# Introduction to LAQ

By ICAO Secretariat

## ICAO STANDARDS AND RECOMMENDED PRACTICES (SARPS), ANNEX 16, VOLUME II

One of ICAO's environmental goals is to limit or reduce the impact of aviation emissions on local air quality (LAQ). Starting the late 1970s, ICAO has been developing measures to address emissions from aircraft engines in the vicinity of the airport and from relevant airport sources. The Volume II of Annex 16 to the Convention on International Civil Aviation contains Standards for aircraft engine emissions and is accompanied by the related guidance material and technical documentation. Following the latest successful adoption of the CAEP/10 nvPM Standard based on visibility criterion, CAEP/11 agreed on nvPM mass and number Standard, moving it towards consideration for adoption by the ICAO Council in the next year. ICAO provisions on LAQ also address liquid fuel venting, smoke (which is expected to be superseded by the nvPM Standard), and the main gaseous exhaust emissions from jet engines, namely: hydrocarbons (HC), oxides of nitrogen (NOx), carbon monoxide (CO).

## ENGINE CERTIFICATION PROCEDURE

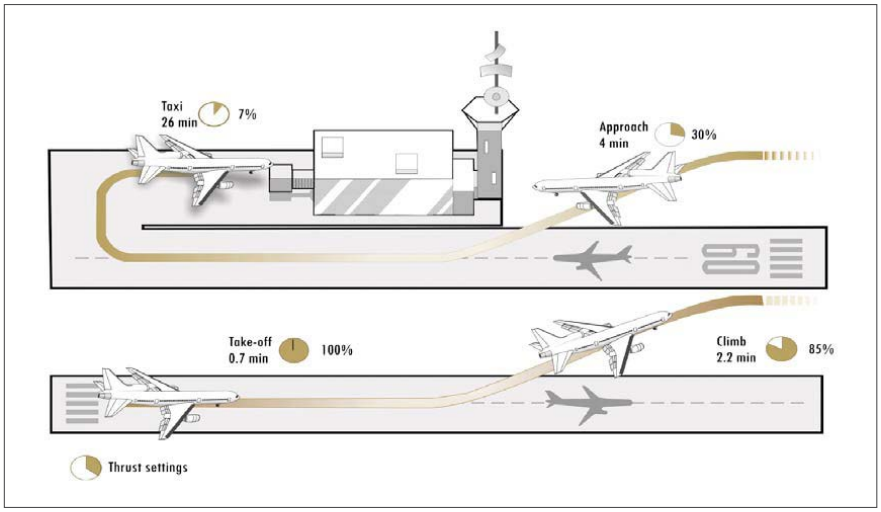
The engine certification process is based on the Landing and Take-off (LTO) cycle. This LTO cycle representing pollutant emissions in the vicinity of airports consists of four operating modes, which involve a thrust setting and a time-in-mode shown in Figure 1.

The engine certification process is performed on a test bed. For each thrust setting and corresponding fuel flow, the pollutant emissions are measured in accordance with the relevant SARPs. The submission of this data to the certificating authority is mandated as part of the engine emissions certification. This certification data is collected and stored in the publically available ICAO emissions databank[1].

Over the past three years, the ICAO Committee on Aviation Environmental Protection (CAEP) has conducted work to ensure the validity and consistency of the technical basis underpinning the ICAO SARPs associated with reducing the impact of civil aviation on LAQ. This work has included, inter alia: development of non-volatile Particulate Matter (nvPM) mass and number Standards; an industry led combustion technology reviews, the update to ICAO SARPs to ensure their completeness; and an overview of the current state of the science regarding LAQ.

The recent approval by (CAEP/11) of non-volatile Particulate Matter (nvPM) mass and number Standards is a ground breaking achievement. The adoption of this new Standard by the ICAO Council will mark the completion of the final

**FIGURE 1:** Illustration of ICAO emissions certification procedure representing the LTO cycle




1 https://www.easa.europa.eu/easa-and-you/environment/icao-aircraft-engine-emissions-databank

component of aircraft environmental certification, closing the full circle on noise, local air quality and $CO_2$ Standards for subsonic aeroplanes. This new Standard would lead to nvPM emissions reductions from international aviation in the coming years.

## NEW NVPM MASS AND NUMBER STANDARDS

During the combustion of hydrocarbon-based fuels, aircraft engines generate gaseous and particulate matter (PM) emissions. At the engine exhaust, particulate emissions consist mainly of ultrafine soot or black carbon emissions. These particles, referred to as "non-volatile" PM (nvPM), are present at high temperatures, in the engine exhaust. Compared to conventional diesel engines, gas turbine engines emit non-volatile particles of smaller mean diameter. Their characteristic size ranges roughly from 15 to 60 nanometres (nm; 1nm = 1/100,000 of a millimetre). These particles are invisible to the human eye and are ultrafine.

The CAEP/11 meeting recommended new nvPM mass and number Standard for aircraft engines and this will be considered by the ICAO Council for adoption in the early part of 2020. The new Standard will apply to new type and in-production engines with rated thrust greater than 26.7kN from 1 January 2023. The limit lines for nvPM mass and number provide some alleviation for engines with rated thrusts below 150kN. This Standard is less stringent for in-production engines and a supplementary "no-backsliding" measure was introduced.

The recommendation on the nvPM emissions Standard was supported by a significant data driven process and the cost-effectiveness modelling analysis of several different stringency options for mass and number. In addition, CAEP agreed on an end date for the Smoke Number Standard, of 1 January 2023, as the new nvPM emissions Standards preserve ICAO smoke visibility limit.

With this new Standard, ICAO will have completed the main environmental Standards for the certification of aircraft and engines, namely for noise, local air quality (NOx, HC, CO, nvPM) and climate change ($CO_2$), making the aviation industry the only sector with mandatory environmental certification requirements at the global level for the operation of its equipment. Once applicable, all new aircraft will need to be certified to these ICAO Standards before operating.

## ADVANCEMENTS IN COMBUSTOR TECHNOLOGIES AND NOX GOALS

Technological innovations in aviation continue to lead the way towards effective and efficient measures in support of ICAO's environmental goals of limiting or reducing the impact of aircraft emissions on LAQ. The objective of ICAO engine emissions Standards is to encourage the implementation of the latest technologies in engine design. Therefore, the setting of standards is closely linked to understanding the research and development of technology. To complement the Standard-setting process, CAEP developed, with the assistance of a panel of independent experts, medium and long-term NOx technology goals (10 and 20 years, respectively).

Following several independent expert technology reviews on NOx, fuel burn and noise, a first of its kind, integrated independent expert technology goals assessment and review for engines and aircraft was performed, and presented to the CAEP/11 meeting. This review provided, inter alia, an assessment of advances in engine combustor design technologies for subsonic aircraft and the degree to which these technologies could influence gaseous emissions, and fuel flow reduction, including the potential interdependencies and trade-offs with noise, and the likely timescales for introduction. The advances in engine combustor design technologies were considered in the context of the existing mid and long-term CAEP technology goals.

CAEP delivered new technology goals for the international aviation sector. For instance, for single-aisle aircraft, the mid-term NOx emission goal (by 2027) is 54 per cent lower relative to the latest ICAO NOx SARPs; and fuel efficiency gains up to 1.3 per cent per annum can be expected for new aircraft entering production. An article on the integrated independent expert technology goals assessment and review for engines and aircraft in provided in the Outlook section of this report.

## UPDATES TO ICAO DOC 9889

ICAO has updated its Doc 9889, *Airport Air Quality Manual,* for consistency with the new nvPM Standards, in particular with respect to providing information on aircraft mass and number PM emissions. Doc 9889 contains both actual sample engine data, and the recommended calculation methodology, for aircraft main engines and auxiliary power units.

## FUTURE WORK

The future work on LAQ related issues embraces a vast majority of topics and directions. ICAO continues to develop measures aimed at mitigating the impact of aviation on LAQ in the vicinity of airports. To this end, ICAO continues to develop Standards, guidance material, and technical documents, as appropriate, for the needs of the international community. This includes the maintenance of Annex 16, all volumes of ICAO Doc 9501, *Environmental Technical Manual*, and the ICAO emissions databank.

Based on the recommendation of the nvPM mass and number Standards, the work of CAEP will now involve further exploratory study and monitoring of various pollutants and $CO_2$ during the CAEP/12 cycle. The ICAO Standards-development process is driven by technological feasibility, environmental benefits and economic reasonableness while considering interdependencies between noise, pollutants and greenhouse gas emissions.

CAEP will also continue to monitor and review technology developments, including combustion technologies and advances in engine combustor design, with a view to understanding how these technologies may impact the production of gaseous emissions and PM in the future. Additionally, in order to assess consequences for all regulated emissions, ICAO monitors various trends in aviation fuels, including fuel composition and sustainable aviation fuels.

The recommendation on the new nvPM mass and number Standard was accompanied by an agreement by CAEP to conduct an early review of the relevant regulatory levels. This will involve the collation and analysis of the certified and certification-like nvPM mass and number emissions data that will become available for all in-production engines during the period 2019 to 2022. The margins to the agreed CAEP/11 nvPM SARPs will be reviewed to assess possible technological advancements to reduce nvPM emissions.

During the CAEP/12 cycle it is also planned to conduct a scoping study for NOx for in-production engines to investigate the feasibility for further NOx stringency analysis. ICAO continues to monitor developments in aeroplane and engine applications, and concepts to develop methodologies for emissions certification. In addition, advancements in supersonic technologies are being monitored to assess possible consequences for aeroplane and engine based emissions and an exploratory study to provide a better understanding of airport noise impacts resulting from the introduction of supersonic aircraft is ongoing.