rule that may affect family well-being. This final rule would not have any impact on the autonomy or integrity of the family as an institution. Accordingly, DOE has concluded that it is not necessary to prepare a Family Policymaking Assessment.

L. Review Under the Treasury and General Government Appropriations Act, 2001

Section 515 of the Treasury and General Government Appropriations Act, 2001 (44 U.S.C. 3516) provides for Federal agencies to review most disseminations of information to the public under guidelines established by each agency pursuant to general guidelines issued by OMB. OMB's guidelines were published at 67 FR 8452 (February 22, 2002), and DOE's guidelines were published at 67 FR 62446 (October 7, 2002). Pursuant to OMB Memorandum M–19–15, *Improving Implementation of the Information Quality Act* (April 24, 2019), DOE published updated guidelines which are available at: *www.energy.gov/sites/prod/files/2019/12/f70/DOE%20Final%20Updated%20IQA%20Guidelines%20Dec%202019.pdf.*

DOE has reviewed this final rule and will ensure that information produced under this regulation remains consistent with the applicable OMB and DOE guidelines.

M. Congressional Review

As required by 5 U.S.C. 801, DOE will report to Congress on the promulgation of this rule prior to its effective date. The report will state that the rule does not, meet the criteria set forth in 5 U.S.C. 804(2).

V. Approval by the Office of the Secretary of Energy

The Secretary of Energy has approved publication of this final rule.

List of Subjects in 10 CFR Part 1008

Administration practice and procedure, Freedom of information, Privacy, Reporting and recordkeeping requirements.

Signing Authority

This document of the Department of Energy was signed on [December 11, 2024, by Ann Dunkin, Senior Agency Official for Privacy, pursuant to delegated authority from the Secretary of Energy. That document with the original signature and date is maintained by DOE. For administrative purposes only, and in compliance with requirements of the Office of the Federal Register, the undersigned DOE Federal Register Liaison Officer has been authorized to sign and submit the document in electronic format for publication, as an official document of the Department of Energy. This administrative process in no way alters the legal effect of this document upon publication in the **Federal Register**.

Signed in Washington, DC, on December 12, 2024.

Treena V. Garrett,

Federal Register Liaison Officer, U.S. Department of Energy.

For the reasons set forth in the preamble, the Department of Energy amends part 1008 of chapter X of title 10 of the Code of Federal Regulations as set forth below:

PART 1008—RECORDS MAINTAINED ON INDIVIDUALS (PRIVACY ACT)

■ 1. The authority citation for part 1008 continues to read as follows:

Authority: 42 U.S.C. 7101 *et seq.;* 50 U.S.C. 2401 *et seq.;* 5 U.S.C. 552; 5 U.S.C. 552a; 42 U.S.C. 7254; and 5 U.S.C. 301. Section 1008.22(c) also issued under 42 U.S.C. 405 note.

■ 2. Amend § 1008.12 by adding paragraph (b)(2)(ii)(Q) to read as follows:

§ 1008.12 Exemptions.

* * * * *

(b) * * *

(2) * * *

(ii) * * *

(Q) Nondiscrimination in Federally Assisted Program Files (DOE–42)

* * * * *

[FR Doc. 2024–29664 Filed 12–16–24; 8:45 am]

BILLING CODE 6450–01–P

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 33

[Docket No. FAA–2022–1641; Special Conditions No. 33–028–SC]

Special Conditions: BETA Technologies Inc. Model H500A Electric Engines

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Final special conditions.

SUMMARY: These special conditions are issued for BETA Technologies Inc. (BETA) Model H500A electric engines that operate using electrical technology installed on the aircraft, for use as an aircraft engine. These engines will have a novel or unusual design feature when compared to the state of technology envisioned in the airworthiness standards applicable to aircraft engines. This design feature is the use of an electric motor, motor controller, and high-voltage systems as the primary source of propulsion for an aircraft. The applicable airworthiness regulations do not contain adequate or appropriate safety standards for this design feature. These special conditions contain the additional safety standards that the Administrator considers necessary to establish a level of safety equivalent to that established by the existing airworthiness standards.

DATES: Effective January 16, 2025.

FOR FURTHER INFORMATION CONTACT: Mark Bouyer, Engine and Propulsion Standards Section, AIR–625, Technical Policy Branch, Policy and Standards Division, Aircraft Certification Service, 1200 District Avenue, Burlington, Massachusetts 01803; telephone (781) 238–7755; *mark.bouyer@faa.gov.*

SUPPLEMENTARY INFORMATION:

Background

On January 27, 2022, BETA applied for a type certificate for its Model H500A electric engines. The BETA Model H500A electric engine initially will be used as a "pusher" electric engine in a single-engine airplane that will be certified separately from the engine. A typical normal category general aviation aircraft locates the engine at the front of the fuselage. In this configuration, the propeller attached to the engine pulls the airplane along its flightpath. A pusher engine is located at the rear of the fuselage, so the propeller attached to the engine pushes the aircraft instead of pulling the aircraft.

The BETA Model H500A electric engine is comprised of a direct drive, radial-flux, permanent-magnet motor, divided in two sections, each section having a three-phase motor, and one electric power inverter controlling each three-phase motor. The magnets are arranged in a Halbach magnet array, and the stator is a concentrated, tooth-wound configuration. A stator is the stationary component in the electric engine that surrounds the rotating hardware; for example: the BETA propeller shaft, which consists of a bonded core with coils of insulated wire, known as the windings. When alternating current is applied to the coils of insulated wire in a stator, a rotating magnetic field is created, which provides the motive force for the rotating components.

Type Certification Basis

Under the provisions of 14 CFR 21.17(a)(1), generally, BETA must show that Model H500A electric engines meet the applicable provisions of 14 CFR part 33 in effect on the date of application for a type certificate.

If the Administrator finds that the applicable airworthiness regulations (*e.g.,* part 33) do not contain adequate or appropriate safety standards for the BETA Model H500A electric engines because of a novel or unusual design feature, special conditions may be prescribed under the provisions of § 21.16.

Special conditions are initially applicable to the model for which they are issued. Should the type certificate for that model be amended later to include any other engine model that incorporates the same novel or unusual design feature, these special conditions would also apply to the other engine model under § 21.101.

The FAA issues special conditions, as defined in § 11.19, in accordance with § 11.38, and they become part of the type certification basis under § 21.17(a)(2).

Novel or Unusual Design Features

The BETA Model H500A electric engines will incorporate the following novel or unusual design features:

An electric motor, motor controller, and high-voltage electrical systems that are used as the primary source of propulsion for an aircraft.

Discussion

Electric propulsion technology is substantially different from the technology used in previously certificated turbine and reciprocating engines. Therefore, these engines introduce new safety concerns that need to be addressed in the certification basis.

BETA's Electric Engines Are Novel or Unusual

The BETA Model H500A electric engines have a novel or unusual design feature, which is the use of electrical sources of energy instead of fuel to drive the mechanical systems that provide propulsion for aircraft. Therefore, part 33 does not contain adequate or appropriate safety standards for the BETA Model H500A electric engine's novel or unusual design feature.

BETA's aircraft engines will operate using electrical power instead of air and fuel combustion to propel the aircraft. These electric engines will be designed, manufactured, and controlled differently than turbine or reciprocating aircraft engines. They will be built with an electric motor, motor controller, and high-voltage electrical systems that draw energy from electrical storage or electrical energy generating systems. The electric motor is a device that converts electrical energy into mechanical energy by electric current flowing through windings (wire coils) in the motor, producing a magnetic field that interacts with permanent magnets mounted on the engine's main rotor. The controller is a system that consists of two main functional elements: the motor controller and an electric power inverter to drive the motor.[1] The high-voltage electrical system is a combination of wires and connectors that integrate the motor and controller.

In addition, the technology comprising these high-voltage and high-current electronic components introduces potential hazards that do not exist in turbine and reciprocating aircraft engines. For example, high-voltage transmission lines, electromagnetic shields, magnetic materials, and high-speed electrical switches are necessary to use the physical properties of an electric engine for propelling an aircraft.

BETA's Electric Engines Require a Mix of Part 33 Standards and Special Conditions

The requirements in part 33 ensure that the design and construction of aircraft engines, including the engine control systems, are proper for the type of aircraft engines considered for certification. However, part 33 does not fully address aircraft engines like the BETA Model H500A, which operates using electrical technology as the primary means of propelling the aircraft.

The requirements in part 33, subpart B, are applicable to reciprocating and turbine aircraft engines. Subparts C and D are applicable to reciprocating aircraft engines. Subparts E through G are applicable to turbine aircraft engines. As such, subparts B through G do not adequately address the use of aircraft engines that operate using electrical technology. Special conditions are needed to ensure a level of safety for electric engines that is commensurate with these subparts, as those regulatory requirements do not contain adequate or appropriate safety standards for electric aircraft engines that are used to propel aircraft.

The FAA proposed special conditions and received comments from many commenters. Some comments resulted in changes to the special conditions. These changes are explained in the Discussion of Comments.

[1] Sometimes the entire system is referred to as an inverter. Throughout this document, it is referred to as the controller.

FAA Special Conditions for the BETA Engine Design

Applicability: Special condition no. 1 requires BETA to comply with part 33, except for those airworthiness standards specifically and explicitly applicable only to reciprocating and turbine aircraft engines.

Engine Ratings and Operating Limitations: Special condition no. 2, in addition to compliance with § 33.7(a), requires BETA to establish engine operating limits related to the power, torque, speed, and duty cycles specific to BETA Model H500A electric engines. The duty or duty cycle is a statement of the load(s) to which the engine is subjected, including, if applicable, starting, no-load and rest, and de-energized periods, including their durations or cycles and sequence in time. This special condition also requires BETA to declare cooling fluid grade or specification, power supply requirements, and to establish any additional ratings that are necessary to define the BETA Model H500A electric engine capabilities required for safe operation of the engine.

Materials: Special condition no. 3 requires BETA to comply with § 33.15, which sets requirements for the suitability and durability of materials used in the engine, and which would otherwise be applicable only to reciprocating and turbine aircraft engines.

Fire Protection: Special condition no. 4 requires BETA to comply with § 33.17, which sets requirements to protect the engine and certain parts and components of the airplane against fire, and which would otherwise be applicable only to reciprocating and turbine aircraft engines. Additionally, this special condition requires BETA to ensure that the high-voltage electrical wiring interconnect systems that connect the controller to the motor are protected against arc faults. An arc fault is a high-power discharge of electricity between two or more conductors. This discharge generates heat, which can break down the wire's insulation and trigger an electrical fire. Arc faults can range in power from a few amps up to thousands of amps and are highly variable in strength and duration.

Durability: Special condition no. 5 requires the design and construction of BETA Model H500A electric engines to minimize the development of an unsafe condition between maintenance intervals, overhaul periods, and mandatory actions described in the

Instructions for Continued Airworthiness (ICA).

Engine Cooling: Special condition no. 6 requires BETA to comply with § 33.21, which requires the engine design and construction to provide necessary cooling, and which would otherwise be applicable only to reciprocating and turbine aircraft engines. Additionally, this special condition requires BETA to document the cooling system monitoring features and usage in the engine installation manual (see § 33.5) if cooling is required to satisfy the safety analysis described in special condition no. 17. Loss of cooling to an aircraft engine that operates using electrical technology can result in rapid overheating and abrupt engine failure, with critical consequences to safety.

Engine Mounting Attachments and Structure: Special condition no. 7 requires BETA and the design to comply with § 33.23, which requires the applicant to define, and the design to withstand, certain load limits for the engine mounting attachments and related engine structure. These requirements would otherwise be applicable only to reciprocating and turbine aircraft engines.

Accessory Attachments: Special condition no. 8 requires the design to comply with § 33.25, which sets certain design, operational, and maintenance requirements for the engine's accessory drive and mounting attachments, and which would otherwise be applicable only to reciprocating and turbine aircraft engines.

Rotor Overspeed: Special condition no. 9 requires BETA to establish by test, validated analysis, or a combination of both, that—

(1) the rotor overspeed must not result in a burst, rotor growth, or damage that results in a hazardous engine effect;

(2) rotors must possess sufficient strength margin to prevent burst; and

(3) operating limits must not be exceeded in service.

The special condition associated with rotor overspeed is necessary because of the differences between turbine engine technology and the technology of these electric engines. Turbine rotor speed is driven by expanding gas and aerodynamic loads on rotor blades. Therefore, the rotor speed or overspeed results from interactions between thermodynamic and aerodynamic engine properties. The speed of an electric engine is directly controlled by electric current, and an electromagnetic field created by the controller. Consequently, electric engine rotor response to power demand and overspeed-protection systems is quicker and more precise. Also, the failure modes that can lead to overspeed between turbine engines and electric engines are vastly different, and therefore this special condition is necessary.

Engine Control Systems: Special condition no. 10(b) requires BETA to ensure that these engines do not experience any unacceptable operating characteristics, such as unstable speed or torque control, or exceed any of their operating limitations.

The FAA originally issued § 33.28 at amendment 33–15 to address the evolution of the means of controlling the fuel supplied to the engine, from carburetors and hydro-mechanical controls to electronic control systems. These electronic control systems grew in complexity over the years, and as a result, the FAA amended § 33.28 at amendment 33–26 to address these increasing complexities. The controller that forms the controlling system for these electric engines is significantly simpler than the complex control systems used in modern turbine engines. The current regulations for engine control are inappropriate for electric engine control systems; therefore, special condition no. 10(b) associated with controlling these engines is necessary.

Special condition no. 10(c) requires BETA to develop and verify the software and complex electronic hardware used in programmable logic devices, using proven methods that ensure that the devices can provide the accuracy, precision, functionality, and reliability commensurate with the hazard that is being mitigated by the logic. RTCA DO–254, ''Design Assurance Guidance for Airborne Electronic Hardware,'' dated April 19, 2000,[2] distinguishes between complex and simple electronic hardware.

Special condition no. 10(d) requires data from assessments of all functional aspects of the control system to prevent errors that could exist in software programs that are not readily observable by inspection of the code. Also, BETA must use methods that will result in the expected quality that ensures the engine control system performs the intended functions throughout the declared operational envelope.

The environmental limits referred to in special condition no. 10(e) include temperature, vibration, high-intensity radiated fields (HIRF), and all others addressed in RTCA DO–160G, ''Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments,'' dated December 8, 2010, which includes RTCA DO–160G, Change 1—''Environmental Conditions and Test Procedures for Airborne Equipment,'' dated December, 16, 2014, and DO–357, ''User Guide: Supplement to DO–160G,'' dated December 16, 2014.[3] Special condition 10(e) requires BETA to demonstrate by system or component tests in special condition no. 27 any environmental limits that cannot be adequately substantiated by the endurance demonstration, validated analysis, or a combination thereof.

Special condition no. 10(f) requires BETA to evaluate various control system failures to ensure that such failures will not lead to unsafe engine conditions. The FAA issued Advisory Circular (AC) 33.28–3, ''Guidance Material for 14 CFR 33.28, Engine Control Systems,'' on May 23, 2014 (AC 33.28–3), for reciprocating and turbine engines.[4] This AC provides guidance for defining an engine control system failure when showing compliance with the requirements of § 33.28. AC 33.28–3 also includes objectives for control system integrity requirements, criteria for a loss of thrust control (LOTC) and loss of power control (LOPC) event, and an acceptable LOTC/LOPC rate. The electrical and electronic failures and failure rates did not account for electric engines when the FAA issued this AC, and therefore performance-based special conditions are established to allow fault accommodation criteria to be developed for electric engines.

The phrase ''in the full-up configuration'' used in special condition no. 10(f)(2) refers to a system without any fault conditions present. The electronic control system must, when in the full-up configuration, be single-fault tolerant, as determined by the Administrator, for electrical, electrically detectable, and electronic failures involving LOPC events.

The term ''local'' in the context of ''local events'' used in special condition no. 10(f)(4) means failures or malfunctions leading to events in the intended aircraft installation such as fire, overheat, or failures leading to damage to engine control system components. These ''local events'' must not result in a hazardous engine effect due to engine control system failures or malfunctions.

Special condition no. 10(g) requires BETA to conduct a safety assessment of the control system to support the safety analysis in special condition no. 17. This control system safety assessment

[2] *https://standards.rtca.org/XanHrK.*

[3] *https://my.rtca.org/NC__Product?id=a1B36000001IcnSEAS.*

[4] *https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_33_28-3.pdf.*

provides engine response to failures, and rates of these failures that can be used at the aircraft-level safety assessment.

Special condition no. 10(h) requires BETA to provide appropriate protection devices or systems to ensure that engine operating limits will not be exceeded in service.

Special condition no. 10(i) is necessary to ensure that the controllers are self-sufficient and isolated from other aircraft systems. The aircraft-supplied data supports the analysis at the aircraft level to protect the aircraft from common mode failures that could lead to major propulsion power loss. The exception ''other than power command signals from the aircraft,'' noted in special condition no. 10(i), is based on the FAA's determination that the engine controller has no reasonable means to determine the validity of any in-range signals from the electrical power system. In many cases, the engine control system can detect a faulty signal from the aircraft, but the engine control system typically accepts the power command signal as a valid value.

The term ''independent'' in the context of ''fully independent engine systems'' referenced in special condition no. 10(i) means the controllers should be self-sufficient and isolated from other aircraft systems or provide redundancy that enables the engine control system to accommodate aircraft data system failures. In the case of loss, interruption, or corruption of aircraft-supplied data, the engine must continue to function in a safe and acceptable manner without hazardous engine effects.

The term ''accommodated,'' in the context of ''detected and accommodated,'' referenced in special condition 10(i)(2) is to assure that, upon detecting a fault, the system continues to function safely.

Special condition no. 10(j) requires BETA to show that the loss of electric power from the aircraft will not cause the electric engine to malfunction in a manner hazardous to the aircraft. The total loss of electric power to the electric engine may result in an engine shutdown.

Instrument Connection: Special condition no. 11 requires BETA to comply with § 33.29(a), (e), and (g), which set certain requirements for the connection and installation of instruments to monitor engine performance. The remaining requirements in § 33.29 apply only to technologies used in reciprocating and turbine aircraft engines.

Instrument connections (wires, wire insulation, potting, grounding, connector designs, etc.) must not introduce unsafe features or characteristics to the aircraft. Special condition no. 11 requires the safety analysis to include potential hazardous effects from failures of instrument connections to function properly. The outcome of this analysis might identify the need for design enhancements or additional ICA to ensure safety.

Stress Analysis: Section 33.62 requires applicants to perform a stress analysis on each turbine engine. This regulation is explicitly applicable only to turbine engines and turbine engine components, and it is not appropriate for the BETA Model H500A electric engines. However, a stress analysis particular to these electric engines is necessary to account for stresses resulting from electric technology used in the engine.

Special condition no. 12 requires a mechanical, thermal, and electrical stress analysis to show that the engine has a sufficient design margin to prevent unacceptable operating characteristics. Also, the applicant must determine the maximum stresses in the engine by tests, validated analysis, or a combination thereof, and show that they do not exceed minimum material properties.

Critical and Life-Limited Parts: Special condition no. 13 requires BETA to show whether rotating or moving components, bearings, shafts, static parts, and non-redundant mount components should be classified, designed, manufactured, and managed throughout their service life as critical or life-limited parts.

The term ''low-cycle fatigue,'' referenced in special condition no. 13(a)(2), is a decline in material strength from exposure to cyclic stress at levels beyond the stress threshold the material can sustain indefinitely. This threshold is known as the ''material endurance limit.'' Low-cycle fatigue typically causes a part to sustain plastic or permanent deformation during the cyclic loading and can lead to cracks, crack growth, and fracture. Engine parts that operate at high temperatures and high mechanical stresses simultaneously can experience low-cycle fatigue coupled with creep. Creep is the tendency of a metallic material to permanently move or deform when it is exposed to the extreme thermal conditions created by hot combustion gasses, and substantial physical loads such as high rotational speeds and maximum thrust. Conversely, high-cycle fatigue is caused by elastic deformation, small strains caused by alternating stress, and a much higher number of load cycles compared to the number of cycles that cause low-cycle fatigue.

The engineering plan referenced in special condition no. 13(b)(1) informs the manufacturing and service management processes of essential information that ensures the life limit of a part is valid. The engineering plan provides methods for verifying the characteristics and qualities assumed in the design data using methods that are suitable for the part criticality. The engineering plan informs the manufacturing process of the attributes that affect the life of the part. The engineering plan, manufacturing plan, and service management plan are related in that assumptions made in the engineering plan are linked to how a part is manufactured and how that part is maintained in service. For example, environmental effects on life limited electric engine parts, such as humidity, might not be consistent with the assumptions used to design the part. BETA must ensure that the engineering plan is complete, available, and acceptable to the Administrator.

The term ''manufacturing plan,'' referenced in special condition no. 13(b)(2), is the collection of data required to translate documented engineering design criteria into physical parts, and to verify that the parts comply with the properties established by the design data. Because engines are not intentionally tested to failure during a certification program, documents and processes used to execute production and quality systems required by § 21.137 guarantee inherent expectations for performance and durability. These systems limit the potential manufacturing outcomes to parts that are consistently produced within design constraints.

The manufacturing plan and service management plan ensure that essential information from the engineering plan, such as the design characteristics that safeguard the integrity of critical and life-limited parts, is consistently produced and preserved over the lifetime of those parts. The manufacturing plan includes special processes and production controls to prevent inclusion of manufacturing-induced anomalies, which can degrade the part's structural integrity. Examples of manufacturing-induced anomalies are material contamination, unacceptable grain growth, heat-affected areas, and residual stresses.

The service-management plan ensures the method and assumptions used in the engineering plan to determine the part's life remain valid by enabling corrections identified from in-service experience, such as service-induced anomalies and unforeseen environmental effects, to be incorporated into the design process. The service-management plan also becomes the ICA for maintenance, overhaul, and repairs of the part.

Lubrication System: Special condition no. 14 requires BETA to ensure that the lubrication system is designed to function properly between scheduled maintenance intervals and to prevent contamination of the engine bearings. This special condition also requires BETA to demonstrate the unique lubrication attributes and functional capability of the BETA Model H500A electric engine design.

The corresponding part 33 regulations include provisions for lubrication systems used in reciprocating and turbine engines. The part 33 requirements account for safety issues associated with specific reciprocating and turbine engine system configurations. These regulations are not appropriate for the BETA Model H500A electric engines. For example, electric engines do not have a crankcase or lubrication oil sump. Electric engine bearings are sealed, so they do not require an oil circulation system. The lubrication system in these engines is also independent of the propeller pitch control system. Therefore, special condition no. 14 incorporates only certain requirements from the part 33 regulations.

Power Response: Special condition no. 15 requires the design and construction of the BETA Model H500A electric engines to enable an increase from the minimum—

(1) power setting to the highest rated power without detrimental engine effects, and

(2) within a time interval appropriate for the intended aircraft application.

The engine control system governs the increase or decrease in power in combustion engines to prevent too much (or too little) fuel from being mixed with air before combustion. Due to the lag in rotor response time, improper fuel/air mixtures can result in engine surges, stalls, and exceedances above rated limits and durations. Failure of the combustion engine to provide thrust, maintain rotor speeds below rotor burst thresholds, and keep temperatures below limits can have engine effects detrimental to the aircraft. Similar detrimental effects are possible in the BETA Model H500A electric engines, but the causes are different. Electric engines with reduced power response time can experience insufficient thrust to the aircraft, shaft over-torque, and over-stressed rotating components, propellers, and critical propeller parts. Therefore, this special condition is necessary.

Continued Rotation: Special condition no. 16 requires BETA to design the Model H500A electric engines such that, if the main rotating systems continue to rotate after the engine is shut down while in-flight, this continued rotation will not result in any hazardous engine effects.

The main rotating system of the BETA Model H500A electric engines consists of the rotors, shafts, magnets, bearings, and wire windings that convert electrical energy to shaft torque. For the initial aircraft application, this rotating system must continue to rotate after the power source to the engine is shut down. The safety concerns associated with this special condition are substantial asymmetric aerodynamic drag that can cause aircraft instability, loss of control, and reduced efficiency; and may result in a forced landing or inability to continue safe flight.

Safety Analysis: Special condition no. 17 requires BETA to comply with § 33.75(a)(1) and (a)(2), which require the applicant to conduct a safety analysis of the engine, and which would otherwise be applicable only to turbine aircraft engines. Additionally, this special condition requires BETA to assess its engine design to determine the likely consequences of failures that can reasonably be expected to occur. The failure of such elements, and associated prescribed integrity requirements, must be stated in the safety analysis.

A primary failure mode is the manner in which a part is most likely going to fail. Engine parts that have a primary failure mode, a predictable life to the failure, and a failure consequence that results in a hazardous effect, are life-limited or critical parts. Some life-limited or critical engine parts can fail suddenly in their primary failure mode, from prolonged exposure to normal engine environments such as temperature, vibration, and stress, if those engine parts are not removed from service before the damage mechanisms progress to a failure. Due to the consequence of failure, these parts are not allowed to be managed by on-condition or probabilistic means because the probability of failure cannot be sensibly estimated in numerical terms. Therefore, the parts are managed by compliance with integrity requirements, such as mandatory maintenance (life limits, inspections, inspection techniques), to ensure the qualities, features, and other attributes that prevent the part from failing in its primary failure mode are preserved throughout its service life. For example, if the number of engine cycles to failure are predictable and can be associated with specific design characteristics, such as material properties, then the applicant can manage the engine part with life limits.

Complete or total power loss is not assumed to be a minor engine event, as it is in the turbine engine regulation § 33.75, to account for experience data showing a potential for higher hazard levels from power loss events in single-engine general aviation aircraft. The criteria in these special conditions apply to an engine that continues to operate at partial power after a single electrical or electronic fault or failure. Total loss of power is classified at the aircraft level using special condition nos. 10(g) and 33(h).

Ingestion: Special condition no. 18 requires BETA to ensure that these engines will not experience unacceptable power loss or hazardous engine effects from ingestion. The associated regulations for turbine engines, §§ 33.76, 33.77, and 33.78, are based on potential performance impacts and damage from birds, ice, rain, and hail being ingested into a turbine engine that has an inlet duct, which directs air into the engine for combustion, cooling, and thrust. By contrast, the BETA electric engines are not configured with inlet ducts.

An ''unacceptable'' power loss, as used in special condition no. 18(b), is such that the power or thrust required for safe flight of the aircraft becomes unavailable to the pilot. The specific amount of power loss that is required for safe flight depends on the aircraft configuration, speed, altitude, attitude, atmospheric conditions, phase of flight, and other circumstances where the demand for thrust is critical to safe operation of the aircraft.

Liquid and Gas Systems: Special condition no. 19 requires BETA to ensure that systems used for lubrication or cooling of engine components are designed and constructed to function properly. Also, if a system is not self-contained, the interfaces to that system would be required to be defined in the engine installation manual. Systems for the lubrication or cooling of engine components can include heat exchangers, pumps, fluids, tubing, connectors, electronic devices, temperature sensors and pressure switches, fasteners and brackets, bypass valves, and metallic chip detectors. These systems allow the electric engine to perform at extreme speeds and temperatures for durations up to the maintenance intervals without exceeding temperature limits or predicted deterioration rates.

Vibration Demonstration: Special condition no. 20 requires BETA to ensure the engine—

(1) is designed and constructed to function throughout its normal operating range of rotor speeds and engine output power without inducing excessive stress caused by engine vibration, and

(2) design undergoes a vibration survey.

The vibration demonstration is a survey that characterizes the vibratory attributes of the engine. It verifies that the stresses from vibration do not impose excessive force or result in natural frequency responses on the aircraft structure. The vibration demonstration also ensures internal vibrations will not cause engine components to fail. Excessive vibration force occurs at magnitudes and forcing functions or frequencies, which may result in damage to the aircraft. Stress margins to failure add conservatism to the highest values predicted by analysis for additional protection from failure caused by influences beyond those quantified in the analysis. The result of the additional design margin is improved engine reliability that meets prescribed thresholds based on the failure classification. The amount of margin needed to achieve the prescribed reliability rates depends on an applicant's experience with a product. The FAA considers the reliability rates when deciding how much vibration is ''excessive.''

Overtorque: Special condition no. 21 requires BETA to demonstrate that the engine is capable of continued operation without the need for maintenance if it experiences a certain amount of overtorque.

BETA's electric engine converts electrical energy to shaft torque, which is used for propulsion. The electric motor, controller, and high-voltage systems control the engine torque. When the pilot commands power or thrust, the engine responds to the command and adjusts the shaft torque to meet the demand. During the transition from one power or thrust setting to another, a small delay, or latency, occurs in the engine response time. While the engine dwells in this time interval, it can continue to apply torque until the command to change the torque is applied by the engine control. The allowable amount of overtorque during operation depends on the engine's response to changes in the torque command throughout its operating range.

Calibration Assurance: Special condition no. 22 requires BETA to subject the engine to calibration tests to establish its power characteristics and the conditions both before and after the endurance and durability demonstrations specified in special condition nos. 23 and 26. The calibration test requirements specified in § 33.85 only apply to the endurance test specified in § 33.87, which is applicable only to turbine engines. The FAA determined that the methods used for accomplishing those tests for turbine engines are not appropriate for electric engines. The calibration tests in § 33.85 have provisions applicable to ratings that are not relevant to the BETA Model H500A electric engines. Special condition no. 22 allows BETA to demonstrate the endurance and durability of the electric engine either together or independently, whichever is most appropriate for the engine qualities being assessed. Consequently, the special condition applies the calibration requirement to both the endurance and durability tests.

Endurance Demonstration: Special condition no. 23 requires BETA to perform an endurance demonstration test that is acceptable to the Administrator. The Administrator will evaluate the extent to which the test exposes the engine to failures that could occur when the engine is operated at up to its rated values, and determine if the test is sufficient to show that the engine design will not exhibit unacceptable effects in service, such as significant performance deterioration, operability restrictions, and engine power loss or instability, when it is run repetitively at rated limits and durations in conditions that represent extreme operating environments.

Temperature Limit: Special condition no. 24 requires BETA to ensure the engine can endure operation at its temperature limits plus an acceptable margin. An ''acceptable margin,'' as used in the special condition, is the amount of temperature above that required to prevent the least capable engine allowed by the type design, as determined by § 33.8, from failing due to temperature-related causes when operating at the most extreme engine and environmental thermal conditions.

Operation Demonstration: Special condition no. 25 requires the engine to demonstrate safe operating characteristics throughout its declared flight envelope and operating range. Engine operating characteristics define the range of functional and performance values the BETA Model H500A electric engines can achieve without incurring hazardous effects. The characteristics are requisite capabilities of the type design that qualify the engine for installation into aircraft and that determine aircraft installation requirements. The primary engine operating characteristics are assessed by the tests and demonstrations that would be required by these special conditions. Some of these characteristics are shaft output torque, rotor speed, power consumption, and engine thrust response. The engine performance data BETA will use to certify the engine must account for installation loads and effects. These are aircraft-level effects that could affect the engine characteristics that are measured when the engine is tested on a stand or in a test cell. These effects could result from elevated inlet cowl temperatures, aircraft maneuvers, flowstream distortion, and hard landings. For example, an engine that is run in a sea-level, static test facility could demonstrate more capability for some operating characteristics than it will have when operating on an aircraft in certain flight conditions. Discoveries like this during certification could affect engine ratings and operating limits. Therefore, the installed performance defines the engine performance capabilities.

Durability Demonstration: Special condition no. 26 requires BETA to subject the engine to a durability demonstration. The durability demonstration must show that the engine is designed and constructed to minimize the development of any unsafe condition between maintenance intervals or between engine replacement intervals if maintenance or overhaul is not defined. The durability demonstration also verifies that the ICA is adequate to ensure the engine, in its fully deteriorated state, continues to generate rated power or thrust, while retaining operating margins and sufficient efficiency, to support the aircraft safety objectives. The amount of deterioration an engine can experience is restricted by operating limitations and managed by the engine ICA. Section 33.90 specifies how maintenance intervals are established; it does not include provisions for an engine replacement. Electric engines and turbine engines deteriorate differently; therefore, BETA will use different test effects to develop maintenance, overhaul, or engine replacement information for their electric engine.

System and Component Tests: Special condition no. 27 requires BETA to show that the systems and components of the engine perform their intended functions in all declared engine environments and operating conditions.

Sections 33.87 and 33.91, which are specifically applicable to turbine engines, have conditional criteria to decide if additional tests will be required after the engine tests. The criteria are not suitable for electric engines. Part 33 associates the need for additional testing with the outcome of the § 33.87 endurance test because it is designed to address safety concerns in combustion engines. For example, § 33.91(b) requires the establishment of temperature limits for components that require temperature-controlling provisions, and § 33.91(a) requires additional testing of engine systems and components where the endurance test does not fully expose internal systems and components to thermal conditions that verify the desired operating limits. Exceeding temperature limits is a safety concern for electric engines. The FAA determined that the § 33.87 endurance test is not appropriate for testing the electronic components of electric engines because mechanical energy is generated differently by electronic systems than it is by the thermal conditions in turbine engines. Additional safety considerations also need to be addressed in the test. Therefore, special condition no. 27 is a performance-based requirement that allows BETA to determine when engine systems and component tests are necessary and to determine the appropriate limitations of those systems and components used in the BETA Model H500A electric engine.

Rotor Locking Demonstration: Special condition no. 28 requires the engine to demonstrate reliable rotor locking performance and that no hazardous effects will occur if the engine uses a rotor locking device to prevent shaft rotation.

Some engine designs enable the pilot to prevent a propeller shaft or main rotor shaft from turning while the engine is running, or the aircraft is in-flight. This capability is needed for some installations that require the pilot to confirm the functionality of certain flight systems before takeoff. The BETA engine installations are not limited to aircraft that will not require rotor locking. Section 33.92 prescribes a test that may not include the appropriate criteria to demonstrate sufficient rotor locking capability for these engines. Therefore, this special condition is necessary.

The special condition does not define ''reliable'' rotor locking but allows BETA to classify the hazard as major or minor and assign the appropriate quantitative criteria that meet the safety objectives required by special condition no. 17 and the applicable portions of § 33.75.

Teardown Inspection: Special condition no. 29 requires BETA to perform a teardown or non-teardown evaluation after the endurance, durability, and overtorque demonstrations, based on the criteria in special condition no. 29(a) or (b).

Special condition no. 29(b) includes restrictive criteria for ''non-teardown evaluations'' to account for electric engines, sub-assemblies, and components that cannot be disassembled without destroying them. Some electrical and electronic components like BETA's are constructed in an integrated fashion that precludes the possibility of tearing them down without destroying them. The special condition indicates that, if a teardown cannot be performed in a non-destructive manner, then the inspection or replacement intervals must be established based on the endurance and durability demonstrations. The procedure for establishing maintenance should be agreed upon between the applicant and the FAA prior to running the relevant tests. Data from the endurance and durability tests may provide information that can be used to determine maintenance intervals and life limits for parts. However, if life limits are required, the lifing procedure is established by special condition no. 13, Critical and Life-Limited Parts, which corresponds to § 33.70. Therefore, the procedure used to determine which parts are life-limited, and how the life limits are established, requires FAA approval, as it does for § 33.70. Sections 33.55 and 33.93 do not contain similar requirements because reciprocating and turbine engines can be completely disassembled for inspection.

Containment: Special condition no. 30 requires the engine to have containment features that protect against likely hazards from rotating components unless BETA can show the margin to rotor burst does not justify the need for containment features. Rotating components in electric engines are typically disks, shafts, bearings, seals, orbiting magnetic components, and the assembled rotor core. However, if the margin to rotor burst does not unconditionally rule out the possibility of a rotor burst, then the special condition requires BETA to assume a rotor burst could occur and design the stator case to contain the failed rotors, and any components attached to the rotor that are released during the failure. In addition, BETA must also determine the effects of subsequent damage precipitated by a main rotor failure and characterize any fragments that are released forward or aft of the containment features. Further, decisions about whether the BETA engine requires containment features, and the effects of any subsequent damage following a rotor burst, should be based on test or validated analysis. The fragment energy levels, trajectories, and size are typically documented in the installation manual because the aircraft will need to account for the effects of a rotor failure in the aircraft design. The intent of this special condition is to prevent hazardous engine effects from structural failure of rotating components and parts that are built into the rotor assembly.

General Conduct of Tests: Special condition no. 32 requires BETA to—

(1) Include any scheduled maintenance.

(2) Include any maintenance, in addition to the scheduled maintenance, which was needed during the test to satisfy the applicable test requirements; and

(3) Conduct any additional tests that the Administrator finds necessary, as warranted by the test results.

For example, certification endurance test shortfalls might be caused by omitting some prescribed engine test conditions, or from accelerated deterioration of individual parts arising from the need to force the engine to operating conditions that drive the engine above the engine cycle values of the type design. If an engine part fails during a certification test, the entire engine might be subjected to penalty runs, with a replacement or newer part design installed on the engine, to meet the test requirements. Also, the maintenance performed to replace the part, so that the engine could complete the test, would be included in the engine ICA. In another example, if the applicant replaces a part before completing an engine certification test because of a test facility failure and can substantiate the part to the Administrator through bench testing, they might not need to substantiate the part design using penalty runs with the entire engine.

The term ''excessive'' is used to describe the frequency of unplanned engine maintenance, and the frequency of unplanned test stoppages, to address engine issues that prevent the engine from completing the tests in special condition nos. 32(b)(1) and (2), respectively. Excessive frequency is an objective assessment from the FAA's analysis of the amount of unplanned maintenance needed for an engine to complete a certification test. The FAA's assessment may include the reasons for the unplanned maintenance, such as the effects test facility equipment may have on the engine, the inability to simulate a realistic engine operating environment, and the extent to which an engine requires modifications to complete a certification test. In some cases, the applicant may be able to show that unplanned maintenance has no effect on the certification test results, or they might be able to attribute the problem to the facility or test-enabling equipment that is not part of the type design. In these cases, the ICA will not be affected. However, if BETA cannot reconcile the amount of unplanned service, then the FAA may consider the unplanned maintenance required during the certification test to be ''excessive,'' prompting the need to add the unplanned maintenance to mandatory ICA to comply with the certification requirements.

Engine electrical systems: The current requirements in part 33 for electronic engine control systems were developed to maintain an equivalent level of safety demonstrated by engines that operate with hydromechanical engine control systems. At the time § 33.28 was codified, the only electrical systems used on turbine engines were low-voltage, electronic engine control systems (EEC) and high-energy spark-ignition systems. Electric aircraft engines use high-voltage, high-current electrical systems and components that are physically located in the motor and motor controller. Therefore, the existing part 33 control system requirements do not adequately address all the electrical systems used in electric aircraft engines. Special condition no. 33 is established using the existing engine control systems requirement as a basis. It applies applicable airworthiness criteria from § 33.28 and incorporates airworthiness criteria that recognize and focus on the electrical power system used in the engine.

Special condition no. 33(b) ensures that all aspects of an electrical system, including generation, distribution, and usage, do not experience any unacceptable operating characteristics.

Special condition no. 33(c) requires the electrical power distribution aspects of the electrical system to provide the safe transfer of electrical energy throughout the electric engine.

The term ''abnormal conditions'' used in special condition no. 33(c)(2) is based on the term ''abnormal operation'' used in MIL–STD–704F ''Aircraft Electric Power Characteristics'' which defines normal operation and abnormal operation. MIL–STD–704F is a standard that ensures compatibility between power sources that provide power to the aircraft's electrical systems and airborne equipment that receive power from the power source. This standard also establishes technical criteria for aircraft electric power. The term ''abnormal conditions'' refers to various engine operating conditions such as:

- System or component characteristics outside of normal statistical variation from circumstances such as systems degradation, installation error, and engine response to fault conditions;
- Unusual environmental conditions from extreme temperature, humidity, vibration, lightning, high-intensity radiated field (HIRF), atmospheric neutron radiation; and
- Unusual and infrequent events such as landing on icy runways, rejected take-offs or go-arounds, extended ground idling or taxiing in a hot environment, and abrupt load changes from foreign object damage or engine contamination.

The phrase ''safe transmission of electric energy'' used in special condition no. 33(c)(3) refers to the transmission of electrical energy in a manner that supports the operation of the electric engine(s) and the aircraft safety objectives without detrimental effects such as uncontrolled fire or structural failure due to severe overheating.

Special condition no. 33(d) requires the engine electrical system to be designed such that the loss, malfunction, or interruption of the electrical power source, or power conditions that exceed design limits, will not result in a hazardous engine effect.

Special condition no. 33(e) requires BETA to identify and declare, in the engine installation manual, the characteristics of any electrical power supplied from the aircraft to the engine, or electrical power supplied from the engine to the aircraft via energy regeneration, and any other characteristics necessary for safe operation of the engine.

Special condition no. 33(f) requires BETA to demonstrate that systems and components will operate properly up to environmental limits, using special conditions, when such limits cannot be adequately substantiated by the endurance demonstration, validated analysis, or a combination thereof. The environmental limits referred to in this special condition include temperature, vibration, HIRF, and all others addressed in RTCA DO–160G, ''Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments.''

Special condition 33(g) requires BETA to evaluate various electric engine system failures to ensure that these failures will not lead to unsafe engine conditions. The evaluation includes single-fault tolerance, ensures no single electrical or electronic fault or failure would result in hazardous engine effects, and ensures that any failure or malfunction leading to local events in the intended aircraft application does not result in certain hazardous engine effects. The special condition also implements integrity requirements, criteria for LOTC/LOPC events, and an acceptable LOTC/LOPC rate.

Special condition 33(h) requires BETA to conduct a safety assessment of the engine electrical system to support the safety analysis in special condition no. 17. This safety assessment provides engine response to failures, and rates of these failures, which can be used at the aircraft safety assessment level.

Discussion of Comments

The FAA issued a notice of proposed special conditions (NPSC) Docket No. FAA–2022–1641 for the BETA Model H500A electric engines, which was published in the **Federal Register** on March 7, 2024 (89 FR 16474).

The FAA Received Comments From Eight Commenters

The FAA received comments from Transport Canada (TC), Transport Canada Civil Aviation (TCCA), United Parcel Service Flight Forward (UPSFF), Association for Uncrewed Vehicle Systems International (AUVSI), magniX USA, Inc. (magniX), General Aviation Manufacturers Association (GAMA), an individual, and an anonymous commenter.

The FAA received comments from TCCA.

TCCA indicated the discussion of proposed special condition no.10(e), Environmental limits of engine cooling systems, in the preamble states that the environmental limits referred to in this special condition are addressed in RTCA DO–160G. However, TCCA explained that some of the existing RTCA DO–160G test specifications, methods, and categories may not be adequate for high voltage systems, such as the high voltage components of this engine. Accordingly, TCCA recommended adding the language ''or other appropriate industry standards'' at the end of the discussion of special condition no. 10(e) in the preamble.

The FAA does not agree with the recommended change. Although RTCA DO–160G is not sufficient for the high voltage systems used in the BETA Model H500A electric engine motor and inverter/controller, tests that are appropriate for the BETA engine will be developed in accordance with special condition nos. 1(b) and 1(c) using the testing techniques in RTCA DO–160G and other aerospace environmental documents. Independent tests are done for radiated and conducted susceptibility and compared to the RTCA DO–160G HIRF spectrum for susceptibility to ensure all electric engine radio frequency energy emissions inherent to the engine design are addressed. If the equipment under test passes the emission test in RTCA–DO–160 the susceptibility spectrum is covered by RTCA DO–160G. The applicant can use the RTCA DO–160G test. If not, the spectrum from the emission test would be analyzed and could be adjusted for the applicant's design and applied during the susceptibility test with FAA concurrence. No changes were made to these special conditions as a result of this comment.

TCCA also indicated special condition no. 2, Engine ratings and operating limits, should require that component life be considered when establishing the engine operating limits. They explained, the engine system or the electrical motor design may have components or parts that require a life limit. For example, the insulation on the high voltage system wiring may degrade with time and operating conditions. TCCA requested the FAA add ''(f) Component life'' to special condition no. 2, Engine Ratings and Operating Limits, and explained that component life should be considered when establishing the engine operating limits, similar to § 33.07(b)(7).

The FAA does not concur with TCCA's request. Component life is an expected outcome of special conditions nos. 13 (Critical and life-limited parts) and 17 (Safety analysis). Special condition no. 17 determines whether special condition no. 13 applies to the engine part. Special condition no 13 determines the mandatory replacement times (component life) and implements a maintenance program to manage these parts composed of an engineering plan, manufacturing plan, and service management plan. No changes were made to these special conditions as a result of this comment.

TCCA requested the FAA confirm that special condition no. 33(a), applicability for engine electrical systems, is not applicable to energy storage systems (ESS) but it does include the interface between the electric engine and the propulsion power source. TCCA further explained this comment is a request for clarification, rather than modification, of this special condition.

Special condition no. 33 does not apply to ESS but does apply to the interface between the engine and ESS. No changes were made to these special conditions as a result of this comment.

TCCA stated that proposed special condition no. 33(b), Electrical systems, is written in a way that implies electrical load shedding is mandatory even when not needed and explained electrical load shedding should only be implemented if required. TCCA recommended adding ''if required'' between parenthesis like the following: ''. . . , and electrical load shedding (if required), . . .'' to special condition no. 33(b).

The FAA concurs with TCCA's recommendation and has revised special condition no. 33(b) accordingly. Load shedding is a capability of the electric engine's power distribution system.

TCCA requested the FAA define the term ''abnormal condition,'' which is used in special condition 33(c)(2), Electrical power distribution, and offered several potential interpretations of the term. They also asked if an abnormal condition is any failure condition not considered extremely improbable, and if it is equivalent to the definition from MIL–STD–704F. The FAA's use of the term ''abnormal conditions'' does not refer to internal malfunctions or failures. It refers to operating conditions such as:

- System or components outside of normal statistical variation due to degradation, or installation error
- Unusual environmental conditions such as extreme temperature, humidity, FOD impact, severe lightning, HIRF, or atmospheric radiation
- Infrequent scenarios such as landing on icy runways, rejected take-offs or balked landings, extended ground idling, or taxiing in hot environments.

TCCA also requested the FAA provide a definition for ''safe transmission,'' which is used in special condition 33(c)(3).

The FAA concurs with TCCA's requests and has added definitions of the terms ''abnormal condition'' and ''safe transmission'' to the preamble discussion for special condition no. 33.

TCCA observed that proposed special condition nos. 33(e)(1) and (e)(2), Electrical power characteristics, were linked with an ''or'' indicating that either condition could be applied, but not both. TCCA stated both (e)(1) and (e)(2) are applicable, and therefore recommended the FAA revise special condition no. 33(e) to replace the ''or'' with an ''and.''

The FAA concurs with TCCA's recommendation and has revised special condition no. 33(e) accordingly.

TCCA indicated that noise certification requirements are applicable at the airframe level and not at the engine level. TCCA explained the NPSC implies that an engine applicant demonstration of compliance to 14 CFR part 36 is part of the special conditions. However, TCCA stated there is no definition of requirements within the special conditions other than the preamble section titled the Type Certification Basis. TCCA requested that the FAA remove the statement ''In addition to the applicable airworthiness regulations and special conditions, the BETA Model H500A electric engines must comply with the noise certification requirements of 14 CFR part 36'' from the preamble. GAMA also commented on this issue and stated the noise certification requirements do not apply to engines and requested the FAA remove this statement from the preamble.

The FAA concurs with TCCA's and GAMA's requests and has updated the preamble of these special conditions accordingly.

TCCA suggested that the reference to ''consensus standards'' in proposed special condition 1(b), Applicability, may not be necessary. TCCA stated that consensus standards are not a means of compliance but instead, they are derived/alternate requirements (*i.e.,* ASTM) that are formulated by industry to be used in lieu of published regulatory guidance material. TCCA further suggested that the use of derived/alternate requirements in lieu of the published standards is to be accepted by the Administrator as being equivalent to the published standards. Then, the means of compliance to the consensus standards are to be accepted by the Administrator. TCCA recommended reducing the text in special condition no. 1(b) to the following: ''(b) the applicant must comply with this part using a means of compliance accepted by the administrator.''

The FAA does not concur with TCCA's suggested change. The reference to consensus standards provides clarification about potential sources of information that may be used to determine a means of compliance. The comment indicates a need to clarify how consensus standards are used. For example, consensus standards developed by the standards development organizations (SDOs) typically function as a method of compliance to 14 CFR requirements or special conditions. Published FAA guidance can function either as a means of compliance, method of compliance, or both. Special condition 1(b) permits consensus standards to be used for showing compliance to certification requirements, but they are not a requirement of that special condition. Therefore, special condition 1(b) supplements the performance-based special conditions by requiring a means of compliance, which could include consensus standards developed by SDOs. Further, special condition 1(b) is intended to be equivalent to § 23.2010(a), which also refers to consensus standards as a potential means of compliance. No changes were made to the special conditions as a result of this comment.

TCCA observed the BETA proposed special condition no. 17 does not include a reference to § 33.75(a)(3) which appears in the magniX special conditions and recommended that the FAA explain this difference in the discussion for that special condition in the preamble to avoid ambiguity between the relative project requirements.

The FAA does not concur with TCCA's recommendation. The NPSC for the magniX magni350 and magni650 model electric engines originally proposed to incorporate § 33.75(a)(3) into special condition no. 17. The FAA received a comment suggesting that § 33.75(a)(3) may not be needed for those engines. In the final special conditions (Docket No. FAA–2020–0894, Special Conditions No. 33–022–SC), the FAA agreed with the comment and removed the reference to § 33.75(a)(3). No changes were made to these special conditions as a result of this comment.

The FAA received comments from TC.

TC disagreed with the text in proposed special condition nos. 17(a) and 17(c) which say, ''The applicant must comply . . .'' TC stated that the onus to show compliance with the applicable requirements with the intent to obtain a type certificate is on the applicant and that the elements that comply with the requirements themselves are those objects of the type certificate, such as the engine and its systems. TC further explained it is not clear to state that the applicant must comply, where it is in fact the engine/systems which must comply with the requirements. Instead, the applicant shows compliance. TC suggested changing the phrase to read ''The applicant must show compliance . . .''

TC's proposed change is not necessary. Section 21.20, ''Compliance with Applicable Requirements'' contains an example that supports the language used in special conditions nos. 17(a) and (c). Specifically, § 21.20(b) specifies the applicant must ''provide a statement certifying that the applicant has complied with the applicable requirements,'' which indicates the applicant complies with the applicable requirements. . No changes were made as a result of this comment.

TC observed the text in proposed special condition no. 17(d)(1), Safety Analysis, does not include special condition no. 31, Operation with Variable Pitch Propeller. TC recommended that the FAA either add a reference to special condition no. 31 in special condition no. 17(d)(1) because BETA's electric engine may be installed with a variable pitch propeller or provide a rationale for not including it.

The FAA does not concur with TC's suggestion to add a reference to special condition no. 31. Adding special condition no. 31 is not necessary because the specific engine model BETA intends to certify is not designed to use a variable pitch propeller. No changes were made to the special conditions as a result of this comment.

TC indicated there is a similar electrical engine special condition in the magniX special conditions (Special Conditions No. 33–022–SC) that contains an ingestion requirement that does not appear in the BETA special conditions. TC referred to special condition no. 18(d) in the magniX special conditions, which requires ingestion sources that are not evaluated must be declared in the engine installation manual. TC recommended that the FAA either revise the BETA special conditions to add this requirement or provide the rationale for not including it.

The FAA does not concur with TC's request to revise the BETA special conditions to include special condition no. 18(d) from the magniX special conditions. Special condition no. 18(d) was intended to ensure ingestion sources that are not applicable to an electric engine are enunciated in the engine documentation. The list of required ingestion sources in BETA special condition nos. 18(a) and (b) are more prescriptive compared to the ingestion requirements in the published magniX special condition no. 18(a). Therefore, the FAA has determined special condition no. 18(d) is not necessary to include in the BETA special conditions because exceptions to the ingestion requirement would be specified and managed using special condition no. 18(c), which is similar to how exceptions are managed by the existing part 33 ingestion requirements. No changes were made to the special conditions as a result of this comment.

TC noted that proposed special condition no. 33(c)(1) introduces the term ''electrical power plant'' and recommended that the FAA update the preamble to describe an electrical power plant.

The FAA disagrees with TC's recommendation to define ''electrical power plant'' because the FAA revised special condition no. 33(c)(1) in these final special conditions to change the term ''electrical power plant'' to ''powerplant,'' as that term is defined in part 23, subpart E, in § 23.2400(a) powerplant installation, to include each component necessary for propulsion, which affects propulsion safety, or provides auxiliary power to the airplane, and in the installation requirements in subpart E of parts 25, 27, and 29.

TC observed that the proposed system safety assessments in proposed special condition no. 33(h), and proposed special condition no.10(g) are different in that special condition no. 10(g) requires the rates of hazardous and major faults to be declared in the engine installation manual and special condition no. 33(h) does not. TC recommended that the FAA either revise special condition no. 33(h) to match special condition no. 10(g) or provide a rationale for why they are different.

The FAA agrees with TC's recommendation and has revised final special condition no. 33(h) to match special condition no. 10(g).

The FAA received comments from GAMA.

GAMA recommended that the FAA align the special conditions for the H500A electric engine with the electric engine requirements included in the certification basis for special class powered lift aircraft that certify an electric engine as part of the aircraft type certification. GAMA stated that there are technical variations between the H500A proposed special conditions and the electric engine airworthiness criteria outlined in the Special Class Airworthiness Criteria for the powered-lift and cited special condition no. 17(c) and special condition no. 33(c) as examples of these technical differences. GAMA further stated these variations could lead to two electric engines used in the same aircraft having different requirements based solely on whether the engine is certified as part of the aircraft or under part 33. AUVSI also commented on the importance of applying consistent requirements across projects and requested the FAA substantiate any inconsistencies introduced to the electric engine requirements.

There are no intended technical differences between the proposed special class airworthiness criteria for the powered lift in draft Advisory

Circular 21.17–4 (AC 21.17–4) and the BETA special conditions. For example, the corresponding criteria to BETA special condition nos. 17(c) and 33(c) are PL.3375(f) and PL.3326(c) respectively. The engine requirements are documented differently between the BETA special conditions and powered-lift airworthiness criteria proposed in draft AC 21.17–4 because special conditions are written in accordance with the requirements of § 21.16, and the powered-lift airworthiness criteria in draft AC 21.17–4 are not specific to one applicant. There are also some minor differences in the documentation requirements because engines are approved with the special class aircraft, so some engine details may be included in the aircraft manuals. No changes were made to the special conditions as a result of this comment.

GAMA indicated proposed special condition no. 9, Overspeed, lacks clarity regarding whether ''rotor'' refers to an internal electric engine component or an actual propulsive propeller. GAMA recommended the FAA provide the necessary clarification to address this ambiguity.

The FAA agrees with GAMA's recommendation. The term ''rotor'' in the proposed special conditions is intended to refer to an engine component and not a propulsive propeller. A rotor in an electric engine may consist of a circular disk and magnets fixed at the outer circumference that rotates inside a stationary casing configured with electrical windings (or coils), or a rotating cylindrical casing with magnets fixed on the inside surface that rotates around a stationary set of windings (or coils). Each configuration is attached to a rotating shaft that drives a propulsive device, such as a propeller. Project-specific decisions will be made regarding which engine parts are applicable to the overspeed requirement. No changes were made to the special conditions as a result of this comment.

GAMA stated that proposed special condition nos. 30(a) and (b), Containment, utilize language tailored to an engine design featuring a non-rotating stator situated outside the rotor. GAMA recommended the FAA explore a rule version that is less design-specific. GAMA advised against presuming that all rotating components possess a case, particularly that the rotor is contained within the stator.

The FAA does not concur with GAMA's recommendation Special condition 30(a) is intended to account for rotor designs with exceedingly large margins to a rotor burst. The special condition does not specify a particular rotor design. However, the amount of margin needed to satisfy the requirement would be determined based on the engine's design. Special condition 30(b) is intended to account for rotors located inside a static stator case. No changes were made to the special conditions as a result of this comment.

GAMA commented proposed special condition nos. 33(c)(1) and (c)(3), Electrical power distribution for engine electrical systems, set forth distinct criteria for the automatic measures needed when electrical-energy generation encounters faults, which diverges from the corresponding requirements in the special class airworthiness criteria for powered-lift. GAMA indicated there are no evident variations in electric engine configurations that warrant this inconsistency. GAMA recommended that the FAA align these regulations to ensure that electric engines certified as part of an aircraft or under part 33 adhere to uniform standards.

Proposed special condition nos. 33(c)(1) and (c)(3) are not the same as the corresponding engine requirements in the powered-lift airworthiness criteria used in another project. Proposed special condition no. 33(c)(1) protects engine electrical systems from faulted electrical energy generation or storage devices. Proposed special condition no. 33(c)(3) prescribes a means of compliance (fault isolation) to address (c)(1), but the means of compliance should be tied to the safety assessment required in special condition no. 33(g), which accounts for aircraft-level effects from faulted electrical-energy generation or storage devices. The aircraft effects should not be assumed in the engine requirements, and therefore the FAA revised special condition no. 33(c)(3) to accommodate other potential protection systems that might be more appropriate. Accordingly, final special condition no. 33(c)(3) is changed to, ''The system must provide mechanical or automatic means of isolating a faulted electrical energy generation or storage device from leading to hazardous engine effects, as defined in special condition no. 17(d)(2) of these special conditions, or detrimental effects in the intended aircraft application.''

The phrase, ''or detrimental engine effects in the intended aircraft application'' was relocated to special condition no. 33(c)(3) to maintain the connection with special condition no. 33(g).

GAMA commented proposed special condition no. 33(g), Electrical system failures of engine electrical systems, extends beyond the comparable part 33 regulation § 33.28(d), which is originally limited to the engine control system. GAMA suggested that expanding this special condition to encompass the engine electrical system instead of solely the engine control system entails subjecting electrical components within the engine, such as windings, to failure requirements historically not applied to engine mechanical components. GAMA also stated that field experience indicates that component failures are unpredictable based on wear and susceptible to random failures. Electric engine components, like windings and insulation, are better addressed using methods akin to those applied to traditional engines to address mechanical failure aspects. GAMA recommended the FAA revise this special condition to align with the existing regulatory framework. The FAA does not concur with GAMA's recommendation. By their nature, FAA special conditions are issued when the ''existing regulatory framework'' is inadequate or insufficient. 14 CFR 21.16; see also Amdt. 21–51. The existing requirements for engine control systems were developed to address the failure characteristics of electrical systems. For combustion engines, the only electrical system is the engine control, but this is not the case for electric engines where electrical systems extend beyond those addressed by § 33.28(d). Special condition no. 33(g) for the BETA electric engine provides the same level of safety as § 33.28(d) by applying the safety criteria for electrical systems to all the electrical systems in the engine. This includes the high-voltage systems used in the electric engine. No changes were made to the special conditions as a result of this comment.

The FAA received several comments from an individual commenter and received similar comments from magniX (although these commenters provided separate comments).

An individual and magniX commented proposed special condition nos. 1(b) and (c) state that a means of compliance, which may include consensus standards, must be ''accepted by the Administrator'' and ''in a form and manner acceptable to the Administrator.'' The individual and magniX stated that these paragraphs are directly out of § 23.2010, which contains performance-based language. The individual and magniX considered the BETA electric engine special conditions to be largely prescriptive and not performance-based, which they stated would make special condition nos. 1(b) and (c) superfluous. The individual suggested these requirements introduce a new regulatory layer to prescriptive requirements and may lead to inadvertent consequences, while magniX stated that requiring a performance-based process for establishing means of compliance with prescriptive regulations is unnecessary and overly burdensome to applicants and regulators. The individual and magniX recommended the FAA not adopt proposed special condition nos. 1(b) and (c), and the individual also recommended holding public consultations with stakeholders as was done when part 23 was being reworked into a performance-based form.

The FAA does not concur with the individual's and magniX's recommendation. While special conditions are rules of particular, not general applicability, the FAA expects that special condition nos. 1(b) and (c) support the FAA's transition to a performance-based approach for developing new requirements. Although the BETA special conditions are not prescriptive, they provide safety criteria that address hazards presented by the new electric engine technology used in the BETA H500A engine. Special condition nos. 1(b) and (c) will be used to incorporate the additional details that apply to the BETA H500A engine design using accepted means of compliance. No changes were made to these special conditions as a result of this comment.

GAMA and magniX commented that special condition nos. 10(g), 15(b), and 17(f) would require applicants to declare proprietary information in the engine installation manual, these documentation requirements establish a precedent beyond that required of their existing reciprocating or turbine counterparts, and these requirements increase the risk that sensitive information is disclosed. MagniX stated that while it is understood this information is used during aircraft-level certification efforts, traditional data sharing agreements sufficiently provide the integrator with the required information while respecting the proprietary nature of the data. MagniX also stated requiring additional data in the engine installation manual overly constrains the means whereby this information is shared when compared with established means, introducing additional commercial risk. GAMA also stated proposed special condition nos. 10(g), 15(b), and 17(f) are a requirement for a manufacturer to disclose sensitive proprietary safety analysis in the engine installation manual, a requirement not currently imposed on part 33 engines. Additionally, GAMA stated the FAA has not provided adequate justification for why an electric engine necessitates this information in a manual. An individual provided a similar comment regarding proposed special condition nos. 10(g) and 17(f), and stated that historically such information was captured in other documents such as the engine control systems interface control document and systems safety assessment, that were only provided to the installer.

MagniX requested the FAA not adopt the documentation requirements in proposed special conditions 10(g), 15(b), and 17(f), and proposed that these data be provided to integrators through generic ''installation instructions'' in lieu of the engine installation manual. GAMA also requested the FAA reconsider its approach and/or provide justification for the added requirement of disclosing sensitive proprietary safety analysis in the engine installation manual. An individual requested the FAA preserve the engine OEM's flexibility to document and protect proprietary data by changing ''installation manual'' to the more generic ''installation instructions,'' which consist of other documents such as interface control drawings, technical memorandums, or other installer requested documentation. The individual further stated that this change would harmonize the special condition with § 23.2400(e) which uses the verbiage of ''installation instructions,'' and this change could be promulgated to other special condition paragraphs which refer to the engine installation manual.

The FAA does not concur with magniX's and GAMA's comments that special conditions 10(g), 15(b), and 17(f) require disclosing sensitive information. The requirements cited in their comment do not require disclosure of sensitive information. As discussed in the NPSC, the documentation requirements in special conditions nos. 10(g), 15(b), and 17(f) are expected to ensure that the engine is used safely and properly by constraining the installation of electric engines to only aircraft types (configurations, flight capabilities, etc.) that were used by the engine manufacturer to determine the engine ratings, limits, performance characteristics, as well as the reliability and criticality of engine systems and parts.

These documentation requirements are intended, and the FAA finds necessary, to ensure enough information is included to safeguard compatibility between the electric engine and aircraft, and to prevent the engine from being used in an aircraft type that requires safety features or performance characteristics that are not available from a type certificated engine. For example, electric engines designed for vertical lift in distributed propulsion tilt-wing aircraft provide propulsion and act as flight control surfaces, and therefore these engines have different performance requirements than those used in conventional normal category airplanes. In addition, the FAA agrees with the commenters' suggestion to remove the requirement that specifies the information must be located in the engine installation manual. These special conditions do not need to specify the document that must have the information, but only that the information must be provided to the installer in accordance with the engine installation instructions under § 33.5, ''Instruction manual for installing and operating the engine.''. The proposed special conditions are modified to incorporate this change.

The FAA received a comment from UPSFF.

UPSFF requested that the FAA align these special conditions with the electric engine requirements included in the certification basis for special class powered lift aircraft that certify an electric engine as part of the aircraft type certification.

As stated previously, the engine requirements in the BETA special conditions are documented differently from proposed powered lift airworthiness criteria in draft AC 21.17–4 because special conditions are written in accordance with the requirements of § 21.16, and the proposed powered-lift airworthiness criteria in draft AC 21.17–4 are not specific to one applicant. Special conditions are project-specific rules of particular applicability, and the special conditions for this electric engine are based on certain novel or unusual design features. Special conditions may evolve to a general standard as more experience is gained with certifying the new technology (see Amdt. 21–51). No changes were made to these special conditions as a result of this comment.

The FAA received an anonymous comment. The commenter stated the reference to § 21.17(a) in the preamble of the NPSC seems contradictory to the language in § 21.17(b). The commenter explained that since § 21.17(b) applies to ''special classes of aircraft, including the engines and propellers installed thereon (*e.g.,* gliders, airships, and other nonconventional aircraft) . . .'' an electric engine would be installed on a special class of aircraft as described in § 21.17(b) and referring to § 21.17(a) seems to contradict the language in paragraph (b) of that section.

The FAA does not concur with the comment that indicates the reference to § 21.17(a) is contradictory to the language in § 21.17(b). Section 21.17(a) provides requirements for developing a certification basis for an established aviation product, which includes aircraft, engines, and propellers. The BETA electric engine is an aircraft engine, which falls under § 21.17(a), and therefore § 21.17(a) is the appropriate reference for this project. Section 21.17(b) provides requirements for developing a certification basis for special classes of aircraft, such as powered-lift. No changes were made as a result of this comment.

The FAA also determined that the following changes were necessary. The phrase, ''In addition'' is added to special condition no. 4, Fire protection, to connect the introduction sentence to (a) and (b) and avoid confusion. The FAA also revised the special conditions to use consistent references to hazardous engine effects. Therefore, the phrase ''as defined in special condition no. 17 of these special conditions'' was added wherever ''hazardous engine effects'' is mentioned.

The FAA recognizes energy regeneration might not be a feature for some electric engines that operate at their limits, so special condition no. 23 was changed to specify that ''The endurance demonstration must include increases and decreases of the engine's power settings, energy regeneration, and dwellings at the power settings and energy regeneration for sufficient durations that produce the extreme physical conditions the engine experiences at rated performance levels, operational limits, and at any other conditions or power settings, including energy regeneration that are required to verify the limit capabilities of the engine.''

In addition, proposed special condition no. 31 was not adopted because the specific engine model BETA intends to certify is not designed to use a variable pitch propeller. Except as discussed above, these special conditions are adopted as proposed.

Applicability

As discussed above, these special conditions are applicable to BETA Model H500A electric engines. Should BETA apply at a later date for a change to the type certificate to include another model on the same type certificate, incorporating the same novel or unusual design feature, these special conditions would apply to that model as well.

Conclusion

This action affects only BETA Model H500A electric engines. It is not a rule of general applicability and affects only the applicant who applied to the FAA for approval of these features on the airplane.

List of Subjects in 14 CFR Part 33

Aircraft, Aviation safety, Reporting and recordkeeping requirements.

Authority Citation

The authority citation for these special conditions is as follows:

Authority: 49 U.S.C. 106(f), 106(g), 40113, 44701, 44702, 44704.

The Special Conditions

▪ Accordingly, pursuant to the authority delegated to me by the Administrator, the following special conditions are issued as part of the type certification basis for BETA Technologies Inc. Model H500A electric engines. The applicant must also comply with the certification procedures set forth in part 21.

(1) Applicability

(a) Unless otherwise noted in these special conditions, the engine design must comply with the airworthiness standards for aircraft engines set forth in part 33, except for those airworthiness standards that are specifically and explicitly applicable only to reciprocating and turbine aircraft engines or as specified herein.

(b) The applicant must comply with this part using a means of compliance, which may include consensus standards, accepted by the Administrator.

(c) The applicant requesting acceptance of a means of compliance must provide the means of compliance to the FAA in a form and manner acceptable to the Administrator.

(2) Engine Ratings and Operating Limits

In addition to § 33.7(a), the engine ratings and operating limits must be established and included in the type certificate data sheet based on:

(a) Shaft power, torque, rotational speed, and temperature for:

(1) Rated takeoff power;

(2) Rated maximum continuous power; and

(3) Rated maximum temporary power and associated time limit.

(b) Duty cycle and the rating at that duty cycle. The duty cycle must be declared in the engine type certificate data sheet.

(c) Cooling fluid grade or specification.

(d) Power-supply requirements.

(e) Any other ratings or limitations that are necessary for the safe operation of the engine.

(3) Materials

The engine design must comply with § 33.15.

(4) Fire Protection

The engine design must comply with § 33.17(b) through (g). In addition—

(a) The design and construction of the engine and the materials used must minimize the probability of the occurrence and spread of fire during normal operation and failure conditions and must minimize the effect of such a fire.

(b) High-voltage electrical wiring interconnect systems must be protected against arc faults that can lead to hazardous engine effects as defined in special condition no. 17(d)(2) of these special conditions. Any non-protected electrical wiring interconnects must be analyzed to show that arc faults do not cause a hazardous engine effect.

(5) Durability

The engine design and construction must minimize the development of an unsafe condition of the engine between maintenance intervals, overhaul periods, or mandatory actions described in the applicable ICA.

(6) Engine Cooling

The engine design and construction must comply with § 33.21. In addition, if cooling is required to satisfy the safety analysis as described in special condition no. 17 of these special conditions, the cooling system monitoring features and usage must be documented and provided to the installer as part of the requirements in § 33.5.

(7) Engine Mounting Attachments and Structure

The engine mounting attachments and related engine structures must comply with § 33.23.

(8) Accessory Attachments

The engine must comply with § 33.25.

(9) Overspeed

(a) A rotor overspeed must not result in a burst, rotor growth, or damage that results in a hazardous engine effect, as defined in special condition no. 17(d)(2) of these special conditions. Compliance with this paragraph must be shown by test, validated analysis, or a combination of both. Applicable assumed rotor speeds must be declared and justified.

(b) Rotors must possess sufficient strength with a margin to burst above certified operating conditions and above failure conditions leading to rotor overspeed. The margin to burst must be shown by test, validated analysis, or a combination thereof.

(c) The engine must not exceed the rotor speed operational limitations that could affect rotor structural integrity.

(10) Engine Control Systems

(a) *Applicability.* The requirements of this special condition apply to any system or device that is part of the engine type design that controls, limits, monitors, or protects engine operation, and is necessary for the continued airworthiness of the engine.

(b) *Engine control.* The engine control system must ensure that the engine does not experience any unacceptable operating characteristics or exceed its operating limits, including in failure conditions where the fault or failure results in a change from one control mode to another, from one channel to another, or from the primary system to the back-up system, if applicable.

(c) *Design Assurance.* The software and complex electronic hardware, including programmable logic devices, must be—

(1) Designed and developed using a structured and systematic approach that provides a level of assurance for the logic commensurate with the hazard associated with the failure or malfunction of the systems in which the devices are located; and

(2) Substantiated by a verification methodology acceptable to the Administrator.

(d) *Validation.* All functional aspects of the control system must be substantiated by test, analysis, or a combination thereof, to show that the engine control system performs the intended functions throughout the declared operational envelope.

(e) *Environmental Limits.* Environmental limits that cannot be adequately substantiated by endurance demonstration, validated analysis, or a combination thereof must be demonstrated by the system and component tests in special condition no. 27 of these special conditions.

(f) *Engine control system failures.* The engine control system must—

(1) Have a maximum rate of loss of power control (LOPC) that is suitable for the intended aircraft application. The estimated LOPC rate must be documented and provided to the installer as part of the requirements in § 33.5;

(2) When in the full-up configuration, be single-fault tolerant, as determined by the Administrator, for electrical, electrically detectable, and electronic failures involving LOPC events;

(3) Not have any single failure that results in hazardous engine effects as defined in special condition no. 17(d)(2) of these special conditions; and

(4) Ensure failures or malfunctions that lead to local events in the aircraft do not result in hazardous engine effects, as defined in special condition no. 17(d)(2) of these special conditions, due to engine control system failures or malfunctions.

(g) *System safety assessment.* The applicant must perform a system safety assessment. This assessment must identify faults or failures that affect normal operation, together with the predicted frequency of occurrence of these faults or failures. The intended aircraft application must be taken into account to assure that the assessment of the engine control system safety is valid. The rates of hazardous and major faults must be documented and provided to the installer as part of the requirements in § 33.5.

(h) *Protection systems.* The engine control devices and systems' design and function, together with engine instruments, operating instructions, and maintenance instructions, must ensure that engine operating limits that can lead to a hazard will not be exceeded in service.

(i) *Aircraft supplied data.* Any single failure leading to loss, interruption, or corruption of aircraft-supplied data (other than power-command signals from the aircraft), or aircraft-supplied data shared between engine systems within a single engine or between fully independent engine systems, must—

(1) Not result in a hazardous engine effect, as defined in special condition no. 17(d)(2) of these special conditions, for any engine installed on the aircraft; and

(2) Be able to be detected and accommodated by the control system.

(j) *Engine control system electrical power.*

(1) The engine control system must be designed such that the loss, malfunction, or interruption of the control system electrical power source will not result in a hazardous engine effect, unacceptable transmission of erroneous data, or continued engine operation in the absence of the control function. Hazardous engine effects are defined in special condition no. 17(d)(2) of these special conditions. The engine control system must be capable of resuming normal operation when aircraft-supplied power returns to within the declared limits.

(2) The applicant must identify, document, and provide to the installer as part of the requirements in § 33.5, the characteristics of any electrical power supplied from the aircraft to the engine control system, including transient and steady-state voltage limits, and any other characteristics necessary for safe operation of the engine.

(11) Instrument Connection

The applicant must comply with § 33.29(a), (e), and (g).

(a) In addition, as part of the system safety assessment of special condition nos. 10(g) and 33(h) of these special conditions, the applicant must assess the possibility and subsequent effect of incorrect fit of instruments, sensors, or connectors. Where practicable, the applicant must take design precautions to prevent incorrect configuration of the system.

(b) The applicant must provide instrumentation enabling the flight crew to monitor the functioning of the engine cooling system unless evidence shows that:

(1) Other existing instrumentation provides adequate warning of failure or impending failure;

(2) Failure of the cooling system would not lead to hazardous engine effects before detection; or

(3) The probability of failure of the cooling system is extremely remote.

(12) Stress Analysis

(a) A mechanical and thermal stress analysis, as well as an analysis of the stress caused by electromagnetic forces, must show a sufficient design margin to prevent unacceptable operating characteristics and hazardous engine effects as defined in special condition no. 17(d)(2) of these special conditions.

(b) Maximum stresses in the engine must be determined by test, validated analysis, or a combination thereof, and must be shown not to exceed minimum material properties.

(13) Critical and Life-Limited Parts

(a) The applicant must show, by a safety analysis or means acceptable to the Administrator, whether rotating or moving components, bearings, shafts, static parts, and non-redundant mount components should be classified, designed, manufactured, and managed throughout their service life as critical or life-limited parts.

(1) Critical part means a part that must meet prescribed integrity specifications to avoid its primary failure, which is likely to result in a hazardous engine effect as defined in special condition no. 17(d)(2) of these special conditions.

(2) Life-limited parts may include but are not limited to a rotor or major

structural static part, the failure of which can result in a hazardous engine effect, as defined in special condition no. 17(d)(2) of these special conditions, due to a low-cycle fatigue (LCF) mechanism. A life limit is an operational limitation that specifies the maximum allowable number of flight cycles that a part can endure before the applicant must remove it from the engine.

(b) In establishing the integrity of each critical part or life-limited part, the applicant must provide to the Administrator the following three plans for approval:

(1) an engineering plan, as defined in § 33.70(a);

(2) a manufacturing plan, as defined in § 33.70(b); and

(3) a service-management plan, as defined in § 33.70(c).

(14) Lubrication System

(a) The lubrication system must be designed and constructed to function properly between scheduled maintenance intervals in all flight attitudes and atmospheric conditions in which the engine is expected to operate.

(b) The lubrication system must be designed to prevent contamination of the engine bearings and lubrication system components.

(c) The applicant must demonstrate by test, validated analysis, or a combination thereof, the unique lubrication attributes and functional capability of (a) and (b).

(15) Power Response

(a) The design and construction of the engine, including its control system, must enable an increase—

(1) From the minimum power setting to the highest rated power without detrimental engine effects;

(2) From the minimum obtainable power while in-flight and while on the ground to the highest rated power within a time interval determined to be appropriate for the intended aircraft application; and

(3) From the minimum torque to the highest rated torque without detrimental engine effects in the intended aircraft application.

(b) The results of (a)(1), (a)(2), and (a)(3) of this special condition must be documented and provided to the installer as part of the requirements in § 33.5.

(16) Continued Rotation

If the design allows any of the engine main rotating systems to continue to rotate after the engine is shut down while in-flight, this continued rotation must not result in any hazardous engine effects, as defined in special condition no. 17(d)(2) of these special conditions.

(17) Safety Analysis

(a) The applicant must comply with § 33.75(a)(1) and (a)(2) using the failure definitions in special condition no. 17(d) of these special conditions.

(b) The primary failure of certain single elements cannot be sensibly estimated in numerical terms. If the failure of such elements is likely to result in hazardous engine effects, then compliance may be shown by reliance on the prescribed integrity requirements of § 33.15 and special condition nos. 9 and 13 of these special conditions, as applicable. These instances must be stated in the safety analysis.

(c) The applicant must comply with § 33.75(d) and (e) using the failure definitions in special condition no. 17(d) of these special conditions, and the ICA in § 33.4.

(d) Unless otherwise approved by the Administrator, the following definitions apply to the engine effects when showing compliance with this condition:

(1) A minor engine effect does not prohibit the engine from performing its intended functions in a manner consistent with § 33.28(b)(1)(i), (b)(1)(iii), and (b)(1)(iv), and the engine complies with the operability requirements of special condition no. 15 and special condition no. 25 of these special conditions, as appropriate.

(2) The engine effects in § 33.75(g)(2) are hazardous engine effects with the addition of:

(i) Electrocution of the crew, passengers, operators, maintainers, or others; and

(ii) Blockage of cooling systems that could cause the engine effects described in § 33.75(g)(2) and special condition 17(d)(2)(i) of these special conditions.

(3) Any other engine effect is a major engine effect.

(e) The intended aircraft application must be taken into account when performing the safety analysis.

(f) The results of the safety analysis, and the assumptions about the aircraft application used in the safety analysis, must be documented and provided to the installer as part of the requirements in § 33.5.

(18) Ingestion

(a) Rain, ice, and hail ingestion must not result in an abnormal operation such as shutdown, power loss, erratic operation, or power oscillations throughout the engine operating range.

(b) Ingestion from other likely sources (birds, induction system ice, foreign objects—ice slabs) must not result in hazardous engine effects defined by special condition no. 17(d)(2) of these special conditions, or unacceptable power loss.

(c) If the design of the engine relies on features, attachments, or systems that the installer may supply, for the prevention of unacceptable power loss or hazardous engine effects, as defined in special condition no. 17(d)(2) of these special conditions, following potential ingestion, then the features, attachments, or systems must be documented and provided to the installer as part of the requirements in § 33.5.

(19) Liquid and Gas Systems

(a) Each system used for lubrication or cooling of engine components must be designed and constructed to function properly in all flight attitudes and atmospheric conditions in which the engine is expected to operate.

(b) If a system used for lubrication or cooling of engine components is not self-contained, the interfaces to that system must be defined, documented and provided to the installer as part of the requirements in § 33.5.

(c) The applicant must establish by test, validated analysis, or a combination of both that all static parts subject to significant pressure loads will not:

(1) Exhibit permanent distortion beyond serviceable limits, or exhibit leakage that could create a hazardous condition when subjected to normal and maximum working pressure with margin;

(2) Exhibit fracture or burst when subjected to the greater of maximum possible pressures with margin.

(d) Compliance with special condition no. 19(c) of these special conditions must take into account:

(1) The operating temperature of the part;

(2) Any other significant static loads in addition to pressure loads;

(3) Minimum properties representative of both the material and the processes used in the construction of the part; and

(4) Any adverse physical geometry conditions allowed by the type design, such as minimum material and minimum radii.

(e) Approved coolants and lubricants must be listed, documented, and provided to the installer as part of the requirements in § 33.5.

(20) Vibration Demonstration

(a) The engine must be designed and constructed to function throughout its normal operating range of rotor speeds and engine output power, including defined exceedances, without inducing excessive stress in any of the engine parts because of vibration and without imparting excessive vibration forces to the aircraft structure.

(b) Each engine design must undergo a vibration survey to establish that the vibration characteristics of those components subject to induced vibration are acceptable throughout the declared flight envelope and engine operating range for the specific installation configuration. The possible sources of the induced vibration that the survey must assess are mechanical, aerodynamic, acoustical, internally induced electromagnetic, installation induced effects that can affect the engine vibration characteristics, and likely environmental effects. This survey must be shown by test, validated analysis, or a combination thereof.

(21) Overtorque

When approval is sought for a transient maximum engine overtorque, the applicant must demonstrate by test, validated analysis, or a combination thereof, that the engine can continue operation after operating at the maximum engine overtorque condition without maintenance action. Upon conclusion of overtorque tests conducted to show compliance with this special condition, or any other tests that are conducted in combination with the overtorque test, each engine part or individual groups of components must meet the requirements of special condition no. 29 of these special conditions.

(22) Calibration Assurance

Each engine must be subjected to calibration tests to establish its power characteristics, and the conditions both before and after the endurance and durability demonstrations specified in special conditions nos. 23 and 26 of these special conditions.

(23) Endurance Demonstration

The applicant must subject the engine to an endurance demonstration, acceptable to the Administrator, to demonstrate the engine's limit capabilities. The endurance demonstration must include increases and decreases of the engine's power settings, energy regeneration, and dwellings at the power settings and energy regeneration for sufficient durations that produce the extreme physical conditions the engine experiences at rated performance levels, operational limits, and at any other conditions or power settings, including energy regeneration that are required to verify the limit capabilities of the engine.

(24) Temperature Limit

The engine design must demonstrate its capability to endure operation at its temperature limits plus an acceptable margin. The applicant must quantify and justify the margin to the Administrator. The demonstration must be repeated for all declared duty cycles and ratings, and operating environments, which would impact temperature limits.

(25) Operation Demonstration

The engine design must demonstrate safe operating characteristics, including but not limited to power cycling, starting, acceleration, and overspeeding throughout its declared flight envelope and operating range. The declared engine operational characteristics must account for installation loads and effects.

(26) Durability Demonstration

The engine must be subjected to a durability demonstration to show that each part of the engine has been designed and constructed to minimize any unsafe condition of the system between overhaul periods, or between engine replacement intervals if the overhaul is not defined. This test must simulate the conditions in which the engine is expected to operate in service, including typical start-stop cycles, to establish when the initial maintenance is required.

(27) System and Component Tests

The applicant must show that systems and components that cannot be adequately substantiated in accordance with the endurance demonstration or other demonstrations will perform their intended functions in all declared environmental and operating conditions.

(28) Rotor Locking Demonstration

If shaft rotation is prevented by locking the rotor(s), the engine must demonstrate:

(a) Reliable rotor locking performance;

(b) Reliable rotor unlocking performance; and

(c) That no hazardous engine effects, as specified in special condition no. 17(d)(2) of these special conditions, will occur.

(29) Teardown Inspection

(a) Teardown evaluation.

(1) After the endurance and durability demonstrations have been completed, the engine must be completely disassembled. Each engine component and lubricant must be eligible for continued operation in accordance with the information submitted for showing compliance with § 33.4.

(2) Each engine component, having an adjustment setting and a functioning characteristic that can be established independent of installation on or in the engine, must retain each setting and functioning characteristic within the established and recorded limits at the beginning of the endurance and durability demonstrations.

(b) Non-Teardown evaluation. If a teardown cannot be performed for all engine components in a non-destructive manner, then the inspection or replacement intervals for these components and lubricants must be established based on the endurance and durability demonstrations and must be documented in the ICA in accordance with § 33.4.

(30) Containment

The engine must be designed and constructed to protect against likely hazards from rotating components as follows—

(a) The design of the stator case surrounding rotating components must provide for the containment of the rotating components in the event of failure, unless the applicant shows that the margin to rotor burst precludes the possibility of a rotor burst.

(b) If the margin to burst shows that the stator case must have containment features in the event of failure, then the stator case must provide for the containment of the failed rotating components. The applicant must define by test, validated analysis, or a combination thereof, and document and provide to the installer as part of the requirements in § 33.5, the energy level, trajectory, and size of fragments released from damage caused by the main-rotor failure, and that pass forward or aft of the surrounding stator case.

(32) General Conduct of Tests

(a) Maintenance of the engine may be made during the tests in accordance with the service and maintenance instructions submitted in compliance with § 33.4.

(b) The applicant must subject the engine or its parts to any additional tests that the Administrator finds necessary if—

(1) The frequency of engine service is excessive;

(2) The number of stops due to engine malfunction is excessive;

(3) Major engine repairs are needed; or

(4) Replacement of an engine part is found necessary during the tests, or due to the teardown inspection findings.

(c) Upon completion of all demonstrations and testing specified in these special conditions, the engine and its components must be—

(1) Within serviceable limits;

(2) Safe for continued operation; and

(3) Capable of operating at declared ratings while remaining within limits.

(33) Engine Electrical Systems

(a) *Applicability.* Any system or device that provides, uses, conditions, or distributes electrical power, and is part of the engine type design, must provide for the continued airworthiness of the engine, and must maintain electric engine ratings.

(b) *Electrical systems.* The electrical system must ensure the safe generation and transmission of power, and electrical load shedding if required, and that the engine does not experience any unacceptable operating characteristics or exceed its operating limits.

(c) *Electrical power distribution.*

(1) The engine electrical power distribution system must be designed to provide the safe transfer of electrical energy throughout the powerplant. The system must be designed to provide electrical power so that the loss, malfunction, or interruption of the electrical power source will not result in a hazardous engine effect, as defined in special condition no. 17(d)(2) of these special conditions.

(2) The system must be designed and maintained to withstand normal and abnormal conditions during all ground and flight operations.

(3) The system must provide mechanical or automatic means of isolating a faulted electrical energy generation or storage device from leading to hazardous engine effects, as defined in special condition no. 17(d)(2) of these special conditions, or detrimental effects in the intended aircraft application.

(d) *Protection systems.* The engine electrical system must be designed such that the loss, malfunction, interruption of the electrical power source, or power conditions that exceed design limits, will not result in a hazardous engine effect, as defined in special condition no. 17(d)(2) of these special conditions.

(e) *Electrical power characteristics.* The applicant must identify, declare, document, and provide to the installer as part of the requirements in § 33.5, the characteristics of any electrical power supplied from—

(1) the aircraft to the engine electrical system, for starting and operating the engine, including transient and steady-state voltage limits, and

(2) the engine to the aircraft via energy regeneration, and any other characteristics necessary for safe operation of the engine.

(f) *Environmental limits.* Environmental limits that cannot adequately be substantiated by endurance demonstration, validated analysis, or a combination thereof must be demonstrated by the system and component tests in special condition no. 27 of these special conditions.

(g) *Electrical system failures.* The engine electrical system must—

(1) Have a maximum rate of loss of power control (LOPC) that is suitable for the intended aircraft application;

(2) When in the full-up configuration, be single-fault tolerant, as determined by the Administrator, for electrical, electrically detectable, and electronic failures involving LOPC events;

(3) Not have any single failure that results in hazardous engine effects; and

(4) Ensure failures or malfunctions that lead to local events in the intended aircraft application do not result in hazardous engine effects, as defined in special condition no. 17(d)(2) of these special conditions, due to electrical system failures or malfunctions.

(h) *System safety assessment.* The applicant must perform a system safety assessment. This assessment must identify faults or failures that affect normal operation, together with the predicted frequency of occurrence of these faults or failures. The intended aircraft application must be taken into account to assure the assessment of the engine system safety is valid. The rates of hazardous and major faults must be declared, documented, and provided to the installer as part of the requirements in § 33.5.

Issued in Kansas City, Missouri, on December 10, 2024.

Patrick R. Mullen,

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DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 129

[Docket No.: FAA–2024–0176; Amdt. No. 129–55]

RIN 2120–AL93

Foreign Air Operator Certificates Issued by a Regional Safety Oversight Organization

AGENCY: Federal Aviation Administration (FAA), Department of Transportation (DOT).

ACTION: Final rule.

SUMMARY: This amendment will allow the FAA to review and, if acceptable to the Administrator, recognize as valid air operator certificates issued by a Regional Safety Oversight Organization to foreign air carriers when the State of the Operator is a member of that Regional Safety Oversight Organization, for purposes of evaluating foreign applicants for operating specifications.

DATES: Effective January 16, 2025.

ADDRESSES: For information on where to obtain copies of rulemaking documents and other information related to this final rule, see ''Additional Information'' in the **SUPPLEMENTARY INFORMATION** section of this document.

FOR FURTHER INFORMATION CONTACT: Tim Shaver, International Program Division/ International Operations Branch, Federal Aviation Administration, 800 Independence Avenue SW, Washington, DC, 20591; telephone (202) 267–1704; email *tim.shaver@faa.gov.*

SUPPLEMENTARY INFORMATION:

I. Authority for This Rulemaking

The FAA's authority to issue rules on aviation safety is found in title 49 of the United States Code. Subtitle I, section 106, describes the authority of the FAA Administrator. Subtitle VII, Aviation Programs, describes in more detail the scope of the FAA's authority.

This rulemaking is issued under the authority described in subtitle VII, part A, subpart III, section 44701(a)(5). Under that section, the FAA is charged with promoting safe flight of civil aircraft in air commerce by prescribing regulations and minimum standards for practices, methods, and procedures the Administrator finds necessary to ensure safety in air commerce. This regulation is within the scope of that authority. Amending the regulations for applications for operations specifications under part 129 submitted by foreign air carriers or foreign persons, and the related standards for denial of