbout	2.2
Approach	4.0
Taxi/Idle	26.0

Engines: number of engines fitted to the aircraft

Time: time in mode (s. above) (in minutes)

Fuelflow: fuel flow per mode (in kg/sec)

NOx_{Emissionfactor} Measured NOx-Emission factor per mode (in g/kg fuel)

Emission factors and fuel flow for the four modes and the hydrocarbon certification value are taken from the ICAO engine database (regulated engines). Emissions data for unregulated engines are taken from the FOI emissions database.

Art. (x.3) Aircraft with piston engines, helicopter and aircraft with engines with no emission data available from ICAO nor from FOI data bases

Aircraft, equipped with

- piston engines
- rotary wing engines

- or any other engine without emission data available from ICAO nor from FOI data bases

are also subject to an emission charge. Specifically, they are assigned an emission value derived from the following table 1 and depending on the type, performance and number of engines fitted to the aircraft.

Table 1: Aircraft Emission Value Matrix

# Eng.	Piston: Turbo-diesel Micro-light	Piston: Conventional	Piston: Conventional	Piston: Conventional	Helicopter	Helicopter	Business Jets	Business Jets	Turbo-props	Turbo-props
		≤200 hp	>200 but ≤400 hp	>400 hp	<1000 shp	≥1000 shp	≤16 kN	>16 but < 26.7 kN	≤2000 shp	>2000 shp
1	0.1	0.2	0.4	0.5	0.2	0.7	0.5	1.0	0,4	0.8
2	0.2	0.4	0.8	1	0.4	1.4	1.0	2.0	0,8	1.6
3	-	0.6	1.2	1.5	-	2.1	1.5	3.0	1,2	2.4
4	-	0.8	1.6	2	-	2.8	-	-	1,6	3.2

Art. (x.4) **Emission tariff**

The applicable tariff is [national currency] *place holder - text to be defined* x.xx per Emission Value_{Aircraft}.

8. UNCERTAINTIES

20. The uncertainties with every calculation are related to the method that has been used or to data with which the calculations have been made. Uncertainties related to data with which the calculations are made are mostly a consequence of incomplete or partly incorrect data. In this chapter some of the uncertainties are listed. This chapter is not intended to be complete nor to quantify the uncertainties. It should be regarded as a caution warning for people dealing with emission calculations.

21. Turboprop and small turboprops engines are currently not subjected to any emissions regulation. Any data provided by authoritative bodies or by engine manufacturers thus need to be considered unapproved, but can be used if they are released by the data proprietor and are sufficient for calculating the Emission Value_{Aircraft}.

22. Engine emissions data used for calculation of the matrix emission values are considered to be accurate in a range of +/-15%. Overall uncertainties depend on the choices made for times in mode and thrust resp. power settings. However, as matrix emission values have been tested for consistency and are very small in absolute terms (most of them being well below a value of 1) the remaining inaccuracy in the matrix emission values can be considered acceptable in absolute terms.