IN UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

CENTER FOR BIOLOGICAL DIVERSITY, FRIENDS OF THE EARTH, and SIERRA CLUB, *Petitioners*, v. UNITED STATES ENVIRONMENTAL PROTECTION AGENCY and MICHAEL S. REGAN, Administrator, U.S. Environmental Protection Agency, *Respondents*.	Case No.23-1019

PETITION FOR REVIEW

Pursuant to Clean Air Act § 307(b)(1), 42 U.S.C. § 7607(b)(1), Federal Rule of Appellate Procedure 15, and D.C. Circuit Rule 15(a)(1), Center for Biological Diversity, Friends of the Earth, and Sierra Club hereby petition this Court for review of the final action taken by Respondents United States Environmental Protection Agency and Michael S. Regan, Administrator, United States Environmental Protection Agency, and entitled "Control of Air Pollution From Aircraft Engines: Emission Standards and Test Procedures," published at 87 Fed. Reg. 72312 (Nov. 23, 2022). A copy of EPA's final rule is attached as Attachment A.

Respectfully submitted,

DATED: January 20, 2023

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IN UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

CENTER FOR BIOLOGICAL DIVERSITY, FRIENDS OF THE EARTH, and SIERRA CLUB

Petitioners,

v.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY and MICHAEL S. REGAN, Administrator, U.S. Environmental Protection Agency,

Respondents.

Case No. ______

RULE 26.1 DISCLOSURE STATEMENT

Pursuant to Federal Rules of Appellate Procedure Rule 26.1 and D.C. Circuit Rule 26.1, the Center for Biological Diversity makes the following disclosures:

Non-Governmental Corporate Party to this Action: Center for Biological Diversity.

Parent Corporations: None.

Publicly Held Company that Owns 10% or More of Party's Stock: None.

Party's General Nature and Purpose: The Center for Biological Diversity is a nonprofit corporation organized and existing under the laws of the State of California that works through science, law, and advocacy to secure a future for all species, great and small, hovering on the brink of extinction, with a focus on protecting the lands, waters, and climate that species need to survive.

Pursuant to Federal Rules of Appellate Procedure Rule 26.1 and D.C. Circuit Rule 26.1, Friends of the Earth makes the following disclosures:

Non-Governmental Corporate Party to this Action: Friends of the Earth.

Parent Corporations: None.

Publicly Held Company that Owns 10% or More of Party's Stock: None.

Party's General Nature and Purpose: Friends of the Earth is a tax-exempt, 501(c)(3) organization and a not-for-profit corporation with offices in Berkeley, California and Washington, DC, where it is incorporated. Friends of the Earth is a membership organization consisting of over 225,000 members and more than 5 million activist supporters on its email list throughout the United States. It is also a member of Friends of the Earth International, which is a network of grassroots groups in 74 countries worldwide. Its mission is to protect our natural environment, including air, water, and land, to achieve a healthier and more just world, using public education, advocacy, legislative processes, and litigation.

Pursuant to Federal Rules of Appellate Procedure Rule 26.1 and D.C. Circuit Rule 26.1, Sierra Club makes the following disclosures:

Non-Governmental Corporate Party to this Action: Sierra Club.

Parent Corporations: None.

Publicly Held Company that Owns 10% or More of Party's Stock: None.

Party's General Nature and Purpose: Sierra Club, a corporation organized and existing under the laws of the State of California, is a national nonprofit organization dedicated to the protection and enjoyment of the environment.

Respectfully submitted,

DATED: January 20, 2023

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CERTIFICATE OF SERVICE

I, Sarah Burt, hereby certify that the foregoing **Petition for Review** and **Rule 26.1 Disclosure Statement** have been served by United States first-class mail, this the 20th day of January 2023, upon the following:

Michael S. Regan, Administrator
United States Environmental Protection Agency
Office of the Administrator
Mail Code 1101A
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

United States Environmental Protection Agency
Office of General Counsel
Mail Code 2310A
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

The Honorable Merrick B. Garland
Attorney General of the United States
U.S. Department of Justice
950 Pennsylvania Avenue, N.W.
Washington, D.C. 20530

Respectfully submitted,

DATED: January 20, 2023

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ATTACHMENT A

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 9, 87, 1030, and 1031

[EPA–HQ–OAR–2019–0660; FRL–7558–02–OAR]

RIN 2060–AU69

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

AGENCY: Environmental Protection Agency (EPA)

ACTION: Final rule.

SUMMARY: The Environmental Protection Agency (EPA) is finalizing particulate matter (PM) emission standards and test procedures applicable to certain classes of engines used by civil subsonic jet airplanes (engines with rated output of greater than 26.7 kilonewtons (kN)) to replace the existing smoke standard for those engines. The EPA is adopting these standards under our authority in the Clean Air Act (CAA). These 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 will apply to both new type design aircraft engines and in-production aircraft engines. The EPA, as well as the U.S. Federal Aviation Administration (FAA), actively participated in the ICAO proceedings in which the ICAO requirements were developed. These standards 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 migrating, modernizing, and streamlining the existing regulations into a new part in the Code of Federal Regulations. As part of this update, the EPA is also aligning with ICAO by applying the smoke number standards to engines less than or equal to 26.7 kilonewtons rated output used on supersonic airplanes.

DATES: This final rule is effective on December 23, 2022. The incorporation by reference of certain material listed in this rule is approved by the Director of the Federal Register as of December 23, 2022.

ADDRESSES: The EPA has established a docket for this 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 EPA Docket Center, WJC West Building, Room 3334, 1301 Constitution Ave. NW, Washington, DC. The Docket Center's hours of operations are 8:30 a.m.–4:30 p.m., Monday–Friday (except Federal Holidays). For further information on the EPA Docket Center services and the current status, see: *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:

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I. General Information

A. Does this action apply to me?

This action will potentially 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 manufacture civil jet engines with a rated output at or below 26.7 kN for use on supersonic airplanes. These potentially 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 the 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, 1030, 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 U.S. Code of Federal Regulations (CFR), common definitions for the words ''airplane,'' ''aircraft,'' ''aircraft engine,'' and ''civil aircraft'' are found at 14 CFR 1.1 and are used as appropriate throughout this new regulation under 40 CFR parts 87, 1030, and 1031.

B. Executive Summary

1. Summary of the Major Provisions of the Regulatory Action

The EPA is regulating PM emissions from certain aircraft engines through the adoption of domestic PM regulations that match the ICAO PM standards, which will be implemented and enforced in the United States. The covered engines are subsonic turbofan and turbojet aircraft engines with rated output (maximum thrust available for takeoff) of greater than 26.7 kN. These aircraft engines are used by civil subsonic jet airplanes generally for the purpose of commercial passenger and freight aircraft, as well as larger business jets. The EPA is adopting 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 vary, as described in the following paragraphs, and more fully in sections IV.A, IV.B, and IV.C respectively.

First, the EPA is finalizing PM engine emission standards, in the form of both PM mass (mg/kN) and PM number (#/kN), for both new type design and in-production covered engines. The standards for in-production engines apply to those engines that are manufactured on or after January 1, 2023. The standards for new type designs apply to those engines whose initial type certification application is submitted on or after January 1, 2023. The in-production standards have different emission levels limits than the standards for new type designs. The different emission limits for new type designs and in-production engines depend on the rated output of the engines. Compliance with the PM mass and number standards will 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 adopting a PM engine emission standard in the form of maximum mass concentration (μg/m^3) for covered engines manufactured on or after January 1, 2023.[1] Compliance with the PM mass concentration standard will be done using the same test data that is developed to demonstrate compliance with the LTO-based PM mass and number standards. The PM mass concentration standard applies to the highest concentration of PM measured across the engine operating thrust range, not just at one of the four LTO thrust settings.

The 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 no longer applying the existing smoke number standard for new engines that will be subject to the 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 approach will essentially change the existing standard for covered engines from being based on a smoke measurement to a PM measurement.

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

The 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 migrating most of 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 are specified in this new 40 CFR part 1031. Along with this migration, the EPA is restructuring the regulations to allow for better ease of use and allow for more efficient future updates. The EPA is also deleting some unnecessary definitions and regulatory provisions. Finally, the EPA is adopting 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 Regulatory Action

In developing these standards, the EPA took into consideration the Agency's legal authority and the explicit requirements under CAA section 231, including those relating to safety, noise, lead time and costs. The EPA further considered the importance of controlling PM emissions, international harmonization of aviation requirements, and the international nature of the aircraft industry and air travel. In addition, the EPA gave significant weight to the United States' 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 conclude that adopting standards for PM emissions from certain classes of

[1] The implementation date for ICAO's PM maximum mass concentration standards is on or after January 1, 2020. The PM maximum mass concentration standards finalized in this action will have an implementation date of January 1, 2023 (instead of January 1, 2020).

[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_2022_en.pdf* (last accessed October 31, 2022). The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services Catalog, English Edition of the 2022 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.

covered aircraft engines that are equivalent in scope, stringency, and effective date to the PM standards adopted by ICAO are appropriate at this time.

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 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 emission 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 that the EPA is adopting were developed using this approach. Thus, the adoption of these aviation standards into U.S. law will 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 meet the United States' treaty obligations under the Chicago Convention.

These standards will also allow U.S. manufacturers of covered aircraft engines to remain competitive in the global marketplace (as described in 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) to market and operate their aircraft engines internationally. U.S. manufacturers could be at a significant disadvantage if the United States 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 adopted by other ICAO member states that certify aircraft engines.[3] The action to adopt in the U.S. PM standards that match the ICAO standards will help ensure international consistency and acceptance of U.S.-manufactured engines worldwide.

3. Environmental Justice

The 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. Section III.G discusses the potential environmental justice concerns associated with exposure to aircraft PM near airports.

Studies have reported that many communities in close proximity to airports are disproportionately represented by people of color and low-income populations (as described in Section III.G). Separate from this rulemaking, the EPA is conducting an analysis of communities residing near airports where jet aircraft operate 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 standards in this final rule are technology-following 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 the standards to result in an improvement in air quality for those who live near airports where these aircraft operate.

C. EPA Future Work on Aircraft Engine PM Standards Beyond the Scope of This Final Rule

While the EPA believes that adopting PM standards that match those developed and adopted by ICAO is the proper course of action in this final rule, the EPA views the standards adopted in this action as just one appropriate step in our efforts to control PM emissions from aircraft engines. Consistent with our statutory authority, which directs the EPA to issue, and permits the EPA to revise, standards ''from time to time,'' CAA section 231(a)(2)(A) and (a)(3), after consultation with the FAA (CAA section 231(a)(2)(B)(i)), the EPA views our regulation of aircraft PM emissions as a long-term process, with the potential for successive standards of increasing stringency. Future stringencies may include technology-forcing standards, where appropriate, provided that such standards do not significantly increase noise and adversely affect safety in accordance with CAA section 231(a)(2)(B)(ii). The EPA intends to continue to assess available emission control technologies and associated lead times, so that if the EPA were to pursue more stringent standards in the future, the EPA would provide the necessary time to permit the development and application of the requisite technology—giving appropriate consideration to the cost of compliance within such period.

The EPA continues to believe that ICAO is the most appropriate venue in which to undertake such work. To that end, the U.S. delegation to ICAO/CAEP, with significant input from EPA, developed a position paper to the CAEP/12 meeting in February 2022.[4] In this paper, the United States proposed several topics for CAEP to consider for future work on emissions items. Among the U.S. proposals was a call to update the PM standards beyond those already adopted by CAEP that would reflect best available technologies for future, to-be-developed, standards. The United States also proposed work to develop an updated metric to improve the effectiveness of future NO_X emission standards, as well as an integrated standards-setting process to simultaneously update both PM and NO_X standards for aircraft engines given the strong interdependency between engine NO_X and PM levels.[5] The EPA also advocated for improved modeling techniques that would better reflect the costs and emission reductions and better inform decision making around proposed CAEP emission standard levels.

[3] Aside from the FAA in the United States, the only other civil aviation authorities that routinely certify airplane engines are Transport Canada and the European Union Aviation Safety Agency, both of which have already adopted the ICAO airplane engine particulate matter emission standards.

[4] U.S. EPA, Mueller, J. Memorandum to Docket ID No. EPA–HQ–OAR–2019–0660, ''United States Position Papers to CAEP/12 Meeting,'' August 19, 2022.

[5] In this context, the metric is the form of the standard (in this case, mass of pollutant per unit of thrust), as well as the form of the regulatory limit line and any correlating parameters included. In the case of aircraft engine NO_X, the regulatory limit line is a function of engine overall pressure ratio.

CAEP did not accept the U.S. request to work on updated aircraft engine NO_X and PM standards during the current CAEP/13 cycle due to concerns that the resources needed for such work would negatively impact efforts to update the international airplane CO_2 and noise standards. However, work on an improved NO_X metric was approved and is underway this CAEP cycle, with an understanding that it is laying the groundwork for a potential update of the NO_X and PM standards during the next CAEP cycle.[6] Further, improving the cost and emission reduction modeling methodology has been agreed to as a work item for this CAEP cycle. The EPA is actively working within CAEP on both these efforts, and the EPA will continue to advocate for efforts in CAEP that will result in the development of future PM emission standards which reflect best available technologies.

D. Judicial Review, Administrative Reconsideration, and Severability

This final action is ''nationally applicable'' within the meaning of CAA section 307(b)(1) because it is expressly listed in the section (*i.e.,* ''any standard under section [231] of this title''). Under CAA section 307(b)(1), petitions for judicial review of this action must be filed in the U.S. Court of Appeals for the District of Columbia Circuit within 60 days from the date this final action is published in the **Federal Register**. Filing a petition for reconsideration by the Administrator of this final action does not affect the finality of the action for the purposes of judicial review, nor does it extend the time within which a petition for judicial review must be filed and shall not postpone the effectiveness of such rule or action. Under CAA section 307(b)(2), the requirements established by this final rule may not be challenged separately in any civil or criminal proceedings brought by the EPA to enforce the requirements.

CAA section 307(d)(7)(B) further provides that only an objection to a rule or procedure which was raised with reasonable specificity during the period for public comment (including any public hearing) may be raised during judicial review. This section also provides a mechanism for the EPA to reconsider the rule if the person raising an objection can demonstrate to the Administrator that it was impracticable to raise such objection within the period for public comment or if the grounds for such objection arose after the period for public comment (but within the time specified for judicial review) and if such objection is of central relevance to the outcome of the rule. Any person seeking to make such a demonstration should submit a Petition for Reconsideration to the Office of the Administrator, U.S. EPA, Room 3000, WJC South Building, 1200 Pennsylvania Ave. NW, Washington, DC 20460, with a copy to both the person listed in the **FOR FURTHER INFORMATION CONTACT** section, and the Associate General Counsel for the Air and Radiation Law Office, Office of General Counsel (Mail Code 2344A), U.S. EPA, 1200 Pennsylvania Ave. NW, Washington, DC 20460. In addition, the EPA requests that an electronic copy of the Petition for Reconsideration also be sent to the person listed in the **FOR FURTHER INFORMATION CONTACT** section.

The following portions of this rulemaking are mutually severable from each other: (1) the PM mass concentration standard in Section IV.C; (2) the PM mass and number standards in sections IV.A and IV.B; (3) the test and measurement procedures in Section IV.D; (4) the reporting requirements in Section IV.E; (5) those changes to 40 CFR parts 87 and 1031 described in Section VII that are not intended solely to implement the new PM standards; and (6) the changes to 40 CFR part 1030 described in Section VII.C.[7] The PM mass concentration standard and the PM mass and number standards serve different purposes, as described in more detail in Section IV. The reporting requirements (including those for PM) in Section IV.E predate this final rule as they were established by a prior Information Collection Request and are simply being added to the CFR in this action for the convenience of the entity required to provide a production report. Similarly, while the test and measurement procedures in Section IV.D will be used in determining compliance with the new PM standards, they are not dependent on the PM standards, and they are also required to be used to comply with the reporting requirements separate from the actual PM standards. The regulatory migration and other technical amendments in Section VII are not related to the implementation of the new PM standards. If any of the portions of this rule the EPA has identified as mutually severable from each other are vacated by a reviewing court, the EPA intends for the portions of this rule which are not vacated by a reviewing court to remain effective, and would only take action to remove the portions of the rule which are vacated from the CFR, leaving the other portions of the rule in effect.[8] Finally, if a reviewing court were to vacate the PM mass concentration standard in Section IV.C, the EPA intends to reinstate the smoke number standard contained in 40 CFR 1031.60(a)(5) for engines with a rated output of greater than 26.7 kN, such that the smoke number standard would go back into effect for those engines.

II. Introduction: Context for This Action

The 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 final rule, which adopts three PM standards for aircraft engines (a PM mass standard, a PM number standard, and a PM mass concentration standard). This section includes a description of the EPA's statutory authority, the U.S. role in ICAO and developing international emission standards, and the relationship between the U.S. standards and the ICAO international standards.

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

CAA section 231(a)(2)(A) directs the Administrator of the 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.[9] 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.[10] 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

[6] ICAO, 2022: Committee on Aviation Environmental Protection (CAEP), Report of the Twelfth Meeting, Montreal, February 7–17, 2022, Doc 10176, CAEP/12.

[7] Certain portions may also be internally severable.

[8] The EPA considers those sections of regulatory text which are included only to implement the new PM standards to all be within 40 CFR part 1031. Specifically, the regulatory text solely related to implementing the PM mass concentration standard is contained in §§ 1031.30(a)(2)(ii), 1031.60(a)(6), and 1031.130(c)(1)(v), as well as the phrase ''before January 1, 2023'' in § 1031.60(a)(5), while the regulatory text solely related to implementing the PM mass and number standards is contained in §§ 1031.30(a)(2)(iii) and (iv), 1031.60(b), and 1031.130(c)(1)(vi) and (vii). All other regulatory changes are severable from the PM standards and are intended to remain in effect if any of the PM standards were to be set aside by a reviewing court.

[9] 42 U.S.C. 7571(a)(2)(A).

[10] 42 U.S.C. 7571(a)(2)(B)(i)–(ii).

appropriate.''[11] 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 within such period.[12]

Consistent with its longstanding approach[13] and the District of Columbia (D.C.) Circuit precedent,[14] 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 statute and other relevant factors, such as applicable international standards. While the statutory language of CAA section 231 is not identical to other provisions of Title II of the CAA that direct the EPA to establish technology-based standards for various types of mobile sources, the EPA interprets its authority under CAA section 231 to be similar to those provisions that authorize us to identify a reasonable balance of specified emissions reduction, cost, safety, noise, and other factors.[15] However, we are not compelled under CAA section 231 to obtain the ''greatest degree of emission reduction achievable'' as per CAA sections 202(a)(3)(A) and 213(a)(3). The EPA does not interpret the Act as requiring the agency to give subordinate status to other factors such as cost, safety, and noise in determining what standards are reasonable for aircraft engines.[16] Rather, the EPA has great flexibility under CAA section 231 in determining what standard is most reasonable for aircraft engines. Moreover, in light of the U.S. ratification of the Chicago Convention, EPA has historically given significant weight to uniformity with international requirements as a factor in setting aircraft engine standards. The fact that most airplanes already meet the standards does not in itself mean that the standards are inappropriate, provided the agency has a reasonable basis after considering all the relevant factors. By the same token, a technology-forcing standard would not be precluded by CAA section 231, in light of the forward-looking language of CAA section 231(b).[17]

Thus, as in past rulemakings, the 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.[18] Once the EPA adopts standards, CAA section 232 then directs the Secretary of Transportation to prescribe regulations to ensure compliance with the EPA's standards.[19] Finally, CAA section 233 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.[20]

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.''[21] 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.[22] [23] 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 air navigation.''[24] 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.[25]

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

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[11] 42 U.S.C. 7571(a)(3).

[12] 42 U.S.C. 7571(b).

[13] See 70 FR 69664, 69676 (November 17, 2005); 86 FR 2136, 2157 (January 11, 2021).

[14] The U.S. Court of Appeals for the D.C. Circuit has held that CAA section 231 confers an unusually ''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).

[15] *See, e.g., Husqvarna AB* v. *EPA,* 254 F.3d 195 (D.C. Cir. 2001) (upholding the EPA's promulgation of technology-based standards for small non-road engines under CAA section 213(a)(3)).

[16] *Cf. Sierra Club* v. *EPA,* 325 F.3d 374, 378–380 (D.C. Cir. 2003) (holding that even a Clean Air Act provision requiring the ''greatest emission reduction achievable'' did not bind the Agency to weigh ''pure technological capability'' to the exclusion of other factors like cost, lead time, safety nor ''resolve how [the EPA] should weigh all these factors'').

[17] *See* 38 FR19088 (July 17, 1973); 41 FR 34722 (August 16, 1976); *see also NACAA,* 489 F.3d at 1229–30.

[18] *See* 70 FR 69664, 69676 (November 17, 2005); 86 FR 2136, 2139–2140 (January 11, 2021).

[19] 42 U.S.C. 7572.

[20] 42 U.S.C. 7573.

[21] ICAO, 2006: *Convention on International Civil Aviation, Ninth Edition,* Document 7300/9. Available at: *http://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed October 31, 2022).

[22] Members of ICAO's Assembly are generally termed member States or contracting States.

[23] There are currently 193 contracting States (member States) according to ICAO's website. The list of ICAO member States is available in the docket for this rulemaking under document identification number EPA–HQ–OAR–2019–0660–0011.

[24] ICAO, 2006: Convention on International Civil Aviation, Article 37, Ninth Edition, Document 7300/9.

[25] Id.

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.[26] 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.[27] 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.[28]

ICAO's Committee on Aviation Environmental Protection (CAEP), which consists of members and observers from States as well as 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.'' [29] 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).[30] [31]

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.[32] These standards limited aircraft engine emissions of HC, CO, and 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.[33] 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 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.[34] [35] 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.[36] [37] 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.[38]

At the CAEP/10 meeting in 2016, the Committee agreed to the first airplane

[26] Id., Article 33.

[27] Id.

[28] Id., Article 38.

[29] ICAO: CAEP Terms of Reference. A copy of the CAEP Terms of reference is available in the docket for this rulemaking under document identification number EPA–HQ–OAR–2019–0660–0006.

[30] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017. The ICAO Annex 16 Volume II is found on page 17 of the ICAO Products & Services English Edition of the 2022 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.

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

[32] ICAO, 2017: *Aircraft Engine Emissions: Foreword,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021.

[33] 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.

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

[35] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021.

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

[37] 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.

[38] 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. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021.

carbon dioxide (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.[39]

C. The Relationship Between the 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.[40] We have periodically revised these regulations.[41] The EPA's actions to regulate certain pollutants emitted from aircraft engines come directly from the authority in CAA section 231, and we have aligned the U.S. emission requirements with those adopted by ICAO. As described in Section II.B, the ICAO/CAEP terms of reference includes technical feasibility.[42] 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.[43] 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 engine emission levels), which are technology-following.

For many years the EPA has regulated aircraft engine PM emissions with smoke number standards.[44] 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[45] and again in 1984.[46] Additionally, the EPA has amended the test procedures for measuring smoke emissions[47] and modified the effective dates and compliance schedule for smoke emission standards periodically.[48] Now, we are adopting three different forms of aircraft engine PM standards: a PM mass concentration standard (μg/m[3]), a PM mass standard (mg/kN), and PM number standard (#/kN). These aircraft engine PM emission standards are a different way of regulating and/or measuring[49] 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 1970s 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 the 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 U.S. Code. This rulemaking will 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 adopting PM standards equivalent to ICAO's three different forms of aircraft engine PM emission standards. Adoption of these standards will meet

[39] More specifically, the international PM maximum mass concentration 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).

[40] Emission Standards and Test Procedures for Aircraft; Final Rule, 38 FR 19088 (July 17, 1973).

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

[42] ICAO: CAEP Terms of Reference. Available in the docket for this rulemaking under document identification number EPA–HQ–OAR–2019–0660–0006.

[43] ICAO, 2019: *Report of the Eleventh Meeting,* Montreal, 4–15 February 2019, Committee on Aviation Environmental Protection, Document 10126, CAEP/11. It is found on page 27 of the English Edition of the ICAO Products & Services 2022 Catalog and is copyright protected: Order No. 10126. The statement on technological feasibility is located in Appendix C of Agenda Item 3 of this report (see page 3C–4, paragraph 2.2).

[44] See 40 CFR 87.1 (July 1, 2021). ''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.''

[45] Control of Air Pollution From Aircraft and Aircraft Engines; Emission Standards and Test Procedures, Final Rule, 47 FR 58462 (December 30, 1982).

[46] 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).

[47] 62 FR 25356 (harmonizing EPA procedures with recent amendments to ICAO test procedures); 70 FR 69664 (same); 77 FR 36342.

[48] Amendment to Standards, Final Rule, 43 FR 12614 (March 24, 1978) (setting back by two years the effective date for all gaseous emission standards for newly manufactured aircraft and aircraft gas turbine engines); 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); 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 emission standards which would otherwise have been effective on January 1,1981, for aircraft gas turbine engines); 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); 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).

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

the United States' obligations under the Chicago Convention and will also help ensure global acceptance of FAA airworthiness certification.

In December 2018, the EPA issued an information collection request (ICR) that matches the CAEP/10 PM reporting requirements described in Section II.B.[50] In addition to the PM standards, this rulemaking codifies the reporting requirements implemented by this 2018 EPA ICR into the EPA regulations, as described in Section IV.E. Also, in a similar time frame as this rulemaking, the 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), 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.[51] Because of the difficulty in measuring volatile PM, which is formed in the engine's exhaust plume and is significantly influenced by ambient conditions, the EPA is adopting 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 U.S. EPA's Integrated Science Assessment for Particulate Matter (PM ISA), which was finalized in December 2019 (2019 PM ISA), with a more targeted evaluation of studies published since the literature cutoff date of the 2019 PM ISA in the Supplement to the Integrated Science Assessment for PM (Supplement).[52] [53] Further discussion of PM-related health effects can also be found in the 2022 Policy Assessment for the review of the PM National Ambient Air Quality Standards (NAAQS).[54] [55]

The 2019 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.).[56] The 2019 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. Recent studies evaluated in the Supplement support the conclusion of the 2019 PM ISA with respect to disparities in both $PM_{2.5}$ exposure and health risk by race and ethnicity and provide additional support for

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[50] Information Collection Request Submitted to OMB for Review and Approval; Comment Request; Aircraft Engines—Supplemental Information Related to Exhaust Emissions (Renewal), 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.

[51] ICAO 2019 Environmental Report. This document is available in the docket for this rulemaking under document identification number EPA–HQ–OAR–2019–0660–0022. 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, gas turbine engines emit non-volatile particles of smaller mean diameter. Their characteristic size ranges roughly from 15 to 60 nanometers. . . . These particles are invisible to the human eye and are ultrafine.'' (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 emissions 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.'' (pages 100 and 101.)

[52] 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.

[53] U.S. EPA. Supplement to the 2019 Integrated Science Assessment for Particulate Matter (Final Report, 2022). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R–22/028, 2022.

[54] U.S. EPA. Policy Assessment for the Reconsideration of the National Ambient Air Quality Standards for Particulate Matter (Final Report, 2022). U.S. Environmental Protection Agency, Washington, DC, EPA–452/R–22–004, 2022.

[55] 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.

[56] 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).

disparities for lower socioeconomic status populations. 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.

The EPA has concluded that recent evidence in combination with evidence evaluated in the 2009 PM 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.[57] 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. Because of remaining uncertainties and limitations in the evidence base, the EPA determined a ''suggestive of, but not sufficient to infer, a causal relationship'' 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.

More detailed information on the health effects of PM can be found in a memorandum to the docket.[58] The EPA is reconsidering a 2020 decision to retain the PM NAAQS.[59]

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 in Section III.B.

$PM_{2.5}$ emissions also adversely impact visibility.[60] 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.[61] In 1999, the EPA finalized the regional haze program to protect the visibility in Mandatory Class I Federal areas.[62] There are 156 national parks, forests and wilderness areas categorized as Mandatory Class I Federal areas.[63] 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. The 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). The secondary (welfare-based) PM NAAQS provide protection against visibility effects. In recent PM NAAQS reviews, EPA evaluated a target level of protection for visibility impairment that is expected to be met through attainment of the existing secondary PM standards.[64]

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.[65] 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.[66]

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 deteriorating building materials such as stone, concrete and marble.[67]

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.[68] 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 activity at airports.[69] 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.[70] The

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

[58] U.S. EPA, Cook, R. Memorandum to Docket EPA–HQ–OAR–2019–0660, ''Health and environmental effects of non-GHG pollutants emitted by turbine engine aircraft—final rule version,'' August 11, 2022.

[59] Id., p. 6.

[60] 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.

[61] See CAA section 169(a).

[62] Regional Haze Regulations; Final Rule, 64 FR 35714 (July 1, 1999).

[63] National Ambient Air Quality Standards for Particulate Matter; Final Rule, 62 FR 38652 (July 18, 1997).

[64] Cook, op. cit., p. 6.

[65] 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.

[66] 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.

[67] 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.

[68] 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.

[69] 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.

[70] 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

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.'' [71]

Furthermore, the report states 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).'' [72] Finally, the report concludes that $PM_{2.5}$ dominates overall health risks posed by airport emissions.[73] 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.[74]

Since the publication of the 2015 ACRP literature review, a number of studies conducted in the United States 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.[75] In another study in the vicinity of Logan airport, Hudda et al. analyzed PNC impacts of aviation activities.[76] 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.[77] Similar findings have been published from European studies.[78] [79] [80] [81] [82] [83] 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.[84] The PM associated with aircraft landing activity was also smaller in size, with lower black carbon concentrations than near-roadway samples. As discussed in Section III.B, $PM_{2.5}$ 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.[85] [86] For example, He et al. (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.[87] The systematic review identified seventy studies for evaluation. These studies consistently showed that particulate matter, in the form of 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 deoxyribonucleic acid (DNA) damage and childhood leukemia. As indicated in the proposal, 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.[88] 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.[89]

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and Public Health Studies Related to Airports. Airport Cooperative Research Program, ACRP Report 135.

[71] Id.

[72] Id. at 40.

[73] Id. at 41.

[74] 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(4).

[75] 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: pp. 1765–1772.

[76] 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: pp. 8514–8521.

[77] Stacey, B. 2019. Measurement of ultrafine particles at airports: A review. Atmos. Environ. 198: pp. 463–477.

[78] Masiol M., Harrison R.M. Quantification of air quality impacts of London Heathrow Airport (UK) from 2005 to 2012. Atmos Environ 2017; 116:308–19.

[79] 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: pp. 132–142.

[80] 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.

[81] Stacey, B., Harrison, R.M., Pope, F., 2020. Evaluation of ultrafine particle concentrations and size distributions at London Heathrow Airport. Atmos. Environ., 222: 117148.

[82] 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: pp. 3763–3775.

[83] 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: pp. 14161–14171.

[84] University of Washington. 2019. Mobile Observations of Ultrafine Particles: The Mov-UP study report.

[85] 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: pp. 48–59.

[86] He, R.-W., Shirmohammadi, F., Gerlofs-Nijland, M.E., Sioutas, C., & Cassee, F.R. 2018. Pro-inflammatory responses to PM (0.25) from airport and urban traffic emissions. *The Science of the total environment, 640–641,* pp. 997–100.

[87] 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.

[88] 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.

[89] 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.

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 FAA Air Traffic Data System (ATADS). 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).[90] Inventory estimates for turbine engine aircraft were adjusted to account for an improved methodology for estimating PM from nvPM measurements. This adjustment is described in detail in Section V.B. 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.[91] At the county level, contributions to total mobile source $PM_{2.5}$ emissions range from less than 1 to about 16 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 about 0.5 to 3 percent. Details of this analysis are described in a memorandum to the docket.[92]

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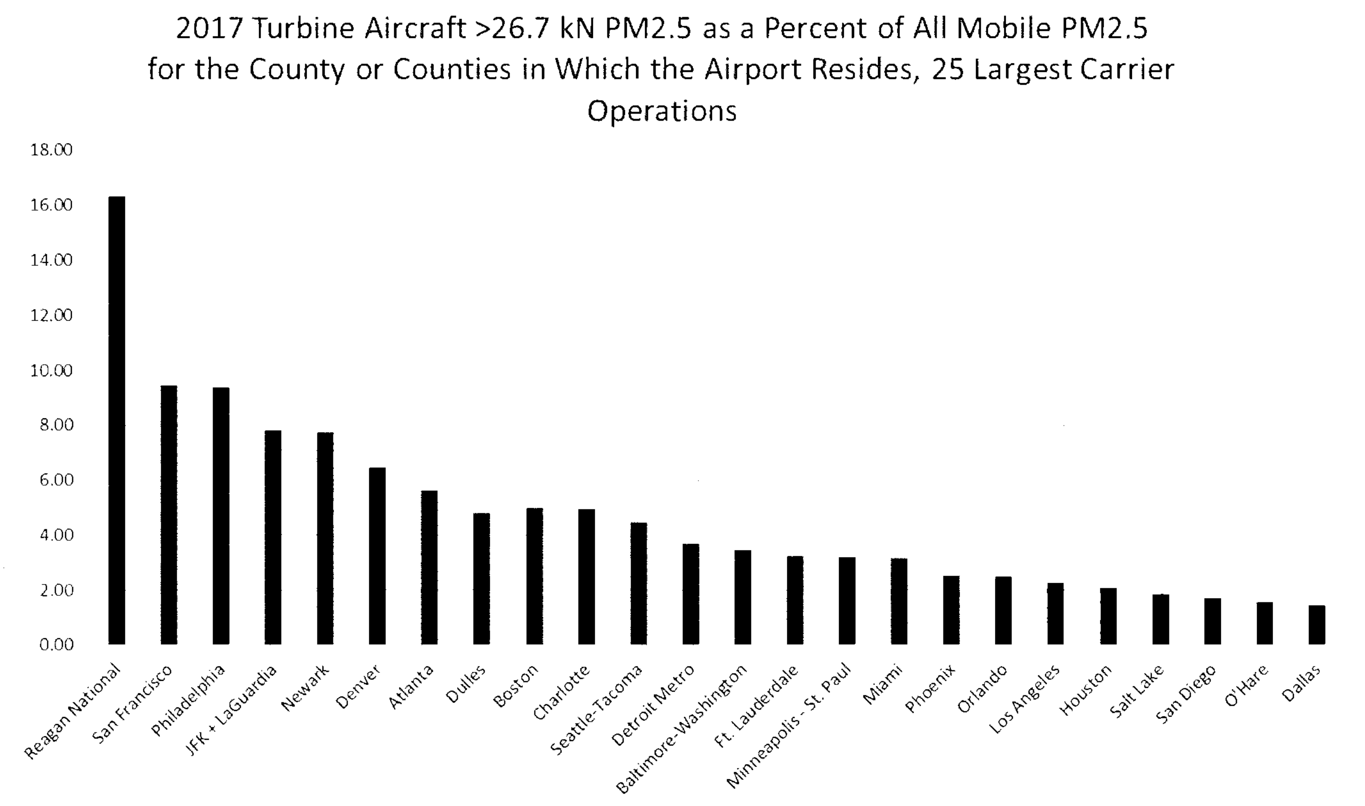

Figure III–1

[90] 2017 National Emissions Inventory: Aviation Component, Eastern Research Group, Inc., June 25, 2020, 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. It should be noted that while identification of the 25 airports with the greatest commercial activity uses 2017 ATADS data, the 2017 NEI relies on 2014 ATADS data.

[91] 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 final PM standards is based on the ratio of total PM emissions from flights by engines with thrust rating greater than 26.7 kN compared to PM emissions from the whole fleet at each airport.

[92] U.S. EPA, Cook, R. Memorandum to Docket EPA–HQ–OAR–2019–0660, ''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—Final Rule,'' June 14, 2022.

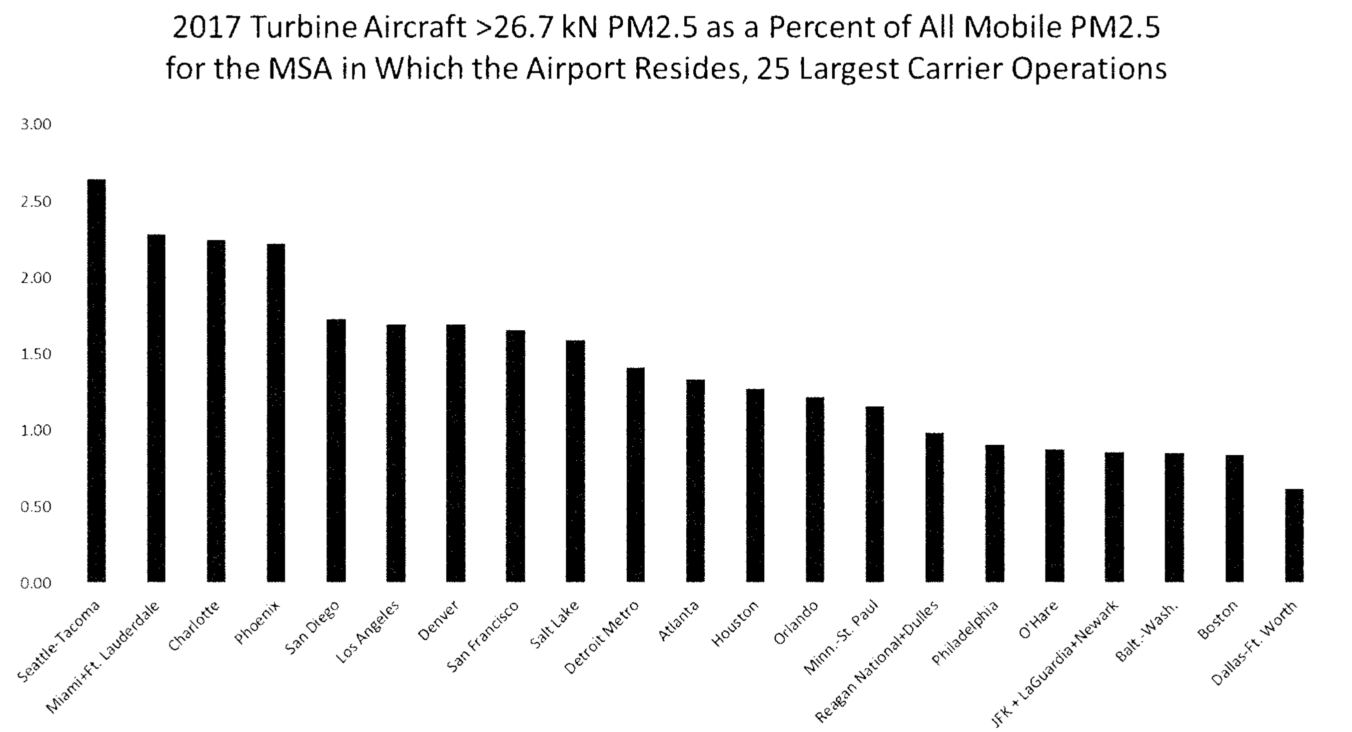

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Figure III–2

F. Other Pollutants Emitted by Aircraft

In addition to particulate matter, a number of other criteria pollutants are emitted by the aircraft subject to this final rule. These pollutants, which are not covered by the rule, include NO_X, including nitrogen dioxide (NO_2), VOC, 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.[93]

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.[94] 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 in Section III.B.

G. Environmental Justice

The 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.[95] The 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.[96]

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

[93] 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.

[94] U.S. EPA, Air Toxics Screening Assessment.

[95] ''Technical Guidance for Assessing Environmental Justice in Regulatory Analysis.'' Environmental Protection Agency (June 2016).

[96] 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.

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.

The 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, the EPA is committed to conducting environmental justice analysis for rulemakings based on a framework similar to what is outlined in the EPA's Technical Guidance, in addition to investigating ways to further weave environmental justice into the fabric of the rulemaking process.

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.[97] [98] [99] [100] [101]

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.[102] 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.[103]

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.[104] 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.[105]

Although not being conducted as part of this rulemaking, the EPA is conducting a demographic analysis to explore whether populations living nearest the busiest runways show patterns of racial and socioeconomic disparity.[106] 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.

The final in-production standards for both PM mass and PM number are levels that all aircraft engines in production currently meet to align with ICAO's standards. Thus, the final standards are not expected to result in emission reductions, beyond the business-as-usual fleet turnover that would occur absent the final standards. Therefore, we do not anticipate an improvement in air quality for those who live near airports where these aircraft operate, beyond what may occur as a result of fleet turnover and from any reductions in emissions from other sectors contributing to air quality near airports.

Response to comments on Section III of this action can be found in the Response to Comments document. In addition, all website addresses for references cited in this section are provided in a memorandum to the docket.[107]

IV. Details of the Final Rule

In determining what final PM standards are appropriate under CAA section 231 and after consultation with FAA, the EPA considered the level of standards that could be met with the application of requisite technology within the necessary period of time that would allow the United States to meet its obligations under the Chicago Convention to at least match the ICAO standards, and gave appropriate consideration to the cost of compliance within this period. This determination also took into account the requirement that EPA's revised standards not significantly increase noise and adversely affect safety. The EPA considered the statutory requirements in CAA section 231 and other relevant factors as described in Section VI of both the proposed rule and this final rule, and we concluded that it was reasonable and appropriate to finalize the new PM standards that match the international standards in scope, stringency, and effective date. The EPA has consulted with FAA and believes sufficient lead time has been provided since the technology has already been developed and implemented by manufacturers to comply with the new PM standards. Also, as described in Section IV.F.1, the EPA is confident that the final standards will not significantly increase noise and adversely affect

[97] Rowangould, G.M. (2013) A census of the near-roadway population: public health and environmental justice considerations. Trans Res D 25: pp. 59–67.

[98] Marshall, J.D., Swor, K.R., Nguyen, N.P. (2014) Prioritizing environmental justice and equality: diesel emissions in Southern California. Environ Sci Technol 48: pp. 4063–4068.

[99] Marshall, J.D. (2000) Environmental inequality: air pollution exposures in California's South Coast Air Basin. Atmos Environ 21: pp. 5499–5503.

[100] 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.

[101] Mohai, P., Pellow, D., Roberts Timmons, J. (2009) Environmental justice. Annual Reviews 34: pp. 405–430.

[102] Henry, R.C., Mohan, S., Yazdani, S. (2019) Estimating potential air quality impact of airports on children attending the surrounding schools. Atmospheric Environment, 212: pp. 128–135.

[103] 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: pp. 234–247.

[104] McNair, A. (2020) Investigation of environmental justice analysis in airport planning practice from 2000 to 2010. Transp. Research Part D 81:102286.

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

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

[107] U.S. EPA, Cook, R. Memorandum to Docket EPA–HQ–OAR–2019–0660, ''Web addresses for references cited in Section III of the preamble for Control of Air Pollution from Aircraft Engines: Emission Standards and Test Procedures; Final Rule,'' November 9, 2022.

safety. Further, as described in Section VI.D, the EPA does not project any costs associated with these standards because all in-production engines meet the in-production standards, nearly all in-production engines meet the new type design standard, and future new type designs are expected to meet the new type design standard. In addition to the statutory requirements of CAA section 231, the EPA, after consultation with FAA, also took into consideration the importance of controlling PM emissions, international harmonization of aviation requirements, and the international nature of the aircraft industry. The EPA gave significant weight to the United States' treaty obligations under the Chicago Convention in determining the need for and appropriate levels of PM standards. U.S. manufacturers could be at a significant disadvantage if the United States fails to adopt standards by the international implementation date. Also, given the short timeframe from this final action and the international implementation date, there would not be enough lead time for manufacturers to respond to more stringent standards that would require them to develop and implement new technologies.

These considerations led the EPA to determine that adopting aircraft engine PM standards based on engine standards adopted by ICAO is appropriate at this time. When developing the PM standards, ICAO adopted 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 emission standards for other sectors. The second is 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.

The EPA's final action will apply to subsonic turbofan and turbojet engines of a type or model with a rated output (maximum thrust available for takeoff) greater than 26.7 kN, hereinafter referred to as covered engines, and consists of three key parts: (1) PM mass and number emission standards for covered engines, (2) a change in test procedure and form of the existing standards for covered engines—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 final mass, number, and mass concentration standards for aircraft engines. Section IV.D describes the test procedures and measurement procedures associated with the PM standards. Section IV.E presents information related to the reporting requirements.

As discussed in Section III.A, $PM_{2.5}$ consists of both volatile and non-volatile PM (nvPM), although only non-volatile PM will be covered by the adopted standards. Only non-volatile 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. To directly measure non-volatile PM, ICAO agreed to adopt a measurement procedure, as described in Section IV.D, which is based on conditions that prevent the formation of volatile PM upstream of the measurement instruments. The intent of this approach is to improve the consistency and repeatability of the non-volatile PM measurement procedure.

Due to the international nature of the aviation industry, there is an advantage to working within ICAO 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 emission 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 adopting were developed using this approach. Thus, the adoption of these aircraft engine standards into U.S. law will simultaneously prevent aircraft engine PM levels from increasing beyond their current levels, align U.S. domestic standards with the ICAO standards for international harmonization, meet the United States' treaty obligations under the Chicago Convention.

These standards will 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 United States 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 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 United States does not adopt standards that are at least as stringent as the ICAO standards for PM emissions. This action to adopt, in the United States, PM standards that match the ICAO standards will 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. See 87 FR 6324, 6337 (February 3, 2022). As noted in the preceding paragraphs, the EPA, after consultation with FAA, considered the statutory requirements under CAA section 231, the importance of controlling PM emissions, international harmonization of aviation requirements, the international nature of the aircraft industry and air travel, and the United States' obligations under the Chicago Convention in evaluating which stringency of standards to propose. These considerations have historically led the EPA to adopt international standards developed through ICAO. The EPA concluded that proposing and now adopting standards equivalent to 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 standards. This is especially true for these final standards because they change our approach to regulating aircraft PM emissions from past smoke measurements to the measurement of nvPM mass concentration, nvPM mass, and nvPM 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 nvPM 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, through the FAA, State Department, and the EPA, played a significant role in the development of these standards through a multi-year process. The EPA believes that international cooperation on aircraft emissions brings substantial benefits overall to the United States. Given that the EPA and FAA invested significant effort and considerable resources 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 emission standards. For these reasons, the EPA placed significant weight on international regulatory uniformity and certainty and is finalizing standards that match the standards which the EPA worked to develop and adopt at ICAO.

A. PM Mass Standards for Aircraft Engines

1. Applicability of Standards

These standards for PM mass, like the ICAO standards, will apply to covered engines whose date of manufacture is on or after January 1, 2023.[108] These standards will not apply to engines manufactured prior to this applicability date.

The level of the standard will vary based on when the initial type certification application is submitted.[109] Covered engines for which the type certificate application was first submitted on or after January 1, 2023 will be subject to the new type level in Section IV.A.2. These engines are new engines that have not been previously certificated.

Covered engines manufactured on or after January 1, 2023 will be subject to the in-production level, in Section IV.A.3.

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

Covered engines 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 milligram (mg) of PM, as determined over the LTO cycle, divided by kN of rated output (rO).

Equation IV-1

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

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

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

Equation IV-2

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

4. Graphical Representation of nvPM Mass Numerical Emission Limits

Figure IV–1 shows how the nvPM mass emission limits compare to known in-production engines. Data shown in this figure is from the ICAO Engine Emissions Databank (EEDB) [110].

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[108] 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. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021.

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

[110] 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.*

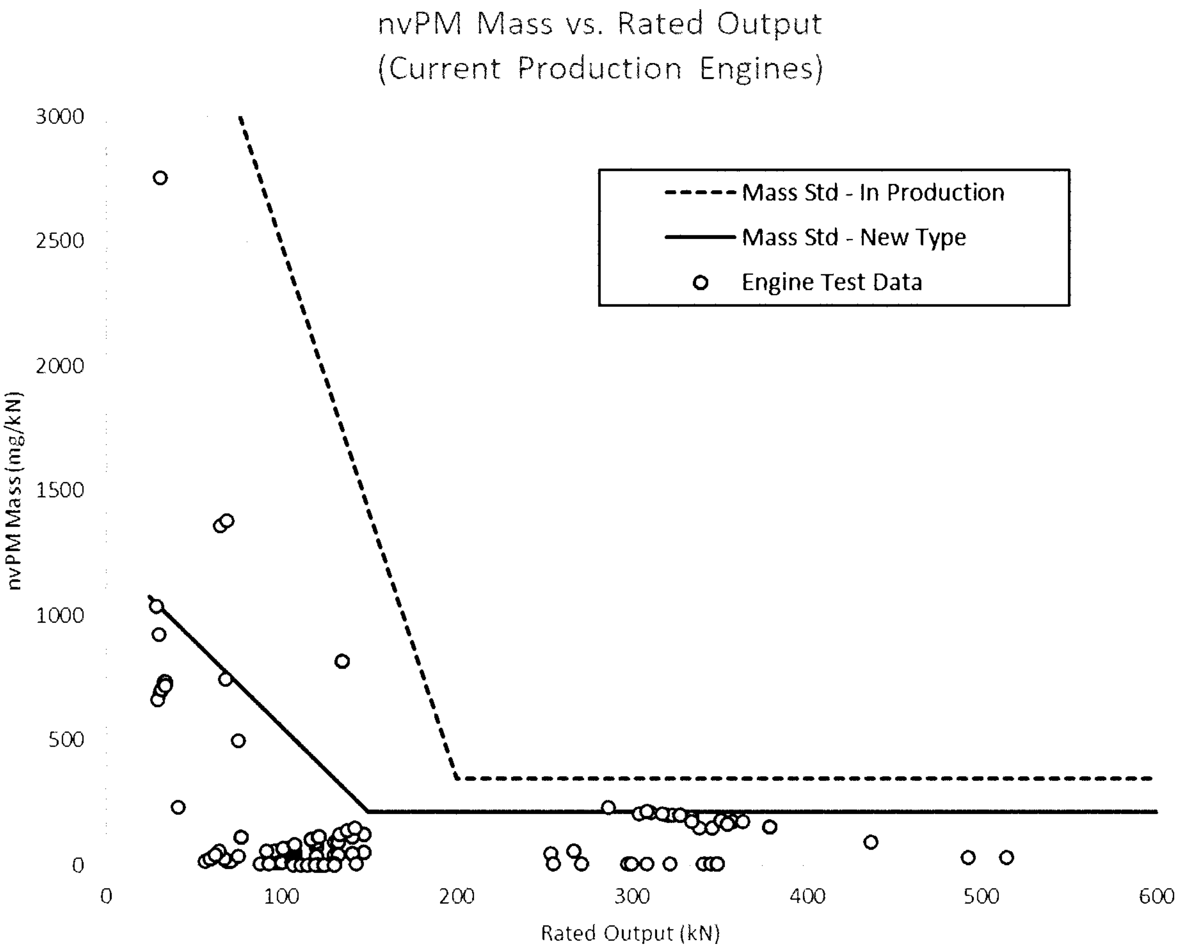

Figure IV–1—nvPM mass standards compared to in-production engine LTO emission rates

B. PM Number Standards for Aircraft Engines

1. Applicability of Standards

These standards for PM number, like the ICAO standards, will apply to covered engines whose date of manufacture is on or after January 1, 2023.[111] These standards will not apply to engines manufactured prior to this applicability date.

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

Covered engines manufactured on or after January 1, 2023 will be subject to the in-production level, in Section IV.B.3.

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

Covered engines 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, as determined over the LTO cycle, divided by kN of rO.

Equation IV-3

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

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

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

[111] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, III–4–4pp. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021.

Equation IV-4

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

4. Graphical Representation of nvPM Number Numerical Emission Limits

Figure IV–2 shows how the nvPM number emission limits compare to known in-production engines. Data shown in this figure is from the ICAO Engine Emissions Databank (EEDB).[112]

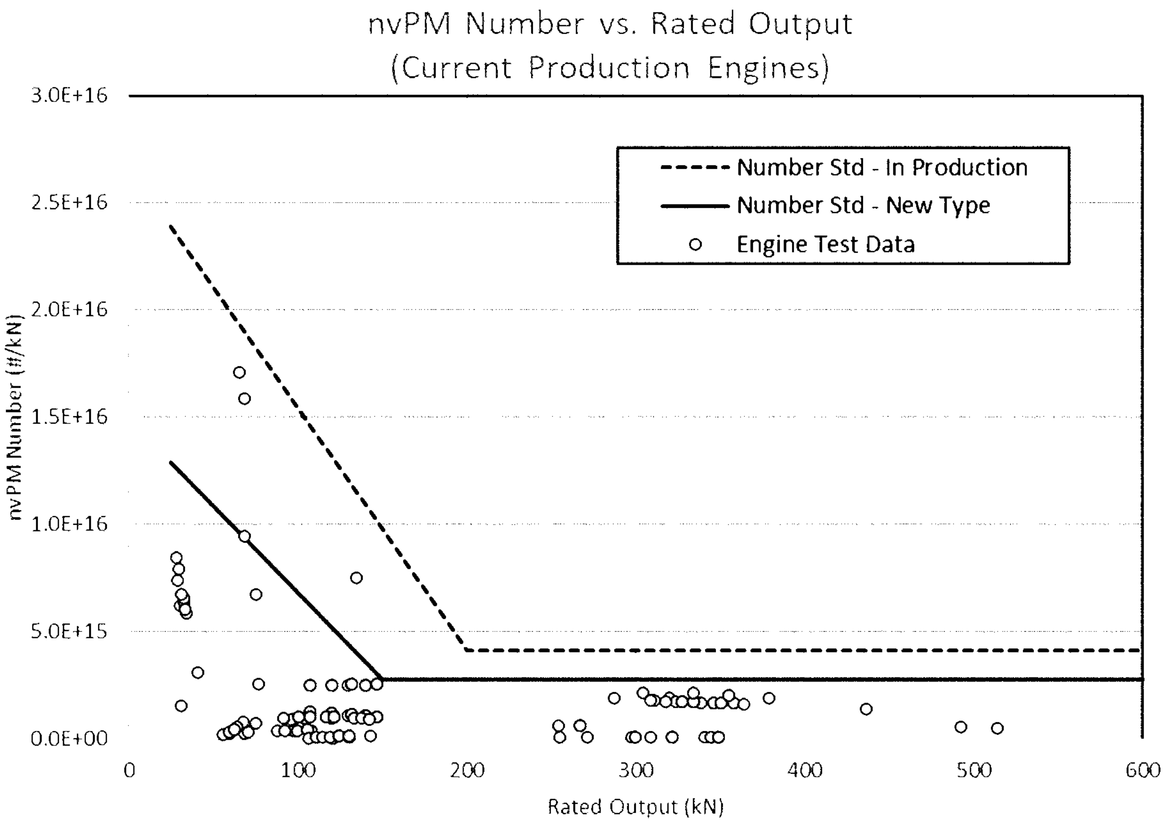

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Figure IV–2—nvPM number standards compared to in-production engine LTO emission rates

C. PM Mass Concentration Standard for Aircraft Engines

The previous 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.[113] 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 p.m. 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. 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.

While the ICAO PM mass concentration standard was intended to have equivalent visibility control as the existing smoke number 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

[112] ICAO Aircraft Engine Emissions Databank, July 20, 2021, ''edb-emissions-databank v28C (web).xlsx,'' European Union Aviation Safety Agency (EASA).

[113] ICAO, 2016: Tenth Meeting Committee on Aviation Environmental Protection Report, Doc 10069, CAEP/10.

during the process, and ultimately concurred with the results.[114] 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 adopting a PM mass concentration standard for all covered engines manufactured on or after January 1, 2023.[115] This standard has the same form, test procedures, and stringency as the CAEP/10 p.m. mass concentration standard adopted by ICAO in 2017. Note, the applicability date of the mass concentration standard, finalized in this action, represents a delay from the January 1, 2020 date agreed to by ICAO[116]. The 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 (m³). This is similar to the previous 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 in Section IV.A and Section IV.B (and described in the introductory paragraphs of Section IV), this is based on the measurement of nvPM only, not total PM emissions.

To determine compliance with the PM mass concentration standard, the maximum nvPM mass concentration [µg/m³] will be obtained from measurements at sufficient thrust settings such that the emission maximum can be determined. The maximum value will 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:

Equation IV-5

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

Engines certificated under the new PM mass concentration standard will not need to certify smoke number values and will not be subject to in-use smoke standards. It is important to note that other smoke number standards remain in effect for turbofan and turbojet aircraft engines at or below 26.7 kN rated output and for 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. In this final rule, the EPA did not reexamine or reopen the existing smoke number standards. Any comments we received on the existing smoke number standards are beyond the scope of this rulemaking.[117]

2. Graphical Representation of nvPM Mass Concentration Numerical Emission Limit

Figure IV–3 shows how the nvPM mass concentration emission limits compare to known in-production engines, which all were certified to the previous smoke standard. Data shown in this figure is from the ICAO Engine Emissions Databank (EEDB).[118]

[114] ICAO, 2019: *Report of Eleventh Meeting, Montreal, 4–15 February 2019, Committee on Aviation Environmental Protection,* Document 10126, CAEP/11. 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.

[115] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, III–4–3. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021.

[116] A second component of the CAEP/10 agreement was data collection by January 1, 2020, so the EPA implemented domestically by updating the Aircraft Engine Emission ICR (EPA ICR Number 2427.04, OMB Control Number 2060–0680) on December 31, 2018 to include PM emission data.

[117] The EPA proposed to extend the applicability of the smoke standards to engines of less than or equal to 26.7 kilonewtons (kN) rated output used in supersonic airplanes, and so the single comment received on the extended applicability is within the scope of this rulemaking and is responded to in the Response to Comments document.

[118] ICAO Aircraft Engine Emissions Databank, July 20, 2021, ''edb-emissions-databank v28C (web).xlsx,'' European Union Aviation Safety Agency (EASA).

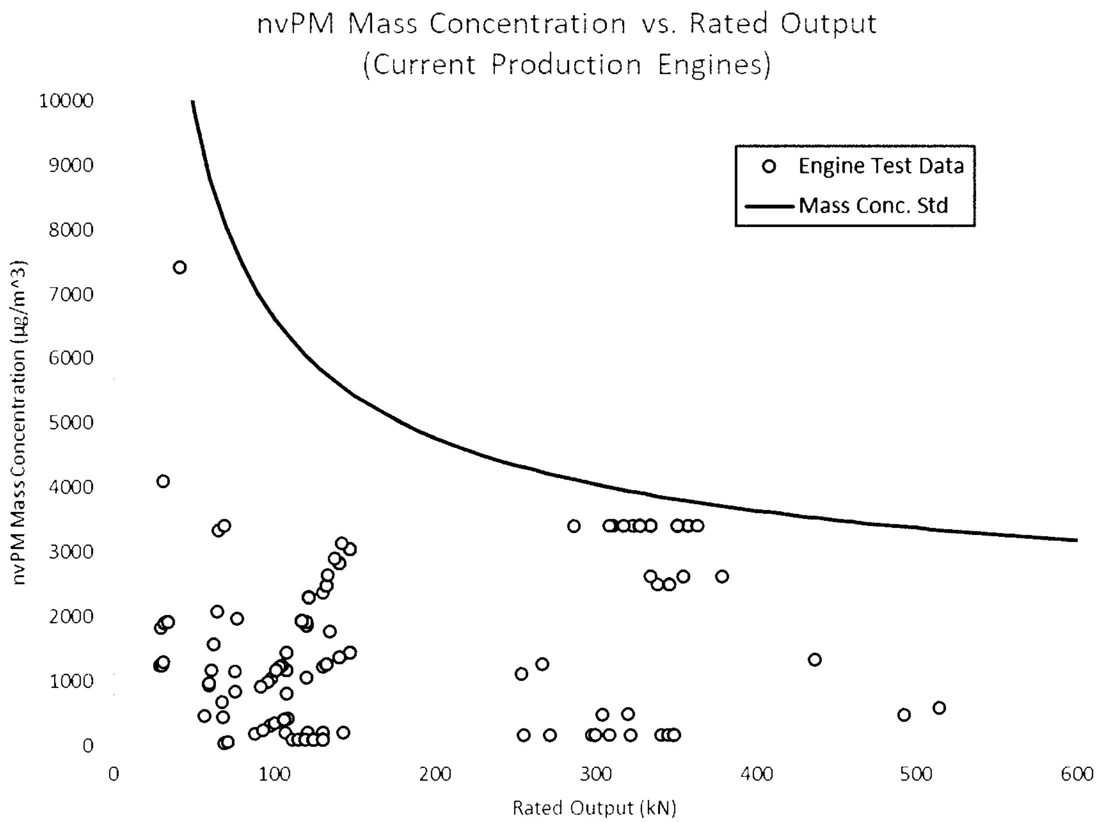

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Figure IV–3—nvPM Mass Concentration Standard

D. Test and Measurement Procedures

1. Aircraft Engine PM Emissions Metrics

When developing the PM standards, ICAO adopted 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. The second is 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 is incorporating 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).

Equation IV-6

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

Equation IV-7

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

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

Regulatory compliance with the emission standards is based on the product of Equation IV–6 or Equation IV–7 or mass concentration divided by the appropriate factor from Table IV–2, to obtain the characteristic level that is used to determine compliance with emission standards (see Section IV.D.4).

2. Test Procedure

The EPA is incorporating by reference the PM test and measurement procedures in ICAO Annex 16, Volume II. These procedures were developed in conjunction with the Society of Automotive Engineers (SAE) E–31 Aircraft Exhaust Emissions

Measurement Committee [119] 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 ICAO Annex 16, Volume II aircraft engine measurement procedures for gaseous pollutants. As described in the Annex 16, at least three engine tests need to be conducted to determine the emissions rates. These tests can be conducted on a single engine or multiple engines.[120] 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 certain other EPA test procedures for mobile source $PM_{2.5}$ standards in two ways. First, as discussed in the introductory paragraphs of Section IV, the procedure is designed to measure only the non-volatile 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 from aircraft engines has proved challenging. Therefore, the development of a procedure for measuring nvPM was prioritized by ICAO and SAE E–31and the result is adopted in this final rule.

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 procedures now incorporated by reference by the EPA 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 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 in Section V.A.2.

3. Test Duty Cycles

Mass and number PM emissions are measured over the LTO cycle shown in Table IV–1. This is the same duty cycle used 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. 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 [121]

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 previous 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 number, the number of tests needed can be reduced, and mass concentration data can be collected concurrently with other PM measurements. Like the previous smoke standard, the PM mass concentration standard is be based on the maximum value at any thrust setting. The engine(s) will 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 in Table IV–1.

The EPA is incorporating by reference ICAO's Annex 16 to the Convention on International Civil Aviation, Environmental Protection, Volume II—Aircraft Engine Emissions, Fourth Edition, July 2017.

4. Characteristic Level

EPA is incorporating by reference Appendix 6 to ICAO Annex 16, Volume II—International Standards and Recommended Practices for correcting engine measurements to characteristic value. Like existing gaseous standards, compliance with the PM standards adopted in this action is based on the characteristic level of the engine. The characteristic level is a statistical

[119] The E–31 Committee develops and maintains standards for measurement of emissions from aircraft engines. (See *https://www.sae.org/works/committeeHome.do?comtID=TEAE31,* last accessed October 31, 2022).

[120] For example, 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.

[121] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, III–4–2. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021.

method of accounting for engine-to-engine variation in the measurement based on the number of engines tested. A minimum of three engine emissions tests is needed to determine the engine type's emissions rates for compliance with emission 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 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.[122] 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

Number of engines tested (i)	CO	HC	NOx	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	$1-\frac{0.13059}{\sqrt{i}}$	$1-\frac{0.24724}{\sqrt{i}}$	$1-\frac{0.09678}{\sqrt{i}}$	$1-\frac{0.15736}{\sqrt{i}}$	$1-\frac{0.15736}{\sqrt{i}}$	$1-\frac{0.19778}{\sqrt{i}}$	$1-\frac{0.19778}{\sqrt{i}}$

For PM mass and PM number, the characteristic level is 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 is 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 139.005 mg/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

[122] ICAO, 2017: *Aircraft Engine Emissions*, International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, App 6–2pp. The ICAO Annex 16, Volume II, Fourth Edition, includes Amendment 10 of January 1, 2021.

5. Derivative Engines for Emissions Certification Purposes

Aircraft engine types can remain in production for many years and be subject to numerous modifications during their production life. As part of the certification process for any change, the type certificate applicant will need to show if the change will have an 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 applicant and certification authorities, ICAO developed criteria to determine whether there has been an emissions change that requires new testing. Such criteria already exist at ICAO and in the EPA regulations for gaseous and smoke standards.

ICAO recommends [123] 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 applicant 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. The EPA is implementing these ICAO recommended practices in this final rule as the regulatory standard in the United States.

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. The EPA is adopting these ICAO criteria in this final rule.[124]

For PM mass measurements described in Section IV.A, the following values 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 in Section IV.B, the following values 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 in Section IV.C, the following values apply:

- ±200 μg/m³ if the characteristic level of maximum nvPM mass concentration is below 1,000 μg/m³.
- ±20% of the characteristic level if the characteristic level for maximum nvPM mass concentration is at or above 1,000 μg/m³.

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

If the engine is not determined to be a derivative engine for emissions certification purposes, the type certificate applicant will 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.[125] 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.[126] [127] 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 rulemaking), and the EPA is including as part of that effort some additional data elements to the ICR (specifically, the emission indices for HC, CO, and NO_X at each mode of the LTO cycle).[128] [129] The EPA is now formally incorporating all aspects of that ICR, as proposed to be renewed, into 40 CFR 1031.150. It is important to note that the incorporation of the PM reporting requirements into the CFR will not create a new requirement for the manufacturers of aircraft engines. Rather, it will 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 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 finalizing the proposal to migrate the existing 40 CFR part 87 regulatory text to a new 40 CFR part 1031. This effort includes clarifying portions of the regulatory text for ease of use. In the old 40 CFR 87.42(c)(6), the regulatory text did not specifically spell out some required data, but instead relied on incorporation by reference of ICAO Annex 16, Volume II's data reporting requirements and listed the data from this Annex that is not required by the EPA's reporting requirement. For future ease of use, 40 CFR 1031.150 explicitly lists all the required items rather than continuing the incorporation by reference approach in the existing reporting regulations. Finally, the EPA is incorporating by reference Appendix 8 of Annex 16, Volume II, which outlines procedures used to estimate measurement system losses, which are a required element of the reporting provisions.

F. Response to Key Comments

The EPA received numerous comments on the proposed rulemaking

[123] ICAO, 2020, Environmental Technical Manual, Doc 9501, Volume II—Procedures for the Emissions Certification of aircraft Engines, Fourth Edition, Section 2, Part III, Chapter 2.

[124] Id.

[125] 77 FR 36342 (June 18, 2012).

[126] 83 FR 44621 (August 31, 2018).

[127] 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 June 8, 2022.

[128] Proposed Information Collection Request; Comment Request; Air Emissions Reporting Requirements (Renewal); EPA ICR No. 2170.08, OMB Control No. 2060–0580, 86 FR 24614 (May 7, 2021).

[129] Documentation and Public comments are available at: *https://www.regulations.gov/docket/EPA-HQ-OAR-2016-0546*, last accessed June 8, 2022.

which are summarized in the Response to Comments document along with the EPA's responses to those comments. Comments in their entirety are available in the docket for this rulemaking action. The following sections summarize the comments related to the stringency of the standards and the EPA's response to these comments. Some adverse comments are addressed more fully in the Response to Comments document.

1. Comments in Support of the Proposed Standards

Comment summary: Some commenters stated that the proposed standards adhere to the statutory requirements of CAA section 231. They say that the proposed standards are well supported by an extensive administrative record. The commenters point out that the D.C. Circuit ruled in 2007 that CAA section 231 confers a broad degree of discretion on the EPA in setting aircraft engine emission standards.[130]

Response: EPA is finalizing the standards as proposed. We agree that the proposed standards, as well as the final standards, satisfy our statutory obligations and are well-supported. The EPA acknowledges that the D.C. Circuit recognized the EPA's broad authority in CAA section 231 *in National Association of Clean Air Agencies* v. *EPA,* 489 F.3d 1221, 1229–30 (D.C. Cir. 2007) (*NACAA*).

Comment summary: Several commenters expressed their support of the EPA adopting PM standards that match the international PM standards because doing so is vital to the competitiveness of U.S. industry and regulatory certainty. They say it would protect U.S. jobs and strengthen the U.S. aviation industry by ensuring the global acceptance of U.S.-manufactured aircraft engines. They also say it will make sure U.S.-manufactured aircraft engines are available to aircraft manufacturers and U.S. airlines, while enabling U.S. airlines to obtain aircraft and aircraft engines at market-driven, competitive prices.

Response: The EPA agrees this rule has the benefit of helping to ensure the acceptance of U.S.-manufactured aircraft engines by member States, aircraft (airframe) manufacturers, and airlines around the world. The EPA notes that under the terms of the Chicago Convention, ICAO member States must recognize as valid certificates of airworthiness issued by other ICAO member States, provided the requirements under which such certificates were issued are as least as stringent as the minimum ICAO standards.[131]

Comment summary: Some commenters urged the EPA to promptly issue the final rule with the standards matching the international standards. They say that this EPA rulemaking and the subsequent FAA certification rulemaking must be completed to start the certification process in the United States. Thus, they believe that prompt EPA action is necessary to provide sufficient time for FAA to promulgate their certification rulemaking and U.S. aircraft engine manufacturers to conduct the lengthy and expensive steps to demonstrate compliance with the standards, for all aircraft engines that will be in-production in 2023. They note that January 1, 2023, is the implementation date for the ICAO standards.

Response: The EPA acknowledges that the international effective date for the ICAO mass concentration standards was January 1, 2020, and that the international effective date for the mass and number standards is January 1, 2023. The EPA also acknowledges that FAA will need to conduct a separate, subsequent certification rulemaking process to implement the EPA's PM standards finalized in this action.

In this action, the EPA is aiming to minimize disruption by finalizing this action before the January 1, 2023, the international effective date of the PM mass and number standards.

For comparison, the EPA notes the EPA finalized the domestic GHG standards for airplanes on January 11, 2021, after the international effective date for new type planes;[132] however, disruption was avoided in practice because no manufacturers applied to FAA for a type certificate for a new type design airplane between January 1, 2020, and January 11, 2021.

Comment summary: Some commenters state that the proposed standards are identical to ICAO's aircraft engine PM standards and that adopting them is consistent with the 1944 Chicago Convention treaty obligations. They say that these standards continue the long collaborative tradition between the EPA and ICAO. The commenters say that the objective of the Chicago Convention is to foster global cooperation and encourage an atmosphere where international civil aviation could be developed in a safe and orderly manner, while being operated soundly and economically. The commenters say that, with both the FAA and the EPA playing key leadership roles, it was only after significant deliberation and technical and economic analyses that CAEP agreed to the ICAO PM standards. The commenters say that the EPA's adoption of standards that align with ICAO standards supports international harmonization and regulatory uniformity.

Response: The EPA agrees adopting the PM standards in this action satisfies the United States' treaty obligations under the Chicago Convention. The EPA also agrees that the EPA and the FAA had key leadership roles in the ICAO PM standard-setting process, and the EPA recognizes the significant deliberations and economic analyses that occurred in CAEP. The EPA agrees that this action promotes international cooperation and harmonization.

Comment summary: Some commenters say that the standards are consistent with the CAEP terms of reference which provide that standards be technologically feasible, economically reasonable, environmentally beneficial, and balanced against interdependencies (aircraft noise and competing emission reductions of other pollutants, such as NO_X). The commenters say that the CAEP terms of reference align well with the considerations in CAA section 231, and ICAO's assessment of each of the criteria of the terms of reference is directly related to the decisions the EPA must make when issuing aircraft engine emission standards. The commenters assert that CAA section 231(b) requires that aircraft engine emission standards allow sufficient lead time for the development of the necessary technology, while giving consideration of the cost to comply within this time period.

Response: The EPA agrees that the final standards are consistent with the CAEP terms of reference and that the standards also meet the requirements of CAA section 231. The EPA would not adopt ICAO standards domestically without exercising the Agency's own independent evaluation of appropriate domestic standards under CAA section 231, which is what the EPA has done in

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[130] *National Association of Clean Air Agencies* v. *EPA,* 489 F.3d 1221, 1229–30 (D.C. Cir. 2007) (''When Congress enacted § 231 providing that the Administrator could, 'from time to time,' act 'in his judgment,' as 'he deems appropriate,' it conferred broad discretion to the Administrator to weigh various factors in arriving at appropriate standards.'').

[131] ICAO, 2006: *Convention on International Civil Aviation,* Article 33, Ninth Edition, Document 7300/9.

[132] CAEP/10 airplane CO_2 standards apply to new type design airplanes for which the application for a type certificate was or 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.

this rulemaking. Any domestic aircraft engine standards adopted by the EPA must comport with the requirements in CAA section 231.

Comment summary: Some commenters say that CAA section 231(a)(2)(B)(ii) expressly prohibits changes in aircraft engine emission standards that ''would significantly increase noise and adversely affect safety.'' The commenters point out that, as the EPA describes in the proposed rulemaking, ICAO/CAEP evaluates ''technological feasibility'' using the Technology Readiness Level (''TRL'') scale and deems technologies that have attained TRL8 (defined as the ''actual system completed and 'flight qualified' through test and demonstration'') to be ''technologically feasible.'' Therefore, the commenters conclude, the use of TRL8 to evaluate ''technological feasibility'' makes sure aircraft engine emission standards reflect what technologies can safely deliver, instead of hypothetical ''technology forcing'' standards that could pose a potential threat to air safety.[133]

Response: The EPA agrees that TRL8 [134] is an adequate and appropriate criteria for identifying proven technologies that are demonstrably safe and of an acceptable noise level for purposes of this rulemaking. The EPA relies on TRL8 to support the PM standards finalized in this rule because TRL8 was used to justify the PM standards by ICAO, as described in Section VI.B. ICAO treats TRL8 as a proxy for what is technologically feasible in the course of establishing new international standards. This conservative approach allows ICAO to ensure that all technology being considered is safe and of acceptable noise level without having to conduct additional evaluation of specific technologies. The EPA agrees this use of TRL8 is a valid means for ICAO to develop standards that will, by definition, be based on technologies that have been proven safe, of acceptable noise level, and technologically feasible. The EPA also agrees that ICAO's use of TRL8 means that technologies considered have been proven safe and of an acceptable noise level, and therefore, that the final PM standards do not adversely affect safety and do not significantly increase noise. In setting the international standards, ICAO 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. Thus, the technology was already demonstrated to be safe and of acceptable noise levels for these standards, and ICAO did not view that a new safety and noise analysis was necessary.

However, in the EPA's view, ICAO's use of TRL8 to define technological feasibility is not the only means to ensure a standard does not adversely affect safety and does not significantly increase noise. The EPA does not view TRL8 to represent the most stringent level of technology that could be required in an EPA aircraft standard setting rulemaking. Nor does the EPA agree with the premise that standards based on technology below TRL8 would necessarily be technology forcing or inherently have a negative effect on safety and noise. In establishing U.S. aircraft engine emission standards, the EPA is not constrained to ICAO's definition of technological feasibility in assessing appropriate aircraft engine standards under CAA section 231(a). *See NACAA,* 489 F.3d at 1229–30. In fact, the EPA has adopted technology-forcing standards under CAA section 231 in the past and found them to be safe and not to significantly increase noise.[135] In the future, if the EPA were to consider setting emission standards based on technology that was not yet at TRL8 or not expected to be at TRL8 by the implementation date of the standards,[136] the Agency, just as it did in this action, in consultation with the FAA, would evaluate the safety and noise impact (also lead time and cost) of such standards before making a determination in this regard. CAA section 231(a)(2)(B) and (a)(3). Any assessment of safety and noise (also lead time and cost) in the context of hypothetical technology-forcing standards would have to occur in the context of the specific standards under consideration.

2. Comments in Support of More Stringent Standards

Comment summary: Several commenters were dissatisfied with the level of stringency of the PM standards. One commenter argued that CAA section 231 requires the EPA to adopt technology-forcing standards. Other comments argued CAA section 231 requires the EPA to set standards according to expectations of the development of technology over time. Some commenters say that, at a minimum, the EPA should establish standards that reduce emissions based on available engine technology. A number of commenters supported these arguments by pointing to the text of the statute, the underlying legislative intent, legislative history, and the purpose of the CAA.

Response: The statutory-based arguments presented by commenters that the level of stringency of the PM standards are not authorized by CAA section 231 import requirements into the statute that do not exist.

As described in Section II.A, CAA section 231(a)(2)(A) directs the Administrator of the 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 the Administrator's judgment causes or contributes to air pollution that may reasonably be anticipated to endanger public health or welfare. CAA section 231(a)(3) provides that after the EPA proposes standards, the Administrator shall issue such standards ''with such modifications as he deems appropriate.'' CAA section 231(b) requires that any emission standards ''take effect after such period as the Administrator finds necessary . . . to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance during such period.'' The D.C. Circuit has held that the delegation of authority in CAA section 231 ''is both explicit and extraordinarily broad'' and that the text confers ''broad discretion . . . to weigh various factors in arriving at appropriate standards.'' *NACAA,* 489 F.3d 1221, 1229–30.

The statutory language of CAA section 231 is not identical to other provisions in the CAA that direct the EPA to establish technology-based standards. CAA section 231(a) states that the EPA must ''issue proposed emission standards applicable to the emission of any air pollutant'' from aircraft engines

[133] Any reference to technology-forcing standards in this rulemaking is not based on the level of the final PM standards, but it is intended to respond to comments.

[134] As described in Section VI.B, 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.

[135] *See* 38 FR 19088 (July 17, 1973); 41 FR 34722 (August 16, 1976).

[136] As described in Section VI.B, for the ICAO PM standard setting, ICAO referred to technical feasibility as any technology demonstrated to be safe and airworthy proven to Technology Readiness Level 8 and available for application over a sufficient range of newly certificated aircraft. This means that the ICAO analysis that informed the international standard considered the emissions performance of aircraft engines assumed to be in-production on the ICAO implementation date for the PM mass and number standards, January 1, 2023.

and to finalize ''such regulations'' with those modifications the EPA ''deems appropriate.'' CAA section 231(a)(2)(A) and (a)(3). This language is in contrast to Congress' direction in other parts of the Act, where it required the EPA to set standards that achieve a particular degree of emission reduction or environmental or public health protection. For example, in setting technology-based emission standards for hazardous air pollutants under CAA section 112(d)(2) and (3), the EPA must ''require the maximum degree of reduction . . . that the Administrator . . . determines is achievable,'' taking into account cost and non-air quality health and environmental impacts. CAA section 112(d)(2). Those standards also ''shall not be less stringent than'' explicitly prescribed levels. CAA section 112(d)(3). Health- and environmental quality-based NAAQS under CAA section 109 must be set at levels ''requisite to protect the public health'' and ''requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of [the] air pollutant in the ambient air.'' CAA section 109(b)(1) and (2). When regulating certain pollutants from motor vehicles and nonroad engine emissions under CAA sections 202(a)(3) and 213(a)(3) and (5), the EPA's standards must ''reflect the greatest degree of emission reduction achievable . . . , giving appropriate consideration to cost, energy, and safety factors associated with the application of such technology.'' CAA sections 202(a)(3) and 213(a)(3) and (5).

CAA section 231 lacks comparable language requiring it to meet a particular threshold of protectiveness, emission reduction, or technological stringency, despite this clear evidence that Congress knew how to impose such obligations when it wished. *See generally* CAA section 231. ''Where Congress uses certain language in one part of a statute and different language in another, it is generally presumed that Congress acts intentionally.'' *Nat'l Fed'n of Indep. Bus.* v. *Sebelius,* 567 U.S. 519, 544 (2012); *Sosa* v. *Alvarez-Machain,* 542 U.S. 692, 711 n.9 (2004) (citing a treatise on statutory construction and calling this principle the ''usual rule'' of judicial interpretation). In certain respects, the EPA's authority is broader than it is under other CAA provisions, in that the EPA is not required in setting aircraft emission standards to achieve a specified degree of emissions reduction.

Some commenters also presented a textual comparison of the House and Senate bills to conclude that Congress intended for CAA section 231 to be based on a consideration of pollution impacts and technological feasibility because the final CAA section 231(a)(1) required the EPA to conduct a study within 90 days after December 31, 1970 of air pollutants from aircraft to determine impact on air quality and technological feasibility of controlling such pollutants. S. Rep. No. 91–1196, at 24, 1 Leg. Hist. at 424; H.R. Rep. No. 91–1783, at 55 (Conf. Rep.). One commenter alleged this means ''the necessary premise [is] that such study should inform the standards themselves.'' [137] However, the study requirement in CAA section 231(a)(1) does not establish a requirement for aircraft engine standards to be forward-looking technology-based regulation. That provision required EPA to conduct a one-time ''study and investigation'' ''to determine'' the extent of aircraft emissions' impacts on air quality and the feasibility of controlling them ''[w]ithin 90 days after December 31, 1970.'' The single study required in CAA section 231(a)(1) is not a continuing obligation that pertains to each exercise of the standard-setting authority under CAA section 231(a)(2) and (3), which contain no discussion of technological feasibility and under which standards are set and may be revised ''from time to time.'' *Cf. Sierra Club,* 325 F.3d 374, 377 (D.C. Cir. 2003) (holding that a provision requiring EPA to set standards ''based on'' such a study did not make the validity of the standards dependent on their connection to that study).

The commenters also quoted to a Senate report accompanying the CAA 1970 amendment Senate bill to suggest CAA section 231 requires standards to be based on the degree of harm caused by aircraft pollution and the technology that can be developed in the future to reduce it. The statement cited by commenters from the Senate Report does not constrain the EPA where the plain text of the statute does not, and where Congress knew how, but declined, to make such constraints mandatory on the Agency. ''Congress' authoritative statement is the statutory text, not the legislative history.'' *Chamber of Com. Of U.S.* v. *Whiting,* 563 U.S. 582, 599 (2011) (quoting *Exxon Mobil Corp.* v. *Allapattah Services, Inc.,* 545 U.S. 546, 568 (2005) (internal quotation marks omitted). Further, the *NACAA* Court rejected an argument that similar statements in the 1970 Senate Report established Congress' intent that the EPA prioritize forward-looking standards. *NACAA,* 489 F.3d at 1229–30; *Sierra Club* v. *EPA,* 325 F.3d 374, 379–380 (D.C. Cir. 2003).

The EPA's interpretation of CAA section 231 is not categorically at odds with the Clean Air Act's general protective purpose. The Act's general goal of reducing air pollution does not, in itself, prescribe regulatory factors for specific programs, nor does it restrict the EPA's discretion as to how best effectuate that goal in a specific action or in a regulatory program over time. Accordingly, while the EPA's discretion under CAA section 231 would allow it to select more stringent standards when appropriate, it does not mandate that the EPA elevate pollution reduction over all relevant factors in the consideration of any particular aircraft standard. *See NACAA,* 489 F.3d at 1229–30.

The final PM standards fall squarely within the EPA's statutory authority under CAA section 231 to promulgate. As described in Section I.B.2 and the introductory text of Section IV, in proposing and adopting the final PM standards, the EPA considered the statutory requirements of CAA section 231. The EPA also took into account the need to control PM emissions, the importance of international harmonization, avoiding adverse impacts that could result from delaying adoption of PM standards at least as stringent as ICAO's PM standards, and gaining experience from the novel approach to implementing PM standards. Further, based on the EPA's independent view that technology at the TRL8 has been demonstrated to be safe and of an acceptable noise-level, the EPA is confident that the final standards will not significantly increase noise or adversely affect safety. The EPA reached the same conclusion as ICAO that a new noise and safety analysis was not necessary. For the same reasons, the EPA believes sufficient lead time has been provided since the technology has already been developed. Costs information for the standards is described in Section VI.D. Based on this assessment, the EPA concludes that it is reasonable to finalize PM standards that match the international standards in scope, stringency, and effective date.

Additional legal issues raised by these comments are addressed in the Response to Comments document.

Comment summary: Some commenters claim the EPA has an obligation to consider the feasibility, costs, and benefits of more stringent standards, including technology-forcing standards, or at least explain why it did

[137] Comments of California, Connecticut, Illinois, Maryland, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Vermont, Washington, and Wisconsin at 13. See also Comment of Sierra Club at 7–8.

not do so. A few commenters proposed suggestions to alternative PM controls such as de-rated takeoff, accelerated implementation of Optimized Profile Descents, reduced power during taxiing, improved taxi time, and reduced usage of auxiliary power units (APUs).

Response: The focused scope of the EPA's proposed PM standards was informed by the January 1, 2023, international effective date for the mass and number PM standards, as well as the other considerations identified elsewhere throughout this preamble. The EPA does not believe it would be feasible to repropose more stringent PM standards and also meet the international effective date of the new mass and number standards. Should the United States miss the January 1, 2023, deadline, U.S. airplane and engine manufacturers could be forced to seek PM emissions certification from an aviation certification of another country to market and operate their airplanes and engines internationally. The United States would also miss its obligations under the Chicago Convention.

The EPA believes that the limited scope of the proposal is permissible under CAA section 231 and, based on the plain language of the statute, disagrees with the premise that the statute requires the Agency to propose multiple levels of stringency of standards. To the extent commenters identified specific alternative levels of stringency they would prefer, the comments did not provide sufficient information about safety, noise, lead time, and costs of those alternatives to support the EPA finalizing more stringent standards in this rulemaking. In light of the reasons the EPA has provided for adopting the PM standards as proposed, the EPA does not view these ''modifications'' requested by commenters to be ''appropriate'' to incorporate into the PM standards adopted in this rulemaking. See CAA section 231(a)(3). The EPA's current and intended future work related to addressing PM emissions from aircraft engines is described in Section I.C.

A number of commenters also provided suggested ideas for alternative methods to regulating PM emissions (*e.g.,* de-rated takeoff, reduced power during taxiing, and improved taxi time). The EPA has carefully reviewed the alternatives raised by the commenters, but has decided not to adopt them in this final rulemaking. The EPA does not believe it would be feasible to assess the legal, technical, and policy issues raised by suggested alternatives put forward by commenters; repropose standards; take public comment; and meet the international effective date of January 1, 2023. More specific comments related to suggested alternative PM controls are addressed in the Response to Comments document.

Comment summary: According to some commenters, the EPA impermissibly factored international harmonization, adverse impacts on U.S. industry, or other non-statutory considerations into its rationale supporting the PM standards.

Response: The EPA's past practice and the D.C. Circuit's holding in *NACAA* that the EPA's historical approach of taking international harmonization into account in setting domestic standards as not ''manifestly contrary to the statute'', *NACAA,* 489 F.3d at 1230, affirm that the EPA's broad discretion includes the ability to weigh considerations such as international harmonization and the competitive effects of the EPA's standards on international aviation. Nothing in CAA section 231 precludes such considerations. Aircraft and their engines are manufactured and sold around the world, and routinely operate in international airspace. Furthermore, CAA section 231 does not list or dictate the EPA's consideration of particular factors and enables the EPA to identify and apply relevant considerations in determining what standards are ''appropriate''. CAA section 231(a)(3). The D.C. Circuit rejected an argument similar to the commenters' in *NACAA:* ''Finding nothing in the text or structure of the statute to indicate that the Congress intended to preclude the EPA from considering '[factors other than air quality],' we refused to infer from congressional silence an intention to preclude the agency from considering factors other than those listed in a statute.'' 489 F.3d at 1230 (quoting *George E. Warren Corp.* v. *EPA,* 159 F.3d 61, 623–24 (D.C. Cir. 1998)). Moreover, the Chicago Convention, ratified by the United States, has the force of Federal law, and therefore, the EPA acts appropriately in implementing our Clean Air Act authorities in a manner that is harmonious and consistent with the Chicago Convention and the United States' international obligations under the treaty.

Having invested significant effort and resources, working with the FAA and the Department of State, to gain international consensus within ICAO to adopt the international PM standards for aircraft engines, the EPA believes that meeting the United States' obligations under the Chicago Convention by aligning domestic standards with the ICAO standards, rather than adopting more stringent standards, will have substantial benefits for future international cooperation on aircraft engine emission standards, and such cooperation is the key for achieving worldwide emission reductions. Deviating from the international PM standards could undermine future efforts by the United States to seek international consensus on aircraft emission standards in general, including more stringent future standards for PM. Reaching this conclusion is not tantamount to a determination that it would never be appropriate for the EPA to adopt more stringent PM standards than ICAO's standards. However, at this time, the EPA finds it appropriate to finalize the standards as proposed.

In addition, the ICAO applicability date of the mass and number standards of January 1, 2023, is fast approaching. The U.S. aircraft engine manufacturers, aircraft manufacturers, and airlines are urging the EPA to promptly promulgate this final rulemaking to adopt ICAO's standards, which were adopted back in 2017 and 2020, so they can build (and sell) or have access to U.S. engines to remain competitive in the global marketplace. Furthermore, the EPA understands that U.S. aircraft engine manufacturers need time to certify their products, after the subsequent FAA rulemaking to enforce the standards, to ensure the aircraft engines comply with standards. Also, the EPA did not conduct the analyses needed to support more stringent standards in the proposed rulemaking, or otherwise develop a sufficient record for more stringent standards, that would be necessary to support finalizing such standards in this final rule. We do not believe we could finalize more stringent standards without conducting significant additional analyses and undertaking a new round of notice and comment, which would certainly cause a significant delay in meeting the United States' obligations under the Chicago Convention. We have decided that the most appropriate course, under CAA section 231, is to adopt aircraft engine PM standards that are harmonized with the standards adopted by ICAO in 2017 and 2020.

In determining what final PM standards are appropriate under CAA section 231 and after consultation with FAA, the EPA considered the level of standards that could be met with the application of requisite technology within the necessary period of time that would allow the United States to meet its obligations under the Chicago Convention to at least match the ICAO standards, and gave appropriate consideration to the cost of compliance within this period. This determination also took into account the requirement that EPA's revised standards not significantly increase noise and adversely affect safety.

Comment summary: Some commenters argued that the EPA's position that it would be appropriate to gain experience from implementation of the novel approach to implementing PM standards before considering whether to adopt more stringent regulations is arbitrary and capricious.

Response: As described the introductory paragraphs of Section IV, these final standards change the approach to regulating aircraft engine PM emissions from past smoke measurements to the measurement of mass and number for the first time for U.S. manufacturers, and international regulatory uniformity and certainty are key elements for these manufacturers as they become familiar with adhering to these standards and test procedures. Further, some manufacturers are still adapting to how best control aircraft engine PM since they designed recent in-production engines to optimize NO_X control, as explained in the succeeding paragraphs.[138] We think that considering the novelty of these approaches and the industry's response to them falls well within our discretion. Moreover, they also pertain to the statutory directive to consider the lead time necessary for the development and application of the requisite technology. See CAA section 231(b).

Comment summary: Some commenters say that proposed standards are far less stringent than PM emission levels that existing aircraft engine technologies already achieve. Some commenters assert that more stringent PM standards compared to the proposed standards are feasible for in-production and new type design aircraft engines. Some commenters argue that the proposed PM standards are not anti-backsliding. These comments say that all in-production engines already meet the proposed standards for in-production engines and most meet the proposed standards for new type design engines by a considerable margin; therefore, no backsliding could reasonably happen absent these standards.

Response: While it may be true that more stringent PM standards compared to the final standards are feasible for some in-production and new type design aircraft engines, for the reasons explained in the proposal and again in this final rule the EPA does not consider more stringent standards than those adopted in this action, applicable to all in-production and new type design engines, to be appropriate at this time. Additionally, the EPA did not propose more stringent standards, and the existing record that has been developed does not support finalizing more stringent standards absent significant additional analyses.

The EPA disagrees that the standards are not anti-backsliding. Although the PM mass concentration standard is replacing the smoke standard for some engines, the PM mass and number standards are the first of their kind. In that regard, PM mass and number are currently unregulated from aircraft engines and the standards finalized in this action represent a new regulatory backstop of those two forms of previously uncontrolled PM emissions. Further, all three PM standards will prevent backsliding by ensuring that all new type design and in-production aircraft engines will not exceed those regulatory levels in the future.

CAEP meets triennially, and in the future, we anticipate ICAO/CAEP considering more stringent aircraft engine PM standards. The U.S. Interagency Group on International Aviation (IGIA) facilitates coordinated recommendations to the Secretary of State on issues pertaining to international aviation (and ICAO/CAEP), and the FAA is the chair of IGIA. Representatives of domestic states, non-governmental organizations, and industry can participate in IGIA to provide input into future standards for ICAO/CAEP. U.S. manufacturers will be better prepared for any future standard change due to their experience with measuring nvPM mass and number for the first time for these final standards. The PM standards adopted in this rulemaking, within the larger context of international aircraft standard-setting, send an important signal that PM emissions is a factor that manufacturers need to consider when building aircraft engines now and going forward—with the anticipation that ICAO/CAEP will consider more stringent PM standards in the future.

In response to the comments that the standards are far less stringent than PM emission levels of existing aircraft engine technologies, the EPA notes that there is a wide range of PM levels for in-production aircraft engines. As described in Section VI.C, for some manufacturers new technologies aimed at reducing aircraft engine NO_X, which were implemented for in-production engines that were recently built, also resulted in an order of magnitude reduction in PM in comparison to most in-service engines. Specifically, the current lean-burn engines and some advanced Rich-Quench-Lean (RQL) engines developed for the purpose of achieving low NO_X emissions coincidentally provided order of magnitude reductions in PM emissions in comparison to existing RQL engines.[139] Other manufacturers did not develop or implement such technologies that resulted in such PM reduction, and thus, their recent in-production aircraft engines are not achieving similar PM control. The final PM standards are anti-backsliding for these aircraft engines by ensuring that they will not exceed the final standards in the future. Further, this information shows that available engine technology includes a wide range of technologies, and the EPA's final standards are standards that can be met by all engines expected to be in production by the implementation date of the PM mass and number standards, January 1, 2023.

Comment summary: Some commenters argued that the EPA is not bound by the Chicago Convention to adopt standards equivalent to ICAO's standards, and relatedly some commenters asserted the EPA is not prohibited from adopting standards more stringent than ICAO's standards. Some comments argued that the EPA cannot allow international agreements to dictate its domestic regulation of PM from aircraft engines.

Response: As explained in the introductory text of Section IV and in Section VI, and reiterated throughout the responses to comments, the EPA conducted its independent assessment of the appropriateness of the ICAO standards for domestic application in the United States and finds it appropriate to adopt domestic PM standards aligned with the international PM standards in this action. The EPA agrees that the United States could adopt standards at a different stringency than ICAO's, even more stringent standards. Under the terms of the Chicago Convention, ICAO member States must recognize as valid certificates of airworthiness issued by other ICAO member States, provided the requirements under which such certificates were issued are as least as

[138] ICAO, 2019: *Independent Expert Integrated Technology Goals Assessment and Review for Engines and Aircraft,* Document 10127. It is found on page 34 of the English Edition of the ICAO Products & Services 2022 Catalog and is copyright protected; Order No. 10127.

[139] ICAO, 2019: *Independent Expert Integrated Technology Goals Assessment and Review for Engines and Aircraft,* Document 10127. It is found on page 34 of the English Edition of the ICAO Products & Services 2022 Catalog and is copyright protected; Order No. 10127.

stringent as the minimum ICAO standards.[140]

The need for direct cooperation between countries gave rise to ICAO, an active regulatory body that sets and revises standards. As described in Section II.B, 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. Compliance with ICAO's standards, including its emission standards, is essential to ensure acceptance by other countries as people, aircraft, and cargo move in international commerce. The EPA recognizes nations have authority to vary from ICAO standards, provided they give the required notice. Also, the EPA has not concluded that the unique features of the aviation industry necessitate a policy to never adopt more stringent emission standards compared to ICAO standards. However, adopting more stringent PM standards than ICAO's PM standards, which change the approach to regulating aircraft engine PM emissions, would risk disruption to international cooperation. The EPA considered the timing of the ICAO PM mass and number standards for new type design and in-production engines, which have a January 1, 2023 implementation date. Given the limited time frame and potential implications of the EPA not adopting a standard, the EPA has acted reasonably in this rulemaking by giving significant weight to the value of international harmonization and to the fact that, in the EPA's judgment, international harmonization would promote ongoing cooperation to control global pollution of PM.

Comment summary: Some commenters urged the EPA to withdraw the proposed rule and issue a proposed rule that would assess the full range of feasible stringency options and propose emission standards that reduce aircraft PM emissions.

Response: The EPA is finalizing the PM standards as proposed. However, as explained in Section I.C, the EPA remains committed to analyzing this issue and will continue to work with the United States' international partners to revisit these standards in the future. We do not believe it would be appropriate to withdraw the proposed rule and issue a new proposal for the reasons stated in the preceding paragraphs.

V. Aggregate PM Inventory Methodology and Impacts

The PM emissions inventory is presented here to provide information on the contribution of aircraft engine emissions to local inventories as context for this regulatory effort. This PM emissions inventory is from the aviation portion of the EPA's 2017 National Emissions Inventory (NEI).[141 142 143] The NEI contains comprehensive emissions data for criteria pollutants and hazardous air pollutants for mobile, point, and nonpoint sources covering both natural and anthropogenic contribution to the overall national PM emissions inventory. For this PM rulemaking, we updated the aviation portion of the PM emissions inventory using newly available measured data reported for most in-production engines and an improved approximation method for engines without measurement data, as described in this section.

The inventory is developed from using actual operations at airports. The number of aircraft operations or landings and takeoffs affects PM emissions that contribute to the local air quality near airports. The landing and take-off (LTO) emissions are defined as emissions between ground level and an altitude of about 3,000 feet. These LTO emissions directly affect the ground level air quality at the vicinity of the airport since they are within the local mixing height. They are composed of emissions during departure operations (taxi-out movement from gate to runway, aircraft take-off run and climb-out to 3,000 feet), and during arrival operations (approach at or below 3,000 feet down to landing on the ground and taxi-in from runway to gate). 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.[144]

As described in Section III.A, aircraft PM emissions are composed of both volatile and non-volatile PM (nvPM) components.[145] With a precisely controlled air-fuel mixture, a typical aircraft engine yields combustion products on the order of 27.6 percent water (H_2O), 72 percent CO_2, about 0.02 percent SO_X, and only about 0.4 percent incomplete residual products. These incomplete residual products can be broken down to 84 percent NO_X, 11.8 percent CO, 4 percent unburned hydrocarbons (UHC), 0.1 percent PM, and trace amounts of other products.[146] Although the PM emissions are a small fraction of total engine exhaust, the composition and morphology of PM are complex and dynamic. While the emissions certification test procedures focus only on measuring non-volatile 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 Modeling Methodologies

This section describes the nvPM approximation method we used in the proposed rulemaking, the use of newly available measured nvPM data, and

[140] ICAO, 2006: *Convention on International Civil Aviation,* Article 33, Ninth Edition, Document 7300/9.

[141] 2017 National Emissions Inventory: Aviation Component, Eastern Research Group, Inc., June 25, 2020, EPA Contract No. EP–C–17–011, Work Order No. 2–19.

[142] 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.

[143] U.S. EPA, 2017 National Emissions Inventory (NEI) Data.

[144] 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. (page 137.) The air in this mixing height is completely mixed and pollutants emitted anywhere within it will be carried down to ground level. (page 143.) ''The aircraft operations of interest within the [mixing height] are defined as the [LTO] cycle.'' (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.

[145] ICAO: 2019, ICAO Environmental Report. A copy of this document is available in the docket for this rulemaking under document identification number EPA–HQ–OAR–2019–0660–0022. 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 emissions 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.)

[146] European Monitoring and Evaluation Programme/European Environment Agency, Air Pollutant Emission Inventory Guidebook 2019.

improvement to the nvPM approximation method for the final rulemaking.

1. PM Emission Indices Used in the Rulemaking

Measured PM data were not available when the EPA first developed the 2017 inventory. Thus, to calculate the baseline aircraft engine PM emissions, we used the First Order Approximation Version 3.0 (FOA3) method defined in the Society of Automotive Engineers (SAE) Aerospace Information Report, AIR5715.[147] For nvPM mass, the FOA3 method is based on an empirical correlation of Smoke Number (SN) values and the 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.[148] 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 PM mass (not number).

In addition, as described in 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[149] and sulfur content. Since the total PM is the emission inventory we are estimating for this rulemaking, we are including the volatile PM emission estimates from the FOA3 method in our emission inventory.

2. Measured nvPM Emission Indices for Inventory Modeling

The measurement and reporting of engine EIs allows for improved accuracy of engine emission inventories. As mentioned in Section IV.D.2, 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 order of 50 percent for nvPM mass and 90 percent for nvPM number.[150] 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. The EPA led the development of two SAE standards publications, AIR 6504[151] and Aerospace Recommended Practice (ARP) 6481,[152] describing this methodology to correct for system losses. Also, the EPA funded and led test campaigns that verified the methodology.[153] ICAO has incorporated this same procedure into Annex 16 Volume 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 EEDB and to the EPA.

When calculating emissions inventories, these corrected EIs are used rather than the values used to show compliance with emission standards as they are more reflective of what is emitted into the atmosphere. These measured EIs are only for the non-volatile component of PM, and an approximation method is still required for quantifying the volatile PM inventory.

3. Improvements to Calculated Emission Indices

As described in Section V.A, an improved approximation method has also been developed since the EPA's 2017 NEI was first published. This new approximation method is needed for modeling PM emissions of in-service engines that do not have measured PM data. 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.[154] The simultaneously collected data of nvPM mass concentration and smoke number from test engines help define a better correlation between nvPM mass concentration and smoke number.[155] The FOA4 estimated nvPM mass concentration tracks closely with FOA3's for some smoke numbers, but it is much higher for other smoke numbers. Overall, we found that fleetwide nvPM mass emissions using the new method (FOA4 and measured data when available) increase by 27 percent over the nvPM mass emissions reported in 2017 NEI using the FOA3 method. Note that the data has significant variation at the individual airport level. For the top airports modeled the effect on total PM ranges from a 3 percent decrease to a 14 percent increase relative to the modeling in the proposed rulemaking.

Recognizing that the development of the first order approximation method is not static and continues to evolve, while more accurate measurement data and better understanding of the underlying mechanisms will certainly help to improve the estimate further, FOA4 represents the state of the science today. It has been used to update the nvPM baseline emission rates for this final rule.

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. PM Emission Inventory

As discussed in the introductory paragraphs of Section V, the PM

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

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

[149] 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.

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

[151] SAE International. 2017. Procedure for the Calculation of non-volatile Particulate Matter Sampling and Measurement System Penetration Functions and System Loss Correction Factors. Aerospace Information Report 6504, Warrendale, PA, October 2017.

[152] SAE International. 2019. Procedure for the Calculation of Non-Volatile Particulate Matter Sampling and Measurement System Losses and System Loss Correction Factors. Aerospace Recommended Practice 6481, Warrendale, PA, February 2019.

[153] D.B. Kittelson, et al., Experimental verification of principal losses in a regulatory particulate matter emissions sampling system for aircraft turbine engines, Aerosol Science & Technology, 2022, 56, 1, 63–74.

[154] 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. It is found on page 78 of the English Edition of the ICAO Products & Services 2022 Catalog and is copyright protected: Order No. 9889.

[155] Agarwal, A. et al., SCOPE11 Method for Estimating Aircraft Black Carbon Mass and Particle Number Emissions, Environmental Science & Technology, 2019, DOI: 10.1021/acs.est.8b04060.

emissions inventory used for this rule is from the aviation portion of the EPA's 2017 National Emissions Inventory (NEI).[156 157 158] The NEI is compiled by the EPA triennially based on comprehensive emissions data for criteria pollutants and hazardous air pollutants for mobile, point, and nonpoint sources. The mobile sources in the NEI include aviation, marine, railroad, on-road vehicles, and nonroad engines. As described in Section V.A, the aircraft emission estimates in the EPA's 2017 NEI (or the baseline PM emissions inventory) are based on the FOA3 method instead of the newly developed FOA4 or measured PM emissions data. For the final rulemaking, we have updated the baseline PM emissions inventory based on measured data reported to the EPA or the European Union Aviation Safety Agency (EASA) for most in-production engines and FOA4 for engines without measurement data.

The aviation emissions developed for the NEI include emissions associated with airport activities in commercial aircraft, air taxi aircraft,[159] general aviation aircraft, military aircraft, auxiliary power units, and ground support equipment. All emissions from aircraft with gas turbine engines of rated output greater than 26.7 kN, except military aircraft, are used in the emissions inventory for this final rule (which is only a subset of the aviation emissions inventory in the 2017 NEI). 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 [160] dataset, 2014 Terminal Area Forecast (TAF) [161] data, 2014 Air Traffic Activity Data System (ATADS) [162] data, and 2014 Airport Master Record (form 5010) [163] data.[164] The NEI used the FAA's Aviation Environmental Design Tool (AEDT) [165] 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, such as general aviation or air taxi).[166]

For aircraft PM contribution in 2017 to total mobile PM emissions in counties and MSAs 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.

We respond to comments on the emissions inventory in Section 7 of the Response to Comments document.

C. Projected Reductions in PM Emissions

Due to the technology-following nature of the PM standards, the final in-production and new type design standards will not result in emission reductions below current levels of engine emissions. The in-production standards for both PM mass and PM number, which are set at levels where all in-production engines meet the standards, will not affect any in-production engines as shown in Figure IV–1 and Figure IV–2. Thus, the in-production standards are not expected to produce emission reductions, beyond the business-as-usual fleet turn over that would occur in the absence of the standards. The EPA projects that all future new type design engines will meet the new type design standards. There are a few in-production engines that do not meet the new type design standards, but because in-production engines will not be subject to these new type design standards, engine manufacturers will not be required to make improvements to these engines to meet the standards. Therefore, the EPA also does not anticipate emission reductions from the new type design standards.

Most of the in-production engines that do not meet the new type design standards are older engines that already have replacement engines that will meet the new type design standards. There is only one newer in-production engine (an engine that recently started being manufactured) that does not meet the new type design standards, and it does not currently have a replacement engine. Since the new type design standards will not apply to in-production engines, the manufacturer of this engine could continue producing and selling its one in-production engine that does not meet the new type design standards. Market forces might drive the manufacturer of this in-production engine to make some improvements to meet the new type design standards, or chose to bring forward its next generation new type design engine to the market a few years earlier than currently planned. The manufacturer has announced plans to develop the next generation of engines to improve emission levels compared to the previous generation of engines.[167 168] We expect that these next generation engines from this manufacturer will meet the new type design standards. Further details on market forces are provided in Section VI.A. In conclusion, when considering the final new type design standards in the context of the in-production engines that already have a replacement engine or the one in-production engine that does not, the EPA expects no emission reductions from the new type design standards.

All website addresses for references cited in this section are provided in a memorandum to the docket.[169]

VI. Technological Feasibility and Economic Impacts

As described in Section IV, we are adopting PM mass concentration, PM mass, and PM number standards that match ICAO's standards. As discussed 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

[156] 2017 National Emissions Inventory: Aviation Component, Eastern Research Group, Inc., June 25, 2020, EPA Contract No. EP–C–17–011, Work Order No. 2–19.

[157] 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.

[158] U.S. EPA, 2017 National Emissions Inventory (NEI) Data.

[159] 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.

[160] 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.

[161] Federal Aviation Administration. Terminal Area Forecast (TAF).

[162] Federal Aviation Administration. ATADS: Airport Operations: Standard Report.

[163] Federal Aviation Administration. 2009. Airport Master Record Form 5010. Published by GCR & Associates.

[164] 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., June 25, 2020, 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).

[165] AEDT is a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences.

[166] See section 4.1.2 of the 2017 National Emissions Inventory: Aviation Component, Eastern Research Group, Inc., June 25, 2020, EPA Contract No. EP–C–17–011, Work Order No. 2–19.

[167] *https://www.rolls-royce.com/products-and-services/civil-aerospace/future-products.aspx#/;* last accessed on October 31, 2022.

[168] Aviation Week, *Rolls-Royce Considers UltraFan Development Pause,* Guy Norris, January 4, 2021.

[169] U.S. EPA, Yen, D. Memorandum to Docket EPA–HQ–OAR–2019–0660, ''website addresses for references cited in Section V of the Preamble for Control of Air Pollution from Aircraft Engines: Emission Standards and Test Procedures; Final Rule,'' November 9, 2022.

standards are set at emission levels where all in-production engines meet these standards. Thus, there will not be costs or emission reductions associated with the final standards for in-production engines. For new type design 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 design standards. In addition, in-production engines will not be required to meet these new type design standards. Only new type design engines will need to comply with the new type design standards. The EPA projects that all new type design engines entering into service into the future will meet these PM mass and number standards. Thus, the EPA expects that there will not be costs and emission reductions from the standards for new type design engines, although the standards would likely prevent backsliding for some new type design engines. In addition, following this final rulemaking for the PM standards, the FAA will issue a rulemaking to enforce compliance to these standards, and any anticipated certification costs for the PM standards will be accounted for in the FAA rulemaking.

As described in Section I.B.2, when developing new emission 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 final standards that match ICAO's standards are anti-backsliding standards that prevent aircraft engine PM levels from increasing beyond their current levels. As discussed in Section IV.F.2, in that regard, PM mass and number are currently unregulated from aircraft engines and the standards finalized in this action represent a new regulatory backstop of those two new standards. Further, all three PM standards will prevent backsliding by ensuring that all new type design and in-production aircraft engines will not exceed those regulatory levels in the future.

As described in Section IV.F.2, for some manufacturers, new technologies aimed at reducing aircraft engine NO_X, which were implemented for in-production engines that were recently built, also resulted in significant PM reductions. Other manufacturers did not develop or implement technologies that resulted in such PM reductions. In either case, the final PM standards ensure that PM emissions do not increase beyond the levels of these PM standards. In addition, the final PM standards send an important signal to manufacturers that they need to consider PM emissions when producing aircraft engines now and going forward—with the anticipation that more stringent PM standards will be adopted by ICAO/CAEP in the future.

U.S. manufacturers could be at a significant disadvantage if the United States fails to adopt standards by the international implementation date, January 1, 2023. Also, given the short timeframe from this final action and the international implementation date, there would not be enough lead time for manufacturers to respond to more stringent standards that would require them to develop and implement new technologies.

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 the EPA rulemaking and subsequent FAA rulemaking enables U.S. manufacturers to obtain internationally recognized U.S. certification, which for the final PM standards will 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 will be removed. The rulemaking will help ensure 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 likely 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 final standards will 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 any technology demonstrated to be safe and airworthy proven to Technology Readiness Level[170] (TRL) 8 and available for application over a sufficient range of newly certificated aircraft.[171] This means that the analysis that informed the international standard considered the emissions performance of aircraft engines assumed to be in-production on the ICAO/CAEP implementation date for the PM mass and number standards, January 1, 2023.[172] 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),[173] 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

[170] 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.

[171] ICAO, 2019: *Report of the Eleventh Meeting,* Montreal, 4–15 February 2019, Committee on Aviation Environmental Protection, Document 10126, CAEP/11. It is found on page 27 of the English Edition of the ICAO Products & Services 2022 Catalog and is copyright protected: Order No. 10126. The statement on technological feasibility is located in Appendix C of Agenda Item 3 of this report (see page 3C–4, paragraph 2.2).

[172] Id., starting on page 3C–1.

[173] Id.

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.[174] 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 non-volatile PM (nvPM) mass and nvPM number in comparison to most in-service engines.[175] (As described in Section IV.D.2, only nvPM emissions will be measured in the final test procedure for the final standards.) Specifically, the current lean-burn engines and some advanced Rich-Quench-Lean (RQL) engines [176] [177] 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.[178] However, achieving these levels of nvPM emissions is more difficult for physically smaller-sized engines due to technical constraints.[179]

In addition, some previous generation engines that are in production meet the final new type design 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 final standards, which match ICAO standards, are technologically feasible.

D. Costs Associated With the Rule

The EPA does not anticipate new technology costs (non-recurring costs) due to the final rule. As described in the introductory paragraph of Section VI, since all in-production engines meet the in-production standards and nearly all in-production engines meet these new type design standards, we project there will not be costs, nor emission reductions, from the final rule. Also, because current in-production engines will not be required to make any changes under this final 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 final new type design standards since all manufacturers currently have engines that meet that level.

Following this final rulemaking for the PM standards, the FAA will issue a rulemaking to enforce compliance to these standards, and any anticipated certification costs for the PM standards will be estimated by FAA.

As described in Section VI.A, manufacturers have already developed or are developing technologies to respond to ICAO standards that are equivalent to the final standards, and they will comply with the ICAO standards in the absence of U.S. regulations. Also, domestic implementation of the ICAO standards will potentially provide for cost savings to U.S. manufacturers since it will enable them to certify their aircraft engine (via subsequent FAA rulemaking) domestically instead of having to certificate with a foreign authority (which will occur without this EPA rulemaking). If the final PM standards, which 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.[180] Any potential costs or cost savings related to certification will be estimated by FAA.

For the same reasons there will be no non-recurring and certification costs for the rule, there also will be no recurring costs (recurring operating and maintenance costs) for the rule. The elements of recurring costs include additional maintenance, material, labor, and tooling costs.

As described in Section IV.E, the EPA is formally incorporating the PM aspects of the existing information collection request (ICR) into the CFR (or regulations) in 40 CFR 1031.150 and 1031.160. This action will not create a new requirement for the manufacturers of aircraft engines. Instead, it will 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 action will not create new costs.

E. Summary of Benefits and Costs

The final standards match the ICAO standards, and as discussed in Section II.C and Section IV.F.1 of this preamble, ICAO intentionally established its standards at a level which is technology following. The final rule takes an appropriate step in controlling aircraft engine PM emissions and prevents backsliding by ensuring that all in-production and new type design engines have at least the PM emission levels of today's aircraft engines. Additionally, this final rule maintains consistency or harmonizes with the international standards and meets the United States' treaty obligations under the Chicago Convention. Also, it allows U.S. manufacturers of covered aircraft engines to remain competitive in the global marketplace by ensuring the acceptance of their engines worldwide (which benefits U.S. manufacturers and consumers), provides uniformity and

[174] ICAO, 2019: *Independent Expert Integrated Technology Goals Assessment and Review for Engines and Aircraft,* Document 10127. It is found on page 34 of the English Edition of the ICAO Products & Services 2022 Catalog and is copyright protected; Order No. 10127.

[175] See id. at 8.

[176] See id. at 47 and 48. For lean-burn engines (or combustors), enough air is introduced with the fuel from the injector so it is never overall rich. For aviation combustors, the fuel is not premixed and pre-vaporized, and in the microscopic region around each droplet, the mixture can be near to stoichiometric. Yet, the mixture remains lean throughout the combustor, and the temperature does not approach the stoichiometric value. For a lean-burn combustor, the peak temperatures are not as high, and thus, the NO_X is low.

[177] See id. at 47. For Rich-Quench-Lean (RQL) engines (or combustors), the fuel first burns rich, and thus, there is little oxygen free to form NO_X. Dilution air is introduced to take the mixture as quickly as possible through the stoichiometric region (when it briefly becomes very hot) to a cooler, lean state.

[178] See id. at 57 and 58. 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. Also, 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.

[179] 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 emission control. *See* 77 FR 36342, 36353 (June 18, 2012).

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

certainty to U.S. manufacturers as they become familiar with the new approach to adhering to these PM standards and test procedures,[181] and prevents U.S. manufacturers from having to seek PM emissions certification from an aviation certification authority of another country (not the FAA) to market and operate their aircraft engines internationally. All engines currently manufactured will meet the ICAO in-production standards, and nearly all these same engines will meet the new type design standards—even though these new type design standards do not apply to in-production engines. Therefore, as further described in the introductory paragraph of Section VI and in Section VI.C, there will be no costs and no emission reductions from complying with these final standards.

VII. Technical Amendments

In addition to the PM-related regulatory provisions discussed in Section IV, the EPA is finalizing technical amendments to the regulatory text that apply more broadly than to just the new PM standards. First, the EPA is migrating 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 restructuring the regulations to allow for better ease of use and allow for more efficient future updates. The EPA is also deleting some regulatory provisions and definitions that are unnecessary, as well as making several other minor technical amendments to the regulations. Finally, the EPA is also revising 40 CFR part 87 to provide continuity during the transition of 40 CFR part 87 to 40 CFR part 1031. In this final rule, the EPA did not reexamine or reopen the substantive provisions of 40 CFR part 87 that were merely migrated to the new 40 CFR part 1031 and streamlined or the substantive provisions of 40 CFR part 1030 and 40 CFR part 1031 beyond those specially discussed in the proposed rule. Any comments we received on the substance of the provisions migrated from 40 CFR part 87 to 40 CFR part 1031 provisions, as opposed to comments pointing out typos or inadvertent impacts on substantive provisions caused by the regulatory streamlining, are beyond the scope of this rulemaking.

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 finalized in this document, as well as any future standards the EPA may adopt, difficult to incorporate.

Therefore, the EPA is migrating 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 restructuring, streamlining, and clarifying the regulatory provisions for ease of use and to facilitate more efficient future updates. Finally, the EPA is deleting 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.

As noted in the amendatory instructions in the regulations, the EPA is making this transition effective on January 1, 2023. The new 40 CFR part 1031 will become effective (*i.e.,* be incorporated into the Code of Federal Regulations) 30 days following the publication of this final rule in the **Federal Register**. However, the applicability language in 40 CFR 1031.1 indicates that the new 40 CFR part 1031 will apply to engines subject to the standards beginning January 1, 2023. Prior to January 1, 2023, the existing 40 CFR part 87 will continue to apply. On January 1, 2023, the existing 40 CFR part 87 will be replaced with a significantly abbreviated version of 40 CFR part 87 whose sole purpose will 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 will 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 adopting language in 40 CFR part 87 that simply states the provisions relating to a particular section of 40 CFR part 87 apply as described in a corresponding section of the new 40 CFR part 1031.

The EPA received a comment regarding some existing equations being incorrectly migrated from 40 CFR part 87 to the new 40 CFR part 1031. Specifically, the equations in the proposed 40 CFR 1031.40(a)(1), 1031.50(a)(1), and 1031.90(a)(1), (b) and (c) contained terms that should have been exponents but were instead expressed as multiplicative terms. Given that the EPA's stated intent with the proposed migration from 40 CFR part 87 to 40 CFR part 1031 was to move, restructure, streamline and clarify the existing regulations without changing the underlying regulatory requirements, the equations contained in the paragraphs in 40 CFR part 1031 should have aligned with the corresponding equations in 40 CFR part 87. Thus, these equations in 40 CFR part 1031 have been accordingly corrected in this final rule.

B. Deletion of Unnecessary Provisions

As previously mentioned, the existing aircraft engine emission regulations contain some unnecessary provisions which the EPA is deleting. These 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 not migrating 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 effectively deleting these provisions by not migrating them to the new 40 CFR part 1031, the underlying standards referred to in these provisions (*i.e.,* the Tier 4 and 6 NO_X standards) remain unchanged. Thus, the underlying certification basis for any engines

[181] The final standards change the approach to regulating aircraft engine PM emissions from past smoke measurements to the measurement of mass and number for the first time for U.S. manufacturers.

certificated under these provisions will remain intact.

The EPA is also deleting several definitions from the current 40 CFR part 87 as it is migrated to the new 40 CFR 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 stand-alone definition unnecessary. 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 is deleting and the reasons for the deletions are listed in Table VII–1.

TABLE VII–1—LIST OF TERMS FOR WHICH DEFINITIONS WILL BE DELETED FROM THE CFR

Term	Reason for deletion
Act	Not used in the regulatory text.
Administrator	No longer needed as not used in revised and streamlined regulatory text.
Class TP	No longer needed as definition was effectively incorporated into regulatory text during migration.
Class TF	No longer needed as definition was effectively incorporated into regulatory text during migration.
Class T3	No longer needed as definition was effectively incorporated into regulatory text during migration.
Class T8	No longer needed as definition was effectively incorporated into regulatory text during migration.
Class TSS	No longer needed as definition was effectively incorporated into regulatory text during migration.
Commercial aircraft	No longer needed as not used in revised and streamlined regulatory text.
Commercial aircraft gas turbine engine	No longer needed as not used in 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 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 revised and streamlined regulatory text.
Production cutoff or the date of production cutoff	No longer needed with 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 migration.
Tier 2	No longer needed as definition was effectively incorporated into regulatory text during migration.
Tier 4	No longer needed as definition was effectively incorporated into regulatory text during migration.
Tier 6	No longer needed as definition was effectively incorporated into regulatory text during migration.
Tier 8	No longer needed as definition was effectively incorporated into regulatory text during migration.
U.S.-registered aircraft	Unnecessary term that is not used in the regulatory text.

The EPA is also not migrating the current 40 CFR 87.3(b) to the new 40 CFR part 1031, which in effect results in its deletion. This paragraph is simply a restatement of an obligation directly imposed under the Clean Air Act that 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 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 adopting some minor technical amendments to the regulations.

The EPA is adding 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 definitions will help provide clarity to the provisions that utilize those terms.

The EPA is modifying the definitions for ''Exception'' and ''Exemption.'' The current definitions of these terms in 40 CFR 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 being moved to the introductory text in 1031.15 and 1031.20, as applicable. These changes are in no way intended to change any regulatory requirement applicable to excepted or exempted engines. Rather, they are intended simply to more clearly separate definitions from the related regulatory requirements.

The EPA is not migrating the existing 40 CFR 87.42(d) to the new 40 CFR part 1031, which in effect results in the deletion of this provision. This paragraph related to the annual production report 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 40 CFR 1031.170). This change will have no impact on the ability of manufacturers to make claims of CBI, or in the EPA's handling of such claims. However, it will assure a more consistent treatment of CBI across mobile source programs.

The EPA is adopting a minor change to the existing emission requirements for spare engines, as found in the existing 40 CFR 87.50(c)(2). In the regulatory text for 40 CFR 1031.20(a), the EPA is deleting 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 retaining and migrating to 40 CFR part 1031 the requirement in 40 CFR 87.50(c)(3) such that a spare engine will need to be certificated to emission standards equal to or lower than those of the engines they are replacing, for all regulated pollutants. This deletion of 40 CFR 87.50(c)(2) aligns 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 change will have any impact on current industry practices. Deleting the provision currently in 40 CFR 87.50(c)(2) will leave in place the requirement that any new engine manufactured as a spare will 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 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 deletion will 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 effective deletion of 40 CFR 87.50(c)(2) for the purposes of uniformity will have any practical impact on current industry practices.

The EPA is aligning 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.[182] 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 in that 2012 action. Thus, the EPA is applying 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 consistent with U.S. efforts to secure the highest practicable degree of uniformity in aviation regulations and standards and will 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 will be covered by the existing smoke number standard. Throughout its regulations, the EPA is aligning with ICAO regarding a common rated output threshold for emission regulations. The applicability and 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 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 EPA is making all instances in the new 40 CFR 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 change will 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 incorporating by reference Appendix 1 of ICAO 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 the complete testing and compliance provisions are clear.

The EPA is streamlining, restructuring, and updating 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 migrating the exceptions section concerning spare engines (40 CFR 87.50(c)) to 40 CFR 1031.20(a), with the changes discussed in the preceding paragraphs. The provisions regarding the annual reporting of exempted and excepted engines are being incorporated into the new annual reporting 40 CFR 1031.150. These reporting provisions otherwise remain unchanged. Section 87.50(a), regarding engines installed on new aircraft, and 40 CFR 87.50(b), regarding temporary exemptions based on flights for short durations at infrequent intervals, are being migrated to a new 40 CFR 1031.15. The temporary exemptions provisions remain unchanged, with the exception of adding "of Transportation" after "Secretary" in 40 CFR 1031.15(b)(4) to improve clarity. The 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.[183] These provisions were only available through December 31, 2016, and they are being deleted in this action. 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 40 CFR 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 deleting them rather than migrating them to the new 40 CFR 1031.15. The EPA is further restoring the general exemption provisions that were 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.[184] The EPA is adopting similarly streamlined general exemption provisions for aircraft engines as well, as contained in 40 CFR 1031.15(a).

The EPA is adopting some changes relative to the prohibition on fuel venting. The fuel venting standard is

[182] 77 FR 36342 (June 18, 2012).

[183] 77 FR 36342 (June 18, 2012).

[184] 86 FR 2136 (January 11, 2021).

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 40 CFR 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 deleting the definition for fuel venting emissions as both unnecessary and contradictory to the actual requirement.

The EPA is adding the word 'liquid' in front of the phrase ''fuel emissions'' in 40 CFR 1031.30(b)(2). That phrase has been interpreted internationally in significantly different ways. Some have interpreted the word ''emissions'' to mean any emission of pollutants from the combustion process. The EPA's rule that promulgated the requirement to control fuel venting emissions, however, dates to 1973 and was intended to address the issue of liquid fuel being released from an aircraft engine after engine shutdown when no combustion processes are occurring.[185] This term addresses both liquid fuel that reaches the ground, and liquid fuel released from the engine after shutdown that comes into contact with hot engine parts and begins to vaporize or evaporate into the atmosphere rather than combust. In the latter situation, fuel venting emissions may be observed visually and may look like an engine is smoking. To reduce confusion, the EPA is adding the word ''liquid'' to this description. Nothing about the intent of the fuel venting rule is changed by this addition. The change is intended only to better describe the phenomenon of fuel venting emissions and will harmonize U.S. regulations with the term as used in ICAO Annex 16 Volume II.

The EPA is modifying the applicability date language associated with the standards applicable to Tier 8 engines, as contained in 1031.60(e)(2). The applicability of new type design standards has traditionally been linked to the date of the first individual production engine of a given type, both for the 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 design began to determine to what standards a new type design 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 type designs. 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 to establish the certification basis for type certification in the future. This approach is reflected in the applicability date provisions of the PM standards being adopted in this action, consistent with ICAO. The EPA is also adopting it in 40 CFR 1031.60(e)(5) for existing standards applicable to Tier 8 engines as well. This change will only impact engines for which an application for an original or amended type certificate is submitted to the FAA in or after January 1, 2023. This change will 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 change in applicability will not result in a change in standards for any engines, and it 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 will be straightforward.

The EPA is revising 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 verify compliance of engines certificated outside the United States, as indicated through existing bilateral agreements with such authorities. Also, the EPA is updating its definition of ''supersonic'' by replacing it with a new definition of ''supersonic airplane.'' The new definition for ''supersonic airplane'' is based on a revised definition for such proposed by the FAA in a recent proposed action regarding noise regulations for supersonic airplanes.[186] This new definition will provide greater assurance that the standards applicable to engines used on supersonic airplanes will apply to the engines for which they are intended.

The EPA is updating several definitions and aligning them with definitions included in the recent airplane GHG regulations.[187] The definitions being updated are for ''Aircraft,'' ''Aircraft engine,'' ''Airplane,'' ''Exempt,'' and ''Subsonic.'' These definitions are being updated in the aircraft engine regulations simply for consistency with the airplane GHG regulations and with FAA regulations. The changes being adopted will not have any impact on the regulatory requirements related to the definitions.

The EPA is also addressing an unintentional applicability gap related to the 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 a maximum takeoff mass (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 adopting new language at 40 CFR 1030.1(a)(1)(ii) to cover these airplanes, should they be produced. This change will 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 in ICAO's GHG standard-setting process and had been intended to be subject to the EPA's GHG standards as well. The structure of 40 CFR 1030.1(a)(1) being finalized is somewhat different than the structure that was proposed to conform to numbering conventions used by the Office of the Federal Register. This renumbering does not change the meaning or requirements from the language that was proposed.

The EPA is correcting 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

[185] See 38 FR 19088 (July 17, 1973).

[186] Noise Certification of Supersonic Airplanes, 85 FR 20431 (April 13, 2020).

[187] 86 FR 2136 (January 11, 2021).

retroactively apply these standards using the ICAO new type design 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 design standards for other categories of airplanes in this part (*e.g.,* 40 CFR 1030.1(a)(1)). Based on consultations with the FAA, this change to 40 CFR part 1030 will not impact any airplanes.

The EPA is adopting a minor word change to the existing applicability language in 40 CFR part 1030 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 replacing 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 language in 40 CFR 1031.1(b)(1), and existing FAA regulations in 14 CFR parts 1 and 33. This change is for consistency among Federal regulations and to avoid any confusion that may be caused by using two different terms. This change will have no material impact on the meaning of the regulatory text.

Following consultation with FAA, the EPA is finalizing some clarifying changes to the proposed provisions related to derivative engines for emissions certification purposes. None of these edits change the fundamental regulatory provisions at hand, but rather serve to clarify the requirements and improve consistency between EPA and FAA regulations. Thus, these changes will have no effect on obligations of regulated parties or on implementing these regulations. In 40 CFR 87.48, the EPA inserted ''for emissions certification purposes'' to properly direct the reader to the correct section of the new 40 CFR part 1031. Most of these changes are in 40 CFR 1031.130(a), and include replacing ''type certificate holder'' with ''applicant'' to better reflect who would request a designation as a derivative engine for emissions certification purposes (this change was also made to 40 CFR 1031.130(c)), a change from ''the FAA may approve'' to ''a type certificate holder may request'' to better reflect the actual process, the inclusion of the phrase ''derived from'' which was in both 14 CFR 34.48 and 40 CFR 87.48, but was inadvertently left out of this paragraph in the proposed migration of the regulatory text, inclusion of the word ''type'' to clarify the design that is being referred to, and the replacement of ''previously certificated (original) engine for purposes of compliance with exhaust emission standards'' with ''an engine that has a type certificate issued in accordance with 14 CFR part 33'' to more precisely indicate that these provisions apply to engines previously certificated under the FAA's engine certification regulations. The EPA is also clarifying 40 CFR 1031.130(c)(2) by adding ''for individual certification applications'' and ''beyond those,'' and clarifying that the FAA should make determinations on using ranges beyond those specified in the regulation consistent with good engineering judgement rather than following consultation with the EPA. Finally, the EPA is revising the proposed definition for ''derivative engine for emissions certification purposes'' in 40 CFR 1031.205 by replacing a description of the requirements of 40 CFR 1031.130 with an actual reference to 40 CFR 1031.130, and other editorial changes to make it consistent with the changes to 40 CFR 1031.130 discussed in this paragraph.

The EPA is making a correction to the proposed regulatory text of 40 CFR 87.50. In the NPRM, an incorrect reference was included to 40 CFR 1031.11. The correct reference is 40 CFR 1031.20. The text of 40 CFR 87.50 has been updated accordingly.

Finally, the EPA is finalizing minor changes to the proposed regulatory text in 40 CFR 1031.140(f)(1) and (f)(2)(i). As stated in the preamble to the proposed rule, the existing smoke standards and the proposed PM mass concentration standard are all based on the maximum value measured at any thrust level across and engine's entire operating thrust range.[188] While it is clear from this preamble language that these standards refer to the maximum value measured at any thrust level across an engine's operating thrust range, and not just at one of the four LTO points, the regulatory text referenced in this paragraph is perhaps less clear on this point. Thus, the EPA is finalizing slight modifications to the regulatory text in these sections to further clarify the regulatory requirement. Specifically, the EPA is adding ''across the engine operating thrust range'' to the end of 40 CFR 1031.140(f)(1) and is replacing the phrase ''at any thrust setting'' with ''across the engine operating thrust range'' in 40 CFR 1031.140(f)(2)(i). Also in 40 CFR 1031.140, the EPA is adding ''percent of'' to 40 CFR 1031.140(f)(2)(ii) and (f)(3) to provide additional clarity without changing the underlying meaning of the regulatory text.

VIII. Statutory Authority and Executive Orders 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 final action is not a significant regulatory action and was therefore not submitted to the Office of Management and Budget (OMB) for review.

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 rule codifies that existing collection by including the current nvPM data collection in the regulatory text, but it will 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 new provisions contained in this document (*i.e.,* engines greater than 26.7 kN rated output). Therefore, this action will not impose any requirements on small entities. Supporting information can be found in the docket.[189]

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.

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[188] As stated in the proposal to this rule: ''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.'' 87 FR 6343 (February 3, 2022).

[189] U.S. EPA, Mueller, J. Memorandum to Docket ID No. EPA–HQ–OAR–2019–0660, ''Determination of no SISNOSE for Final Aircraft Engine Emission Standards,'' August 19, 2022. This memorandum describes that the only small entity is Williams Int'l, which only make engines below 26.7 kN, and does not make engines for use in civil supersonic airplanes. Thus, they are not subject to the final standards.

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 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. The EPA believes that the environmental health risks or safety risks of particulate matter, which is addressed by this action, may have a disproportionate effect on children. The 2021 Policy on Children's Health also applies to this action. This action's health and risk assessments are contained in Section III. Children make up a substantial fraction of the U.S. population, and often have unique factors that contribute to their increased risk of experiencing a health effect from exposures to ambient air pollutants because of their continuous growth and development. Children are more susceptible than adults to many air pollutants because they have (1) a developing respiratory system, (2) increased ventilation rates relative to body mass compared with adults, (3) an increased proportion of oral breathing, particularly in boys, relative to adults, and (4) behaviors that increase chances for exposure.

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

This action is not subject to Executive Order 13211, because it is not a significant regulatory action under Executive Order 12866.

I. National Technology Transfer and Advancement Act (NTTAA) and 1 CFR Part 51

This action involves technical standards for testing emissions from aircraft gas turbine engines. The EPA is adopting test procedures contained in ICAO's Annex 16 to the Convention on International Civil Aviation, Environmental Protection, Volume II—Aircraft Engine Emissions, Fourth Edition, July 2017, 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 emission 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) and 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 being 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). This final rule removes those references to ICAO Annex 16, Volume II.

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

Executive Order 12898 (59 FR 7629, February 16, 1994) directs Federal agencies, to the greatest extent practicable and permitted by law, to make 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 (people of color and/or Indigenous peoples) and low-income populations.

The EPA believes that the human health or environmental conditions that exist prior to this action result in or have the potential to result in disproportionate and adverse human health or environmental effects on people of color, low-income populations and/or Indigenous peoples. The EPA provides a summary of the evidence for potentially disproportionate and adverse effects among people of color and low-income populations residing near airports in Section III.G.

The EPA believes that this action is not likely to change existing disproportionate and adverse effects on people of color, low-income populations and/or Indigenous peoples, as specified in Executive Order 12898. The information supporting this Executive Order review is contained in Section III.G, and all supporting documents have been placed in the public docket for this action.

This action will not achieve emission reductions and will therefore result in no improvement in per-aircraft emissions for all communities living near airports. The 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. The EPA, in an analysis separate from this rulemaking, is conducting an analysis of the communities residing near airports where jet aircraft operate 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.

The EPA additionally engaged with Environment Justice organizations in several ways for this rulemaking, including: (1) contacting members of Environmental Justice organizations to provide information on pre-registration for the public hearings for the proposed rule; (2) contacting members of Environmental Justice organizations when the proposed rule was published in the **Federal Register** to provide an overview of the proposed action and to explain methods for commenting on the proposal; this outreach included sessions during evening hours; (3) providing information on our website in both Spanish and English, as well as providing access to Spanish translation during the public hearings for the rule, if requested.

K. Congressional Review Act

This action is subject to the CRA, and the EPA will submit a rule report to each House of the Congress and to the Comptroller General of the United States. This action is not a ''major rule'' as defined by 5 U.S.C. 804(2).

List of Subjects

40 CFR Part 9

Reporting and recordkeeping requirements.

40 CFR Part 87

Environmental protection, Aircraft, Air pollution control.

40 CFR Part 1030

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

40 CFR Part 1031

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

Michael S. Regan,
Administrator.

For the reasons set forth in the preamble, the EPA is amending title 40, chapter I of the Code of Federal Regulations as set forth below.

PART 9—OMB APPROVALS UNDER THE PAPERWORK REDUCTION ACT

■ 1. The authority citation for part 9 continues to read as follows:

Authority: 7 U.S.C. 135 *et seq.,* 136–136y; 15 U.S.C. 2001, 2003, 2005, 2006, 2601–2671; 21 U.S.C. 331j, 346a, 31 U.S.C. 9701; 33 U.S.C. 1251 *et seq.,* 1311, 1313d, 1314, 1318, 1321, 1326, 1330, 1342, 1344, 1345 (d) and (e), 1361; E.O. 11735, 38 FR 21243, 3 CFR, 1971–1975 Comp. p. 973; 42 U.S.C. 241, 242b, 243, 246, 300f, 300g, 300g–1, 300g–2, 300g–3, 300g–4, 300g–5, 300g–6, 300j–1, 300j–2, 300j-3, 300j–4, 300j–9, 1857 *et seq.,* 6901–6992k, 7401–7671q, 7542, 9601–9657, 11023, 11048.

■ 2. Amend § 9.1 in the table by adding the undesignated center heading entitled ''Control of Air Pollution From Aircraft Engines'' and entries for sections ''1031.150'' and ''1031.160'' in numerical order to read as follows:

§ 9.1 OMB approvals under the Paperwork Reduction Act.

* * * * *

40 CFR citation	OMB control No.
* * * * * * *	
Control of Air Pollution From Aircraft Engines	
1031.150	2060–0680
1031.160	2060–0680
* * * * *	

■ 3. 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) NOX 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 for emissions certification purposes apply as described in 40 CFR 1031.130.

§ 87.50 Exemptions and exceptions.

Provisions related to exceptions apply as described in 40 CFR 1031.20. 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

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

Authority: 42 U.S.C. 7401–7671q.

■ 5. Amend § 1030.1 by revising paragraphs (a) introductory text, (a)(1), (a)(3)(ii), and (c)(7) to 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 14 CFR chapter I, the airplane may not exceed the Greenhouse Gas (GHG) standards of this part when original civil certification under 14 CFR chapter I is sought.

(1) A subsonic jet airplane that has —

(i) Either—

(A) A type-certificated maximum passenger seating capacity of 20 seats or more,

(B) A maximum takeoff mass (MTOM) greater than 5,700 kg, and

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

(ii) Or—

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

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

(C) An application for original type certification that is submitted on or after December 23, 2022.

* * * * *

(3) * * *

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

* * * * *

(c) * * *

(7) Airplanes powered by reciprocating engines.

■ 6. 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/m³.

(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.* 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:

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

(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.* 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:

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

(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/m³ exceeding the following emission standard:

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

(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	$1.490 \cdot 10^{16} - 8.080 \cdot 10^{13} \cdot rO$
rO > 150	214.0	$2.780 \cdot 10^{15}$

(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	$2.669 \cdot 10^{16} - 1.126 \cdot 10^{14} \cdot rO$
rO > 200	347.5	$4.170 \cdot 10^{15}$

(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:

$NO_X = 40+2 \cdot rPR$ 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:

$NO_X = 32+1.6 \cdot rPR$ 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
(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.* 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:

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

(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:

$HC = 140 \cdot 0.92^{rPR}$

(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:

$CO = 4550 \cdot rPR^{-1.03}$

(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:

$NO_X = 36+2.42 \cdot rPR$

§ 1031.130 Derivative engines for emissions certification purposes.

(a) *Overview.* For purposes of compliance with exhaust emission standards of this part, a type certificate applicant may request from the FAA a determination that an engine configuration be considered a derivative engine for emissions certification purposes. The applicant must demonstrate that the configuration is derived from and similar in type design to an engine that has a type certificate issued in accordance with 14 CFR part 33, 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 applicant 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/m³ if the characteristic level of maximum $nvPM_{MC}$ is below 1,000 μg/m³.

(B) ±20% of the characteristic level if the characteristic level for maximum $nvPM_{MC}$ is at or above 1,000 μg/m³.

(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, for individual certification applications, adjust the ranges beyond those specified in paragraph (c)(1) of this section to evaluate a proposed derivative engine, consistent with good engineering judgment.

§ 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 across the engine operating thrust range.

(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 across the engine operating thrust range, 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 percent of 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 percent of 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.

This part uses the following abbreviations:

TABLE 1 TO § 1031.200—ABBREVIATIONS

°	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
µg	Microgram
NO_X	oxides of nitrogen
Num	Number
nvPM	non-volatile particulate matter
$nvPM_{mass}$	non-volatile particulate matter mass
$nvPM_{num}$	non-volatile particulate matter number
$nvPM_{MC}$	non-volatile 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 chapter I 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 is derived from and similar in type design to an engine that has a type certificate issued in accordance with 14 CFR part 33, and complies with the requirements of § 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 § 1031.20 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 § 1031.20.

Standard day conditions means the following ambient conditions: temperature = 15 °C, specific humidity = 0.00634 kg H2O/kg dry air, and pressure = 101.325 kPa.

Subsonic means relating to an aircraft that has not been certificated under 14 CFR chapter I 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.

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 EPA 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 EPA and at the National Archives and Records Administration (NARA). Contact EPA 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. For information on the availability of this material at NARA, visit *www.archives.gov/federal-register/cfr/ibr-locations.html* or email *fr.inspection@nara.gov.* The material may be obtained from International Civil Aviation Organization, Document Sales Unit, 999 University Street, Montreal, Quebec, Canada H3C 5H7; (514) 954–8022; *sales@icao.int; www.icao.int.*

(a) Annex 16 to the Convention on International Civil Aviation, Environmental Protection, Volume II—Aircraft Engine Emissions, Fourth Edition, July 2017 (including Amendment No. 10, applicable January 1, 2021); IBR approved for §§ 1031.140; 1031.205.

(b) [Reserved]

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