ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 87, 1030, and 1031

[EPA–HQ–OAR–2019–0660; FRL–7558–01–OAR]

RIN 2060–AU69

Control of Air Pollution From Aircraft Engines: Emission Standards and Test Procedures

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The Environmental Protection Agency (EPA) is proposing particulate matter (PM) emission standards and test procedures applicable to certain classes of engines used by civil subsonic jet airplanes (those engines with rated output of greater than 26.7 kilonewtons (kN)) to replace the existing smoke standard for aircraft. These proposed standards and test procedures are equivalent to the engine standards adopted by the United Nations' International Civil Aviation Organization (ICAO) in 2017 and 2020 and would apply to both new type design aircraft engines and in-production aircraft engines. The EPA, as well as the United States Federal Aviation Administration (FAA), actively participated in the ICAO proceedings in which these requirements were developed. These proposed standards would reflect the importance of the control of PM emissions and U.S. efforts to secure the highest practicable degree of uniformity in aviation regulations and standards. Additionally, the EPA is proposing to migrate, modernize, and streamline the existing regulations into a new part. As part of this update, the EPA is also proposing to align with ICAO by applying the smoke number standards to engines less than or equal to 26.7 kilonewtons rated output used in supersonic airplanes.

DATES: Comments on this proposal must be received on or before April 4, 2022.

Public hearing: EPA will announce the public hearing date and location for this proposal in a supplemental **Federal Register** document.

ADDRESSES:

Comments: EPA solicits comments on all aspects of the proposed standards.

Written comments: Submit your comments, identified by Docket ID No. EPA–HQ–OAR–2019–0660, at *https://www.regulations.gov.* Follow the online instructions for submitting comments. Once submitted, comments cannot be edited or removed from *Regulations.gov.* The EPA may publish any comment received to its public docket. Do not submit electronically any information you consider to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Multimedia submissions (audio, video, etc.) must be accompanied by a written comment. The written comment is considered the official comment and should include discussion of all points you wish to make. The EPA will generally not consider comments or comment contents located outside of the primary submission (*i.e.,* on the web, cloud, or other file sharing system). For additional submission methods, the full EPA public comment policy, information about CBI or multimedia submissions, and general guidance on making effective comments, please visit *https://www.epa.gov/dockets/commenting-epa-dockets.*

The EPA is temporarily suspending its Docket Center and Reading Room for public visitors, with limited exceptions, to reduce the risk of transmitting COVID–19. Our Docket Center staff will continue to provide remote customer service via email, phone, and webform. We encourage the public to submit comments via *https://www.regulations.gov* as there may be a delay in processing mail and faxes. For further information and updates on EPA Docket Center services, please visit us online at *https://www.epa.gov/dockets.*

The EPA continues to carefully and continuously monitor information from the Centers for Disease Control and Prevention (CDC), local area health departments, and our Federal partners so that we can respond rapidly as conditions change regarding COVID–19.

Docket: EPA has established a docket for the action under Docket ID No. EPA–HQ–OAR–2019–0660. All documents in the docket are listed on the *www.regulations.gov* website. Although listed in the index, some information is not publicly available, *e.g.,* confidential business information or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material is not placed on the internet and will be publicly available only in hard copy form. Publicly available docket materials are available either electronically through *www.regulations.gov* or in hard copy at the following location:

Air and Radiation Docket and Information Center, EPA Docket Center, EPA/DC, EPA WJC West Building, 1301 Constitution Ave. NW, Room 3334, Washington, DC.

Out of an abundance of caution for members of the public and our staff, the EPA Docket Center and Reading Room was closed to public visitors on March 31, 2020, to reduce the risk of transmitting COVID–19. Our Docket Center staff will continue to provide remote customer service via email, phone, and webform. We encourage the public to submit comments via *https://www.regulations.gov* or email, as there is a temporary suspension of mail delivery to EPA, and no hand deliveries are currently accepted. For further information on EPA Docket Center services and the current status, please visit us online at *https://www.epa.gov/dockets.*

FOR FURTHER INFORMATION CONTACT:
Bryan Manning, Office of Transportation and Air Quality, Assessment and Standards Division (ASD), Environmental Protection Agency, 2000 Traverwood Drive, Ann Arbor, MI 48105; telephone number: (734) 214–4832; email address: *manning.bryan@epa.gov.*

SUPPLEMENTARY INFORMATION:

Table of Contents

I. General Information

A. Does this action apply to me?

This proposed action would affect companies that design and or manufacture civil subsonic jet aircraft engines with a rated output of greater than 26.7 kN and those that design and or manufacturer civil jet engines for use on supersonic airplanes with a rated output at or below 26.7 kN. These affected entities include the following:

Category	NAICS code [a]	Examples of potentially affected entities
Industry	336412	Manufacturers of new aircraft engines.

[a] North American Industry Classification System (NAICS).

This table lists the types of entities that EPA is now aware could potentially be affected by this action. Other types of entities not listed in the table could also be regulated. To determine whether your activities are regulated by this action, you should carefully examine the relevant applicability criteria in 40 CFR parts 87 and 1031. If you have any questions regarding the applicability of this action to a particular entity, consult the person listed in the preceding **FOR FURTHER INFORMATION CONTACT** section.

For consistency purposes across the United States Code of Federal Regulations (CFR), common definitions for the words ''airplane,'' ''aircraft,'' ''aircraft engine,'' and ''civil aircraft'' are found in Title 14 CFR part 1, and are used as appropriate throughout this new proposed regulation under 40 CFR parts 87 and 1031.

B. Executive Summary

1. Summary of the Major Provisions of the Proposed Regulatory Action

The EPA is proposing to regulate PM emissions from covered aircraft engines through the adoption of domestic PM regulations that match the ICAO PM standards, which would be implemented and enforced in the U.S. The proposed standards would apply to new type design and in-production aircraft engines with rated output (maximum thrust available for takeoff) of greater than 26.7 kN used by civil subsonic jet airplanes: Those engines generally used in commercial passenger and freight aircraft, as well as larger business jets. The EPA is proposing to adopt three different forms of PM standards: A PM mass standard in milligrams per kilonewton (mg/kN), a PM number standard in number of particles per kilonewton (#/kN), and a PM mass concentration standard in micrograms per cubic meter (μg/m^3). The applicable dates and coverage of these standards would vary, as described in the following paragraphs, and more fully in in IV.A, IV.B, and IV.C respectively.

First, the EPA is proposing PM engine emissions standards, in the form of both PM mass (mg/kN) and PM number (#/kN), for new type designs and in-production aircraft turbofan and turbojet engines with rated output greater than 26.7 kN. The proposed standards for in-production engines would apply to those engines that would be manufactured on or after January 1, 2023, even if type certificated before that date. The proposed standards for new type designs would apply to those engines whose initial type certification application was submitted on or after January 1, 2023. The in-production standards would have different emission levels limits than would the standards for new type designs. The different emission levels limits for new type designs and in-production engines would depend on the rated output of the engines. Compliance with the proposed PM mass and number standards would be done in accordance with the standard landing and take-off (LTO) test cycle, which is currently used for demonstrating compliance with gaseous emission standards (oxides of nitrogen (NO_X), hydrocarbons (HC), and carbon monoxide (CO) standards) for the covered engines.

Second, the EPA is proposing a PM engine emissions standard in the form of maximum mass concentration (μg/m^3) for in-production aircraft turbofan and turbojet engines with rated output greater than 26.7 kN manufactured on or after January 1, 2023.[1] Compliance with the PM mass concentration standard would be done using the same test data that is developed to demonstrate compliance with the LTO-based PM mass and number standards. The proposed PM mass concentration standard would apply to the highest concentration of PM measured across the engine operating thrust range, not

[1] The implementation date for ICAO's PM maximum mass concentration standards is on or after January 1, 2020. The final rulemaking that would follow this proposed rulemaking for these standards is expected to be completed before January 1, 2023. Thus, the standards would have an implementation date of January 1, 2023 (instead of January 1, 2020).

just at one of the four LTO thrust settings.

The proposed PM mass concentration standard was developed by ICAO to provide, through a PM mass measurement, the equivalent smoke opacity or visibility control as afforded by the existing smoke number standard for the covered engines. Thus, the EPA is also proposing to no longer apply the existing smoke number standard for new engines that would be subject to the proposed PM mass concentration standard after January 1, 2023, but the EPA is maintaining smoke number standards for new engines not covered by the PM mass concentration standard (*e.g.,* in-production aircraft turbofan and turbojet engines with rated output less than or equal to 26.7 kN) and for engines already manufactured. This proposed approach would essentially change the existing standard for covered engines from being based on a smoke measurement to a PM measurement.

Third, the EPA is proposing testing and measurement procedures for the PM emission standards and various updates to the existing gaseous exhaust emissions test procedures. These proposed test procedure provisions would implement the recent additions and amendments to ICAO's regulations, which are codified in ICAO Annex 16, Volume II. As we have historically done, we propose to incorporate these test procedure additions and amendments to the ICAO Annex 16, Volume II into our regulations by reference.

The proposed aircraft engine PM standards, test procedures and associated regulatory requirements are equivalent to the international PM standards and test procedures adopted by ICAO in 2017 and 2020 and promulgated in Annex 16, Volume II.[2] The United States and other member States of ICAO, as well as the world's aircraft engine manufacturers and other interested stakeholders, participated in the deliberations leading up to ICAO's adoption of the international aircraft engine PM emission standards.

In addition to the PM standards just discussed, the EPA is proposing to migrate the existing aircraft engine emissions regulations from 40 CFR part 87 to a new 40 CFR part 1031, and all the aircraft engine standards and requirements described earlier would be specified in this new part 1031. Along with this migration, the EPA is proposing to restructure the regulations to allow for better ease of use and allow for more efficient future updates. The EPA is also proposing to delete some unnecessary definitions and regulatory provisions. Finally, the EPA is proposing several other minor technical amendments to the regulations, including applying smoke number standards to engines of less than or equal to 26.7 kilonewtons (kN) rated output used in supersonic airplanes.

2. Purpose of the Proposed Regulatory Action

In developing these proposed standards, the EPA took into consideration the importance of both controlling PM emissions and international harmonization of aviation requirements. In addition, the EPA gave significant weight to the U.S.'s treaty obligations under the Chicago Convention, as discussed in Section II.B, in determining the need for and appropriate levels of PM standards. These considerations led the EPA to propose standards for PM emissions from certain classes of covered aircraft engines that are equivalent in scope, stringency, and effective date to the PM standards adopted by ICAO.

The new ICAO aircraft PM emission standards will take effect on January 1, 2023 but will not apply in the U.S. unless adopted into domestic law. One of the core functions of ICAO is to adopt Standards and Recommended Practices on a wide range of aviation-related matters, including aircraft emissions. As a member State of ICAO, the United States actively participates in the development of new environmental standards, within ICAO's Committee on Aviation Environmental Protection (CAEP), including the PM standards adopted by ICAO in both 2017 and 2020. Due to the international nature of the aviation industry, there is an advantage to working within ICAO, in order to secure the highest practicable degree of uniformity in international aviation regulations and standards. Uniformity in international aviation regulations and standards is a goal of the Chicago Convention, because it ensures that passengers and the public can expect similar levels of protection for safety and human health and the environment regardless of manufacturer, airline, or point of origin of a flight. Further, it helps reduce barriers in the global aviation market, benefiting both U.S. aircraft engine manufacturers and consumers.

When developing new emissions standards, ICAO/CAEP seeks to capture the technological advances made in the control of emissions through the adoption of anti-backsliding standards reflecting the current state of technology. The PM standards the EPA is proposing were developed using this approach. Thus, the adoption of these aviation standards into U.S. law would simultaneously prevent aircraft engine PM levels from increasing beyond their current levels, align U.S. domestic standards with the ICAO standards for international harmonization, and help the U.S. meet its treaty obligations under the Chicago Convention.

These proposed standards would also allow U.S. manufacturers of covered aircraft engines to remain competitive in the global marketplace (as described later in the introductory text of Section IV). In the absence of U.S. standards implementing the ICAO aircraft engine PM emission standards, U.S. civil aircraft engine manufacturers could be forced to seek PM emissions certification from an aviation certification authority of another country (not the FAA) in order to market and operate their aircraft engines internationally. U.S. manufacturers could be at a significant disadvantage if the U.S. fails to adopt standards that are at least as stringent as the ICAO standards for PM emissions. The ICAO aircraft engine PM emission standards have been or are being adopted by other ICAO member states that certify aircraft engines. The proposed action to adopt in the U.S. PM standards that match the ICAO standards would help ensure international consistency and acceptance of U.S. manufactured engines worldwide.

3. Environmental Justice

Executive Orders 12898 (59 FR 7629, February 16, 1994) and 14008 (86 FR 7619, February 1, 2021) direct federal agencies, to the greatest extent practicable and permitted by law, to make achieving environmental justice (EJ) part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the United States. Section III.G discusses these executive orders in greater detail, along with the potential environmental justice concerns associated with exposure to aircraft PM near airports. EPA defines environmental justice as the fair

[2] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services Catalog, English Edition of the 2021 catalog, and it is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Studies have reported that many communities in close proximity to airports are disproportionately represented by people of color and low-income populations (as described later in Section III.G). In an action separate from this proposed rulemaking, EPA will be conducting an analysis of the communities residing near airports where jet aircraft operate in order to more fully understand disproportionately high and adverse human health or environmental effects on people of color, low-income populations and/or indigenous peoples. The results of this analysis could help inform additional policies to reduce pollution in communities living in close proximity to airports.

As described in Section V.C, while newer aircraft engines typically have significantly lower emissions than existing aircraft engines, the proposed standards in this action are technology-following in order to align with ICAO's standards and are not expected to, in and of themselves, result in further reductions in PM from these engines. Therefore, we do not anticipate an improvement in air quality for those who live near airports where these aircraft operate.

II. Introduction: Context for This Proposed Action

EPA has been regulating PM emissions from aircraft engines since the 1970s when the first smoke number standards were adopted. This section provides context for the proposed rule, which proposes three PM standards for aircraft engines. This section includes a description of EPA's statutory authority, the United States' role in ICAO and developing international emission standards, and the relationship between United States' standards and ICAO's international standards.

A. EPA Statutory Authority and Responsibilities Under the Clean Air Act

Section 231(a)(2)(A) of the Clean Air Act (CAA) directs the Administrator of EPA to, from time to time, propose aircraft engine emission standards applicable to the emission of any air pollutant from classes of aircraft engines which in his or her judgment causes or contributes to air pollution that may reasonably be anticipated to endanger public health or welfare. (See 42 U.S.C. 7571(a)(2)(A)). CAA section 231(a)(2)(B) directs the EPA to consult with the Administrator of the Federal Aviation Administration (FAA) on such standards, and it prohibits the EPA from changing aircraft emission standards if such a change would significantly increase noise and adversely affect safety. (See 42 U.S.C. 7571(a)(2)(B)(i)–(ii)). CAA section 231(a)(3) provides that after we provide notice and an opportunity for a public hearing on standards, the Administrator shall issue such standards ''with such modifications as he deems appropriate.'' (See 42 U.S.C. 7571(a)(3)). In addition, under CAA section 231(b) the EPA is required to ensure, in consultation with the U.S. Department of Transportation (DOT), that the effective date of any standard provides the necessary time to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance. (See 42 U.S.C. 7571(b)).

Consistent with its longstanding approach and D.C. Circuit precedent,[3] the EPA interprets its authority under CAA section 231 as providing the Administrator wide discretion in determining what standards are appropriate, after consideration of the factors specified in the statute and other relevant factors, such as applicable international standards. We are not compelled under CAA section 231 to obtain the ''greatest degree of emission reduction achievable'' as per sections 213(a)(3) and 202(a)(3)(A) of the CAA, and so the EPA does not interpret the Act as requiring the agency to give subordinate status to factors such as cost, safety, and noise in determining what standards are reasonable for aircraft engines. Rather, the EPA has greater flexibility under section 231 in determining what standard is most reasonable for aircraft engines. Thus, as in past rulemakings, EPA notes its authority under the CAA to issue reasonable aircraft engine standards with either technology-following or technology-forcing results, provided that, in either scenario, the Agency has a reasonable basis after considering all the relevant factors for setting the standard.[4] Once EPA adopts standards, CAA section 232 then directs the Secretary of Transportation to prescribe regulations to ensure compliance with the EPA's standards. (See 42 U.S.C. 7572). Finally, section 233 of the CAA vests the authority to promulgate emission standards for aircraft or aircraft engines only in the Federal Government. States are preempted from adopting or enforcing any standard respecting aircraft or aircraft engine emissions unless such standard is identical to the EPA's standards. (See 42 U.S.C. 7573).

B. The Role of the United States in International Aircraft Agreements

The Convention on International Civil Aviation (commonly known as the 'Chicago Convention') was signed in 1944 at the Diplomatic Conference held in Chicago. It was ratified by the United States on August 9, 1946. The Chicago Convention establishes the legal framework for the development of international civil aviation. The primary objective is ''that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically.'' [5] In 1947, ICAO was established, and later in that same year, ICAO became a specialized agency of the United Nations (UN). ICAO sets international standards for aviation safety, security, efficiency, capacity, and environmental protection and serves as the forum for cooperation in all fields of international civil aviation. ICAO works with the Chicago Convention's member States and global aviation organizations to develop international Standards and Recommended Practices (SARPs), which member States reference when developing their domestic civil aviation regulations. The United States is one of 193 currently participating ICAO member States.[6] [7] ICAO standards are not self-implementing. They must first be adopted into domestic law to be legally binding in any member State.

In the interest of global harmonization and international air commerce, the Chicago Convention urges its member States to ''collaborate in securing the highest practicable degree of uniformity in regulations, standards, procedures and organization in relation to aircraft, [. . .] in all matters which such uniformity will facilitate and improve

[3] The U.S. Court of Appeals for the D.C. Circuit has held that CAA section 231 confers an ''extraordinarily broad'' degree of discretion on EPA to ''weigh various factors'' and adopt aircraft engine emission standards as the Agency determines are reasonable. *Nat'l Ass'n of Clean Air Agencies* v. *EPA,* 489 F.3d 1221, 1229–30 (D.C. Cir. 2007) (NACAA).

[4] *See* 70 FR 69664, 69676 (November 17, 2005).

[5] ICAO, 2006: *Convention on International Civil Aviation, Ninth Edition,* Document 7300/9. Available at: *https://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed July 20, 2021).

[6] Members of ICAO's Assembly are generally termed member States or contracting States. These terms are used interchangeably throughout this preamble.

[7] There are currently 193 contracting states according to ICAO's website: *https://www.icao.int/MemberStates/Member%20States.English.pdf* (last accessed July 12, 2021).

air navigation.'' [8] The Chicago Convention also recognizes that member States may adopt national standards that are more or less stringent than those agreed upon by ICAO or standards that are different in character or that comply with the ICAO standards by other means. Any member State that finds it impracticable to comply in all respects with any international standard or procedure, or that determines it is necessary to adopt regulations or practices differing in any particular respect from those established by an international standard, is required to give notification to ICAO of the differences between its own practice and that established by the international standard.[9]

ICAO's work on the environment focuses primarily on those problems that benefit most from a common and coordinated approach on a worldwide basis, namely aircraft noise and engine emissions. SARPs for the certification of aircraft noise and aircraft engine emissions are covered by Annex 16 of the Chicago Convention. To continue to address aviation environmental issues, in 2004, ICAO established three environmental goals: (1) Limit or reduce the number of people affected by significant aircraft noise; (2) limit or reduce the impact of aviation emissions on local air quality; and (3) limit or reduce the impact of aviation greenhouse gas (GHG) emissions on the global climate.

The Chicago Convention has a number of other features that govern international commerce. First, member States that wish to use aircraft in international transportation must adopt emission standards that are at least as stringent as ICAO's standards if they want to ensure recognition of their airworthiness certificates by other member States. Member States may ban the use of any aircraft within their airspace that does not meet ICAO standards.[10] Second, the Chicago Convention indicates that member States are required to recognize the airworthiness certificates issued or rendered valid by the contracting State in which the aircraft is registered provided the requirements under which the certificates were issued are equal to or above ICAO's minimum standards.[11] Third, to ensure that international commerce is not unreasonably constrained, a member State that cannot meet or deems it necessary to adopt regulations differing from the international standard is obligated to notify ICAO of the differences between its domestic regulations and ICAO standards.[12]

ICAO's Committee on Aviation Environmental Protection (CAEP), which consists of members and observers from States, intergovernmental and non-governmental organizations representing the aviation industry and environmental interests, undertakes ICAO's technical work in the environmental field. The Committee is responsible for evaluating, researching, and recommending measures to the ICAO Council that address the environmental impacts of international civil aviation. CAEP's terms of reference indicate that ''CAEP's assessments and proposals are pursued taking into account: Technical feasibility; environmental benefit; economic reasonableness; interdependencies of measures (for example, among others, measures taken to minimize noise and emissions); developments in other fields; and international and national programs.'' [13] The ICAO Council reviews and adopts the recommendations made by CAEP. It then reports to the ICAO Assembly, the highest body of the organization, where the main policies on aviation environmental protection are adopted and translated into Assembly Resolutions. If ICAO adopts a CAEP proposal for a new environmental standard, it then becomes part of ICAO standards and recommended practices (Annex 16 to the Chicago Convention).[14] [15]

The FAA plays an active role in ICAO/CAEP, including serving as the representative (member) of the United States at annual ICAO/CAEP Steering Group meetings, as well as the ICAO/CAEP triennial meetings, and contributing technical expertise to CAEP's working groups. The EPA serves as an advisor to the U.S. member at the annual ICAO/CAEP Steering Group and triennial ICAO/CAEP meetings, while also contributing technical expertise to CAEP's working groups and assisting and advising the FAA on aviation emissions, technology, and environmental policy matters. In turn, the FAA assists and advises the EPA on aviation environmental issues, technology, and airworthiness certification matters.

CAEP's predecessor at ICAO, the Committee on Aircraft Engine Emissions (CAEE), adopted the first international SARPs for aircraft engine emissions which were proposed in 1981.[16] These standards limited aircraft engine emissions of hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_X). The 1981 standards applied to newly manufactured engines, which are those engines manufactured after the effective date of the regulations—also referred to as in-production engines. In 1993, ICAO adopted a CAEP/2 proposal to tighten the original NO_X standard by 20 percent and amend the test procedures.[17] These 1993 standards applied both to newly certificated turbofan engines (those engine models that received their initial type certificate after the effective date of the

[8] ICAO, 2006: Convention on International Civil Aviation, Article 37, Ninth Edition, Document 7300/9. Available at *https://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed July 20, 2021).

[9] ICAO, 2006: *Doc 7300-Convention on International Civil Aviation, Ninth Edition,* Document 7300/9. Available at *https://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed July 20, 2021).

[10] ICAO, 2006: *Convention on International Civil Aviation, Article* 33, *Ninth Edition,* Document 7300/9. Available at *https://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed July 20, 2021).

[11] ICAO, 2006: *Convention on International Civil Aviation, Article 33, Ninth Edition,* Document 7300/9. Available at *https://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed July 20, 2021).

[12] ICAO, 2006: *Convention on International Civil Aviation, Article 38, Ninth Edition,* Document 7300/9. Available at *https://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed July 20, 2021).

[13] ICAO: CAEP Terms of Reference. Available at *https://www.icao.int/environmental-protection/Pages/Caep.aspx#ToR* (last accessed July 20, 2021).

[14] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services English Edition of the 2021 catalog, and it is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

[15] CAEP develops new emission standards based on an assessment of the technical feasibility, cost, and environmental benefit of potential requirements.

[16] ICAO, 2017: *Aircraft Engine Emissions: Foreword,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services English Edition 2021 catalog and is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

[17] CAEP conducts its work triennially. Each 3-year work cycle is numbered sequentially and that identifier is used to differentiate the results from one CAEP meeting to another by convention. The first technical meeting on aircraft emission standards was CAEP's predecessor, *i.e.,* CAEE. The first meeting of CAEP, therefore, is referred to as CAEP/2.

regulations, also referred to as new type design engines) and to in-production engines; the standards had different effective dates for newly certificated engines and in-production engines. In 1995, CAEP/3 recommended a further tightening of the NO_X standards by 16 percent and additional test procedure amendments, but in 1997 the ICAO Council rejected this stringency proposal and approved only the test procedure amendments. At the CAEP/4 meeting in 1998, the Committee adopted a similar 16 percent NO_X reduction proposal, which ICAO approved in 1998. Unlike the CAEP/2 standards, the CAEP/4 standards applied only to new type design engines after December 31, 2003, and not to in-production engines, leaving the CAEP/2 standards applicable to in-production engines. In 2004, CAEP/6 recommended a 12 percent NO_X reduction, which ICAO approved in 2005.[18] [19] The CAEP/6 standards applied to new engine designs certificated after December 31, 2007, again leaving the CAEP/2 standards in place for in-production engines before January 1, 2013. In 2010, CAEP/8 recommended a further tightening of the NO_X standards by 15 percent for new engine designs certificated after December 31, 2013.[20] [21] The Committee also recommended that the CAEP/6 standards be applied to in-production engines on or after January 1, 2013, which cut off the production of CAEP/2 and CAEP/4 compliant engines with the exception of spare engines; ICAO adopted these as standards in 2011.[22]

[18] CAEP/5 did not address new aircraft engine emission standards.

[19] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed June 16, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services Catalog, English Edition of the 2021 catalog, and it is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

[20] CAEP/7 did not address new aircraft engine emission standards.

[21] ICAO, 2010: Committee on Aviation Environmental Protection (CAEP), Report of the Eighth Meeting, Montreal, February 1–12, 2010, CAEP/8–WP/80 Available in Docket EPA–HQ–OAR–2010–0687.

[22] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, Amendment 10. CAEP/8 corresponds to Amendment 7 effective on July 18, 2011. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services Catalog, English Edition of the 2021 catalog, and it is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

At the CAEP/10 meeting in 2016, the Committee agreed to the first airplane CO_2 emission standards, which ICAO approved in 2017. The CAEP/10 CO_2 standards apply to new type design airplanes for which the application for a type certificate will be submitted on or after January 1, 2020, some modified in-production airplanes on or after January 1, 2023, and all applicable in-production airplanes manufactured on or after January 1, 2028.

At the CAEP/10 and CAEP/11 meetings in 2016 and 2019, the Committee agreed to three different forms of international PM standards for aircraft engines. Maximum PM mass concentration standards were agreed to at CAEP/10, and PM mass and number standards were agreed to at CAEP/11. ICAO adopted the PM maximum mass concentration standards in 2017 and the PM mass and number standards in 2020. The CAEP/10 PM standards apply to in-production engines on or after January 1, 2020, and the CAEP/11 PM standards apply to new-type and in-production engines on or after January 1, 2023. In addition to CAEP/10 agreeing to a maximum PM mass concentration standard, CAEP/10 adopted a reporting requirement where aircraft engine manufacturers were required to provide PM mass concentration, PM mass, and PM number emissions data—and other related parameters—by January 1, 2020 for in-production engines.[23]

C. The Relationship Between EPA's Regulation of Aircraft Engine Emissions and International Standards

Domestically, as required by the CAA, the EPA has been engaged in reducing harmful air pollution from aircraft engines for over 40 years, regulating gaseous exhaust emissions, smoke, and fuel venting from engines.[24] We have periodically revised these regulations.[25] The EPA's actions to regulate certain pollutants emitted from aircraft engines come directly from the authority in section 231 of the CAA, and we have aligned the U.S. emissions requirements with those promulgated by ICAO. As described above in Section II.B, the ICAO/CAEP terms of reference includes technical feasibility.[26] Technical feasibility has been interpreted by CAEP as technology demonstrated to be safe and airworthy and available for application over a sufficient range of newly certificated aircraft.[27] This interpretation resulted in all previous ICAO emission standards, and the EPA's standards reflecting them, being anti-backsliding standards (*i.e.,* the standards would not reduce aircraft PM emissions below current levels of engine emissions), which are technology following.

For many years the EPA has regulated aircraft engine PM emissions through the use of smoke number standards.[28] Since setting the original smoke number standards in 1973, the EPA has periodically revised these standards. The EPA amended its smoke standards to align with ICAO's smoke standards in 1982 [29] and again in 1984.[30] Additionally, EPA has amended the test procedures for measuring smoke

[23] More specifically, the international PM standard applies to all turbofan and turbojet engines of a type or model, and their derivative versions, with a rated output greater than 26.7 kN and whose date of manufacture of the individual engine is on or after January 1, 2020 (or those engines manufactured on or after January 1, 2020).

[24] U.S. EPA, 1973: Emission Standards and Test Procedures for Aircraft; Final Rule, 38 FR 19088 (July 17, 1973).

[25] The following are the most recent EPA rulemakings that revised these regulations. U.S. EPA, 1997: Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule, 62 FR 25355 (May 8, 1997). U.S. EPA, 2005: Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule, 70 FR 69664 (November 17, 2005). U.S. EPA, 2012: Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule, 77 FR 36342 (June 18, 2012). U.S. EPA, 2021: Control of Air Pollution From Airplanes and Airplane Engines: GHG Emission Standards and Test Procedures; Final Rule, 86 FR 2136 (January 11, 2021).

[26] ICAO: CAEP Terms of Reference. Available at *https://www.icao.int/environmental-protection/Pages/Caep.aspx#ToR* (last accessed July 20, 2021).

[27] ICAO, 2019: *Report of the Eleventh Meeting,* Montreal, 4–15 February 2019, Committee on Aviation Environmental Protection, Document 10126, CAEP11. It is found on page 26 of the English Edition of the ICAO Products & Services 2021 Catalog and is copyright protected: Order No. 10126. For purchase and available at: *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed June 21, 2021). The statement on technological feasibility is located in Appendix C of Agenda Item 3 of this report (see page 3C–4, paragraph 2.2).

[28] U.S. EPA, 40 CFR 87.1. ''Smoke means the matter in exhaust emissions that obscures the transmission of light, as measured by the test procedures specified in subpart G of this part.'' ''Smoke number means a dimensionless value quantifying smoke emission as calculated according to ICAO Annex 16.''

[29] U.S. EPA, Control of Air Pollution From Aircraft and Aircraft Engines; Emission Standards and Test Procedures, Final Rule, 47 FR 58462, December 30, 1982.

[30] U.S. EPA, Control of Air Pollution From Aircraft and Aircraft Engines; Smoke Emission Standard, Final Rule, 49 FR 31873, August 9, 1984 (bifurcating EPA's smoke standard for new engines into two regimes—one for engines with rated output less than 26.7 kilonewtons and one for engines with rated output equal to or greater than 26.7 kilonewtons).

emissions[31] and modified the effective dates and compliance schedule for smoke emissions standards periodically.[32] Now, we are proposing to adopt three different forms of aircraft engine PM standards: A PM mass concentration standard (μg/m³), a PM mass standard (mg/kN), and PM number standard (#/kN). These proposed aircraft engine PM emission standards are a different way of regulating and/or measuring[33] aircraft engine PM emissions in comparison to smoke number emission standards.

Internationally, the EPA and the FAA have worked within the standard-setting process of ICAO (CAEP and its predecessor, CAEE) since the 1970's to help establish international emission standards and related requirements, which individual member States adopt into domestic law and regulations. Historically, under this approach, international emission standards have first been adopted by ICAO, and subsequently the EPA has initiated rulemakings under CAA section 231 to establish domestic standards that are harmonized with ICAO's standards. After EPA promulgates aircraft engine emission standards, CAA section 232 requires the FAA to issue regulations to ensure compliance with the EPA aircraft engine emission standards when certificating aircraft pursuant to its authority under Title 49 of the United States Code. This proposed rule would continue this historical rulemaking approach.

The EPA and FAA worked from 2009 to 2019 within the ICAO/CAEP standard setting process on the development of the three different forms of international aircraft engine PM emission standards (a PM mass concentration standard, a PM mass standard, and a PM particle number standard). In this action, we are proposing to adopt PM standards equivalent to ICAO's three different forms of aircraft engine PM emission standards. Adoption of the proposed standards would meet the United States' obligations under the Chicago Convention and would also ensure global acceptance of FAA airworthiness certification.

In December 2018, the EPA issued an information collection request (ICR) that matches the CAEP/10 p.m. reporting requirements described earlier.[34] In addition to the PM standards, the proposed rulemaking would codify the reporting requirements implemented by this 2018 EPA ICR into the EPA regulations, as described later in Section IV.E. Also, in a similar time frame as this proposed rulemaking, EPA will be renewing this ICR (the ICR needs to be renewed triennially).

III. Particulate Matter Impacts on Air Quality and Health

A. Background on Particulate Matter

Particulate matter (PM) is a highly complex mixture of solid particles and liquid droplets distributed among numerous atmospheric gases which interact with solid and liquid phases. Particles range in size from those smaller than 1 nanometer (10^{-9} meter) to over 100 micrometers (μm, or 10^{-6} meter) in diameter (for reference, a typical strand of human hair is 70 μm in diameter and a grain of salt is about 100 μm). Atmospheric particles can be grouped into several classes according to their aerodynamic and physical sizes. Generally, the three broad classes of particles include ultrafine particles (UFPs, generally considered as particulates with a diameter less than or equal to 0.1 μm (typically based on physical size, thermal diffusivity or electrical mobility)), ''fine'' particles ($PM_{2.5}$; particles with a nominal mean aerodynamic diameter less than or equal to 2.5 μm), and ''thoracic'' particles (PM_{10}; particles with a nominal mean aerodynamic diameter less than or equal to 10 μm). Particles that fall within the size range between $PM_{2.5}$ and PM_{10}, are referred to as ''thoracic coarse particles'' ($PM_{10-2.5}$, particles with a nominal mean aerodynamic diameter less than or equal to 10 μm and greater than 2.5 μm).

Particles span many sizes and shapes and may consist of hundreds of different chemicals. Particles are emitted directly from sources and are also formed through atmospheric chemical reactions between PM precursors; the former are often referred to as ''primary'' particles, and the latter as ''secondary'' particles. Particle concentration and composition varies by time of year and location, and, in addition to differences in source emissions, is affected by several weather-related factors, such as temperature, clouds, humidity, and wind. Ambient levels of PM are also impacted by particles' ability to shift between solid/liquid and gaseous phases, which is influenced by concentration, meteorology, and especially temperature.

Fine particles are produced primarily by combustion processes and by transformations of gaseous emissions (*e.g.,* sulfur oxides (SO_X), nitrogen oxides (NO_X) and volatile organic compounds (VOCs)) in the atmosphere. The chemical and physical properties of $PM_{2.5}$ may vary greatly with time, region, meteorology, and source category. Thus, $PM_{2.5}$ may include a complex mixture of different components including sulfates, nitrates, organic compounds, elemental carbon, and metal compounds. These particles can remain in the atmosphere for days to weeks and travel through the atmosphere hundreds to thousands of kilometers.

Particulate matter is comprised of both volatile and non-volatile PM. PM emitted from the engine is known as non-volatile PM (nvPM), and PM formed from transformation of an engine's gaseous emissions are defined as volatile PM.[35] Because of the

[31] U.S. EPA, Control of Air Pollution From Aircraft and Aircraft Engines; Emission Standards and Test Procedures, Final Rule, 62 FR 25356, May 8, 1997 (harmonizing EPA procedures with recent amendments to ICAO test procedures); U.S. EPA, Control of Air Pollution From Aircraft and Aircraft Engines; Emission Standards and Test Procedures, Final Rule, 70 FR 69664, November 17, 2005 (same); U.S. EPA, Control of Air Pollution From Aircraft and Aircraft Engines; Emission Standards and Test Procedures, Final Rule, 77 FR 36342, June 18, 2012.

[32] U.S. EPA, Amendment to Standards, Final Rule, 43 FR 12614, March 24, 1978 (setting back by two years the effective date for all gaseous emissions standards for newly manufactured aircraft and aircraft gas turbine engines); U.S. EPA, Control of Air Pollution from Aircraft and Aircraft Engines; Extension of Compliance Date for Emission Standards Applicable to JT3D Engines, Final Rule, 44 FR 64266, November 6, 1979 (extending the final compliance date for smoke emission standards applicable to the JT3D aircraft engines by roughly 3.5 years); U.S. EPA, Control of Air Pollution from Aircraft; Amendment to Standards, Final Rule, 45 FR 86946, December 31, 1980 (setting back by two years the effective date for all gaseous emissions standards which would otherwise have been effective on January 1,1981, for aircraft gas turbine engines); U.S. EPA, Control of Air Pollution from Aircraft and Aircraft Engines, Final Rule, 46 FR 2044, January 8, 1981 (extending the applicability of the temporary exemption provision of the standards for smoke and fuel venting emissions from some in-use aircraft engines); U.S. EPA, Control of Air Pollution From Aircraft and Aircraft Engines; Smoke Emission Standard, Final Rule, 48 FR 46481, October 12, 1983 (staying the smoke regulations for new turbojet and turbofan engines rated below 26.7 kN thrust).

[33] Also, as described in Section IV.D, the proposed PM standards employ a different method for measuring aircraft engine PM emissions compared to the historical smoke number emission standards.

[34] 83 FR 44621, August 31, 2018. U.S. EPA, *Aircraft Engines—Supplemental Information Related to Exhaust Emissions (Renewal),* OMB Control Number 2060–0680, ICR Reference Number 201809–2060–08, December 17, 2018.

[35] The ICAO 2019 Environmental Report, Available at *https://www.icao.int/environmental-protection/Documents/ICAO-ENV-Report2019-F1-WEB%20(1).pdf* (*last accessed September 1, 2021*). See pages 98, 100, and 101 for a description of non-volatile PM and volatile PM.

''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, difficulty in measuring volatile PM, which is formed in the engine's exhaust plume and is significantly influenced by ambient conditions, the EPA is proposing standards only for the emission of nvPM.

B. Health Effects of Particulate Matter

Scientific studies show exposure to ambient PM is associated with a broad range of health effects. These health effects are discussed in detail in the Integrated Science Assessment for Particulate Matter (PM ISA), which was finalized in December 2019.[36] The PM ISA concludes that human exposures to ambient $PM_{2.5}$ are associated with a number of adverse health effects and characterizes the weight of evidence for broad health categories (*e.g.,* cardiovascular effects, respiratory effects, etc.).[37] The PM ISA additionally notes that stratified analyses (*i.e.,* analyses that directly compare PM-related health effects across groups) provide strong evidence for racial and ethnic differences in $PM_{2.5}$ exposures and in $PM_{2.5}$-related health risk. As described in Section III.D, concentrations of PM increase with proximity to an airport. Further, studies described in Section III.G report that many communities in close proximity to airports are disproportionately represented by people of color and low-income populations.

EPA has concluded that recent evidence in combination with evidence evaluated in the 2009 p.m. ISA supports a ''causal relationship'' between both long- and short-term exposures to $PM_{2.5}$ and mortality and cardiovascular effects and a ''likely to be causal relationship'' between long- and short-term $PM_{2.5}$ exposures and respiratory effects.[38] Additionally, recent experimental and epidemiologic studies provide evidence supporting a ''likely to be causal relationship'' between long-term $PM_{2.5}$ exposure and nervous system effects, and long-term $PM_{2.5}$ exposure and cancer. In addition, EPA noted that there was more limited and uncertain evidence for long-term $PM_{2.5}$ exposure and reproductive and developmental effects (*i.e.,* male/female reproduction and fertility; pregnancy and birth outcomes), long- and short-term exposures and metabolic effects, and short-term exposure and nervous system effects resulting in the ISA concluding ''suggestive of, but not sufficient to infer, a causal relationship.''

More detailed information on the health effects of PM can be found in a memorandum to the docket.[39]

C. Environmental Effects of Particulate Matter

Environmental effects that can result from particulate matter emissions include visibility degradation, plant and ecosystem effects, deposition effects, and materials damage and soiling. These effects are briefly summarized here and discussed in more detail in the memo to the docket cited above.

$PM_{2.5}$ emissions also adversely impact visibility.[40] In the Clean Air Act Amendments of 1977, Congress recognized visibility's value to society by establishing a national goal to protect national parks and wilderness areas from visibility impairment caused by manmade pollution.[41] In 1999, EPA finalized the regional haze program (64 FR 35714) to protect the visibility in Mandatory Class I Federal areas. There are 156 national parks, forests and wilderness areas categorized as Mandatory Class I Federal areas (62 FR 38680–38681, July 18, 1997). These areas are defined in CAA section 162 as those national parks exceeding 6,000 acres, wilderness areas and memorial parks exceeding 5,000 acres, and all international parks which were in existence on August 7, 1977. EPA has also concluded that $PM_{2.5}$ causes adverse effects on visibility in other areas that are not targeted by the Regional Haze Rule, such as urban areas, depending on $PM_{2.5}$ concentrations and other factors such as dry chemical composition and relative humidity (*i.e.,* an indicator of the water composition of the particles). EPA established the secondary 24-hour $PM_{2.5}$ NAAQS in 1997 and has retained the standard in subsequent reviews.[42] This standard is expected to provide protection against visibility effects through attainment of the existing secondary standards for $PM_{2.5}$. EPA is reconsidering the 2020 decision, as announced on June 10, 2021.[43]

1. Deposition of Metallic and Organic Constituents of PM

Several significant ecological effects are associated with deposition of chemical constituents of ambient PM such as metals and organics.[44] Like all internal combustion engines, turbine engines covered by this rule may emit trace amounts of metals due to fuel contamination or engine wear. Ecological effects of PM include direct effects to metabolic processes of plant foliage; contribution to total metal loading resulting in alteration of soil biogeochemistry and microbiology, plant and animal growth and reproduction; and contribution to total organics loading resulting in bioaccumulation and biomagnification.

2. Materials Damage and Soiling

Deposition of PM is associated with both physical damage (materials damage effects) and impaired aesthetic qualities (soiling effects). Wet and dry deposition of PM can physically affect materials, adding to the effects of natural weathering processes, by potentially promoting or accelerating the corrosion of metals, by degrading paints and by

gas turbine engines emit non-volatile particles of smaller mean diameter. Their characteristic size ranges roughly from 15 to 60 nanometers (nm; 1nm = 1/100,000 of a millimeter). These particles are invisible to the human eye and are ultrafine.'' (See page 98.)

''Additionally, gaseous emissions from engines can also condense to produce new particles (*i.e.,* volatile particulate matter—vPM) or coat the emitted soot particles. Gaseous emissions species react chemically with ambient chemical constituents in the atmosphere to produce the so called secondary particulate matter. Volatile particulate matter is dependent on these gaseous precursor emissions. While these precursors are controlled by gaseous emission certification and the fuel composition (*e.g.,* sulfur content) for aircraft gas turbine engines, the volatile particulate matter is also dependent on the ambient air background composition.'' (See pages 100 and 101.)

[36] U.S. EPA. Integrated Science Assessment (ISA) for Particulate Matter (Final Report, 2019). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R–19/188, 2019.

[37] The causal framework draws upon the assessment and integration of evidence from across epidemiological, controlled human exposure, and toxicological studies, and the related uncertainties that ultimately influence our understanding of the evidence. This framework employs a five-level hierarchy that classifies the overall weight of evidence and causality using the following categorizations: Causal relationship, likely to be causal relationship, suggestive of a causal relationship, inadequate to infer a causal relationship, and not likely to be a causal relationship (U.S. EPA. (2009). Integrated Science Assessment for Particulate Matter (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R–08/139F, Table 1–3).

[38] Short term exposures are usually defined as less than 24 hours duration.

[39] Cook, R. Memorandum to Docket EPA–HQ–OAR–2019–0660, ''Health and environmental effects of non-GHG pollutants emitted by turbine engine aircraft,'' August 23, 2021.

[40] U.S. EPA. Integrated Science Assessment (ISA) for Particulate Matter (Final Report, 2019). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R–19/188, 2019.

[41] See Section 169(a) of the Clean Air Act.

[42] In the 2012 review of the PM NAAQS, the EPA eliminated the option for spatial averaging for the 24-hour $PM_{2.5}$ standard (78 FR 3086, January 15, 2013).

[43] *https://www.epa.gov/newsreleases/epa-reexamine-health-standards-harmful-soot-previous-administration-left-unchanged.*

[44] U.S. Environmental Protection Agency (U.S. EPA). 2018. Integrated Science Assessment (ISA) for Oxides of Nitrogen, Oxides of Sulfur and Particulate Matter Ecological Criteria Second External Review Draft). EPA–600–R–18–097. Washington, DC. December. Available on the internet at *https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=340671.*

deteriorating building materials such as stone, concrete and marble.[45]

D. Near-Source Impacts on Air Quality and Public Health

Airport activity can adversely impact air quality in the vicinity of airports. Furthermore, these adverse impacts may disproportionately impact sensitive subpopulations. A recent study by Yim et al. (2015) assessed global, regional, and local health impacts of civil aviation emissions, using modeling tools that address environmental impacts at different spatial scales.[46] The study attributed approximately 16,000 premature deaths per year globally to global aviation emissions, with 87 percent attributable to $PM_{2.5}$. The study concludes that about a third of these mortalities are attributable to $PM_{2.5}$ exposures within 20 kilometers of an airport. Another study focused on the continental United States estimated 210 deaths per year attributable to $PM_{2.5}$ from aircraft.[47] While there are considerable uncertainties associated with such estimates, these results suggest that in addition to the contributions of $PM_{2.5}$ emissions to regional air quality, impacts on public health of these emissions in the vicinity of airports are an important public health concern.

A significant body of research has addressed pollutant levels and potential health effects in the vicinity of airports. Much of this research was synthesized in a 2015 report published by the Airport Cooperative Research Program (ACRP), conducted by the Transportation Research Board.[48] The report concluded that $PM_{2.5}$ concentrations in and around airports vary considerably, ranging from ''relatively low levels to those that are close to the NAAQS, and in some cases, exceeding the standards.'' [49]

Furthermore, the report states (p. 40) that ''existing studies indicate that ultrafine particle concentrations are highly elevated at an airport (*i.e.,* near a runway) with particle counts that can be orders of magnitude higher than background with some persistence many meters downwind (*e.g.,* 600 m). Finally, the report concludes that $PM_{2.5}$ dominates overall health risks posed by airport emissions. Moreover, one recently published study concluded that emissions from aircraft play an etiologic role in pre-term births, independent of noise and traffic-related air pollution exposures.[50]

Since the publication of the 2015 ACRP literature review, a number of studies conducted in the U. S. have been published which concluded that ultrafine particle number concentrations were elevated downwind of commercial airports, and that proximity to an airport also increased particle number concentrations within residences. Hudda et al. investigated ultrafine particle number concentrations (PNC) inside and outside 16 residences in the Boston metropolitan area. They found elevated outdoor PNC within several kilometers of the airport. They also found that aviation-related PNC infiltrated indoors and resulted in significantly higher indoor PNC.[51] In another study in the vicinity of Logan airport, Hudda et al. analyzed PNC impacts of aviation activities.[52] They found that, at sites 4.0 and 7.3 km from the airport, average PNCs were 2 and 1.33-fold higher, respectively, when winds were from the direction of the airport compared to other directions, indicating that aviation impacts on PNC extend many kilometers downwind of Logan airport. Stacey (2019) conducted a literature survey and concluded that the literature consistently reports that particle numbers close to airports are significantly higher than locations distant and upwind of airports, and that the particle size distribution is different from traditional road traffic, with more extremely fine particles.[53] Similar findings have been published from European studies.[54] [55] [56] [57] [58] [59] Results of a monitoring study of communities near Seattle-Tacoma International Airport also found higher levels of ultrafine PM near the airport, and an impacted area larger than at near-roadway sites.[60] The PM associated with aircraft landing activity was also smaller in size, with lower black carbon concentrations than near-roadway samples. As discussed above, $PM_{2.5}$ exposures are associated with a number of serious, adverse health effects. Further, the PM attributable to aircraft emissions has been associated with potential adverse health impacts.[61] [62] For example, He et al.

[45] U.S. Environmental Protection Agency (U.S. EPA). 2018. Integrated Science Assessment (ISA) for Oxides of Nitrogen, Oxides of Sulfur and Particulate Matter Ecological Criteria Second External Review Draft). EPA–600–R–18–097. Washington, DC. December. Available on the internet at *https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=340671.*

[46] Yim, S.H.L., Lee, G.L., Lee, I.H., Allrogen, F., Ashok, A., Caiazzo, F., Eatham, S.D., Malina, R., Barrett, S. R.H. 2015. Global, regional, and local health impacts of civil aviation emissions. Environ. Res. Lett. 10: 034001. *https://iopscience.iop.org/article/10.1088/1748-9326/10/3/034001.*

[47] Brunelle-Yeung, E., Masek, T., Rojo, J., Levy, J., Arunachalam, S., Miller, S., Barrett, S., Kuhn, S., Waitz, I. 2014. Assessing the impact of aviation environmental policies on public health. Transport Policy 34: 21–28. *https://www.sciencedirect.com/science/article/pii/S0967070X14000468?via%3Dihub.*

[48] Kim, B., Nakada, K., Wayson, R., Christie, S., Paling, C., Bennett, M., Raper, D., Raps, V., Levy, J., Roof, C. 2015. Understanding Airport Air Quality and Public Health Studies Related to Airports. Airport Cooperative Research Program, ACRP Report 135. *https://trid.trb.org/view/1364659.*

[49] Kim, B., Nakada, K., Wayson, R., Christie, S., Paling, C., Bennett, M., Raper, D., Raps, V., Levy, J., Roof, C. 2015. Understanding Airport Air Quality and Public Health Studies Related to Airports. Airport Cooperative Research Program, ACRP Report 135, p. 39. *https://trid.trb.org/view/1364659.*

[50] Wing, S.E., Larson, T.V., Hudda, N., Boonyarattaphan, S., Fruin, S., Ritz, B. 2020. Preterm birth among infants exposed to in utero ultrafine particles from aircraft emissions. Environ. Health Perspect. 128, *https://doi.org/10.1289/EHP5732.*

[51] Hudda, N., Simon, N.C., Zamore, W., Durant, J.L. 2018. Aviation-related impacts on ultrafine number concentrations outside and inside residences near an airport. Environ. Sci. Technol. 52: 1765–1772. *https://pubs.acs.org/doi/abs/10.1021/acs.est.7b05593.*

[52] Hudda, N., Simon, M.C., Zamore, W., Brugge, D., Durant, J.L. 2016. Aviation emissions impact ultrafine particle concentrations in the greater Boston area. Environ. Sci. Technol. 50: 8514–8521. *https://pubs.acs.org/doi/abs/10.1021/acs.est.6b01815.*

[53] Stacey, B. 2019. Measurement of ultrafine particles at airports: A review. Atmos. Environ. 198: 463–477. *https://www.sciencedirect.com/science/article/pii/S1352231018307313.*

[54] Masiol M, Harrison RM. Quantification of air quality impacts of London Heathrow Airport (UK) from 2005 to 2012. Atmos Environ 2017;116:308–19. *https://doi.org/10.1016/j.atmosenv.2015.06.048.*

[55] Keuken, M.P., Moerman, M., Zandveld, P., Henzing, J.S., Hoek, G., 2015. Total and size-resolved particle number and black carbon concentrations in urban areas near Schiphol airport (the Netherlands). Atmos. Environ. 104: 132–142. *https://www.sciencedirect.com/science/article/pii/S1352231015000175?via%3Dihub.*

[56] Pirhadi, M., Mousavi, A., Sowlat, M.H., Janssen, N.A.H., Cassee, F.R., Sioutas, C., 2020. Relative contributions of a major international airport activities and other urban sources to the particle number concentrations (PNCs) at a nearby monitoring site. Environ. Pollut, 260: 114027. *https://www.sciencedirect.com/science/article/pii/S0269749119344987?via%3Dihub.*

[57] Stacey, B., Harrison, R.M., Pope, F., 2020. Evaluation of ultrafine particle concentrations and size distributions at London Heathrow Airport. Atmos. Environ., 222: 117148. *https://www.sciencedirect.com/science/article/pii/S1352231019307873?via%3Dihub.*

[58] Ungeheuer, F., Pinxteren, D., Vogel, A. 2021. Identification and source attribution of organic compounds in ultrafine particles near Frankfurt International Airport. Atmos. Chem. Phys. 21: 3763–3775. *https://doi.org/10.5194/acp-21-3763-2021.*

[59] Zhang, X., Karl, M. Zhang, L. Wang, J., 2020. Influence of Aviation Emission on the Particle Number Concentration near Zurich Airport. Environ. Sci. Technol. 54: 14161–14171. *https://doi.org/10.1021/acs.est.0c02249.*

[60] University of Washington. 2019. Mobile Observations of Ultrafine Particles: The Mov-UP study report. *https://deohs.washington.edu/mov-up.*

[61] Habre. R., Zhou, H., Eckel, S., Enebish, T., Fruin, S., Bastain, T., Rappaport, E. Gilliland, F. 2018. Short-term effects of airport-associated ultrafine particle exposure on lung function and inflammation in adults with asthma. Environment International 118: 48–59. *https://doi.org/10.1016/j.envint.2018.05.031.*

[62] He, R.W., Shirmohammadi, F., Gerlofs-Nijland, M.E., Sioutas, C., & Cassee, F.R. 2018. Pro-

(2018) found that particle composition, size distribution and internalized amount of particles near airports all contributed to promotion of reactive organic species in bronchial epithelial cells.

Because of these potential impacts, a systematic literature review was recently conducted to identify peer-reviewed literature on air quality near commercial airports and assess the quality of the studies.[63] The systematic review identified seventy studies for evaluation. These studies consistently showed that particulate matter, in the form of ultrafine PM (UFP), is elevated in and around airports. Furthermore, many studies showed elevated levels of black carbon, criteria pollutants, and polycyclic aromatic hydrocarbons as well. Finally, the systematic review, while not focused on health effects, identified a limited number of references reporting adverse health effects impacts, including increased rates of premature death, pre-term births, decreased lung function, oxidative DNA damage and childhood leukemia. More research is needed linking particle size distributions to specific airport activities, and proximity to airports, characterizing relationships between different pollutants, evaluating long-term impacts, and improving our understanding of health effects.

A systematic review of health effects associated with exposure to jet engine emissions in the vicinity of airports was also recently published.[64] This study concluded that literature on health effects was sparse, but jet engine emissions have physicochemical properties similar to diesel exhaust particles, and that exposure to jet engine emissions is associated with similar adverse health effects as exposure to diesel exhaust particles and other traffic emissions. A 2010 systematic review by the Health Effects Institute (HEI) concluded that evidence was sufficient to support a causal relationship between exposure to traffic-related air pollution and exacerbation of asthma among children, and suggestive of a causal relationship for childhood asthma, non-asthma respiratory symptoms, impaired lung function and cardiovascular mortality.[65]

E. Contribution of Aircraft Emissions to PM in Selected Areas

This section provides background on the contribution of aircraft engine emissions to local PM concentrations. In some areas with large commercial airports, turbine engine aircraft can make a significant contribution to ambient $PM_{2.5}$. To evaluate these potential impacts, we identified the 25 airports where commercial aircraft operations are the greatest, based on data for 2017 from the Federal Aviation Administration (FAA) Air Traffic Data System (ATADS).[66] These 25 commercial airports are located in 24 counties and 22 metropolitan statistical areas (MSAs). We compared the contributions of these airports to emissions at both the county and MSA levels. Comparisons at both scales provide a fuller picture of how airports are impacting local air quality. Figure III–1 depicts the contribution to county-level $PM_{2.5}$ direct emissions from all turbine aircraft in that county with rated output of greater than 26.7 kN. Emissions data were obtained from the EPA 2017 National Emissions Inventory (NEI).[67] The contributions of engines greater than 26.7 kN rated output to total turbine engine emissions at individual airports were estimated based on FAA data.[68] At the county level, contributions to total mobile source $PM_{2.5}$ emissions range from less than 1 to almost 14 percent. However, it should be noted that two airports cross county lines—Hartsfield-Jackson Atlanta International Airport (Clayton and Fulton counties) and O'Hare (Cook and DuPage counties). For those airports, percentages are calculated for the sum of the two counties. In addition, five of these counties are in nonattainment for either the $PM_{2.5}$ or PM_{10} standard. When emissions from these airports are considered as part of the entire MSA, the contribution is much smaller. Figure III–2 depicts the contributions at the metropolitan statistical area (MSA) instead of the county level, and contributions across airports range from 0.4 to 3 percent. Details of this analysis are described in a memorandum to the docket.[69]

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inflammatory responses to PM(0.25) from airport and urban traffic emissions. *The Science of the total environment, 640–641,* 997–100. *https://www.sciencedirect.com/science/article/pii/S0048969718320394?via%3Dihub.*

[63] Riley, K., Cook, R., Carr, E., Manning, B. 2021. A Systematic Review of The Impact of Commercial Aircraft Activity on Air Quality Near Airports. City and Environment Interactions, 100066. *https://doi.org/10.1016/j.cacint.2021.100066.*

[64] Bendtsen, K. M., Bengtsen, E., Saber, A., Vogel, U. 2021. A review of health effects associated with exposure to jet engine emissions in and around airports. Environ. Health 20:10. *https://doi.org/10.1186/s12940-020-00690-y.*

[65] Health Effects institute. ''Special Report 17: A Special Report of the Institute's Panel on the Health Effects of Traffic-Related Air Pollution.'' January, 2010. *https://www.healtheffects.org/publication/traffic-related-air-pollution-critical-review-literature-emissions-exposure-and-health.*

[66] *https://aspm.faa.gov/opsnet/sys/main.asp.*

[67] 2017 National Emissions Inventory: Aviation Component, Eastern Research Group, Inc., July 25, 2019, EPA Contract No. EP–C–17–011, Work Order No. 2–19. Available at *https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data* (last accessed on June 27, 2021). See section 3.2 for airports and aircraft related emissions in the Technical Supporting Document for the 2017 National Emissions Inventory, January 2021 Updated Release. Available at *https://www.epa.gov/sites/production/files/2021-02/documents/nei2017_tsd_full_jan2021.pdf* (last accessed on June 27, 2021).

[68] These data were obtained using radar-informed data from the FAA Enhanced Traffic Management System (ETMS). The annual fuel burn and emissions inventories at selected top US airports were based on the 2015 FAA flight operations database. The fraction of total PM emissions from aircraft covered by the proposed PM standards is based on the ratio of total PM emissions from flights by engines with thrust rating >26.7 kN compared to PM emissions from the whole fleet at each airport.

[69] Cook, R. Memorandum to Docket EPA–HQ–OAR–2019–0660, July 28, 2021, '' Estimation of 2017 Emissions Contributions of Turbine Aircraft >26.7 kN to NO_X and $PM_{2.5}$ as a Percentage of All Mobile $PM_{2.5}$ for the Counties and MSAs in Which the Airport Resides, 25 Largest Carrier Operations.''

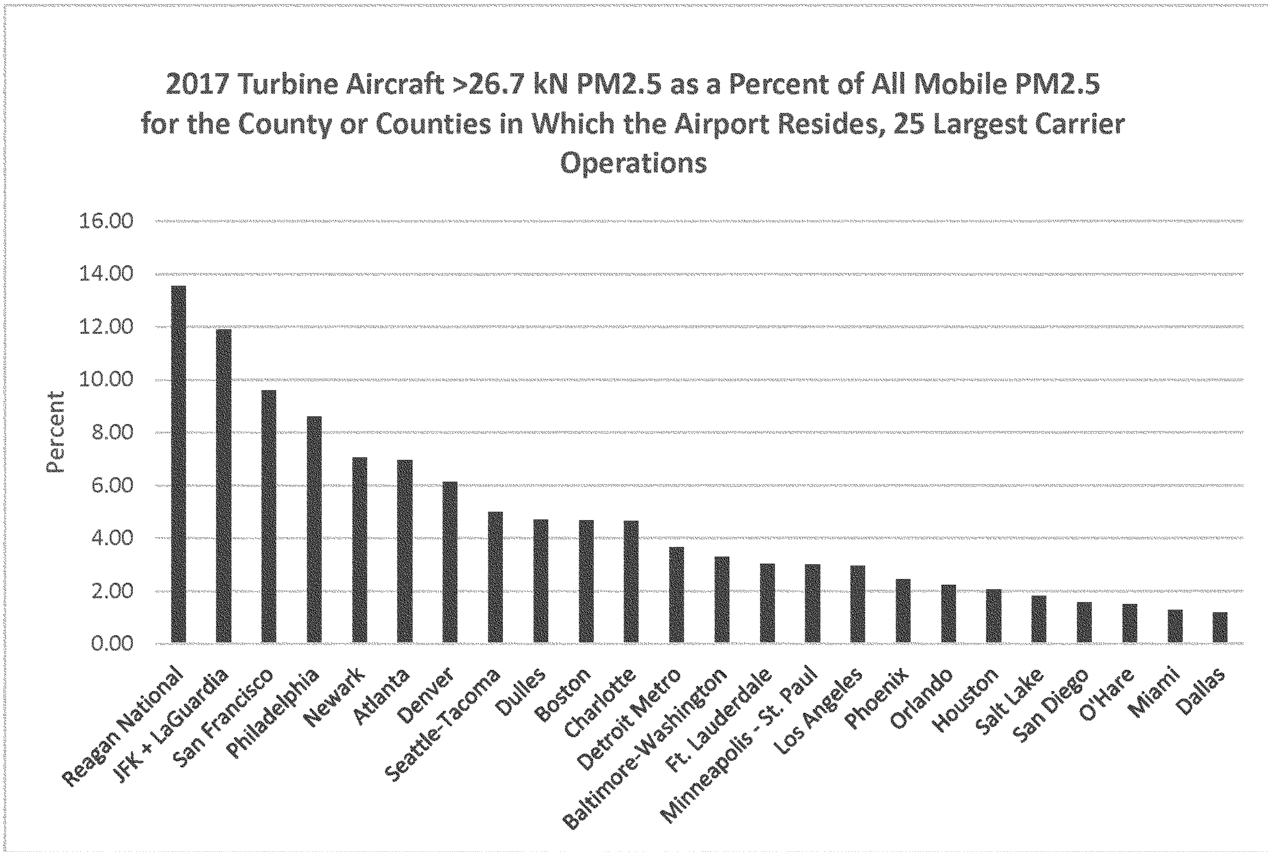

Figure III-1

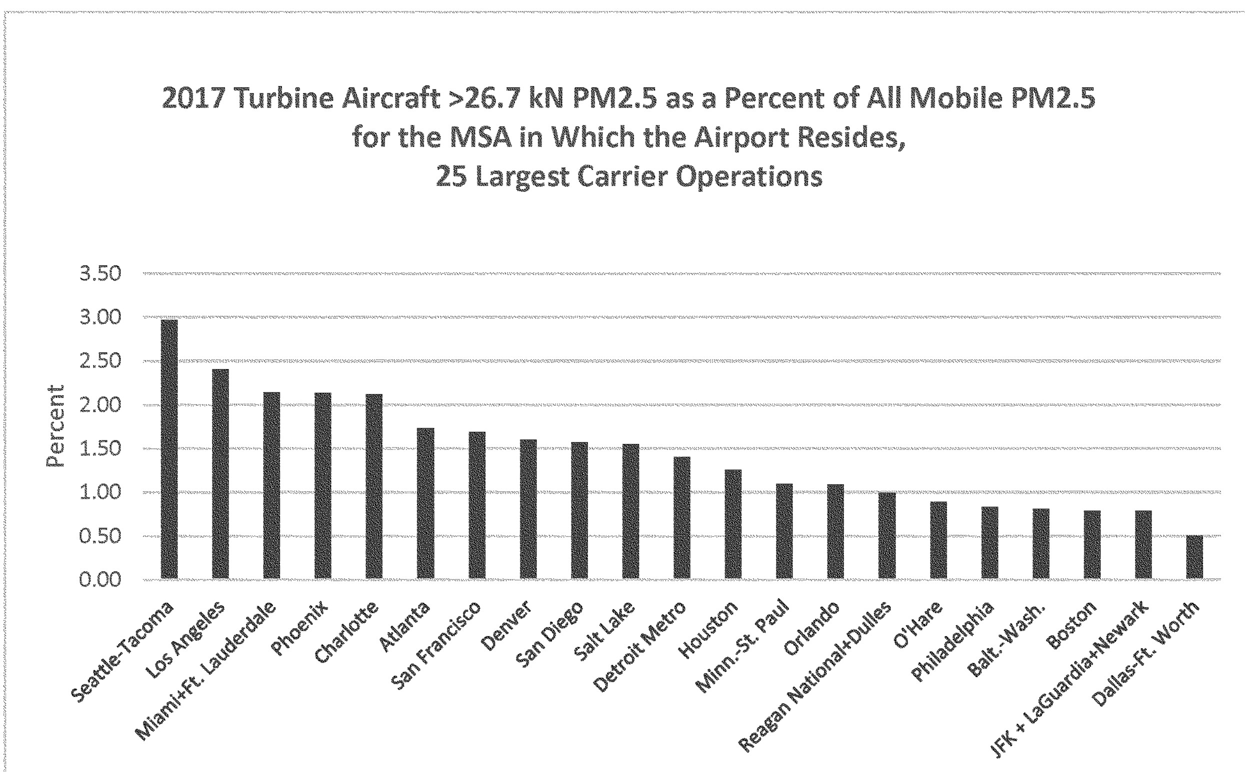

Figure III-2

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F. Other Pollutants Emitted by Aircraft

In addition to particulate matter, a number of other criteria pollutants are emitted by the aircraft which are the subject of this proposed rule. These pollutants, which are not covered by the rule, include nitrogen oxides (NO_X), including nitrogen dioxide (NO_2), volatile organic compounds (VOC), carbon monoxide (CO), and sulfur dioxide (SO_2). Aircraft also contribute to ambient levels of hazardous air pollutants (HAP), compounds that are known or suspected human or animal carcinogens, or that have noncancer health effects. These compounds include, but are not limited to, benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, polycyclic organic matter (POM), and certain metals. Some POM and HAP metals are components of $PM_{2.5}$ mass measured in turbine engine aircraft emissions.[70]

The term polycyclic organic matter (POM) defines a broad class of compounds that includes the polycyclic aromatic hydrocarbon compounds (PAHs). POM compounds are formed primarily from combustion and are present in the atmosphere in gas and particulate form. Metal compounds emitted from aircraft turbine engine combustion include chromium, manganese, and nickel. Several POM compounds, as well as hexavalent chromium, manganese compounds and nickel compounds are included in the National Air Toxics Assessment, based on potential carcinogenic risk.[71] In addition, as mentioned previously, deposition of metallic compounds can have ecological effects. Impacts of POM and metals are further discussed in the memorandum to the docket referenced above.

G. Environmental Justice

Executive Order 12898 (59 FR 7629, February 16, 1994) establishes federal executive policy on environmental justice. It directs federal agencies, to the greatest extent practicable and permitted by law, to make achieving environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the United States. EPA defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.[72]

Executive Order 14008 (86 FR 7619, February 1, 2021) also calls on federal agencies to make achieving environmental justice part of their missions ''by developing programs, policies, and activities to address the disproportionately high and adverse human health, environmental, climate-related and other cumulative impacts on disadvantaged communities, as well as the accompanying economic challenges of such impacts.'' It also declares a policy ''to secure environmental justice and spur economic opportunity for disadvantaged communities that have been historically marginalized and overburdened by pollution and under-investment in housing, transportation, water and wastewater infrastructure and health care.'' Under Executive Order 13563, federal agencies may consider equity, human dignity, fairness, and distributional considerations, where appropriate and permitted by law.

EPA's June 2016 ''Technical Guidance for Assessing Environmental Justice in Regulatory Analysis'' provides recommendations on conducting the highest quality analysis feasible, recognizing that data limitations, time and resource constraints, and analytic challenges will vary by media and regulatory context.[73]

When assessing the potential for disproportionately high and adverse health or environmental impacts of regulatory actions on minority populations, low-income populations, tribes, and/or indigenous peoples, the EPA strives to answer three broad questions: (1) Is there evidence of potential EJ concerns in the baseline (the state of the world absent the regulatory action)? Assessing the baseline will allow the EPA to determine whether pre-existing disparities are associated with the pollutant(s) under consideration (*e.g.,* if the effects of the pollutant(s) are more concentrated in some population groups). (2) Is there evidence of potential EJ concerns for the regulatory option(s) under consideration? Specifically, how are the pollutant(s) and its effects distributed for the regulatory options under consideration? And, (3) do the regulatory option(s) under consideration exacerbate or mitigate EJ concerns relative to the baseline? It is not always possible to quantitatively assess these questions.

EPA's 2016 Technical Guidance does not prescribe or recommend a specific approach or methodology for conducting an environmental justice analysis, though a key consideration is consistency with the assumptions underlying other parts of the regulatory analysis when evaluating the baseline and regulatory options. Where applicable and practicable, the Agency endeavors to conduct such an analysis. Going forward, EPA is committed to conducting environmental justice analysis for rulemakings based on a framework similar to what is outlined in EPA's Technical Guidance, in addition to investigating ways to further weave environmental justice into the fabric of the rulemaking process.

[70] Kinsey, J.S., Hays, M.D., Dong, Y., Williams, D.C. Logan, R. 2011. Chemical characterization of the fine particle emissions from commercial aircraft engines during the aircraft particle emissions experiment (APEX) 1–3. Environ. Sci. Technol. 45:3415–3421. *https://pubs.acs.org/doi/10.1021/es103880d*.

[71] *https://www.epa.gov/national-air-toxics-assessment.*

[72] Fair treatment means that ''no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from the negative environmental consequences of industrial, governmental and commercial operations or programs and policies.'' Meaningful involvement occurs when ''(1) potentially affected populations have an appropriate opportunity to participate in decisions about a proposed activity [*e.g.,* rulemaking] that will affect their environment and/or health; (2) the public's contribution can influence [the EPA's rulemaking] decision; (3) the concerns of all participants involved will be considered in the decision-making process; and (4) [the EPA will] seek out and facilitate the involvement of those potentially affected'' A potential EJ concern is defined as ''the actual or potential lack of fair treatment or meaningful involvement of minority populations, low-income populations, tribes, and indigenous peoples in the development, implementation and enforcement of environmental laws, regulations and policies.'' See ''Guidance on Considering Environmental Justice During the Development of an Action.'' Environmental Protection Agency, *https://www.epa.gov/environmentaljustice.*

[73] ''Technical Guidance for Assessing Environmental Justice in Regulatory Analysis.'' *Epa.gov,* Environmental Protection Agency, *https://www.epa.gov/sites/production/files/2016-06/documents/ejtg_5_6_16_v5.1.pdf* (June 2016).

Numerous studies have found that environmental hazards such as air pollution are more prevalent in areas where people of color and low-income populations represent a higher fraction of the population compared with the general population, including near transportation sources.[74 75 76 77 78]

As described in Section III.D, concentrations of PM increase with proximity to an airport. Air pollution can disproportionately impact sensitive subpopulations near airports. Henry et al. (2019) studied impacts of several California airports on surrounding schools and found that over 65,000 students spend 1 to 6 hours a day during the academic year being exposed to airport pollution, and the percentage of impacted students was higher for those who were economically disadvantaged.[79] Rissman et al. (2013) studied $PM_{2.5}$ at the Hartsfield-Jackson Atlanta International Airport and found that the relationship between minority population percentages and aircraft-derived PM was found to grow stronger as concentrations increased.[80]

Additional studies have reported that many communities in close proximity to airports are disproportionately represented by minorities and low-income populations. McNair (2020) describes nineteen major airports that underwent capacity expansion projects between 2000 and 2010, thirteen of which met characteristics of race, ethnicity, nationality and/or income that indicate a disproportionate impact on these residents.[81] Woodburn (2017) reports on changes in communities near airports from 1970–2010, finding suggestive evidence that at many hub airports over time, the presence of marginalized groups residing in close proximity to airports increased.[82]

Although not being conducted as part of this rulemaking, EPA is conducting a demographic analysis to explore whether populations living nearest the busiest runways show patterns of racial and socioeconomic disparity.[83] This will help characterize the state of environmental justice concerns and inform potential future actions. Finely resolved population data (*i.e.,* 30 square meters) will be paired with census block group demographic characteristics to evaluate if people of color, children, indigenous populations, and low-income populations are disproportionately living near airport runways compared to populations living further away. The results of this analysis could help inform additional policies to reduce pollution in communities living in close proximity to airports.

In summary, the proposed in-production standards for both PM mass and PM number are levels that all aircraft engines in production currently meet in order to align with ICAO's standards. Thus, the proposed standards are not expected to result in emission reductions, beyond the business-as-usual fleet turnover that would occur absent of the proposed standards. Therefore, we do not anticipate an improvement in air quality for those who live near airports where these aircraft operate.

IV. Details for the Proposed Rule

In considering what PM emissions standards for aircraft engines are appropriate to adopt under section 231 of the CAA, EPA, after consultation with FAA, took into consideration the importance of both controlling PM emissions and international harmonization of aviation requirements. In addition, the EPA gave significant weight to the U.S.'s treaty obligations under the Chicago Convention in determining the need for and appropriate levels of PM standards. These considerations led the EPA to propose aircraft engine PM standards based on engine standards adopted by ICAO. When developing the PM standards, ICAO looked at three different methods of measuring the amount of PM emitted. The first is PM mass, or a measure of the total weight of the particles produced over the test cycle. This is how the EPA has historically set PM emissions standards for other sectors. Second, ICAO considered PM number, or the number of particles produced by the engine over the test cycle. These are two different methods of measuring the same pollutant, PM, but each provides distinct and valuable information. Third, ICAO developed PM mass concentration standards, as a replacement to the existing standards based on smoke number.

EPA's proposed action consists of three key parts: (1) A proposal for PM mass and number emissions standards for aircraft gas turbine engines, (2) a change in test procedure and form of the existing standards—from smoke number to PM mass concentration, and (3) new testing and measurement procedures for the PM emission standards and various updates to the existing gaseous exhaust emissions test procedures.

Sections IV.A through IV.C describe the proposed mass, number, and mass concentration standards for aircraft engines. Section IV.D describes the proposed test procedures and measurement procedures associated with the PM standards. Section IV.E presents information related to the proposed reporting requirements.

As discussed above in Section III.A, $PM_{2.5}$ consists of both volatile and nonvolatile PM, although only nonvolatile PM would be covered by the proposed standards. Only nonvolatile PM is present at the engine exit because the exhaust temperature is too high for volatile PM to form. The volatile PM (or secondary PM) is formed as the engine exhaust plume cools and mixes with the ambient air. The result of this is that the volatile PM is significantly influenced by the ambient conditions (or ambient air background composition). Because of this complexity, a test procedure to measure volatile PM has not yet been developed for aircraft engines. In order to directly measure nonvolatile PM, ICAO agreed to adopt a measurement procedure, as described below in Section IV.D, which is based on conditions that prevent the formation of volatile PM upstream of the measurement instruments. The intent of

[74] Rowangould, G.M. (2013) A census of the near-roadway population: Public health and environmental justice considerations. Trans Res D 25: 59–67. *https://dx.doi.org/10.1016/j.trd.2013.08.003.*

[75] Marshall, J.D., Swor, K.R., Nguyen, N.P. (2014) Prioritizing environmental justice and equality: Diesel emissions in Southern California. Environ Sci Technol 48: 4063–4068. *https://doi.org/10.1021/es405167f.*

[76] Marshall, J.D. (2000) Environmental inequality: Air pollution exposures in California's South Coast Air Basin. Atmos Environ 21: 5499–5503. *https://doi.org/10.1016/j.atmosenv.2008.02.005.*

[77] Tessum, C.W., Paolella, D.A., Chambliss, SE, Apte, J.S., Hill, J.D., Marshall, J.D. (2021) $PM_{2.5}$ polluters disproportionately and systemically affect people of color in the United States. Science Advances 7:eabf4491. *https://www.science.org/doi/10.1126/sciadv.abf4491.*

[78] Mohai, P., Pellow, D., Roberts Timmons, J. (2009) Environmental justice. Annual Reviews 34: 405–430. *https://doi.org/10.1146/annurev-environ-082508-094348.*

[79] Henry, R.C., Mohan, S., Yazdani, S. (2019) Estimating potential air quality impact of airports on children attending the surrounding schools. Atmospheric Environment, 212: 128–135. *https://www.sciencedirect.com/science/article/pii/S1352231019303516?via%3Dihub.*

[80] Rissman, J., Arunachalam, S., BenDor, T., West, J.J. (2013) Equity and health impacts of aircraft emissions at the Hartfield-Jackson Atlanta International Airport, Landscape and Urban Planning 120: 234–247. *https://www.sciencedirect.com/science/article/pii/S0169204613001382.*

[81] McNair, A. (2020) Investigation of environmental justice analysis in airport planning practice from 2000 to 2010. Transp. Research Part D 81:102286. *https://www.sciencedirect.com/science/article/pii/S1361920919311149?via%3Dihub.*

[82] Woodburn, A. (2017) Investigating neighborhood change in airport-adjacent communities in multiairport regions from 1970 to 2010. Journal of the Transportation Research Board, 2626, 1–8.

[83] EPA anticipates that the results of the study will be released publicly in a separate document from the final rule.

this approach is to improve the consistency and repeatability of the nvPM measurement procedure.

Due to the international nature of the aviation industry, there is an advantage to working within ICAO, in order to secure the highest practicable degree of uniformity in international aviation regulations and standards. Uniformity in international aviation regulations and standards is a goal of the Chicago Convention, because it ensures that passengers and the public can expect similar levels of protection for safety and human health and the environment regardless of manufacturer, airline, or point of origin of a flight. Further, it helps prevent barriers in the global aviation market, benefiting both U.S. aircraft engine manufacturers and consumers.

When developing new emissions standards, ICAO/CAEP seeks to capture the technological advances made in the control of emissions through the adoption of anti-backsliding standards reflecting the current state of technology. The PM standards the EPA is proposing were developed using this approach. Thus, the adoption of these aircraft engine standards into U.S. law would simultaneously prevent aircraft engine PM levels from increasing beyond their current levels, align U.S. domestic standards with the ICAO standards for international harmonization, and help the U.S. meet its treaty obligations under the Chicago Convention.

These proposed standards would also allow U.S. manufacturers of covered aircraft engines to remain competitive in the global marketplace. The ICAO aircraft engine PM emission standards have been, or are being, adopted by other ICAO member states that certify aircraft engines. In the absence of U.S. standards implementing the ICAO aircraft engine PM emission standards, the U.S. would not be able to certify aircraft engines to the PM standards. In this case, U.S. civil aircraft engine manufacturers could be forced to seek PM emissions certification from an aviation certification authority of another country in order to market and operate their aircraft engines internationally. Foreign certification authorities may not have the resources to certify aircraft engines from U.S. manufacturers in a timely manner, which could lead to delays in these engines being certified. Thus, U.S. manufacturers could be at a disadvantage if the U.S. does not adopt standards that are at least as stringent as the ICAO standards for PM emissions. The proposed action to adopt in the U.S. PM standards that match the ICAO standards would help ensure international consistency and acceptance of U.S. manufactured engines worldwide.

The EPA considered whether to propose standards more stringent than the ICAO standards. As noted above, the EPA considered both the need for emissions reductions and the international nature of the aircraft industry and air travel in evaluating whether to propose more stringent standards. These considerations have historically led the EPA to adopt international standards developed through ICAO. The EPA concluded that proposing to adopt the ICAO PM standards in place of more stringent standards is appropriate in part because international uniformity and regulatory certainty are important elements of these proposed standards. This is especially true for these proposed standards because they change our approach to regulating aircraft PM emissions from past smoke measurements to the measurement of nvPM mass and number for the first time. It is appropriate to gain experience from the implementation of these nvPM standards before considering whether to adopt more stringent nvPM mass and/or number standards, or whether another approach to PM regulation would better address the health risks of PM emissions from aircraft engines. Additionally, the U.S. Government played a significant role in the development of these proposed standards. The EPA believes that international cooperation on aircraft emissions brings substantial benefits overall to the United States. Having invested significant effort to develop these standards and obtain international consensus for ICAO to adopt these standards, a decision by the United States to deviate from them might well undermine future efforts by the United States to seek international consensus on aircraft emissions standards. For these reasons, EPA placed significant weight on international regulatory uniformity and certainty and is proposing standards that match the standards which EPA worked to develop and adopt at ICAO, and is not proposing more stringent standards.

A. PM Mass Standards for Aircraft Engines

1. Applicability of Standards

These proposed standards for PM mass, like the ICAO standards, would apply to all subsonic turbofan and turbojet engines of a type or model with a rated output (maximum thrust available for takeoff) greater than 26.7 kN whose date of manufacture is on or after January 1, 2023.[84] These proposed standards would not apply to engines manufactured prior to this applicability date.

The level of the proposed standard would vary based on when the initial type certification application is submitted.[85] Engines for which the type certificate application was first submitted on or after January 1, 2023 would be subject to the new type level in Section IV.A.2 below. These engines are new engines that have not been previously certificated.

Engines manufactured on or after January 1, 2023 would be subject to the in-production level, in Section IV.A.3 below.

[84] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, III–4–3 & III–4–4pp. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services Catalog, English Edition of the 2021 catalog, and it is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

[85] In most cases, the engine manufacturer applies to FAA for the type certification; however, in some cases the applicant may be different than the manufacturer (*e.g.,* designer).

2. New Type nvPM Mass Numerical Emission Limits for Aircraft Engines

Aircraft engines with a rated output (rO), maximum thrust available for take-off, greater than 26.7 kN and whose initial type certification application is submitted to the FAA on or after January 1, 2023 shall not exceed the level, as defined by Equation IV–1. As described in Section IV.D, the nvPM Mass limit is based on mg of PM divided by kN of thrust, as determined over the LTO cycle.

$$nvPM_{Mass} = \begin{cases} 1251.1 - 6.914 * rO, & 26.7 < rO \leq 150kN \\ 214.0, & rO > 150kN \end{cases}$$

Equation IV-1

3. In Production nvPM Mass Numerical Emission Limits for Aircraft Engines

Aircraft engines that are manufactured on or after January 1, 2023 shall not exceed the level, as defined by Equation IV–2.

$$nvPM_{Mass} = \begin{cases} 4646.9 - 21.497 * rO, & 26.7 < rO \leq 200kN \\ 347.5, & rO > 200kN \end{cases}$$

Equation IV-2

4. Graphical Representation of nvPM Mass Numerical Emission Limits

Figure IV–1 shows how the proposed nvPM mass emission limits compare to known in-production engines. Data shown in this figure is from the ICAO Engine Emissions Databank (EEDB).[86 87]

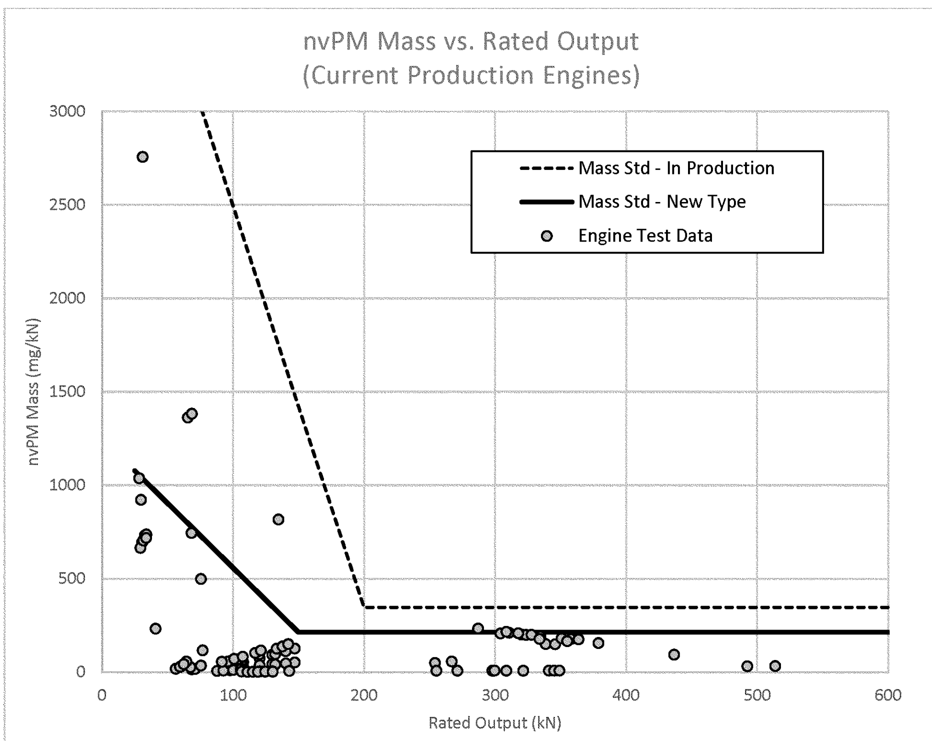

Figure IV-1 - nvPM mass standards compared to in-production engine LTO emission rates

B. PM Number Standards for Aircraft Engines

1. Applicability of Standards

These proposed standards for PM number, like the ICAO standards, would apply to all subsonic turbofan and turbojet engines of a type or model with a rated output greater than 26.7 kN whose date of manufacture is on or after January 1, 2023.[88] These proposed standards would not apply to engines manufactured prior to this applicability date.

The level of the proposed standard would vary based on when the initial type certification application is submitted. Engines for which the type

[86] ICAO Aircraft Engine Emissions Databank, July 20, 2021, ''edb-emissions-databank v28C (web).xlsx'', European Union Aviation Safety Agency (EASA), *https://www.easa.europa.eu/domains/environment/icao-aircraft-engine-emissions-databank.*

[87] Note, EPA ICR number 2427.06 ''Aircraft Engines—Supplemental information related to Exhaust Emissions'' also collects aircraft nvPM data. In the interest of using the most up to date information, the ICAO EDB was used because it has been updated more recently than EPA data. The EPA should be receiving new data from this ICR in Feb. 2022.

certificate application was first submitted on or after January 1, 2023 would be subject to the new type level in Section IV.B.2 below. These are new engines that have not been previously certificated.

Engines manufactured on or after January 1, 2023 would be subject to the in-production level, in IV.B.3 below.

2. New Type nvPM Number Numerical Emission Limits for Aircraft Engines

Aircraft engines with a rated output greater than 26.7 kN and whose initial type certification application is submitted to the FAA on or after January 1, 2023 shall not exceed the level, as defined by Equation IV–3. As described in Section IV.D, the nvPM number limit is based on number of particles divided by kN of thrust, as determined over the LTO cycle.

$$nvPM_{num} = \begin{cases} 1.490 * 10^{16} - 8.080 * 10^{13} * rO, & 26.7 < rO \leq 150kN \\ 2.780 * 10^{15}, & rO > 150kN \end{cases}$$

Equation IV-3

3. In Production nvPM Number Numerical Emission Limits for Aircraft Engines

Aircraft engines that are manufactured on or after January 1, 2023 shall not exceed the level, as defined by Equation IV–4.

$$nvPM_{num} = \begin{cases} 2.669 * 10^{16} - 1.126 * 10^{14} * rO, & 26.7 < rO \leq 200kN \\ 4.170 * 10^{15}, & rO > 200kN \end{cases}$$

Equation IV-4

4. Graphical Representation of nvPM Number Numerical Emission Limits

Figure IV–2 shows how the proposed nvPM number emission limits compare to known in-production engines. Data shown in this figure is from the ICA O Engine Emissions Databank (EEDB).[89]

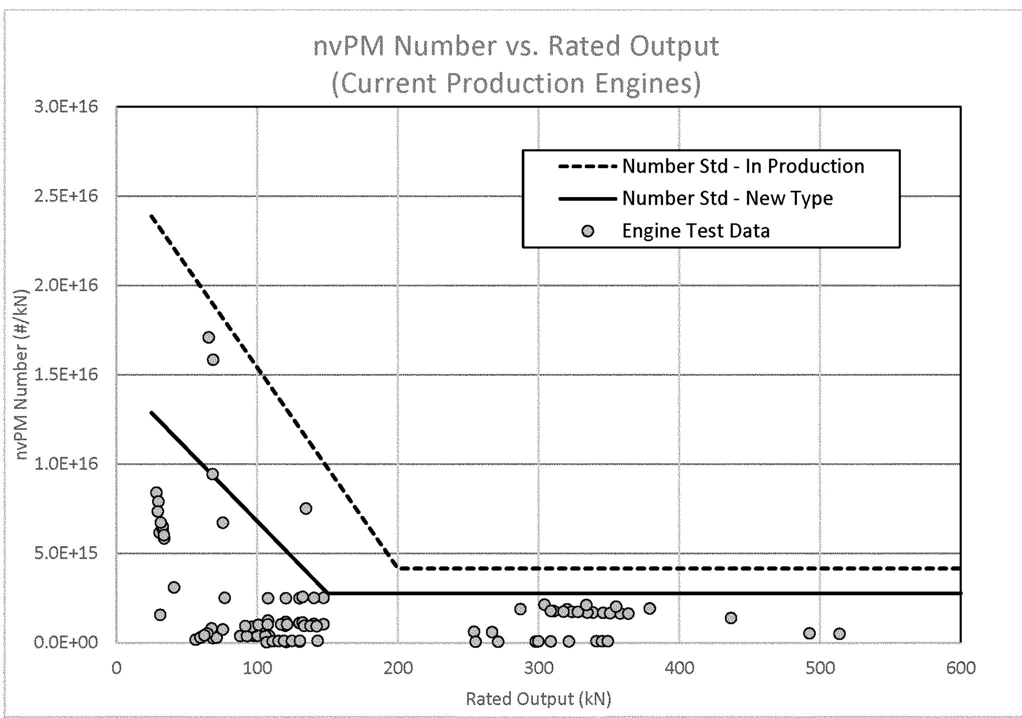

Figure IV-2 - nvPM number standards compared to in-production engine LTO emission rates

[88] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, III–4–4pp. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services Catalog, English Edition of the 2021 catalog, and it is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

[89] ICAO Aircraft Engine Emissions Databank, July 20, 2021, ''edb-emissions-databank v28C (web).xlsx'', European Union Aviation Safety Agency (EASA), *https://www.easa.europa.eu/domains/environment/icao-aircraft/-engine-emissions/-databank* (last accessed November 15, 2021).

C. PM Mass Concentration Standard for Aircraft Engines

The current smoke number-based standards were adopted to reduce the visible smoke emitted by aircraft engines. Smoke number is quantified by measuring the opacity of a filter after soot has been collected upon it during the test procedure. Another means of quantifying the smoke from an engine exhaust is through PM mass concentration (PM_{mc}).

ICAO developed a PM mass concentration standard during the CAEP/10 cycle and adopted it in 2017. This PM mass concentration standard was developed to provide equivalent exhaust visibility control as the existing smoke number standard starting on January 1, 2020. With the EPA's involvement, the ICAO PM mass concentration limit line was developed using measured smoke number and PM mass concentration data from several engines to derive a smoke number-to-PM mass concentration correlation. This correlation was then used to transform the existing smoke number-based limit line into a generally equivalent PM mass concentration limit line, which was ultimately adopted by ICAO as the CAEP/10 PM mass concentration standard. The intention when the equivalent PM mass concentration standard was adopted was that equivalent visibility control would be maintained and testing would coincide with the PM mass and PM number measurement, thus removing the need to separately test and measure smoke number.

While the ICAO PM mass concentration standard was intended to have equivalent visibility control as the existing SN standard, the method used to derive it was based on limited data and needed to be confirmed for regulatory purposes. Additional analysis was conducted during the CAEP/11 cycle to confirm this equivalence. The EPA followed this work as it progressed, provided input during the process, and ultimately concurred with the results.[90] The analysis, based on aerosol optical theory and visibility criterion, demonstrated with a high level of confidence that the ICAO PM mass concentration standard did indeed provide equivalent visibility control as the existing smoke number standard. This provided the justification for ICAO to agree to end applicability of the existing smoke number standard for engines subject to the PM mass concentration standard, effective January 1, 2023.

1. PM Mass Concentration Standard

The EPA is proposing to adopt a PM mass concentration standard for all aircraft engines with rated output greater than 26.7 kN and manufactured on or after January 1, 2023.[91] This proposed standard has the same form, test procedures, and stringency as the CAEP/10 PM mass concentration standard adopted by ICAO in 2017. However, the applicability date proposed here is different than that agreed to by ICAO. The proposed PM mass concentration standard is based on the maximum concentration of PM emitted by the engine at any thrust setting, measured in micrograms (µg) per meter cubed (m^3). This is similar to the current smoke standard, which is also based on the measured maximum at any thrust setting. Section IV.D describes the measurement procedure. Like the LTO-based PM mass and PM number standards discussed above, this is based on the measurement of nvPM only, not total PM emissions.

To determine compliance with the proposed PM mass concentration standard, the maximum nvPM mass concentration [µg/m^3] would be obtained from measurement at sufficient thrust settings such that the emission maximum can be determined. The maximum value would then be converted to a characteristic level in accordance with the procedures in ICAO Annex 16, Volume II, Appendix 6. The resultant characteristic level must not exceed the regulatory level determined from the following formula:

$$nvPM\ mass\ concentration = 10^{3+2.9\,rO^{-0.274}}$$

Equation IV-5

Engines certificated under the new PM mass concentration standard would not need to certify smoke number values and would not be subject to in-use smoke standards. It is important to note that other smoke number standards remain in effect for in-production aircraft turbofan and turbojet engines at or below 26.7 kN rated output and for in-production turboprop engines. Also, the in-use smoke standards will continue to apply to some already manufactured aircraft engines that were certified to smoke number standards.

2. Graphical Representation of nvPM Mass Concentration Numerical Emission Limit

Figure IV–3 shows how the proposed nvPM mass concentration emission limits compare to known in-production engines. Data shown in this figure is from the ICAO Engine Emissions Databank EEDB).[92]

[90] ICAO, 2019: *Report of Eleventh Meeting, Montreal, 4–15 February 2019, Committee on Aviation Environmental Protection,* Document 10126, CAEP/11. It is found on page 26 of the English Edition of the ICAO Products & Services 2021 Catalog and is copyright protected; Order No. 10126. For purchase available at: *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed November 15, 2021). The analysis performed to confirm the equivalence of the PM mass concentration standard and the SN standard is located in Appendix C (starting on page 3C–33) of this report.

[91] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, III–4–3. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services Catalog, English Edition of the 2021 catalog, and it is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

[92] ICAO Aircraft Engine Emissions Databank, July 20, 2021, ''edb-emissions-databank v28C (web).xlsx'', European Union Aviation Safety Agency (EASA), *https://www.easa.europa.eu/domains/environment/icao-aircraft/-engine-emissions/-databank.*

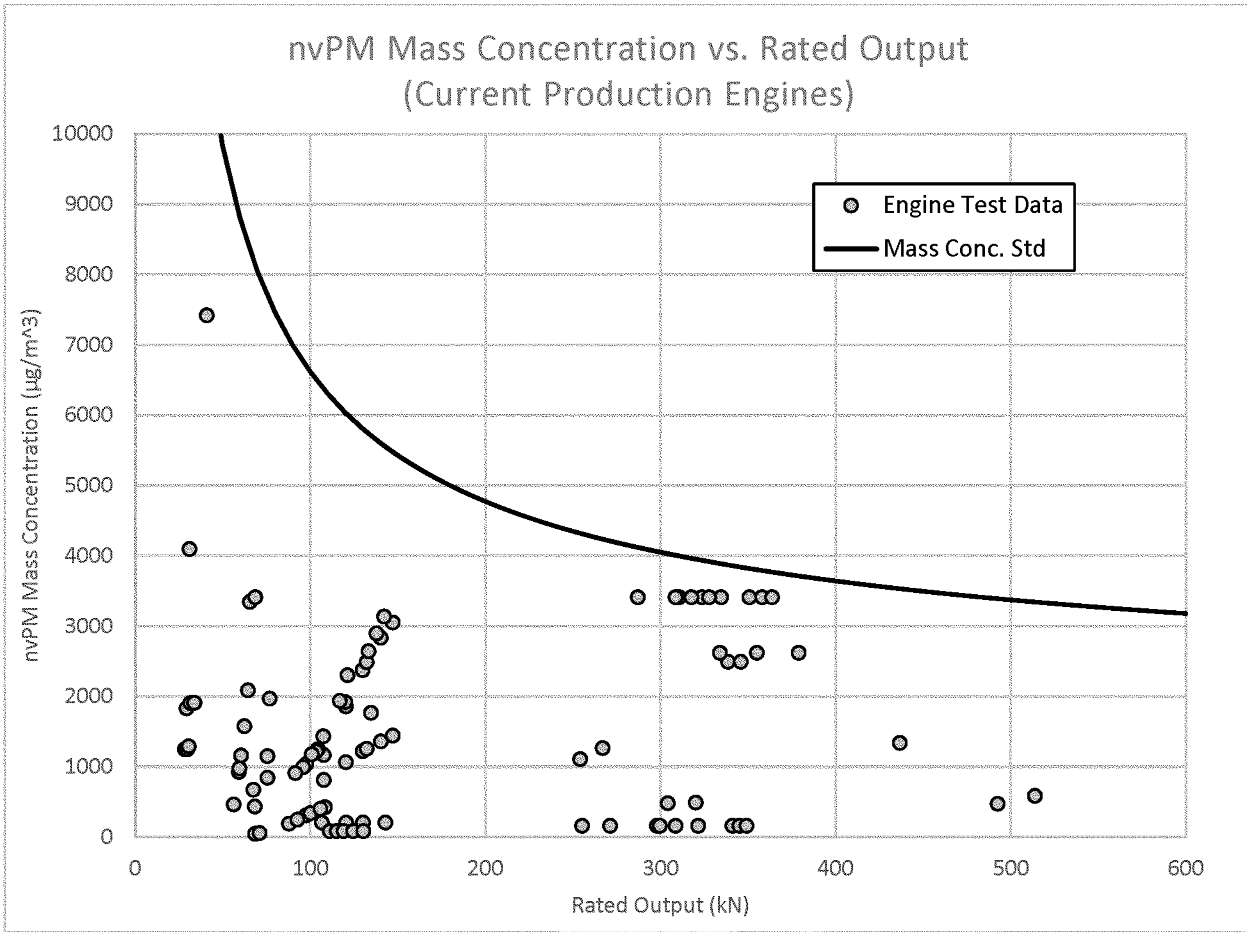

Figure IV-3 - nvPM Mass Concentration Standard

D. Test and Measurement Procedures

1. Aircraft Engine PM Emissions Metrics

When developing the PM standards, ICAO looked at three different methods of measuring the amount of PM emitted. The first is PM mass, or a measure of the total weight of the particles produced over the test cycle. This is how the EPA has historically measured PM emissions subject to standards for other sectors. Second, ICAO considered PM number, or the number of particles produced by the engine over the test cycle. These are two different methods of measuring the same pollutant, PM, but each provides valuable information. Third, ICAO developed PM mass concentration standards, as an alternative to the existing visibility standards based on smoke.

The EPA proposes to incorporate by reference the metrics agreed at ICAO and incorporated into Annex 16 Volume II, to measure PM mass (Equation IV–6) and PM number (Equation IV–7). These metrics are based on a measurement of the nvPM emissions, as measured at the instrument, over the LTO cycle and is normalized by the rated output of the engine (rO).

$$nvPM_{mass} = \frac{\sum nvPM_{Mass}}{rO}\left[{}^{mg}/_{kN}\right]$$

Equation IV-6

$$nvPM_{num} = \frac{\sum nvPM_{number}}{rO}\left[{}^{\#}/_{kN}\right]$$

Equation IV-7

The EPA proposes the PM mass concentration standard be based on the maximum mass concentration, in micrograms per meter cubed, produced by the engine at any thrust setting.

Regulatory compliance with the emissions standards is based on the product of Equation IV–6 or Equation

IV–7 or mass concentration divided by a correction factor in Table IV–2, to obtain the characteristic level that is used to determine compliance with emissions standards (see IV.D.4 below).

2. Test Procedure

The emission test and measurement procedures adopted by ICAO were produced in conjunction with the Society of Automotive Engineers (SAE) E–31 Aircraft Exhaust Emissions Measurement Committee.[93] These procedures were developed in SAE E–31 in close consultation between government and industry, and subsequently they were adopted by ICAO and incorporated into ICAO Annex 16, Volume II.

These procedures build off the existing aircraft engine measurement system for gaseous pollutants. At least 3 engine tests need to be conducted to determine the emissions rates. These tests can be conducted on a single engine or multiple engines.[94] A representative sample of the engine exhaust is sampled at the engine exhaust exit. The exhaust then travels through a heated sample line where it is diluted and kept at a constant temperature prior to reaching the measurement instruments.

The methodology for measuring PM from aircraft engines differs from other test procedures for mobile source $PM_{2.5}$ standards in two ways. First, as discussed above, the procedure is designed to measure only the nonvolatile component of PM. The measurement of volatile PM is very dependent on the environment where it is measured. The practical development of a standardized method of measuring volatile PM has proved challenging. Therefore, the development of a procedure for nvPM was prioritized and the result is proposed here today.

Second, the sample is measured continuously rather than being collected on a filter and measured after the test. This approach was taken primarily for the practical reasons that, due to high dilution rates leading to relatively low concentrations of PM in the sample, collecting enough particulate on a filter to analyze has the potential to take hours. Given the high fuel flow rates of these engines, such lengthy test modes would be very expensive. Additionally, because of the high volume of air required to run a jet engine and the extreme engine exhaust temperatures, it is not possible to collect the full exhaust stream in a controlled manner as is done for other mobile source $PM_{2.5}$ measurements.

Included in the proposed procedures, to be incorporated by reference, are measurement system specifications and requirements, instrument specifications and calibration requirements, fuel specifications, and corrections for fuel composition, dilution, and thermophoretic losses in the collection part of the sampling system.

To create a uniform sampling system design that works across gas turbine engine testing facilities, the test procedure calls for a 35-meter sample line. This results in a significant portion of the PM being lost in the sample lines, on the order of 50 percent for PM mass and 90 percent for PM number. These particle losses in the sampling system are not corrected for in the regulatory compliance levels (standards). Compliance with the standard is based on the measurement at the instruments rather than the exit plane of the engine (instruments are 35 meters from engine exit). This is due to the lack of robustness of the sampling system particle loss correction methodology and that a more stringent standard at the instrument will lead to a reduction in the nvPM emissions at the engine exit plane. A correction methodology has been developed to better estimate the actual PM emitted into the atmosphere. This correction is described below in Section V.A.2.

3. Test Duty Cycles

Mass and number PM emissions are proposed to be measured over the Landing and Take-Off (LTO) cycle shown in Table IV–1. This is the same duty cycle used today to measure gaseous emissions from aircraft engines and is intended to represent operations and flight under an altitude of 3,000 feet near an airport. Due to challenges in measuring at these exact conditions and atmospheric and fuel corrections that need to be applied after testing; it is not necessary to measure exactly at these points. Emissions rates for each mode can be calculated by testing the engine(s) over a sufficient range of thrust settings such that the emission rates at each condition in Table IV–1 can be determined.

TABLE IV–1—LANDING AND TAKE-OFF CYCLE THRUST SETTINGS AND TIME IN MODE [95]

LTO operating mode	Thrust setting Percent rO	Time in operating mode (minutes)
Take-off	100	0.7
Climb	85	2.2
Approach	30	4.0
Taxi/ground idle	7	26.0

The existing smoke number standard was adopted to reduce the visible smoke emitted from aircraft engines. Smoke number has been determined by measuring the visibility or opacity of a filter after soot has been collected upon it during the test procedure. Another means of measuring this visibility is by direct measurement of the particulate matter mass concentration. By measuring visibility based on mass concentration rather than smoke

[93] ''E–31 Committee was formed to develop and maintain cognizance of standards for measurement of emissions from aircraft powerplants and to promote a rational and uniform approach to the measurement of emissions form aircraft engines and combustion systems to support the practical assessment of the industry. The E–31 Committee, in its operation uses an Executive Committee, Membership Panel, Subcommittees and working technical panels as required to achieve its objectives.'' (See *https://www.sae.org/works/committeeHome./do?comtID=TEAE31,* last accessed November 15, 2021).

[94] All three tests could be conducted on a single engine. Or two tests could be conducted on one engine and one test on a second engine. Or three separate engines could each be tested a single time.

[95] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, III–4–2. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services Catalog, English Edition of the 2021 catalog, and it is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

number, the number of tests needed can be reduced, and mass concentration data can be collected concurrently with other PM measurements. Like the existing smoke standard, the proposed PM mass concentration standard would be based on the maximum value at any thrust setting. The engine(s) would be tested over a sufficient range of thrust settings that the maximum can be determined. This maximum could be at any thrust setting and is not limited to the LTO thrust points.

We are proposing to incorporate by reference ICAO's International Standards and Recommended Practices for aircraft engine PM testing and certification—ICAO Annex 16, Volume II.

4. Characteristic Level

Like existing gaseous standards, compliance with the PM standards is proposed to be determined based on the characteristic level of the engine. The characteristic level is a statistical method of accounting for engine-to-engine variation in the measurement based on the number of engines tested. A minimum of 3 engine emissions tests is needed to determine the engine type's emissions rates for compliance with emissions standards. The more engines that are used for testing increases the confidence that the emissions rate measured is from a typical engine rather than a high or low engine.

Table IV–2 below is reproduced from Annex 16 Volume II Appendix 6 Table A6–1 and shows how these factors change based on the number of engines tested. As the number of engines tested increases, the factor also increases resulting in a smaller adjustment and reflecting the increased confidence that the emissions rate is reflective of the average engine off the production line. In this way, there is an incentive to test more engines to reduce the characteristic adjustment while also increasing confidence that the measured emissions rate is representative of the typical production engine.

TABLE IV–2—FACTORS TO DETERMINE CHARACTERISTIC VALUES [96]

Number of engines tested (i)	CO	HC	NO_X	SN	nvPM mass concentration	nvPM LTO mass	nvPM LTO number
1	0.814 7	0.649 3	0.862 7	0.776 9	0.776 9	0.719 4	0.719 4
2	0.877 7	0.768 5	0.909 4	0.852 7	0.852 7	0.814 8	0.814 8
3	0.924 6	0.857 2	0.944 1	0.909 1	0.909 1	0.885 8	0.885 8
4	0.934 7	0.876 4	0.951 6	0.921 3	0.921 3	0.901 1	0.901 1
5	0.941 6	0.889 4	0.956 7	0.929 6	0.929 6	0.911 6	0.911 6
6	0.946 7	0.899 0	0.960 5	0.935 8	0.935 8	0.919 3	0.919 3
7	0.950 6	0.906 5	0.963 4	0.940 5	0.940 5	0.925 2	0.925 2
8	0.953 8	0.912 6	0.965 8	0.944 4	0.944 4	0.930 1	0.930 1
9	0.956 5	0.917 6	0.967 7	0.947 6	0.947 6	0.934 1	0.934 1
10	0.958 7	0.921 8	0.969 4	0.950 2	0.950 2	0.937 5	0.937 5
more than 10	$1-0.13059/\sqrt{i}$	$1-0.24724/\sqrt{i}$	$1-0.09678/\sqrt{i}$	$1-0.15736/\sqrt{i}$	$1-0.15736/\sqrt{i}$	$1-0.19778/\sqrt{i}$	$1-0.19778/\sqrt{i}$

For PM mass and PM number, the characteristic level would be based on the mean of all engines tested, and appropriately corrected, divided by the factor corresponding to the number of engine tests performed in Table IV–1. For PM mass concentration, the characteristic level would be based on the mean of the maximum values of all engines tested, and appropriately corrected, divided by the factor corresponding to the number of engine tests performed in Table IV–2.

For example, an engine type where three measurements were obtained from the same engine has an nvPM mass metric value of 100 mg/kN (mean metric value of all engine tests). The nvPM LTO Mass factor (or nvPM mass characteristic factor) from Table IV–2 for three engines is 0.7194. The metric value, with applicable corrections applied, is then divided by the factor to obtain the characteristic level of the engine. Therefore, the resulting characteristic level for this engine type, to determine compliance with the nvPM mass standard is 139.005mg/kN. If instead three engines are each tested once, the characteristic factor would be 0.8858 and the nvPM mass characteristic level to determine compliance with the standard would be 112.892 mg/kN.

An engine type's characteristic level can also be further improved by testing additional engines. For example, if 10 separate engines were tested of the same type, the nvPM mass characteristic factor becomes 0.9375. The resulting characteristic level (assuming the average nvPM mass metric value remains 100 mg/kN) would be 106.667 mg/kN. This approach could be used if an engine exceeds the standard at the time it is initially tested or there is a desire to increase the margin to the standard for whatever reason. Table IV–3 shows these three different examples for nvPM LTO Mass.

TABLE IV–3—IMPACT OF THE NUMBER OF ENGINES TESTED ON RESULTING CHARACTERISTIC LEVEL

Number of engines tested	Number of tests per engine	Measured nvPM LTO mass (mg/kN)	Characteristic factor	Characteristic level (mg/kN)
1	3	100	0.7194	139.005
3	1	100	0.8858	112.892
10	1	100	0.9375	106.667

[96] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, App 6–2pp. Available at *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services Catalog, English Edition of the 2021 catalog, and it is copyright protected; Order No. AN16–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021. Amendment 10 is also found on page 17 of this ICAO catalog, and it is copyright protected; Order No. AN 16–2/E/12.

We are proposing to incorporate by reference ICAO's International Standards and Recommended Practices for correcting engine measurements to characteristic value—ICAO Annex 16, Volume II, Appendix 6.

5. Derivative Engines for Emissions Certification Purposes

Aircraft engines can remain in production for many years and be subject to numerous modifications during its production life. As part of the certification process for any change, the type certificate holder will need to show that the change does not impact the engine emissions. While some of these changes could impact engine emissions rates, many of them will not. To simplify the certification process and reduce burden on both type certificate holder and certification authorities, ICAO developed criteria to determine whether there has been an emissions change that requires new testing. Such criteria already exist for gaseous and smoke standards.

ICAO recommends that if the characteristic level for an engine was type certificated at a level that is at or above 80 percent of the PM mass, PM number, or PM mass concentration standard, the type certificate holder would be required to test the proposed derivative engine. If the engine is below 80 percent of the standard, engineering analysis can be used to determine new emission rates for the proposed derivative engines. Today, the EPA proposes to adopt these ICAO provisions.

Subsequently, ICAO evaluated the measurement uncertainty to develop criteria for determining if a proposed derivative engine's emissions are similar to the previously certificated engine's emissions, which are described below. Today, the EPA proposes to adopt these ICAO criteria.

For PM Mass measurements described above in Section IV.A, the following values would apply:

- 80 mg/kN if the characteristic level for $nvPM_{mass}$ emissions is below 400 mg/kN.
- ±20% of the characteristic level if the characteristic level for $nvPM_{mass}$ emissions is greater than or equal to 400 mg/kN.

For PM number measurements, described above in Section IV.B, the following values would apply:

- 4 × 10∧14 particles/kN if the characteristic level for $nvPM_{num}$ emissions is below 2 × 10∧15 particles/kN.
- ±20% of the characteristic level if the characteristic level for $nvPM_{num}$ emissions is greater than or equal to 2 × 10∧15 particles/kN.

For PM mass concentration measurements described above in Section IV.C, the following values would apply:

- ±200 μg/m∧3 if the characteristic level of maximum nvPM mass concentration is below 1,000 μg/m∧3.
- ±20% of the characteristic level if the characteristic level for maximum nvPM mass concentration is at or above 1,000 μg/m∧3.

If a type certificate holder can demonstrate that the engine's emissions are within these ranges, then new emissions rates would not need to be developed and the proposed derivative engine for emissions certification purposes could keep the existing emissions rates.

If the engine is not determined to be a derivative engine for emissions certification purposes, the certificate holder would need to certify the new emission rates for the engine.

E. Annual Reporting Requirement

In 2012, the EPA adopted an annual reporting requirement as part of a rulemaking to adopt updated aircraft engine NO_X standards.[97] This provision, adopted into 40 CFR 87.42, requires the manufacturers of covered engines to annually report data to the EPA which includes information on engine identification and characteristics, emissions data for all regulated pollutants, and production volumes. In 2018, the EPA issued an information collection request (ICR) which renewed the existing ICR and added PM information to the list of required data.[98] [99] However, that 2018 ICR was not part of a rulemaking effort, and the new PM reporting requirements were not incorporated into the CFR at that time. Further, that 2018 ICR is currently being renewed (in an action separate from this proposal), and the EPA is proposing as part of that effort to add some additional data elements to the ICR (specifically, the emission indices for HC, CO, and NO_X at each mode of the LTO cycle).[100] [101] The EPA is now proposing to formally incorporate all aspects of that ICR, as proposed to be renewed, into the CFR in the proposed section 1031.150. It is important to note that the incorporation of the PM reporting requirements into the CFR would not create a new requirement for the manufacturers of aircraft engines. Rather, it would simply incorporate the existing reporting requirements (as proposed to be amended and renewed in a separate action) into the CFR for ease of use by having all the reporting requirements readily available in the CFR.

The EPA uses the collection of information to help conduct technology assessments, develop aircraft emission inventories (for current and future inventories), and inform our policy decisions—including future standard-setting actions. The information enables the EPA to further understand the characteristics of aircraft engines that are subject to emission standards—and engines proposed to be subject to the PM emission standards—and engines impact on emission inventories. In addition, the information helps the EPA set appropriate and achievable emission standards and related requirements for aircraft engines. Annually updated information helps in assessing technology trends and their impacts on national emissions inventories. Also, it assists the EPA to stay abreast of developments in the aircraft engine industry.

As discussed in Section VII, the EPA is proposing to migrate the existing 40 CFR part 87 regulatory text to a new 40 CFR part 1031. Part of that effort includes clarifying portions of the regulatory text for ease of use. In the existing 40 CFR 87.42(c)(6), the regulatory text does not specifically spell out some required data, but instead relies on incorporation by reference for a detailed listing of required items. 40 CFR 87.42(c)(6) references the data reporting provisions in ICAO's Annex 16, Volume II and lists the data from this Annex that is not required by the EPA's reporting requirement. For future ease of use, the EPA is proposing in the new 40 CFR 1031.150 to explicitly list all the required items rather than continuing the incorporation by reference approach in the existing reporting regulations. The reader is encouraged to consult the proposed 40 CFR 1031.150 text for a complete list of the required reporting items. However, as previously mentioned, this list contains all the currently required items as well as the HC, CO and NO_X emission indices as proposed in the separate ICR renewal action. Finally, the EPA is proposing to incorporate by reference Appendix 8 of

[97] 77 FR 36342, June 18, 2012.

[98] 83 FR 44621, August 31, 2018.

[99] U.S. EPA, Aircraft Engines—*Supplemental Information Related to Exhaust Emissions (Renewal),* OMB Control Number 2060–0680, ICR Reference Number 201809–2060–08, December 17, 2018. Available at *https://www.reginfo.gov/public/do/PRAViewICR?ref_nbr=201809-2060-008,* last accessed November 15, 2021.

[100] 86 FR 24614, May 7, 2021.

[101] Documentation and Public comments are available at: *https://www.regulations.gov/docket/EPA-HQ-OAR-2016-0546,* last accessed November 15, 2021.

Annex 16, Volume II, which outlines procedures used to estimate measurement system losses, which are a required element of the proposed reporting provisions.

V. Aggregate PM Inventory Impacts

The number of aircraft landings and takeoffs (LTO) affects PM emissions that contribute to the local air quality near airports. The LTO emissions are defined as emissions between ground level and an altitude of about 3,000 feet. They are composed of emissions during departure operations (from taxi-out movement from gate to runway, aircraft take-off run and climb-out to 3,000 feet), and during arrival operations (emissions from approach at or below 3,000 feet down to landing on the ground and taxi-in from runway to gate). These LTO emissions directly affect the ground level air quality at the vicinity of the airport since they are within the local mixing height. Depending on the meteorological conditions, the emissions will be mixed with ambient air down to ground level, dispersed, and transported to areas downwind from the airport with elevated concentration levels.[102]

As described earlier in Section III, aircraft PM emissions are composed of both volatile and nonvolatile PM components.[103] Starting from an air and fuel mixture of 16.3 percent oxygen (O_2), 75.2 percent nitrogen (N_2), and 8.5 percent fuel, an aircraft engine yields combustion products of 27.6 percent water (H_2O), 72 percent carbon dioxide (CO_2), and ~0.02 percent sulfur oxide (SO_X) with only 0.4 percent incomplete residual products which can be broken down to 84 percent nitrogen oxide (NO_X), 11.8 percent carbon monoxide (CO), 4 percent unburned hydrocarbons (UHC), 0.1 percent PM and trace amount of other products.[104] Although the PM emissions are a small fraction of total engine exhaust, the composition and morphology of PM are complex and dynamic. While the proposed emission test procedures focus only on measuring nonvolatile PM (black carbon), our emissions inventory includes estimates for volatile PM (organic, lubrication oil residues and sulfuric acid) as well.

A. Aircraft Engine PM Emissions for Modeling

To quantify the aircraft PM emissions for the purposes of developing or modeling an emissions inventory for this proposed rulemaking (for an inventory in the year 2017), we used an approximation method as described in Section V.A.1. For future emission inventories, this approximation method will not be needed for newly manufactured engines which will have measured PM emission indices (EIs) going forward. However, to accurately estimate the nvPM emissions at the engine exit for emission inventory purposes, loss correction factors for nvPM mass and nvPM number will need to be applied to the measured PM EIs due to particle losses in the nvPM sampling and measurement system. An improved approximation method as described in Section V.A.3 is expected to be used for modeling PM emissions of in-service engines that do not have measured PM data. For the final rulemaking, we expect to develop an updated PM emissions inventory based on available measured PM EIs data with loss correction and the improved approximation method for engines without measured PM EIs.

1. Baseline PM Emission Indices

Measured PM data was not available to calculate the 2017 inventory. Thus, to calculate the baseline aircraft engine PM emissions, we used the FOA3 (First Order Approximation Version 3.0) method defined in the SAE Aerospace Information Reports, AIR5715.[105] For non-volatile PM mass, the FOA3 method is based on an empirical correlation of Smoke Number (SN) values and the non-volatile PM (nvPM) mass concentrations of aircraft engines. The nvPM mass concentration (g/m^3) derived from SN can then be converted into an nvPM mass emission index (EI) in gram of nvPM per kg fuel using the method developed by Wayson et al,[106] based on a set of empirically determined Air Fuel Ratios (AFR) and engine volumetric flow rates at the four ICAO LTO thrust settings (see Table IV–1). Subsequently, the nvPM mass EI can be used to calculate the nvPM mass for the four LTO modes with engine fuel flow rate and time-in-mode information. As the name suggests, the FOA3 method is a rough estimate, and it is only for nvPM mass.

In addition, as described earlier (Sections III.A and IV), volatile PM and nvPM together make up total PM. The FOA3 method for volatile PM is based on the jet fuel organics[107] and sulfur content. Since the total PM inventory is the emissions inventory we are estimating for this proposed rulemaking, we are including the volatile PM emission estimates from the FOA3 method in our emission inventory.

2. Measured nvPM EIs for Inventory Modeling

The measurement and reporting of engine EIs will improve the development of future engine emission inventories. As mentioned in Section IV, the regulatory compliance level is based on the amount of particulate that is directly measured by the instruments. The test procedures specify a sampling line that can be up to 35 meters long. This length results in significant particle loss in the measurement system, on the

[102] A local air quality ''. . . emissions inventory for aircraft focuses on the emission characteristics of this source relative to the vertical column of air that ultimately affects ground level pollutant concentrations. This portion of the atmosphere, which begins at the earth's surface and is simulated in air quality models, is often referred to as the mixing zone'' or mixing height. (See page 137.) The air in this mixing height is completely mixed and pollutants emitted anywhere within it will be carried down to ground level. (See page 143.) ''The aircraft operations of interest within the [mixing height] are defined as the [LTO] cycle.'' (See page 137.) The default mixing height in the U.S. is 3,000 feet. (EPA, 1992: Procedures for Emission Inventory Preparation—Volume IV: Mobile Sources, EPA420–R–92–009. Available at *https://nepis.epa.gov* (last accessed June 23, 2021).

[103] ICAO: 2019, ICAO Environmental Report, Available at *https://www.icao.int/environmental-protection/Documents/ICAO-ENV-Repor/t2019-F1-WEB%20(1).pdf* (last accessed on November 15, 2021,2021). See pages 100 and 101 for a description of non-volatile PM and volatile PM.

''At the engine exhaust, particulate emissions mainly consist of ultrafine soot or black carbon emissions. Such particles are called ''non-volatile'' (nvPM). They are present at the high temperatures at the engine exhaust and they do not change in mass or number as they mix and dilute in the exhaust plume near the aircraft. The geometric mean diameter of these particles is much smaller than $PM_{2.5}$ (geometric mean diameter of 2.5 Microns) and ranges roughly from 15nm to 60nm (0.06 Microns). These are classified as ultrafine particles (UFP).'' (See page 100.) ''The new ICAO standard is a measure to control the ultrafine non-volatile particulate matter emissions emitted at the engine exit . . .'' (See page 101.)

''Additionally, gaseous emissions from engines can also condense to produce new particles (*i.e.,* volatile particulate matter—vPM), or coat the emitted soot particles. Gaseous emissions species react chemically with ambient chemical constituents in the atmosphere to produce the so called secondary particulate matter. Volatile particulate matter is dependent on these gaseous precursor emissions. While these precursors are controlled by gaseous emission certification and the fuel composition (*e.g.,* sulfur content) for aircraft gas turbine engines, the volatile particulate matter is also dependent on the ambient air background composition.'' (See pages 100 and 101.)

[104] European Monitoring and Evaluation Programme/European Environment Agency, Air Pollutant Emission Inventory Guidebook 2019; Available at *https://www.eea.europa.eu/themes/air/air-pollution-sources-1/emep-eea-air-/pollutant-/emission-/inventory-guidebook/emep* (last accessed June 26, 2021).

[105] SAE Aerospace Information Reports, AIR5715, Procedure for the Calculation of Aircraft Emissions, 2009, SAE International.

[106] Wayson RL, Fleming GG, Iovinelli R. Methodology to Estimate Particulate Matter Emissions from Certified Commercial Aircraft Engines. J Air Waste Management Assoc. 2009 Jan 1; 59(1).

[107] In this context, organics refers to hydrocarbons in the exhaust that coat on existing particles or condense to form new particles after the engine exit.

order of 50 percent for nvPM mass and 90 percent for nvPM number.[108] Further the particle loss is size dependent, and thus the losses will be dependent on the engine operating condition (*e.g.,* idle vs take-off thrust), engine combustor design, and technology. To assess the emissions contribution of aircraft engines for inventory and modeling purposes, and subsequently for human health and environmental effects, it is necessary to know the emissions rate at the engine exit. Thus, the measured PM mass and PM number values must be corrected for system losses to determine the engine exit emissions rate.

The EPA led the effort within the SAE E–31 committee to develop the methodology to correct for system losses. This effort at E–31 resulted in the development and publication of AIR 6504 and ARP 6481 describing how to correct for system losses. ICAO has incorporated this same procedure into Annex 16 Vol. II Appendix 8.

The engine exit emissions rate, which is corrected for system losses, is specific to each measurement system and to each engine. The calculation is an iterative function based upon the measured nvPM mass and nvPM number values and the geometry of the measurement system. Manufacturers provide the corrected emissions values to the ICAO EDB and to the EPA.

When calculating emissions inventories, these corrected EIs will be used rather than the values used to show compliance with emission standards. These measured EIs are only for the nonvolatile component of PM, and an approximation method will still be required for quantifying the volatile PM inventory.

3. Improvements to Calculated EIs

The new version of the approximation method, known as FOA4, has been developed by CAEP to improve nvPM mass estimation and to extend the methodology to nvPM number based on the newly available PM measurement data.[109] Since PM mass and PM number are two different measurement metrics of the same pollutant, PM, they can be converted to each other if the size and density distribution of the pollutant can be characterized.[110] FOA4 was not used in the baseline emission rates for this proposed rulemaking.

The calculation of volatile PM has not changed between FOA3 and FOA4 because no improved data or method has become available to inform improvements.

B. Baseline PM Emission Inventory

The baseline PM emissions inventory used for this proposed rule is from the aviation portion of EPA's 2017 National Emissions Inventory (NEI).[111] [112] [113] The NEI is compiled by EPA triennially based on comprehensive emissions data for criteria pollutants and hazardous air pollutants (HAPs) for mobile, point, and nonpoint sources. The mobile sources include aviation, marine, railroad, on-road vehicles, and nonroad engines. As described earlier in Section V.A, the aircraft emission estimates in this 2017 NEI (or the baseline PM emissions inventory) are based on the FOA instead of measured PM emissions data from aircraft engines proposed to be regulated by this rulemaking. For the final rulemaking, we anticipate potentially having an updated baseline PM emissions inventory based on measured data from numerous in-production engines (we would likely have PM data for nearly all in-production engines proposed to be regulated by this rulemaking).

The aviation emissions developed for the NEI include emissions associated with airport activities in commercial aircraft, air taxi aircraft,[114] general aviation aircraft, military aircraft, auxiliary power units, and ground support equipment. All emissions from aircraft with gas turbine engines greater than 26.7 kN rated output from the aircraft categories described earlier, except military aircraft, are used in the emissions inventory for this proposed rule (which is a subset of the aviation emissions inventory). To estimate emissions, 2017 activity data by states were compiled and supplemented with publicly available FAA data. The FAA activity data included 2017 T–100 [115] dataset, 2014 Terminal Area Forecast (TAF) [116] data, 2014 Air Traffic Activity Data System (ATADS) [117] data, and 2014 Airport Master Record (form 5010) [118] data.[119] The NEI used the FAA's Aviation Environmental Design Tool (AEDT) [120] version 2d to estimate emissions for aircraft that were in the AEDT database. The NEI used a more general estimation methodology to account for emissions from aircraft types not available in AEDT by multiplying the reported activities by fleet-wide average emission factors of generic aircraft types (or by aircraft category—*e.g.,* general aviation or air taxi).[121]

For aircraft PM contribution in 2017 to total mobile PM emissions in counties and MSA's for the top 25 airports (inventories for aircraft with engines >26.7 kN), see Figure III–1 and Figure III–2 in Section III.E.

As described earlier, the baseline emissions inventory is based on the total PM emissions, which includes both the nvPM and volatile PM components of total PM. The 2017 NEI does not provide inventories for these components of total PM. However, we estimate that nvPM is about 70 percent

[108] Annex 16 Vol. II Appendix 8 Note 2.

[109] ICAO: Second edition, 2020: Doc 9889, Airport Air Quality Manual. Order Number 9889. See Attachment D to Appendix 1 of Chapter 3. Doc 9889 can be ordered from ICAO website: *https://store.icao.int/en/airport-air-/quality-manual/-doc-9889* (last accessed June 28, 2021).

[110] Based on the newly available measurement data and inputs from technical experts in SAE E–31 Aircraft Exhaust Emissions Measurement Committee, CAEP has determined that a set of fixed geometric mean diameters (GMDs) of 20/20/40/40 nanometers for the four LTO modes (idle-taxi/approach/climbout/take-off) fits the data the best. Along with the assumptions of a log-normal size distribution, a geometric standard deviation of 1.8, and an effective density of 1,000 kg/m^3 for the exhaust plume at the engine exit plane, nvPM mass EI and nvPM number EI of LTO mode k can be converted to each other.

[111] 2017 National Emissions Inventory: Aviation Component, Eastern Research Group, Inc., July 25, 2019, EPA Contract No. EP–C–17–011, Work Order No. 2–19.

[112] See section 3.2 for airports and aircraft related emissions in the Technical Supporting Document for the 2017 National Emissions Inventory, January 2021 Updated Release; *https://www.epa.gov/sites/production/files/2021-02/documents/nei2017_tsd_full_jan2021.pdf.*

[113] *https://www.epa.gov/air-emissions/-inventories/2017-/national-emissions-/inventory-nei-data.*

[114] Air taxis fly scheduled service carrying passengers and/or freight, but they usually are smaller aircraft and operate on a more limited basis compared to the commercial aircraft operated by airlines.

[115] Title 14—Code of Federal Regulations—Part 241 Uniform System of Accounts and Reports for Large Certificated Air Carriers. T–100 Segment (All Carriers)—Published Online by Bureau of Transportation Statistics. *https://www.transtats.bts.gov/Fields.asp?Table_ID=293.* Accessed May 9, 2018.

[116] Federal Aviation Administration. Terminal Area Forecast (TAF). *https://aspm.faa.gov/main/taf.asp.* Accessed April 21, 2018.

[117] Federal Aviation Administration. ATADS: Airport Operations: Standard Report. *https://aspm.faa.gov/opsnet/sys/Airport.asp.* Accessed May 23, 2018.

[118] Federal Aviation Administration. 2009. Airport Master Record Form 5010. Published by GCR & Associates. *https://www.gcr1.com/5010WEB/*. Accessed May 21, 2009.

[119] The rationale for the use of multiple FAA activity databases is described in the 2017 NEI report (2017 National Emissions Inventory: Aviation Component, Eastern Research Group, Inc., July 25, 2019, EPA Contract No. EP–C–17–011, Work Order No. 2–19. See section 3.2 for airports and aircraft related emissions in the Technical Supporting Document for the 2017 National Emissions Inventory, January 2021 Updated Release; *https://www.epa.gov/sites/production/files/2021-02/documents/nei2017_tsd_full_jan2021.pdf,* last accessed June 26, 2021.)

[120] AEDT is a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences. It is available at *https://aedt.faa.gov/* (*last accessed on June 26, 2021*).

[121] Ibid.

(range 51 percent to 72 percent based on modal EIs of a sample engine) of the total PM.[122] We intend to improve this estimate for the final rulemaking. Applying the nvPM percentage (or fraction) to the total fleet-wide baseline PM inventory, or the 2017 NEI PM inventory for aircraft with gas turbine engines greater than 26.7 kN, would better enable us to estimate the nvPM portion of the aircraft contribution to total mobile PM accordingly.

C. Projected Reductions in PM Emissions

Due to the technology-following nature of the PM standards, the proposed in-production and new type standards would not result in emission reductions below current levels of engine emissions. The proposed in-production standards for both PM mass and PM number, which would be set at levels where all in-production engines meet the standards, would not affect any in-production engines as shown in Figure IV–1 and Figure IV–2. Thus, the proposed standards are not expected to produce any emission reductions, beyond the business-as-usual fleet turn over that would occur absent of the proposed standards. The EPA projects that all future new type engines would meet the proposed new type standards. There are a few in-production engines that do not meet the proposed new type standards, but since in-production engines would not be subject to these new type standards, engine manufacturers would not be required to make any improvements to these engines to meet the standards. Therefore, there would be no emission reductions from the proposed new type standards.

Most of the in-production engines that do not meet the proposed new type standards are older engines that already have replacement in-production engines that would meet the proposed new type standards. There is only one newer in-production engine (an engine that recently started being manufactured) that would not meet the proposed new type standards and does not currently have a replacement in-production engine. Market forces might drive the manufacturer of this in-production engine to make some improvements to meet the proposed new type standards, but even in this scenario, this manufacturer would still have the option to retest the engine and/or make minor adjustments or design modifications to improve the test result. The other option for this manufacturer would be to bring forward its next generation new type engine to the market a few years earlier than currently planned.[123 124] Since the new type standards would not apply to the in-production engines, this manufacturer could continue producing and selling its one in-production engine that does not meet the proposed new type standards. Further details on market forces are provided later in Section VI.A. In conclusion, when considering the proposed new type standards in the context of the in-production engines that already have a replacement engine or the one in-production engine that does not, there would be no emission reductions from the proposed new type standards.

VI. Technological Feasibility and Economic Impacts

As described earlier, we are proposing PM mass concentration, PM mass, and PM number standards that match ICAO's standards. As discussed previously in Section V.C, for in-production aircraft engines, the 2017 ICAO PM maximum mass concentration standard and the 2020 ICAO PM mass and number standards are set at emission levels where all in-production engines meet these standards. Thus, there would not be costs or emission reductions associated with the proposed standards for in-production engines. For new type engines, the 2020 ICAO PM mass and number standards are set at more stringent emission levels compared to the PM mass and number standards for in-production engines, but nearly all in-production engines meet these new type standards. In addition, in-production engines would not be required to meet these new type standards. Only new type engines would need to comply with the new type standards. The EPA projects that all new type engines entering into service into the future will meet these PM mass and number standards. Thus, EPA expects that there would not be costs and emission reductions from the proposed standards for new type engines. In addition, following the final rulemaking for the PM standards, the FAA would issue a rulemaking to enforce compliance to these standards, and any anticipated certification costs for the PM standards would be accounted for in the FAA rulemaking.

A. Market Considerations

Aircraft and aircraft engines are sold around the world, and international aircraft emission standards help ensure the worldwide acceptability of these products. Aircraft and aircraft engine manufacturers make business decisions and respond to the international market by designing and building products that conform to ICAO's international standards. However, ICAO's standards need to be implemented domestically for products to prove such conformity. Domestic action through EPA rulemaking and subsequent FAA rulemaking enables U.S. manufacturers to obtain internationally recognized U.S. certification, which for the proposed PM standards would ensure type certification consistent with the requirements of the international PM emission standards. This is important, as compliance with the international standards (via U.S. type certification) is a critical consideration in aircraft manufacturer and airlines' purchasing decisions. By implementing the requirements in the United States that align with ICAO standards, any question regarding the compliance of aircraft engines certificated in the United States would be removed. The proposed rule would facilitate the acceptance of U.S. aircraft engines by member States, aircraft manufacturers, and airlines around the world. Conversely, without this domestic action, U.S. aircraft engine manufacturers would be at a competitive disadvantage compared with their international competitors.

In considering the aviation market, it is important to understand that the international PM emission standards were predicated on demonstrating ICAO's concept of technological feasibility; *i.e.,* that manufacturers have already developed or are developing improved technology that meets the ICAO PM standards, and that the new technology will be integrated in aircraft engines throughout the fleet in the time frame provided before the standards' effective date. Therefore, the EPA projects that these proposed standards would impose no additional burden on manufacturers.

B. Conceptual Framework for Technology

The long-established ICAO/CAEP terms of reference were taken into account when deciding the international PM standards, principal among these being technical feasibility. For the ICAO PM standard setting, technical feasibility refers to refers to any

[122] ICAO: Second edition, 2020: Doc 9889, Airport Air Quality Manual. Order Number 9889. See Attachment D to Appendix 1 of Chapter 3. Doc 9889 can be ordered from ICAO website: *https://store.icao.int/en/airport-air-/quality-manual-/doc-9889* (last accessed June 28, 2021).

[123] *https://www.rolls-royce.com/products-and-services/civil-aerospace/future-products.aspx#/;* last accessed on June 26, 2021.

[124] *https://aviationweek.com/mro/rolls-royce-/considers-ultrafan-/development-pause;* last accessed on June 26, 2021.

technology demonstrated to be safe and airworthy proven to Technical Readiness Level [125] (TRL) 8 and available for application over a sufficient range of newly certificated aircraft.[126] This means that the analysis that informed the international standard considered the emissions performance of aircraft engines assumed to be in-production on the implementation date for the PM mass and number standards, January 1, 2023.[127] The analysis included the current in-production fleet and engines scheduled for entry into the fleet by this date. (ICAO/CAEP's analysis was completed in 2018 and considered at the February 2019 ICAO/CAEP meeting.)

C. Technological Feasibility

The EPA and FAA participated in the ICAO analysis that informed the adoption of the international aircraft engine PM emission standards. A summary of that analysis was published in the report of ICAO/CAEP's eleventh meeting (CAEP/11),[128] which occurred in February 2019. However, due to the commercial sensitivity of much of the data used in the ICAO analysis, the publicly available, published version of the ICAO report of the CAEP/11 meeting only provides limited supporting data for the ICAO analysis. Separately from this ICAO analysis and the CAEP/11 meeting report, information on technology for the control of aircraft engine PM emissions is provided in an Independent Expert Review document on technology goals for engines and aircraft, which was published in 2019.[129] Although this ICAO document is primarily used for setting goals, and is not directly related to ICAO's adoption of the PM emission standards, information from the Independent Expert Review is helpful in understanding the state of aircraft engine technology.

The 2019 ICAO Independent Expert Review document indicates that new technologies aimed at reducing aircraft engine NO_X also resulted in an order of magnitude reduction in nvPM mass and nvPM number in comparison to most in-service engines.[130] (As described earlier in Section IV.D.1, only nvPM emissions would be measured in the proposed test procedure for the proposed standards.) Specifically, the current lean-burn engines and some advanced Rich-Quench-Lean (RQL) engines [131] developed for the purpose of achieving low NO_X emissions coincidentally provide order of magnitude reductions in nvPM emissions in comparison to existing RQL engines. However, achieving these levels of nvPM emissions will be more difficult for physically smaller-sized engines due to technical constraints.[132] In addition, some previous generation engines that are in production meet the proposed new type standards, which match the ICAO standards, with considerable margin. When considering the nvPM emission levels for current in-production engines and those engines expected to be in production by the effective date of the ICAO standard, January 1, 2023, the lean-burn, advanced RQL, and some previous generation technologies (with relatively low levels of nvPM emissions) of many of the engines demonstrate that the proposed standards, which match ICAO standards, are technologically feasible.

D. Costs Associated With the Proposed Rule

EPA does not anticipate new technology costs due to the proposed rule. Nevertheless, it is informative to describe the elements of cost analysis for technology improvements, such as non-recurring costs (NRC), certification costs, and recurring costs. As described in the summary of the ICAO analysis for the PM emission standards,[133] generally, CAEP considered certain factors as pertinent to the non-recurring cost estimates of a technology level for engine changes for PM mass and number. The first technology level was regarded as a minor change, and it could include minor improvements, and additional testing and re-certification of emissions. The PM mass and number

[125] TRL is a measure of Technology Readiness Level. CAEP has defined TRL8 as the ''actual system completed and 'flight qualified' through test and demonstration.'' TRL is a scale from 1 to 9, TRL1 is the conceptual principle, and TRL9 is the ''actual system 'flight proven' on operational flight.'' The TRL scale was originally developed by NASA. ICF International, *CO_2 Analysis of CO_2-Reducing Technologies for Aircraft,* Final Report, EPA Contract Number EP–C–12–011, see page 40, March 17, 2015.

[126] ICAO, 2019: *Report of the Eleventh Meeting,* Montreal, 4–15 February 2019, Committee on Aviation Environmental Protection, Document 10126, CAEP11. It is found on page 26 of the English Edition of the ICAO Products & Services 2021 Catalog and is copyright protected: Order No. 10126. For purchase and available at: *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The statement on technological feasibility is located in Appendix C of Agenda Item 3 of this report (see page 3C–4, paragraph 2.2).

[127] ICAO, 2019: *Report of the Eleventh Meeting,* Montreal, 4–15 February 2019, Committee on Aviation Environmental Protection, Document 10126, CAEP11. It is found on page 26 of the English Edition of the ICAO Products & Services 2021 Catalog and is copyright protected: Order No. 10126. For purchase and available at: *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). The summary of technological feasibility and cost information is located in Appendix C to the report on Agenda Item 3 (starting on page 3C–1).

[128] Ibid.

[129] ICAO, 2019: *Independent Expert Integrated Technology Goals Assessment and Review for Engines and Aircraft,* Document 10127. It is found on page 32 of the English Edition of the ICAO Products & Services 2021 Catalog and is copyright protected; Order No. 10127. For purchase and available at: *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021).

[130] Ibid. See page 8 of this document.

[131] For lean-burn engines, ''. . . enough air is introduced with the fuel from the injector so that it is never overall rich. In aviation combustors, the fuel is not premixed and pre-vaporized and in the microscopic region around each droplet, the mixture can be close to stoichiometric. However, the mixture remains lean throughout the combustor and temperature does not approach the stoichiometric value. . . . In a lean-burn combustor, the peak temperatures are not as high, so NO_X is low.'' (See pages 47 and 48.) From previous generation rich-burn to lean-burn technology, an order of magnitude improvement in nvPM mass and nvPM number is likely for the LTO cycle. (See pages 57 and 58.)

For Rich-Quench-Lean (RQL) engines, ''. . . the fuel first burns rich so there is little oxygen free to form NO_X. Dilution air is introduced to take the mixture as quickly as possible through stoichiometric region (when it briefly gets very hot) to a cooler, lean state.'' (See page 47.) Potentially, an order of magnitude improvement in nvPM mass and nvPM number could be achieved for the LTO cycle from previous generation rich-burn to advanced rich-burn combustor technology. (See pages 57 and 58.)

ICAO, 2019: *Independent Expert Integrated Technology Goals Assessment and Review for Engines and Aircraft, Document 10127.* It is found on page 32 of the English Edition of the ICAO Products & Services 2021 Catalog and is copyright protected; Order No. 10127. For purchase and available at: *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). See pages, 47, 48, 57, and 58 of this document.

[132] For example, the relatively small combustor space and section height of these engines creates constraints on the use of low NO_X combustor concepts, which inherently require the availability of greater flow path cross-sectional area than conventional combustors. Also, fuel-staged combustors need more fuel injectors, and this need is not compatible with the relatively smaller total fuel flows of lower thrust engines. (Reductions in fuel flow per nozzle are difficult to attain without having clogging problems due to the small sizes of the fuel metering ports.) In addition, lower thrust engine combustors have an inherently greater liner surface-to combustion volume ratio, and this requires increased wall cooling air flow. Thus, less air will be available to obtain acceptable turbine inlet temperature distribution and for emissions control. U.S. EPA, 2012: Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule, 77 FR 36342, June 18, 2012. (See page 36353.)

[133] ICAO, 2019: *Report of the Eleventh Meeting,* Montreal, 4–15 February 2019, Committee on Aviation Environmental Protection, Document 10126, CAEP11. It is found on page 26 of the English Edition of the ICAO Products & Services 2021 Catalog and is copyright protected: Order No. 10126. For purchase and available at: *https://www.icao.int/publications/catalogue/cat_2021_en.pdf* (last accessed November 15, 2021). See pages 3C–17 to 3C–19 in Appendix C to the report on Agenda Item 3 (starting on page 3C–1).

U.S. EPA, 2012: Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule, 77 FR 36342, June 18, 2012. (See pages 36375 and 36376.)

emission reductions for the first technology level would be from 1 to 10 percent, and the estimated associated costs would be $15 million. The second technology level was considered a scaled proven technology. At this level an engine manufacturer applies its best-proven, combustion technology that was already been certificated in at least one other engine type to another engine type. This second technology level would include substantial modeling, design, combustion rig testing, modification and testing of development engines, and flight-testing. The PM mass and number emission reductions for the second technology level would be a minimum of 10 percent, and the estimated associated costs would be $150 million and $250 million, respectively for PM mass and number. The third technology level was regarded as new technology or current industry best practice, and it was considered where a manufacturer has no proven technology that can be scaled to provide a solution and some technology acquisition activity is required. (One or more manufacturers have demonstrated the necessary technology, while the remaining manufacturers would need to acquire the technology to catch up.) The PM mass and number emission reductions for the third technology level would be a minimum of 25 percent, and the estimated costs would be $500 million. As described earlier, since all in-production engines meet the in-production standards and nearly all in-production engines meet these new type standards—even though they do not have to, we believe that there would not be costs, nor emission reductions, from the proposed rule. Also, because current in-production engines would not be required to make any changes under this proposed rule, there will not be any adverse impact on noise and safety of these engines. Likewise, the noise and safety of future type designs should not be adversely impacted by compliance with these proposed new type standards since all manufacturers currently have engines that meet that level.

Following the final rulemaking for the PM standards, the FAA would issue a rulemaking to enforce compliance to these standards, and any anticipated certification costs for the PM standards would be estimated by FAA. The EPA is not making any attempt to quantify the costs associated with certification actions required by the FAA to enforce these standards.

As described earlier, manufacturers have already developed or are developing technologies to respond to ICAO standards that are equivalent to the proposed standards, and they will comply with the ICAO standards in the absence of U.S. regulations. Also, domestic implementation of the ICAO standards would potentially provide for a cost savings to U.S. manufacturers since it would enable them to certify their aircraft engine (via subsequent FAA rulemaking) domestically instead of having to certificate with a foreign authority (which would occur without this EPA rulemaking). If the proposed PM standards, which would match the ICAO standards, are not ultimately adopted in the United States, U.S. civil aircraft engine manufacturers will have to certify to the ICAO standards at higher costs because they will have to move their entire certification program(s) to a non-U.S. certification authority.[134] Thus, there would be no new certification costs for the proposed rule, and the proposed rule could potentially provide a costs savings.

For the same reasons there would be no NRC and certification costs for the proposed rule as discussed earlier, there would be no recurring costs (recurring operating and maintenance costs) for the proposed rule. The elements of recurring costs would include additional maintenance, material, labor, and tooling costs.

As described earlier in Section IV.E, the EPA is proposing to formally incorporate the PM aspects of the existing information collection request (ICR) into the CFR (or regulations) in the proposed section 1031.150. This proposed action would not create a new requirement for the manufacturers of aircraft engines. Instead, it would simply incorporate the existing reporting requirements into the CFR for ease of use by having all the reporting requirements readily available in the CFR. Thus, this proposed action would not create new costs.

E. Summary of Benefits and Costs

The proposed standards match the ICAO standards, and ICAO intentionally established its standards at a level which is technology following. In doing this, ICAO adheres to its technical feasibility definition for the standard setting process, which is meant to consider the emissions performance of existing in-production engines and those engines expected to be in production by 2023. Independent of the ICAO standards all engines currently manufactured will meet the ICAO in-production standards, and nearly all these same engines will meet the new type standards—even though these new type standards do not apply to in-production engines. Therefore, there would be no costs and no additional benefits from complying with these proposed standards—beyond the benefits from maintaining consistency or harmonizing with the international standards and preventing backsliding by ensuring that all in-production and new type engines have at least the PM emission levels of today's aircraft engines.

[134] In addition, European authorities charge fees to aircraft engine manufacturers for the certification of their engines, but FAA does not charge fees for certification.

VII. Technical Amendments

In addition to the PM-related regulatory provisions discussed earlier in this document, the EPA is proposing technical amendments to the regulatory text that apply more broadly than to just the proposed new PM standards. First, the EPA is proposing to migrate the existing aircraft engine emissions regulations from 40 CFR part 87 to a new 40 CFR part 1031. Along with this migration, the EPA is proposing to restructure the regulations to allow for better ease of use and allow for more efficient future updates. The EPA is also proposing to delete some regulatory provisions and definitions that are unnecessary, as well as make several other minor technical amendments to the regulations. Finally, as explained in more detail below, EPA is also proposing revisions to 40 CFR part 87 to provide continuity during the transition of 40 CFR part 87 to 40 CFR part 1031.

A. Migration of Regulatory Text to New Part

In the 1990s, the EPA began an effort to migrate all transportation-related air emissions regulations to new parts, such that all mobile source regulations are contained in a single group of contiguous parts of the CFR. In addition to the migration, that effort has included clarifications to regulations and improvements to the ease of use through plain language updates and restructuring. To date, the aircraft engine emission regulations contained in 40 CFR part 87 are the only mobile source emission regulations which have not undergone this migration and update process.

The current 40 CFR part 87 was initially drafted in the early 1970s and has seen numerous updates and revisions since then. This has led to a set of aircraft engine emission regulations that is difficult to navigate and contains numerous unnecessary provisions. Further, the current structure of the regulations would make the adoption of the PM standards proposed in this document, as well as any future standards the EPA may propose, difficult to incorporate into the existing regulatory structure.

Therefore, the EPA is proposing to migrate the existing aircraft engine regulations from 40 CFR part 87 to a new 40 CFR part 1031, directly after the airplane GHG standards contained in 40 CFR part 1030. In the process, the EPA is proposing to restructure, streamline and clarify the regulatory provisions for ease of use and to facilitate more efficient future updates. Finally, the EPA is proposing to delete unnecessary regulatory provisions, which are discussed in detail in the next section.

This regulatory migration and restructuring effort is not intended to change any substantive provision of the existing regulatory provisions. Thus, the EPA is not seeking comment on the proposed migration and restructuring, except in cases where a commenter believes that the proposed structure unintentionally changes the meaning of the regulatory text. The following two sections on the deletion of unnecessary provisions and additional technical amendments specify areas where the EPA invites comment on proposed changes to the regulations separate from the proposed migration and restructuring.

As is noted in the amendatory text to the proposed regulations, the EPA is proposing to make this transition effective on January 1, 2023. The new 40 CFR part 1031 would become effective (*i.e.,* be incorporated into the Code of Federal Regulations) 30 days following the publication of the final rule in the **Federal Register**. However, the applicability language in the proposed section 1031.1 indicates that the new 40 CFR part 1031 would apply to engines subject to the standards beginning January 1, 2023. Prior to January 1, 2023, the existing 40 CFR part 87 would continue to apply. On January 1, 2023, the existing 40 CFR part 87 would be replaced with a significantly abbreviated version of 40 CFR part 87 whose sole purpose would be to direct readers to the new 40 CFR part 1031. Additionally, a reference in the current 40 CFR part 1030 to 40 CFR part 87 would be updated to reference 40 CFR part 1031 at that time. The purpose of the abbreviated 40 CFR part 87 is to accommodate any references to 40 CFR part 87 that currently exist in the type certification documentation and advisory circulars issued by the FAA, as well as any other references to 40 CFR part 87 that currently exist elsewhere. Since it would be extremely difficult to identify and update all such documents prior to January 1, 2023, the EPA is instead proposing to adopt language in 40 CFR part 87 that simply states the provisions relating to a particular section of the 40 CFR part 87 apply as described in a corresponding section of the proposed new 40 CFR part 1031.

B. Deletion of Unnecessary Provisions

As previously mentioned, the existing aircraft engine emissions regulations contain some unnecessary provisions which the EPA proposes to delete. These proposed deletions include transitional exemption provisions that are no longer available, several definitions, and some unnecessary language regarding the Secretary of the Department of Transportation, as detailed in the following paragraphs.

The EPA is proposing to not migrate the current 40 CFR 87.23(d)(1) and (3) to the new 40 CFR part 1031. Both these paragraphs contain specific phase-in provisions available for a short period after the Tier 6 NO_X standards began to apply, and their availability as compliance provisions ended on August 31, 2013. Thus, they are no longer needed. It should be noted that while the EPA is proposing to effectively delete these provisions by not migrating them to the proposed new 40 CFR part 1031, the underlying standards referred to in these provisions (*i.e.,* the Tier 4 and 6 NOx standards) are proposed to remain unchanged. Thus, the underlying certification basis for any engines certificated under these provisions will remain intact.

The EPA is also proposing to delete a number of definitions from the current 40 CFR part 87 as it is migrated to the new proposed Part 1031 for two reasons. First, in the effort to streamline and clarify the regulations, some of these definitions have effectively been incorporated directly into the regulatory text where they are used, making a standalone definition unnecessary and redundant. Second, some of these definitions are simply not needed for any regulatory purpose and are likely artifacts of previous revisions to the regulations (*e.g.,* where a regulatory provision was deleted but the associated definition was not).

The definitions that the EPA proposes to delete and the reasons for the proposed deletions are listed in Table VII–1.

TABLE VII–1—LIST OF TERMS FOR WHICH DEFINITIONS ARE PROPOSED TO BE DELETED

Term	Reason for proposed deletion
Act	Not used in the regulatory text.
Administrator	No longer needed as not used in proposed revised and streamlined regulatory text.
Class TP	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.
Class TF	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.
Class T3	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.
Class T8	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.
Class TSS	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.
Commercial aircraft	No longer needed as not used in proposed revised and streamlined regulatory text.
Commercial aircraft gas turbine engine.	No longer needed as not used in proposed revised and streamlined regulatory text.
Date of introduction	Unnecessary definition that is not used in existing regulatory text and not needed in revised regulatory text.
Engine	For regulatory purposes, definition of engine not needed given existing definitions of Aircraft engine, Engine model, and Engine sub-model.
In-use aircraft gas turbine engine	No longer needed in light of proposed deletion of unnecessary provisions and technical amendments to fuel venting requirements.
Military aircraft	Not needed as regulatory text applies to commercial engines.
Operator	No longer needed as not used in proposed revised and streamlined regulatory text.
Production cutoff or the date of production cutoff.	No longer needed with proposed deletion of unnecessary exemption provisions and streamlining of exemption regulatory text.
Tier 0	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.
Tier 2	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.
Tier 4	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.
Tier 6	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.
Tier 8	No longer needed as definition was effectively incorporated into regulatory text during proposed migration.

TABLE VII–1—LIST OF TERMS FOR WHICH DEFINITIONS ARE PROPOSED TO BE DELETED—Continued

Term	Reason for proposed deletion
U.S.-registered aircraft	Unnecessary term that is not used in the regulatory text.

The EPA is also proposing to not migrate the current 40 CFR 87.3(b) to the new 40 CFR part 1031, which in effect will result in its deletion. This paragraph is simply a restatement of an obligation directly imposed under the Clean Air Act the Secretary shall issue regulations to assure compliance with the regulations issued under the Act. This is not a regulatory requirement related to the rest of the part, and as such it is not needed in the proposed 40 CFR part 1031.

C. Other Technical Amendments and Minor Changes

In addition to the migration of the regulations to a new part and the removal of unnecessary provisions just discussed, the EPA is proposing some minor technical amendments to the regulations.

The EPA is proposing to add definitions for ''Airplane'' and ''Emission index.'' Both these terms are used in the current aircraft engine emissions regulations, but they are currently undefined. The new proposed definitions would help provide clarity to the provisions that utilize those terms.

The EPA proposes to modify the definitions for ''Exception'' and ''Exemption.'' The current definitions of these terms in Part 87.1 go beyond simply defining the terms and contain what could more accurately be described as regulatory requirements stating what provisions an excepted or exempted engine must meet. These portions of the definitions, which are more accurately described as regulatory requirements, are proposed to be moved to the introductory text in 1031.15 and 1031.20, as applicable. These proposed changes are in no way intended to change any regulatory requirement applicable to excepted or exempted engines. Rather, they are proposed simply to more clearly separate definitions from the related regulatory requirements.

The EPA is proposing to not migrate the existing 87.42(d) to the proposed new Part 1031, which in effect will result in the deletion of this provision. This paragraph in the annual production report section regards the identification and treatment of confidential business information (CBI) in manufacturers' annual production reports. The EPA is instead relying on the existing CBI regulations in 40 CFR 1068.10 (as referenced in the proposed 1031.170). This proposed change would have no impact on the ability of manufacturers to make claims of CBI, or in the EPA's handling of such claims. However, it would assure a more consistent treatment of CBI across mobile source programs.

The EPA is proposing a minor change to the existing emissions requirements for spare engines, as found in 87.50(c)(2). In the proposed regulatory text for 1031.20(a), the EPA is proposing to delete the existing provision that a spare engine is required to meet standards applicable to Tier 4 or later engines (currently contained in 40 CFR 87.50(c)(2)). The EPA is proposing to retain and migrate to part 1031 the requirement in 40 CFR 87.50(c)(3) such that a spare engine would need to be certificated to emission standards equal to or lower than those of the engines they are replacing, for all regulated pollutants. This proposed deletion of 40 CFR 87.50(c)(2) would align with ICAO's current guidance on the emissions of spare engines and is consistent with U.S. efforts to secure the highest practicable degree of uniformity in aviation regulations and standards. The EPA does not believe this proposed change would have any impact on current industry practices. Deleting the provision currently in 40 CFR 87.50(c)(2) would leave in place the requirement that any new engine manufactured as a spare would need to be at least as clean as the engine it is replacing (as stated in the current 40 CFR 87.50(c)(3)), but with no requirement that it meet standards applicable to Tier 4 or later engines. Thus, under this proposed deletion a new spare engine could, in theory, be manufactured that only met pre-Tier 4 standards. The Tier 4 standards became effective in 2004, so the proposed deletion would only impact spare engines manufactured to replace engines manufactured roughly before 2004. It is extremely unlikely that a manufacturer would build a new engine as a replacement for such an old design as it would be very disruptive to the manufacturing of current designs for new aircraft. Rather, it is common practice that spares for use in replacing older engines would not be newly manufactured engines of an old design, but engines that have been taken from similar aircraft that have been retired. The EPA does not believe that any engines would be manufactured to pre-Tier 4 designs for use as spare engines given current practices. Thus, the EPA does not believe that this proposed deletion of 40 CFR 87.50(c)(2) for the purposes of uniformity would have any practical impact on current industry practices.

The EPA is proposing to align the applicability of smoke number standards for engines used in supersonic airplanes with ICAO's applicability. The EPA adopted emission standards for engines used on supersonic airplanes in 2012.[135] Those standards were equivalent to ICAO's existing standards with one exception. ICAO's emission standards fully apply to all engines to be used on supersonic airplanes, regardless of rated output. In an apparent oversight, the EPA only applied the smoke number standards to engines of greater than or equal to 26.7 kN rated output. Thus, the EPA is proposing to apply smoke number standards to include engines below 26.7 kN rated output for use on supersonic airplanes which are equivalent to ICAO's provisions. This change is proposed consistent with U.S. efforts to secure the highest practicable degree of uniformity in aviation regulations and standards and would have no practical impact on engine manufacturers. The EPA is currently unaware of any engines in production which could be used on supersonic airplanes, and those being developed for application to future supersonic airplanes are expected to be well above 26.7 kN rated output, and thus, they would be covered by the existing smoke number standard. Throughout its regulations, the EPA is proposing to align with ICAO regarding a common rated output threshold for emission regulations. The applicability and/or stringency of several aircraft engine emission standards can be different depending on whether an engine's rated output is above or below 26.7 kN. In the ICAO regulations, the threshold is consistently stated as either greater than, or less than or equal to 26.7 kN. In the current 40 CFR part 87, the equal to portion of the threshold is applied inconsistently. In some cases, it

[135] 77 FR 36342, June 18, 2012.

is expressed as less than, and greater than or equal to. In other cases, it is expressed as greater than, and less than or equal to. The proposal is to make all instances in the proposed Part 1031 consistent with ICAO, *i.e.,* greater than, and less than or equal to. As there are no current engines with a rated output of exactly at 26.7 kN, this proposed change would have no practical impact. However, it is consistent with U.S. efforts to secure the highest practicable degree of uniformity in aviation regulations and standards.

The EPA is proposing to incorporate by reference Appendix 1 of ICAO's Annex 16, Volume II. This appendix deals with the determination of a test engine's reference pressure ratio, and its exclusion from the U.S. regulations was an oversight. Other Annex 16, Volume II appendices which contain test procedures, fuel specifications, and other compliance-related provisions have been incorporated by reference into the U.S. regulations for many years, and it is important to correct this oversight so that the complete testing and compliance provisions are clear.

The EPA is proposing to streamline, restructure, and update the exemption provisions currently in 40 CFR 87.50. First, this section contains provisions regarding exemptions, exceptions, and annual reporting provisions relating to exempted and excepted engines. The EPA is proposing to migrate the exceptions section concerning spare engines (87.50(c)) to its own new section 1031.20(a), with the proposed changes discussed earlier in this section. The provisions regarding the annual reporting of exempted and excepted engines are proposed to be incorporated into the new annual reporting section 1031.150. These reporting provisions otherwise remain unchanged. Section 87.50(a), regarding engines installed on new aircraft, and section 87.50(b), regarding temporary exemptions based on flights for short durations at infrequent intervals, are proposed to be migrated to a new section 1031.15. The temporary exemptions provisions remain unchanged, with the exception of the addition of ''of Transportation'' after ''Secretary'' in 1031.15(b)(4) to provide additional clarity. The proposed changes to the exemptions for engines installed on new aircraft are a bit more extensive, as discussed in the next paragraph.

In 2012, the EPA adopted new exemption provisions specifically to provide flexibility during the transition to Tier 6 and Tier 8 NO_X standards.[136] These provisions were only available through December 31, 2016 and are proposed to be deleted, as previously discussed. However, during the adoption of those transitional flexibilities, the EPA inadvertently replaced the existing exemption provisions with the new transitional provisions rather than appending the transitional provisions to the existing ones. This left 87.50 with no general exemption language, only those provisions specific to the newly adopted NO_X standards. Given that the transitional NO_X exemption provisions have expired and are now obsolete, the EPA is proposing to delete them rather than migrate them to the new 1031.15. The EPA is further proposing to restore the general exemption authority that was inadvertently removed in 2012. In a recent action which established GHG standards for airplanes, the EPA adopted much more streamlined exemption provisions for airplanes in consultation with the FAA.[137] The EPA is proposing to adopt similarly streamlined general exemption provisions for aircraft engines as well, as contained in the proposed 1031.15(a).

The EPA is proposing some changes relative to the prohibition on fuel venting. The fuel venting standard is intended to prevent the discharge of fuel to the atmosphere following engine shutdown, as explicitly stated in 40 CFR 87.11(a). The existing definition for fuel venting emissions in 87.1 defines fuel venting emissions as fuel discharge during all normal ground and flight operations. As the standard section itself limits the applicability only to venting that occurs following engine shutdown, consistent with ICAO's fuel venting provisions, the EPA is proposing to delete the definition for fuel venting emissions as both unnecessary and contradictory to the actual requirement. Further, the EPA is proposing to add the word ''liquid'' before fuel in the fuel venting requirements, consistent with the ICAO fuel venting provisions. Neither of these proposed changes would have any practical effect on the requirements on engine manufacturers, but these changes both clarify the requirements and fully align with ICAO standards and recommended practices, consistent with U.S. efforts to secure the highest practicable degree of uniformity in aviation regulations and standards.

The EPA is proposing to modify the applicability date language associated with the standards applicable to Tier 8 engines, as contained in the proposed 1031.60(e)(2). The applicability of new type standards has traditionally been linked to the date of the first individual production engine of a given type, both for EPA regulations and ICAO regulations. This approach has been somewhat cumbersome in the past because a manufacturer would have to estimate what standards would be in effect when actual production of a new type began in order to determine to what standards a new type engine would be subject. Given that the engine type certification process can take up to three years, this approach has proven problematic during periods of transition from one standard to another. To address this concern, ICAO agreed at the CAEP/11 meeting in 2019 to transition from the date of manufacture of the first production engine to the date of application for a type certificate to determine standards applicability for new types. The EPA was actively involved in the deliberations that led to this agreement and supported the transition from date of first individual production model to date of application for type certification as the basis for standards applicability in the future. This approach is reflected in the applicability date provisions of the proposed PM standards, consistent with ICAO. The EPA is also proposing to adopt it for existing standards applicable to Tier 8 engines as well. This proposed change would have no impact on manufacturers as the existing standards applicable to Tier 8 engines have been in place since 2014, and there are no new gaseous or smoke number standards set to take effect for such engines. Thus, this proposed change is solely intended to improve consistency with ICAO and to structure the regulations such that the adoption of any future standards using this applicability date approach would be straightforward.

The EPA is proposing to revise the definition of ''date of manufacture'' by replacing ''competent authority'' with ''recognized airworthiness authority'' in two places. The term ''competent'' has no specific meaning in the context of either the EPA's or the FAA's regulations. However, the FAA does recognize other airworthiness authorities for engines certificated outside the United States, as indicated through existing bilateral agreements with such authorities. Also, the EPA is proposing to update its definition of ''supersonic'' by replacing it with a new definition of ''supersonic airplane.'' The proposed new definition for ''supersonic airplane'' is based on a revised definition for such proposed by the FAA in a recent proposed action

[136] 77 FR 36342, June 18, 2012.

[137] 86 FR 2136, January 11, 2021.

regarding noise regulations for supersonic airplanes.[138] This proposed new definition would provide greater assurance that the proposed standards applicable to engines used on supersonic airplanes would apply to the engines for which they are intended.

The EPA is proposing to update several definitions and align them with definitions included in the recent airplane GHG regulations.[139] The definitions proposed to be updated are for ''Aircraft,'' ''Aircraft engine,'' ''Airplane,'' ''Exempt,'' and ''Subsonic.'' These definitions are proposed to be updated in the aircraft engine regulations simply for consistency with the airplane GHG regulations and with FAA regulations. The changes being proposed would not have any impact on the regulatory requirements related to the definitions.

The EPA is also proposing to address an unintentional applicability gap related to EPA's airplane GHG standards that could potentially exclude some airplanes from being subject to the standards. The intention of the international standards was to cover all jet airplanes with an MTOM greater than 5,700 kg. At ICAO it was agreed that airplanes with an MTOM less than 60,000 kg and with 19 seats or fewer could have extra time to comply with the standards (incorporated at 40 CFR 1030.1(a)(2)). With that in mind, 40 CFR 1030.1(a)(1) was written to cover airplanes with 20 or more seats and an MTOM greater than 5,700 kg. However, this means that airplanes with 19 seats or fewer and an MTOM greater than 60,000 kg are not covered by the current regulations but would be covered by the ICAO CO_2 standard. While the EPA is not aware of any airplanes in this size range, the intent of the EPA's GHG rule was to cover all jet airplanes with MTOM greater than 5,700 kg. The EPA is proposing to adopt new language at 40 CFR 1030.1(a)(1)(iv)–(vi) to cover these airplanes, should they be produced. This proposed change would expand the current applicability of the GHG standards on the date this final rulemaking goes into effect. However, airplanes in this size category were considered as part of the GHG standard setting process and had been intended to be subject to the GHG standards.

The EPA is proposing to correct the effective date of new type design GHG standards for turboprop airplanes (with a maximum takeoff mass greater than 8,618 kg), which is currently specified in 40 CFR 1030.1(a)(3)(ii) as January 1, 2020. The EPA did not intend to retroactively apply these standards using the ICAO new type start date for these airplanes. Rather, this effective date should have been January 11, 2021, to be consistent with the effective date of new type standards for other categories of airplanes in this part (*e.g.,* 40 CFR 1030.1(a)(1)). Based on consultations with the FAA, this proposed change to part 1030 will not impact any airplanes.

Finally, the EPA is proposing a minor word change to the existing applicability language in 40 CFR part 1030 in order to make it consistent with the current applicability language in the EPA's airplane engine regulations as well as FAA regulations. Specifically, the current language in 40 CFR 1030.1(c)(7) refers to airplanes powered with piston engines. The EPA is proposing to replace the word ''piston'' with ''reciprocating'' in 40 CFR 1030.1(c)(7) to align it with the existing 40 CFR 87.3(a)(1), the proposed language in 40 CFR 1031.1(b)(1), and existing FAA regulations in 14 CFR parts 1 and 33. This proposed change is for consistency among federal regulations and to avoid any confusion that may be caused by the use of two different terms. This proposed change would have no material impact on the meaning of the regulatory text.

VIII. Statutory Authority and Executive Order Reviews

Additional information about these statutes and Executive orders can be found at *https://www.epa.gov/laws-regulations/laws-and-executive-orders.*

A. Executive Order 12866: Regulatory Planning and Review and Executive Order 13563: Improving Regulation and Regulatory Review

This action is a significant regulatory action that was submitted to the Office of Management and Budget (OMB) for review. This action raises ''. . . novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in this Executive Order.'' This action promulgates new aircraft engine emissions regulations and as such, requires consultation and coordination with the Federal Aviation Administration (FAA). Accordingly, the EPA submitted this action to the OMB for review under E.O. 12866 and E.O. 13563. Any changes made in response to OMB recommendations have been documented in the docket. Section VI.E of this preamble summarizes the cost and benefits of this action.

B. Paperwork Reduction Act (PRA)

This action does not impose any new information collection burden under the PRA. OMB has previously approved the information collection activities contained in the existing regulations and has assigned OMB control number 2060–0680. This proposed rule would codify that existing collection by including the current nvPM data collection in the proposed regulatory text, but it would not add any new reporting requirements.

C. Regulatory Flexibility Act (RFA)

I certify that this action will not have a significant economic impact on a substantial number of small entities under the RFA. Among the potentially affected entities (manufacturers of aircraft engines) there is only one small entity, and that aircraft engine manufacturer does not make engines in the category subject to the proposed new provisions contained in this document (*i.e.,* engines greater than 26.7 kN rated output) and has not indicated any plans to begin such production. Therefore, this action will not impose any requirements on small entities. Supporting information can be found in the docket.[140]

D. Unfunded Mandates Reform Act (UMRA)

This action does not contain any unfunded mandate as described in UMRA, 2 U.S.C. 1531–1538, and does not significantly or uniquely affect small governments. The action imposes no enforceable duty on any state, local or tribal governments or the private sector.

E. Executive Order 13132: Federalism

This action does not have federalism implications. It will not have substantial direct effects on the states, on the relationship between the national government and the states, or on the distribution of power and responsibilities among the various levels of government.

F. Executive Order 13175: Consultation and Coordination With Indian Tribal Governments

This action does not have tribal implications as specified in Executive Order 13175. This action regulates the manufacturers of aircraft engines and will not have substantial direct effects on one or more Indian tribes, on the relationship between the Federal Government and Indian tribes, or on the distribution of power and

[138] 85 FR 20431, April 13, 2020.

[139] 86 FR 2136, January 11, 2021.

[140] U.S. EPA, 2021: *Determination of no SISNOSE for Proposed Aircraft Engine Emission Standards,* Memorandum to Docket ID No. EPA–HQ–OAR–2019–0660. This memorandum describes that the only small entity is Williams Int'l, which only make engines below 26.7 kN. Thus, they are not subject to the proposed standards.

responsibilities between the Federal Government and Indian tribes. Thus, Executive Order 13175 does not apply to this action.

G. Executive Order 13045: Protection of Children From Environmental Health Risks and Safety Risks

This action is not subject to Executive Order 13045 because it is not economically significant as defined in Executive Order 12866. This action's health and risk assessments are contained in Section III.

H. Executive Order 13211: Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution or Use

This action is not a ''significant energy action'' because it is not likely to have a significant adverse effect on the supply, distribution or use of energy. These aircraft engine emissions regulations are not expected to result in any changes to aircraft fuel consumption.

I. National Technology Transfer and Advancement Act (NTTAA)

This action involves technical standards for testing emissions for aircraft gas turbine engines. EPA is proposing to use test procedures contained in ICAO's International Standards and Recommended Practices Environmental Protection, Annex 16, Volume II along with the modifications contained in this rulemaking as described in Section IV. These procedures are currently used by all manufacturers of aircraft gas turbine engines to demonstrate compliance with ICAO emissions standards.

In accordance with the requirements of 1 CFR 51.5, we are incorporating by reference the use of test procedures contained in ICAO's International Standards and Recommended Practices Environmental Protection, Annex 16, Volume II, along with the modifications contained in this rulemaking. This includes the following standards and test methods:

Standard or test method	Regulation	Summary
ICAO 2017, *Aircraft Engine Emissions,* Annex 16, Volume II, Fourth Edition, July 2017, as amended by Amendment 10, January 1, 2021.	40 CFR 1031.140(a), (b), (f), (g), and (h), and 40 CFR 1031.205.	Test method describes how to measure PM, gaseous and smoke emissions from aircraft engines.

The version of the ICAO Annex 16, Volume II that is proposed to be incorporated into the new 40 CFR part 1031 is the same version that is currently incorporated by reference in 40 CFR 87.1, 40 CFR 87.42(c), and 40 CFR 87.60(a) and (b).

The referenced standards and test methods may be obtained through the International Civil Aviation Organization, Document Sales Unit, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (514) 954–8022, *www.icao.int,* or *sales@icao.int.*

J. Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations

The EPA believes that this action does not have disproportionately high and adverse human health or environmental effects on minority populations, low-income populations and/or indigenous peoples, as specified in Executive Order 12898 (59 FR 7629, February 16, 1994). This proposed action would not achieve emission reductions and would therefore result in no improvement in per-aircraft emissions for all communities living near airports. EPA describes in Section III.G the existing literature reporting on disparities in potential exposure to aircraft emissions for people of color and low-income populations. EPA, in an action separate from this proposed rulemaking, will be conducting an analysis of the communities residing near airports where jet aircraft operate in order to more fully understand disproportionately high and adverse human health or environmental effects on people of color, low-income populations and/or indigenous peoples, as specified in Executive Order 12898. The results of this analysis could help inform additional policies to reduce pollution in communities living in close proximity to airports.

List of Subjects

40 CFR Parts 87 and 1031

Environmental protection, Air pollution control, Aircraft, Incorporation by reference.

40 CFR Part 1030

Environmental protection, Air pollution control, Aircraft, Greenhouse gases.

Michael S. Regan,

Administrator.

For the reasons set forth in the preamble, EPA proposes to amend 40 CFR parts 87, 1030, and 1031 as follows:

PART 87—CONTROL OF AIR POLLUTION FROM AIRCRAFT AND AIRCRAFT ENGINES

■ 1. Revise part 87 to read as follows:

PART 87—CONTROL OF AIR POLLUTION FROM AIRCRAFT AND AIRCRAFT ENGINES

Authority: 42 U.S.C. 7401 *et seq.*

§ 87.1 Definitions.

Definitions apply as described in 40 CFR 1031.205.

§ 87.2 Abbreviations.

Abbreviations apply as described in 40 CFR 1031.200.

§ 87.3 General applicability and requirements.

Provisions related to the general applicability and requirements of aircraft engine standards apply as described in 40 CFR 1031.1.

§ 87.10 Applicability—fuel venting.

Fuel venting standards apply to certain aircraft engines as described in 40 CFR 1031.30(b).

§ 87.11 Standard for fuel venting emissions.

Fuel venting standard apply as described in 40 CFR 1031.30(b).

§ 87.20 Applicability—exhaust emissions.

Exhaust emission standards apply to certain aircraft engines as described in 40 CFR 1031.40 through 1031.90.

§ 87.21 Exhaust emission standards for Tier 4 and earlier engines.

Exhaust emission standards apply to new aircraft engines as described in 40 CFR 1031.40 through 1031.90.

§ 87.23 Exhaust emission standards for Tier 6 and Tier 8 engines.

Exhaust emission standards apply to new aircraft engines as follows:

(a) New turboprop aircraft engine standards apply as described in 40 CFR 1031.40.

(b) New supersonic engine standards apply as described in 40 CFR 1031.90.

(c) New subsonic turbofan or turbojet aircraft engine standards apply as follows:

(1) Standards for engines with rated output at or below 26.7 kN thrust apply as described in 40 CFR 1031.50.

(2) Standards for engines with rated output above 26.7 kN thrust apply as described in 40 CFR 1031.60.

(d) NO_X standards apply based on the schedule for new type and in-production aircraft engines as described in 40 CFR 1031.60.

§ 87.31 Exhaust emission standards for in-use engines.

Exhaust emission standards apply to in-use aircraft engines as described in 40 CFR 1031.60.

§ 87.48 Derivative engines for emissions certification purposes.

Provisions related to derivative engines apply as described in 40 CFR 1031.130.

§ 87.50 Exemptions and exceptions.

Provisions related to exceptions apply as described in 40 CFR 1031.11. Provisions related to exemptions apply as described in 40 CFR 1031.10.

§ 87.60 Testing engines.

Test procedures for measuring gaseous emissions and smoke number apply as described in 40 CFR 1031.140.

PART 1030—CONTROL OF GREENHOUSE GAS EMISSIONS FROM ENGINES INSTALLED ON AIRPLANES

■ 2. The authority citation for part 1030 continues to read as follows:

Authority: 42 U.S.C. 7401–7671q.

■ 3. Amend § 1030.1 by:
■ a. Revising paragraphs (a) introductory text and (a)(1)(iii);
■ b. Adding paragraphs (a)(1)(iv) through (vi);
■ c. Revising paragraphs (a)(3)(ii) and (c)(7).

The revisions and additions read as follows:

§ 1030.1 Applicability.

(a) Except as provided in paragraph (c) of this section, when an aircraft engine subject to 40 CFR part 1031 is installed on an airplane that is described in this section and subject to title 14 of the Code of Federal Regulations, the airplane may not exceed the Greenhouse Gas (GHG) standards of this part when original civil certification under title 14 is sought.

(1) * * *

(iii) An application for original type certification that is submitted on or after January 11, 2021; or

(iv) A type-certificated maximum passenger seating capacity of 19 seats or fewer, and

(v) A MTOM greater than 60,000 kg, and

(vi) An application for original type certification that is submitted on or after [DATE OF PUBLICATION OF FINAL RULE IN THE FEDERAL REGISTER].

* * * * *

(3) * * *

(ii) An application for original type certification that is submitted on or after January 11, 2021.

* * * * *

(c) * * *

(7) Airplanes powered by reciprocating engines.

■ 4. Add part 1031 to read as follows:

PART 1031—CONTROL OF AIR POLLUTION FROM AIRCRAFT ENGINES

Subpart A—Scope and Applicability

Subpart B—Emission Standards and Measurement Procedures

Subpart C—Reporting and Recordkeeping

Subpart D—Reference Information

Authority: –42 U.S.C. 7401–7671q.

Subpart A—Scope and Applicability

§ 1031.1 Applicability.

This part applies to aircraft gas turbine engines on and after January 1, 2023. Emission standards apply as described in subpart B of this part.

(a) Except as provided in paragraph (b) of this section, the regulations of this part apply to aircraft engines subject to 14 CFR part 33.

(b) The requirements of this part do not apply to the following aircraft engines:

(1) Reciprocating engines (including engines used in ultralight aircraft).

(2) Turboshaft engines such as those used in helicopters.

(3) Engines used only in aircraft that are not airplanes.

(4) Engines not used for propulsion.

§ 1031.5 Engines installed on domestic and foreign aircraft.

The Secretary of Transportation shall apply these regulations to aircraft of foreign registry in a manner consistent with obligations assumed by the United States in any treaty, convention or agreement between the United States and any foreign country or foreign countries.

§ 1031.10 State standards and controls.

No State or political subdivision of a State may adopt or attempt to enforce any aircraft or aircraft engine standard with respect to emissions unless the standard is identical to a standard that applies to aircraft or aircraft engines under this part.

§ 1031.15 Exemptions.

Individual engines may be exempted from current standards as described in this section. Exempted engines must conform to regulatory conditions specified for an exemption in this part and other applicable regulations. Exempted engines are deemed to be ‘‘subject to’’ the standards of this part even though they are not required to comply with the otherwise applicable requirements. Engines exempted with respect to certain standards must comply with other standards as a condition of the exemption.

(a) Engines installed in new aircraft. Each person seeking relief from compliance with this part at the time of certification must submit an application for exemption to the FAA in accordance with the regulations of 14 CFR parts 11 and 34. The FAA will consult with the EPA on each exemption application request before the FAA takes action. Exemption requests under this paragraph (a) are effective only with FAA approval and EPA's written concurrence.

(b) Temporary exemptions based on flights for short durations at infrequent intervals. The emission standards of this part do not apply to engines that power aircraft operated in the United States for short durations at infrequent intervals. Exemption requests under this paragraph (b) are effective with FAA approval. Such operations are limited to:

(1) Flights of an aircraft for the purpose of export to a foreign country, including any flights essential to demonstrate the integrity of an aircraft prior to its flight to a point outside the United States.

(2) Flights to a base where repairs, alterations or maintenance are to be performed, or to a point of storage, and flights for the purpose of returning an aircraft to service.

(3) Official visits by representatives of foreign governments.

(4) Other flights the Secretary of Transportation determines to be for short durations at infrequent intervals. A request for such a determination shall be made before the flight takes place.

§ 1031.20 Exceptions.

Individual engines may be excepted from current standards as described in this section. Excepted engines must conform to regulatory conditions specified for an exception in this part and other applicable regulations. Excepted engines are deemed to be ''subject to'' the standards of this part even though they are not required to comply with the otherwise applicable requirements. Engines excepted with respect to certain standards must comply with other standards from which they are not excepted.

(a) *Spare engines.* Newly manufactured engines meeting the definition of ''spare engine'' are automatically excepted as follows:

(1) This exception allows production of a newly manufactured engine for installation on an in-use aircraft. It does not allow for installation of a spare engine on a new aircraft.

(2) Spare engines excepted under this paragraph (a) may be used only if they are certificated to emission standards equal to or lower than those of the engines they are replacing, for all regulated pollutants.

(3) Engine manufacturers do not need to request approval to produce spare engines, but must include information about spare engine production in the annual report specified in § 1031.150(d).

(4) The permanent record for each engine excepted under this paragraph (a) must indicate that the engine was manufactured as an excepted spare engine.

(5) Engines excepted under this paragraph (a) must be labeled with the following statement: ''EXCEPTED SPARE''.

(b) [Reserved]

Subpart B—Emission Standards and Measurement Procedures

§ 1031.30 Overview of emission standards and general requirements.

(a) *Overview of standards.* Standards apply to different types and sizes of aircraft engines as described in §§ 1031.40 through 1031.90. All new engines and some in-use engines are subject to smoke standards (either based on smoke number or nvPM mass concentration). Some new engines are also subject to standards for gaseous emissions (HC, CO, and NO_X) and nvPM (mass and number).

(1) Where there are multiple tiers of standards for a given pollutant, the named tier generally corresponds to the meeting of the International Civil Aviation Organization's (ICAO's) Committee on Aviation Environmental Protection (CAEP) at which the standards were agreed to internationally. Other standards are named Tier 0, Tier 1, or have names that describe the standards.

(2) Where a standard is specified by a formula, determine the level of the standard as follows:

(i) For smoke number standards, calculate and round the standard to the nearest 0.1 smoke number.

(ii) For maximum nvPM mass concentration standards, calculate and round the standard to the nearest 1 µg/m^3.

(iii) For LTO nvPM mass standards, calculate and round the standard to three significant figures.

(iv) For LTO nvPM number standards calculate and round the standard to three significant figures.

(v) For gaseous emission standards, calculate and round the standard to three significant figures, or to the nearest 0.1 g/kN for turbojet and turbofan standards at or above 100 g/kN.

(3) Perform tests using the procedures specified in § 1031.140 to measure emissions for comparing to the standard. Engines comply with an applicable standard if test results show that the engine type certificate family's characteristic level does not exceed the numerical level of that standard.

(4) Engines that are covered by the same type certificate and are determined to be derivative engines for emissions certification purposes under the requirements of § 1031.130 are subject to the emission standards of the previously certified engine. Otherwise, the engine is subject to the emission standards that apply to a new engine type.

(b) *Fuel venting.* (1) The fuel venting standard in paragraph (b)(2) of this section applies to new subsonic and supersonic aircraft engines subject to this part. This fuel venting standard also applies to the following in-use engines:

(i) Turbojet and turbofan engines with rated output at or above 36 kN thrust manufactured after February 1, 1974.

(ii) Turbojet and turbofan engines with rated output below 36 kN thrust manufactured after January 1, 1975.

(iii) Turboprop engines manufactured after January 1, 1975.

(2) Engines may not discharge liquid fuel emissions into the atmosphere. This standard is directed at eliminating intentional discharge of liquid fuel drained from fuel nozzle manifolds after engines are shut down and does not apply to normal fuel seepage from shaft seals, joints, and fittings. Certification for the fuel venting standard will be based on an inspection of the method designed to eliminate these emissions.

§ 1031.40 Turboprop engines.

The following standards apply to turboprop engines with rated output at or above 1,000 kW:

(a) *Smoke.* (1) Engines of a type or model for which the date of manufacture of the individual engine is on or after January 1, 1984, may not have a characteristic level for smoke number exceeding the following value:

$SN = 187 \cdot rO^{-0.168}$

(2) [Reserved]

(b) [Reserved]

§ 1031.50 Subsonic turbojet and turbofan engines at or below 26.7 kN thrust.

The following standards apply to new turbofan or turbojet aircraft engines with rated output at or below 26.7 kN thrust that are installed in subsonic aircraft:

(a) *Smoke.* (1) Engines of a type or model for which the date of manufacture of the individual engine is on or after August 9, 1985 may not have a characteristic level for smoke number exceeding the lesser of 50 or the following value:

$SN = 83.6 \cdot rO - 0.274$

(2) [Reserved]

(b) [Reserved]

§ 1031.60 Subsonic turbojet and turbofan engines above 26.7 kN thrust.

The following standards apply to new turbofan or turbojet aircraft engines with rated output above 26.7 kN thrust that are installed in subsonic aircraft:

(a) *Smoke.* (1) Tier 0. Except as specified in (a)(2) of this section, engines of a type or model with rated output at or above 129 kN, and for which the date of manufacture of the individual engine after January 1, 1976 and is before January 1, 1984 may not have a characteristic level for smoke number exceeding the following emission standard:

$SN = 83.6 \cdot rO^{-0.274}$

(2) *JT8D and JT3D engines.* (i) Engines of the type JT8D for which the date of manufacture of the individual engine is on or after February 1, 1974 and before January 1, 1984 may not have a characteristic level for smoke number exceeding an emission standard of 30.

(ii) Engines of the type JT3D for which the date of manufacture of the individual engine is on or after January 1, 1978 and before January 1, 1984 may not have a characteristic level for smoke number exceeding an emission standard of 25.

(3) *Tier 0 in-use.* Except for engines of the type JT8D and JT3D, in-use engines with rated output at or above 129 kN thrust may not exceed the following smoke number standard:

$SN = 83.6 \cdot rO^{-0.274}$

(4) *JT8D in-use.* In-use aircraft engines of the type JT8D may not exceed a smoke number standard of 30.

(5) *Tier 1.* Engines of a type or model for which the date of manufacture of the individual engine is on or after January 1, 1984 and before January 1, 2023 may not have a characteristic level for smoke number exceeding an emission standard that is the lesser of 50 or the following:

$SN = 83.6 \cdot rO^{-0.274}$

(6) *Tier 10.* Engines of a type or model for which the date of manufacture of the individual engine is on or after January 1, 2023 may not have a characteristic level for the maximum nvPM mass concentration in µg/m^3 exceeding the following emission standard:

$nvPM_{MC} = 10^{(3 + 2.9 \cdot rO^{-0.274})}$

(b) *LTO nvPM mass and number.* An engine's characteristic level for nvPM mass and nvPM number may not exceed emission standards as follows:

(1) *Tier 11 new type.* The following emission standards apply to engines of a type or model for which an application for original type certification is submitted on or after January 1, 2023 and for engines covered by an earlier type certificate if they do not qualify as derivative engines for emission purposes as described in § 1031.130:

TABLE 1 TO § 1031.60(b)(1)—TIER 11 NEW TYPE nvPM STANDARDS

Rated output (rO) in kN	$nvPM_{mass}$ in milligrams/kN	$nvPM_{num}$ in particles/kN
26.7 < rO ≤ 150	1251.1 − 6.914·rO	1.490·10^16 − 8.080·10^13·rO
rO > 150	214.0	2.780·10^15

(2) *Tier 11 in-production.* The following emission standards apply to engines of a type or model for which the date of manufacture of the individual engine is on or after January 1, 2023:

TABLE 2 TO § 1031.60(b)(2)—TIER 11 IN-PRODUCTION nvPM STANDARDS

Rated output (rO) in kN	$nvPM_{mass}$ in milligrams/kN	$nvPM_{num}$ in particles/kN
26.7 < rO ≤ 200	4646.9 − 21.497·rO	2.669·10^16 − 1.126·10^14·rO
rO > 200	347.5	4.170·10^15

(c) *HC.* Engines of a type or model for which the date of manufacture of the individual engine is on or after January 1, 1984 may not have a characteristic level for HC exceeding an emission standard of 19.6 g/kN.

(d) *CO.* Engines of a type or model for which the date of manufacture of the individual engine is on or after July 7, 1997 may not have a characteristic level for CO exceeding an emission standard of 118 g/kN.

(e) *NO_X.* An engine's characteristic level for NO_X may not exceed emission standards as follows:

(1) *Tier 0.* The following NO_X emission standards apply to engines of a type or model for which the date of manufacture of the first individual production model was on or before December 31, 1995 and for which the date of manufacture of the individual engine was on or after December 31, 1999 and before December 31, 2003:

$NO_X + (40 + 2(rPR))\ g/kN$

(2) *Tier 2.* The following NO_X emission standards apply to engines of a type or model for which the date of manufacture of the first individual production model was after December 31, 1995 or for which the date of manufacture of the individual engine was on or after December 31, 1999 and before December 31, 2003:

$NO_X + (32 + 1.6(rPR))\ g/kN$

(3) *Tier 4 new type.* The following NO_X emission standards apply to engines of a type or model for which the date of manufacture of the first individual production model was after December 31, 2003 and before July 18, 2012:

TABLE 3 TO § 1031.60(e)(3)—TIER 4 NEW TYPE NO_X STANDARDS

If the rated pressure ratio (rPR) is—	and the rated output (kN) is—	the NO_X emission standard (g/kN) is—
(i) rPR ≤ 30	(A) 26.7 < rO ≤ 89	37.572 + 1.6(rPR) − 0.2087(rO)
	(B) rO > 89	19 + 1.6·rPR

TABLE 3 TO § 1031.60(e)(3)—TIER 4 NEW TYPE NO_X STANDARDS—Continued

If the rated pressure ratio (rPR) is—	and the rated output (kN) is—	the NO_X emission standard (g/kN) is—
(ii) 30 < rPR < 62.5	(A) 26.7 < rO ≤ 89	42.71 + 1.4286(rPR) − 0.4013(rO) + 0.00642(rPR × rO)
	(B) rO > 89	7 + 2·rPR
(iii) rPR ≥ 82.6	All	32 + 1.6·rPR

(4) *Tier 6 in-production.* The following NO_X emission standards apply to engines of a type or model for which the date of manufacture of the individual engine is on or after July 18, 2012:

TABLE 4 TO § 1031.60(e)(4)—TIER 6 IN-PRODUCTION NO_X STANDARDS

If the rated pressure ratio (rPR) is—	and the rated output (kN) is—	the NO_X emission standard (g/kN) is—
(i) rPR ≤ 30	(A) 26.7 < rO ≤ 89	38.5486 + 1.6823·rPR − 0.2453·rO − 0.00308·rPR·rO
	(B) rO > 89	16.72 + 1.4080·rPR
(ii) 30 < rPR < 82.6	(A) 26.7 < rO ≤ 89	46.1600 + 1.4286·rPR − 0.5303·rO + 0.00642·rPR·rO
	(B) rO > 89	−1.04 + 2.0·rPR
(iii) rPR ≥ 82.6	All	32 + 1.6·rPR

(5) *Tier 8 new type.* The following NO_X standards apply to engines of a type or model for which the date of manufacture of the first individual production model was on or after January 1, 2014; or for which an application for original type certification is submitted on or after January 1, 2023; or for engines covered by an earlier type certificate if they do not qualify as derivative engines for emission purposes as described in § 1031.130:

TABLE 5 TO § 1031.60(e)(5)—TIER 8 NEW TYPE NO_X STANDARDS

If the rated pressure ratio (rPR) is—	and the rated output (kN) is—	the NO_X emission standard (g/kN) is—
(i) rPR ≤ 30	(A) 26.7 < rO ≤ 89	40.052 + 1.5681·rPR − 0.3615·rO − 0.0018·rPR·rO
	(B) rO > 89	7.88 + 1.4080·rPR
(ii) 30 < rPR < 104.7	(A) 26.7 < rO ≤ 89	41.9435 + 1.505·rPR − 0.5823·rO + 0.005562·rPR·rO
	(B) rO > 89	−9.88 + 2.0·rPR
(iii) rPR ≥ 104.7	All	32 + 1.6·rPR

§ 1031.90 Supersonic engines.

The following standards apply to new engines installed in supersonic airplanes:

(a) *Smoke.* (1) Engines of a type or model for which the date of manufacture was on or after January 1, 1984, may not have a characteristic level for smoke number exceeding an emission standard that is the lesser of 50 or the following:

SN = 83.6·rO − 0.274

(2) [Reserved]

(b) [Reserved]

(c) *HC.* Engines of a type or model for which the date of manufacture was on or after January 1, 1984, may not have a characteristic level for HC exceeding the following emission standard in g/kN rated output:

HC = 140·0.92rPR

(d) *CO.* Engines of a type or model for which the date of manufacture was on or after July 18, 2012, may not have a characteristic level for CO exceeding the following emission standard in g/kN rated output:

CO = 4550·rPR − 1.03

(e) *NO_X.* Engines of a type or model for which the date of manufacture was on or after July 18, 2012, may not have a characteristic level for NO_X engines exceeding the following emission standard in g/kN rated output:

NO_X = 36+2.42·rPR

§ 1031.130 Derivative engines for emissions certification purposes.

(a) *Overview.* FAA may approve a type certificate holder's request for an engine configuration to be considered a derivative engine for emission purposes under this part if the type certificate holder demonstrates the engine configuration is similar in design to a previously certificated (original) engine for purposes of compliance with exhaust emission standards and at least one of the following circumstances applies:

(1) The FAA determines that a safety issue requires an engine modification.

(2) All regulated emissions from the proposed derivative engine are lower than the corresponding emissions from the previously certificated engine.

(3) The FAA determines that the proposed derivative engine's emissions are similar to the previously certificated engine's emissions as described in paragraph (c) of this section.

(b) *Determining emission rates.* To determine new emission rates for a derivative engine for demonstrating compliance with emission standards under § 1031.30(a)(4) and for showing emissions similarity in paragraph (c) of this section, testing may not be required in all situations. If the previously certificated engine model or any associated sub-models have a characteristic level before modification that is at or above 95% of any applicable standard for smoke number, HC, CO, or NO_X or at or above 80% of any applicable nvPM standard, you must test the proposed derivative engine. Otherwise, you may use engineering analysis to determine the new emission rates, consistent with good engineering judgment. The engineering analysis must address all modifications from the previously certificated engine, including those approved for previous derivative engines.

(c) *Emissions similarity.* (1) A proposed derivative engine's emissions are similar to the previously certificated engine's emissions if the type certificate holder demonstrates that the engine meets the applicable emission standards and differ from the previously certificated engine's emissions only within the following ranges:

(i) ±3.0 g/kN for NO_X.

(ii) ±1.0 g/kN for HC.

(iii) ±5.0 g/kN for CO.

(iv) ±2.0 SN for smoke number.

(v) The following values apply for $nvPM_{MC}$:

(A) ±200 µg/m^3 if the characteristic level of maximum $nvPM_{MC}$ is below 1,000 µg/m^3.

(B) ±20% of the characteristic level if the characteristic level for maximum $nvPM_{MC}$ is at or above 1,000 µg/m^3.

(vi) The following values apply for $nvPM_{mass}$:

(A) 80 mg/kN if the characteristic level for $nvPM_{mass}$ emissions is below 400 mg/kN.

(B) ±20% of the characteristic level if the characteristic level for $nvPM_{mass}$ emissions is greater than or equal to 400 mg/kN.

(vii) The following values apply for $nvPM_{num}$:

(A) 4 × 10^14 particles/kN if the characteristic level for $nvPM_{num}$ emissions is below 2 × 10^15 particles/kN.

(B) ±20% of the characteristic level if the characteristic level for $nvPM_{num}$ emissions is greater than or equal to 2 × 10^15 particles/kN.

(2) In unusual circumstances, the FAA may adjust the ranges specified in paragraph (c)(1) of this section to evaluate a proposed derivative engine, after consulting with the EPA.

§ 1031.140 Test procedures.

(a) *Overview.* Measure emissions using the equipment, procedures, and test fuel specified in Appendices 1 through 8 of ICAO Annex 16 (incorporated by reference, see § 1031.210) as described in this section (referenced in this section as ''ICAO Appendix #''). For turboprop engines, use the procedures specified in ICAO Annex 16 for turbofan engines, consistent with good engineering judgment.

(b) *Test fuel specifications.* Use a test fuel meeting the specifications described in ICAO Appendix 4. The test fuel must not have additives whose purpose is to suppress smoke, such as organometallic compounds.

(c) *Test conditions.* Prepare test engines by including accessories that are available with production engines if they can reasonably be expected to influence emissions.

(1) The test engine may not extract shaft power or bleed service air to provide power to auxiliary gearbox-mounted components required to drive aircraft systems.

(2) Test engines must reach a steady operating temperature before the start of emission measurements.

(d) *Alternate procedures.* In consultation with the EPA, the FAA may approve alternate procedures for measuring emissions. This might include testing and sampling methods, analytical techniques, and equipment specifications that differ from those specified in this part. An applicant for type certification may request this approval by sending a written request with supporting justification to the FAA and to the Designated EPA Program Officer. Such a request may be approved only in the following circumstances:

(1) The engine cannot be tested using the specified procedures.

(2) The alternate procedure is shown to be equivalent to or better (*e.g.,* more accurate or precise) than the specified procedure.

(e) *LTO cycles.* The following landing and take-off (LTO) cycles apply for emission testing and calculating weighted LTO values:

TABLE 1 TO § 1031.140(E)—LTO TEST CYCLES

Mode	Subsonic				Supersonic	
	Turboprop		Turbojet and turbofan			
	Percent of rO	Time in mode (minutes)	Percent of rO	Time in mode (minutes)	Percent of rO	Time in mode (minutes)
Take-off	100	0.5	100	0.7	100	1.2
Climb	90	2.5	85	2.2	65	2.0
Descent	NA	NA	NA	NA	15	1.2
Approach	30	4.5	30	4.0	34	2.3
Taxi/ground idle	7	26.0	7	26.0	5.8	26.0

(f) *Pollutant-specific test provisions.* Use the following provisions to demonstrate whether engines meet the applicable standards:

(1) *Smoke number.* Use the equipment and procedures specified in ICAO Appendix 2 and ICAO Appendix 6. Test the engine at sufficient thrust settings to determine and compute the maximum smoke number.

(2) *nvPM.* Use the equipment and procedures specified in ICAO Appendix 7 and ICAO Appendix 6, as applicable:

(i) *Maximum nvPM mass concentration.* Test the engine at sufficient thrust settings to determine and compute the maximum nvPM mass concentration produced by the engine at any thrust setting, according to the procedures of ICAO Appendix 7.

(ii) *LTO nvPM mass and number.* Test the engine at sufficient thrust settings to determine the engine's nvPM mass and nvPM number at the rated output identified in table 1 to paragraph (e) of this section.

(3) *HC, CO,* and *NO_X.* Use the equipment and procedures specified in ICAO Appendix 3, ICAO Appendix 5, and ICAO Appendix 6, as applicable. Test the engine at sufficient thrust settings to determine the engine's HC, CO, and NO_X emissions at the rated output identified in table 1 to paragraph (e) of this section.

(4) *CO_2.* Calculate CO_2 emission values from fuel mass flow rate measurements in ICAO Appendix 3 and ICAO Appendix 5 or, alternatively, according to the CO_2 measurement criteria in ICAO Appendix 3 and ICAO Appendix 5.

(g) *Characteristic level.* The compliance demonstration consists of establishing a mean value from testing some number of engines, then calculating a ''characteristic level'' by applying a set of statistical factors in ICAO Appendix 6 that take into account the number of engines tested. Round each characteristic level to the same number of decimal places as the corresponding standard. Engines comply with an applicable standard if the testing results show that the engine type certificate family's characteristic level does not exceed the numerical level of that standard.

(h) *System loss corrected nvPM emission indices.* Use the equipment and procedures specified in ICAO Appendix 8, as applicable, to determine system loss corrected nvPM emission indices.

Subpart C—Reporting and Recordkeeping

§ 1031.150 Production reports.

Engine manufacturers must submit an annual production report for each calendar year in which they produce any engines subject to emission standards under this part.

(a) The report is due by February 28 of the following calendar year. Include emission data in the report as described in paragraph (c) of this section. If you produce exempted or excepted engines, submit a single report with information on exempted/excepted and normally certificated engines.

(b) Send the report to the Designated EPA Program Officer.

(c) In the report, specify your corporate name and the year for which you are reporting. Include information as described in this section for each engine sub-model subject to emission standards under this part. List each engine sub-model manufactured or certificated during the calendar year, including the following information for each sub-model:

(1) The type of engine (turbofan, turboprop, etc.) and complete sub-model name, including any applicable model name, sub-model identifier, and engine type certificate family identifier.

(2) The certificate under which it was manufactured. Identify all the following:

(i) The type certificate number. Specify if the sub-model also has a type certificate issued by a certificating authority other than FAA.

(ii) Your corporate name as listed in the certificate.

(iii) Emission standards to which the engine is certificated.

(iv) Date of issue of type certificate (month and year).

(v) Whether or not this is a derivative engine for emissions certification purposes. If so, identify the previously certificated engine model.

(vi) The engine sub-model that received the original type certificate for an engine type certificate family.

(3) Identify the combustor of the sub-model, where more than one type of combustor is available.

(4) The calendar-year production volume of engines from the sub-model that are covered by an FAA type certificate. Record zero for sub-models with no engines manufactured during the calendar year, or state that the engine model is no longer in production and list the date of manufacture (month and year) of the last engine manufactured. Specify the number of these engines that are intended for use on new aircraft and the number that are intended for use as non-exempt engines on in-use aircraft. For engines delivered without a final sub-model status and for which the manufacturer has not ascertained the engine's sub-model when installed before submitting its production report, the manufacturer may do any of the following in its initial report, and amend it later:

(i) List the sub-model that was shipped or the most probable sub-model.

(ii) List all potential sub-models.

(iii) State ''Unknown Sub-Model.''

(5) The number of engines tested and the number of test runs for the applicable type certificate.

(6) Test data and related information required to certify the engine sub-model for all the standards that apply. Round reported values to the same number of decimal places as the standard. Include the following information, as applicable:

(i) The engine's rated pressure ratio and rated output.

(ii) The following values for each mode of the LTO test cycle:

(A) Fuel mass flow rate.

(B) Smoke number.

(C) nvPM mass concentration.

(D) mass of CO_2

(E) Emission Indices for HC, CO, NO_X, and CO_2.

(F) The following values related to nvPM mass and nvPM number:

(*1*) Emission Indices as measured.

(*2*) System loss correction factor.

(*3*) Emissions Indices after correcting for system losses.

(iii) Weighted total values calculated from the tested LTO cycle modes for HC, CO, NO_X, CO_2, and nvPM mass and nvPM number. Include nvPM mass and nvPM number values with and without system loss correction.

(iv) The characteristic level for HC, CO, NO_X, smoke number, nvPM mass concentration, nvPM mass, and nvPM number.

(v) The following maximum values:

(A) Smoke number.

(B) nvPM mass concentration.

(C) nvPM mass Emission Index with and without system loss correction.

(D) nvPM number Emission Index with and without system loss correction.

(d) Identify the number of exempted or excepted engines with a date of manufacture during the calendar year, along with the engine model and sub-model names of each engine, the type of exemption or exception, and the use of each engine (for example, spare or new installation). For purposes of this paragraph (d), treat spare engine exceptions separate from other new engine exemptions.

(e) Include the following signed statement and endorsement by an authorized representative of your company: ''We submit this report under 40 CFR 1031.150. All the information in this report is true and accurate to the best of my knowledge.''

(f) Where information provided for the previous annual report remains valid and complete, you may report your production volumes and state that there are no changes, without resubmitting the other information specified in this section.

§ 1031.160 Recordkeeping.

(a) You must keep a copy of any reports or other information you submit to us for at least three years.

(b) Store these records in any format and on any media, as long as you can promptly send us organized, written records in English if we ask for them. You must keep these records readily available. We may review them at any time.

§ 1031.170 Confidential business information.

The provisions of 40 CFR 1068.10 apply for information you consider confidential.

Subpart D—Reference Information

§ 1031.200 Abbreviations.

The abbreviations used in this part have the following meanings:

° Degree
% Percent
CO carbon monoxide
CO_2 carbon dioxide
EI emission index
G Gram
HC hydrocarbon(s)
Kg Kilogram
kN Kilonewton
kW Kilowatt
LTO landing and takeoff
M Meter
Mg Milligram
Mg microgram
NO_X oxides of nitrogen
Num number
nvPM nonvolatile particulate matter
$nvPM_{mass}$ nonvolatile particulate matter mass
$nvPM_{num}$ nonvolatile particulate matter number
$nvPM_{MC}$ nonvolatile particulate matter mass concentration

rO rated output
rPR rated pressure ratio
SN smoke number

§ 1031.205 Definitions.

The following definitions apply to this part. Any terms not defined in this section have the meaning given in the Clean Air Act (42 U.S.C. 7401–7671q). The definitions follow:

Aircraft has the meaning given in 14 CFR 1.1, a device that is used or intended to be used for flight in the air.

Aircraft engine means a propulsion engine that is installed on or that is manufactured for installation on an airplane for which certification under 14 CFR is sought.

Aircraft gas turbine engine means a turboprop, turbojet, or turbofan aircraft engine.

Airplane has the meaning given in 14 CFR 1.1, an engine-driven fixed-wing aircraft heavier than air, that is supported in flight by the dynamic reaction of the air against its wings.

Characteristic level has the meaning given in Appendix 6 of ICAO Annex 16 (incorporated by reference, see § 1031.210). The characteristic level is a calculated emission level for each pollutant based on a statistical assessment of measured emissions from multiple tests.

Date of manufacture means the date on which a manufacturer is issued documentation by FAA (or other recognized airworthiness authority for engines certificated outside the United States) attesting that the given engine conforms to all applicable requirements. This date may not be earlier than the date on which engine assembly is complete. Where the manufacturer does not obtain such documentation from FAA (or other recognized airworthiness authority for engines certificated outside the United States), date of manufacture means the date of final engine assembly.

Derivative engine for emissions certification purposes means an engine that has the same or similar emissions characteristics as an engine covered by a U.S. type certificate issued under 14 CFR part 33. These characteristics are specified in § 1031.130.

Designated EPA Program Officer means the Director of the Assessment and Standards Division, 2000 Traverwood Drive, Ann Arbor, Michigan 48105.

Emission index means the quantity of pollutant emitted per unit of fuel mass used.

Engine model means an engine manufacturer's designation for an engine grouping of engines and/or engine sub-models within a single engine type certificate family, where such engines have similar design, including being similar with respect to the core engine and combustor designs.

Engine sub-model means a designation for a grouping of engines with essentially identical design, especially with respect to the core engine and combustor designs and other emission-related features. Engines from an engine sub-model must be contained within a single engine model. For purposes of this part, an original engine model configuration is considered a sub-model. For example, if a manufacturer initially produces an engine model designated ABC and later introduces a new sub-model ABC–1, the engine model consists of two sub-models: ABC and ABC–1.

Engine type certificate family means a group of engines (comprising one or more engine models, including sub-models and derivative engines for emissions certification purposes of those engine models) determined by FAA to have a sufficiently common design to be grouped together under a type certificate.

EPA means the U.S. Environmental Protection Agency.

Except means to routinely allow engines to be manufactured and sold that do not meet (or do not fully meet) otherwise applicable standards. Note that this definition applies only with respect to § 1031.11 and that the term ''except'' has its plain meaning in other contexts.

Exempt means to allow, through a formal case-by-case process, an engine to be certificated and sold that does not meet the applicable standards of this part.

Exhaust emissions means substances emitted to the atmosphere from exhaust discharge nozzles, as measured by the test procedures specified in § 1031.140.

FAA means the U.S. Department of Transportation, Federal Aviation Administration.

Good engineering judgment involves making decisions consistent with generally accepted scientific and engineering principles and all relevant information, subject to the provisions of 40 CFR 1068.5.

ICAO Annex 16 means Volume II of Annex 16 to the Convention on International Civil Aviation (see § 1031.210 for availability).

New means relating to an aircraft or aircraft engine that has never been placed into service.

Non-volatile particulate matter (nvPM) means emitted particles that exist at a gas turbine engine exhaust nozzle exit plane that do not volatilize when heated to a temperature of 350 °C.

Rated output (rO) means the maximum power or thrust available for takeoff at standard day conditions as approved for the engine by FAA, including reheat contribution where applicable, but excluding any contribution due to water injection. Rated output is expressed in kilowatts for turboprop engines and in kilonewtons for turbojet and turbofan engines to at least three significant figures.

Rated pressure ratio (rPR) means the ratio between the combustor inlet pressure and the engine inlet pressure achieved by an engine operating at rated output, expressed to at least three significant figures.

Round has the meaning given in 40 CFR 1065.1001.

Smoke means the matter in exhaust emissions that obscures the transmission of light, as measured by the test procedures specified in § 1031.140.

Smoke number means a dimensionless value quantifying smoke emissions as calculated according to ICAO Annex 16.

Spare engine means an engine installed (or intended to be installed) on an in-use aircraft to replace an existing engine. See § 1031.11.

Standard day conditions means the following ambient conditions: Temperature = 15 °C, specific humidity = 0.00634 kg H_2O/kg dry air, and pressure = 101.325 kPa.

Subsonic means relating to an aircraft that has not been certificated under 14 CFR to exceed Mach 1 in normal operation.

Supersonic airplane means an airplane for which the maximum operating limit speed exceeds a Mach number of 1.

System losses means the loss of particles during transport through a sampling or measurement system component or due to instrument performance. Sampling and measurement system loss is due to various deposition mechanisms, some of which are particle-size dependent. Determining an engine's actual emission rate depends on correcting for system losses in the nvPM measurement.

Turbofan engine means a gas turbine engine designed to create its propulsion from exhaust gases and from air that bypasses the combustion process and is accelerated in a ducted space between the inner (core) engine case and the outer engine fan casing.

Turbojet engine means a gas turbine engine that is designed to create its propulsion entirely from exhaust gases.

Turboprop engine means a gas turbine engine that is designed to create most of its propulsion from a propeller driven by a turbine, usually through a gearbox.

Turboshaft engine means a gas turbine engine that is designed to drive a rotor transmission system or a gas turbine engine not used for propulsion.

We (us, our) means the EPA Administrator and any authorized representatives.

§ 1031.210 Incorporation by reference.

(a) Certain material is incorporated by reference into this part with the approval of the Director of the Federal Register under 5 U.S.C. 552(a) and 1 CFR part 51. To enforce any edition other than that specified in this section, the Environmental Protection Agency must publish a document in the **Federal Register** and the material must be available to the public. All approved material is available for inspection at U.S. EPA, Air and Radiation Docket Center, WJC West Building, Room 3334, 1301 Constitution Ave NW, Washington, DC 20004, *www.epa.gov/dockets,* (202) 202–1744, and is available from the sources listed in this section. It is also available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, email *fr.inspection@nara.gov* or go to *www.archives.gov/federal-register/cfr/ibr-locations.html.*

(b) International Civil Aviation Organization, Document Sales Unit, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (514) 954–8022, *www.icao.int,* or *sales@icao.int.*

(1) Annex 16 to the Convention on International Civil Aviation, Environmental Protection, as follows:

(i) Volume II—Aircraft Engine Emissions, Fourth Edition, July 2017, Including Amendment 10 of January 1, 2021 (as indicated in footnoted pages). IBR approved for §§ 1031.140 and 1031.205.

(ii) [Reserved]

(2) [Reserved]

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