



BILLING CODE 4910-13

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 33

[Docket No. FAA-2020-0894; Notice No. 33-19-01-SC]

Special Conditions: magniX USA, Inc., magni250 and magni500 Model Engines

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of proposed special conditions.

SUMMARY: This action proposes special conditions for magniX USA, Inc. (magniX), magni250 and magni500 model engines that operate using electrical technology installed on the aircraft for use as an aircraft engine. These engines have a novel or unusual design feature when compared to the state of technology envisioned in the airworthiness standards applicable to aircraft engines. The design feature is the use of an electric 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 proposed 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: Send comments on or before **[INSERT DATE 30 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER]**.

ADDRESSES: Send comments identified by Docket No. FAA-2020-0894 using any of the following methods:

- *Federal eRegulations Portal:* Go to <http://www.regulations.gov/> and follow the online instructions for sending your comments electronically.
- *Mail:* Send comments to Docket Operations, M-30, U.S. Department of Transportation (DOT), 1200 New Jersey Avenue, SE., Room W12-140, West Building Ground Floor, Washington, DC, 20590-0001.
- *Hand Delivery or Courier:* Take comments to Docket Operations in Room W12-140 of the West Building Ground Floor at 1200 New Jersey Avenue, SE., Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.
- *Fax:* Fax comments to Docket Operations at 202-493-2251.

Privacy: Except for Confidential Business Information (CBI) as described in the following paragraph, and other information as described in 14 CFR 11.35, the FAA will post all comments received, without change, to <http://www.regulations.gov/>, including any personal information you provide. The FAA will also post a report summarizing each substantive verbal contact we received about this proposal.

Confidential Business Information

Confidential Business Information (CBI) is commercial or financial information that is both customarily and actually treated as private by its owner. Under the Freedom of Information Act (FOIA) (5 U.S.C. 552), CBI is exempt from public disclosure. If your comments responsive to this Notice contain commercial or financial information that is customarily treated as private, that you actually treat as private, and that is relevant or responsive to this Notice, it is important that you clearly designate the submitted comments as CBI. Please mark each page of your submission containing CBI as

“PROPIN.” The FAA will treat such marked submissions as confidential under the FOIA, and they will not be placed in the public docket of this Notice. Submissions containing CBI should be sent to Gary Horan, AIR-6A1, Engine and Propeller Standards Branch, Aircraft Certification Service, 1200 District Avenue, Burlington, Massachusetts, 01803; telephone (781) 238-7164; gary.horan@faa.gov. Any commentary that the FAA receives which is not specifically designated as CBI will be placed in the public docket for this rulemaking.

Docket: Background documents or comments received may be read at <http://www.regulations.gov/> at any time. Follow the online instructions for accessing the docket or go to Docket Operations in Room W12-140 of the West Building Ground Floor at 1200 New Jersey Avenue, SE., Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: Gary Horan, AIR-6A1, Engine and Propeller Standards Branch, Aircraft Certification Service, 1200 District Avenue, Burlington, Massachusetts, 01803; telephone (781) 238-7164; gary.horan@faa.gov.

SUPPLEMENTARY INFORMATION:

Comments Invited

The FAA invites interested people to take part in this rulemaking by sending written comments, data, or views. The most helpful comments reference a specific portion of the proposed special conditions, explain the reason for any recommended change, and include supporting data.

The FAA will consider all comments received by the closing date for comments. The FAA may change these proposed special conditions based on the comments received.

Background

On June 4, 2019, magniX applied for a type certificate for its magni250 and magni500 model electric engines. The FAA has not previously type certificated an engine that uses electrical technology for propulsion of the aircraft. 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.

There is a growing interest within the aviation industry to utilize electric propulsion technology. As a result, international agencies and industry stakeholders formed a new committee under ASTM International Committee F39 to identify the appropriate technical criteria for aircraft engines using electrical technology that has not been previously certificated for aircraft propulsion systems. ASTM International, formerly known as American Society for Testing and Materials, is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. ASTM International published ASTM F3338-18, *Standard Specification for Design of Electric Propulsion Units for General Aviation Aircraft*, in December 2018.¹ The FAA used the technical criteria from the ASTM standard and engine information from magniX to

¹ <https://www.astm.org/Standards/F3338.htm>.

develop special conditions to establish an equivalent level of safety to that required by title 14, Code of Federal Regulations (14 CFR) part 33.

Type Certification Basis

Under the provisions of 14 CFR 21.17(a)(1), generally, magniX must show that magni250 and magni500 model engines meet the applicable provisions of part 33 in effect on the date of application for a type certificate.

If the Administrator finds that the applicable airworthiness regulations (e.g., 14 CFR part 33) do not contain adequate or appropriate safety standards for the magni250 and magni500 model 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.

In addition to the applicable airworthiness regulations and special conditions, the magni250 and magni500 model engines must comply with the noise certification requirements of 14 CFR part 36.

The FAA issues special conditions, as defined in 14 CFR 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 magni250 and magni500 model engines will incorporate the following novel or unusual design features:

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

Discussion

Part 33 Developed for Gas-Powered Turbine and Reciprocating Engines

Aircraft engines make use of an energy source to drive mechanical systems that provide propulsion for the aircraft. Energy can be generated from various sources such as petroleum and natural gas. The turbine and reciprocating aircraft engines certified under part 33 use aviation fuel for an energy source. The reciprocating and turbine engine technology that was anticipated in the development of part 33 converts air and fuel to energy using an internal combustion system, which generates heat and mass flow of combustion products for turning shafts that are attached to propulsion devices such as propellers and ducted fans. Part 33 regulations set forth standards for these engines and mitigate potential hazards resulting from failures and malfunctions. The nature, progression, and severity of engine failures are tied closely to the technology that is used to design and manufacture aircraft engines. These technologies involve chemical, thermal, and mechanical systems. Therefore, the existing engine regulations in part 33 address certain chemical, thermal, and mechanically induced failures that are specific to air and fuel combustion systems operating with cyclically loaded high-speed, high-temperature, and highly-stressed components.

magniX's Proposed Electric Engines are Novel or Unusual

The existing part 33 airworthiness standards for aircraft engines date back to 1965. These airworthiness standards are based on fuel-burning reciprocating and turbine engine technology. The magni250 and magni500 model engines are not turbine or

reciprocating engines. These 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. The aircraft engine is also exposed to chemical, thermal, and mechanical operating conditions, unlike those observed in internal combustion systems. Therefore, part 33 does not contain adequate or appropriate safety standards for the magni250 and magni500 model engine's novel design feature.

magniX's proposed 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, controller, and high-voltage systems that draw energy from electrical storage or generating systems. The electric motor is a device that converts electrical energy into mechanical energy by electric current flowing through wire coils in the motor producing a magnetic field that interacts with the magnets on the rotating shaft. The controller is a system that consists of two main functional elements: the motor controller and an electric power inverter to drive the motor.² The high voltage system is a combination of wires and the connectors that couple the motor and the controller.

In addition, the technology required to produce 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,

² Sometimes this entire system is referred to as an inverter. Throughout this document, it will be referred to as the controller.

electromagnetic shields, magnetic materials, and high-speed electrical switches are necessary to use the physical properties essential to the electric engine. However, this technology also exposes the aircraft to potential failures that are not common to gas-powered turbine and reciprocating engines, which could adversely affect safety.

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

Although the electric aircraft engines proposed by magniX use novel or unusual design features that are not addressed in the existing part 33 airworthiness standards, there are some basic similarities in configuration and function that require similar provisions to prevent hazards that are common to aircraft engines using air and fuel combustion (e.g., fire, uncontained high-energy debris, and loss of thrust control). However, the primary failure concerns and the probability of exposure to common hazards are different for the proposed electric aircraft engines. This creates a need to develop special conditions to ensure the engine's safety and reliability.

The requirements in part 33 ensure the design and construction of aircraft engines, including the engine control systems, are proper for the engine type design and operating limits. However, part 33 does not fully address the use of aircraft engines like magniX's, which operate using electrical technology as the primary means of propelling the aircraft. This necessitates the development of special conditions to provide adequate airworthiness standards for these aircraft engines.

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. This necessitates the development of special conditions to ensure a level of safety commensurate with these subparts, as those regulatory requirements do not contain adequate or appropriate safety standards for aircraft engines that operate using electrical technology to propel the aircraft.

The special conditions that the FAA proposes for magniX's engine design include:

Applicability: Proposed special condition no. 1 would require magniX to comply with 14 CFR part 33, except for those airworthiness standards specifically and explicitly applicable only to reciprocating and turbine aircraft engines.

Engine Ratings and Operating Limitations: Proposed special condition no. 2 would require magniX, in addition to compliance with 14 CFR 33.7(a), to establish engine operating limits related to the power, torque, speed, and duty cycles specific to the magni250 and magni500 model 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.

Materials: Proposed special condition no. 3 would require magniX to comply with 14 CFR 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: Proposed special condition no. 4 would require magniX to comply with 14 CFR 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 proposed special condition would require magniX to ensure 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: Proposed special condition no. 5 would require the proposed engine design and construction to ensure safe engine operation between maintenance intervals, overhaul periods, and mandatory actions. This proposed condition would also require magniX to develop maintenance instructions and scheduling information.

Engine Cooling: Proposed special condition no. 6 would require magniX to comply with 14 CFR 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 proposed special condition would require magniX to document the cooling system monitoring features and usage in the engine installation manual, in accordance with § 33.5, if cooling is required to satisfy the safety analysis described in proposed special condition no. 17. Loss of adequate cooling to an 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: Proposed special condition no. 7 would require magniX and the proposed design to comply with 14 CFR 33.23, which requires the applicant to define, and the proposed 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: Proposed special condition no. 8 would require the proposed design to comply with 14 CFR 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.

Overspeed: Proposed special condition no. 9 would require magniX 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 proposed special condition associated with rotor overspeed is necessary because of the differences between turbine engine technology and the technology of these electric engines. Turbine speed is driven by hot air expansion and is impacted by the aerodynamic loads on the rotor blades. Therefore, the speed or overspeed is not directly controlled in turbine engines. The speed of an electric engine is directly controlled by the electric field created by the controller. The failure modes that can lead to overspeed between turbine engines and these engines are vastly different, and therefore this special condition is necessary.

Engine Control Systems: Proposed special condition no. 10(b) would require magniX 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, the proposed special condition no. 10(b) associated with controlling these engines is necessary.

Proposed special condition no. 10(c) would require magniX to develop and verify the software and complex electronic hardware used in programmable logic devices, using proven methods that ensure it 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, 2000,³ distinguish between complex and simple electronic hardware.

Proposed special condition no. 10(d) would require 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, magniX 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 proposed special condition no. 10(e) include temperature, vibration, high-intensity radiated fields (HIRF), and others addressed in RTCA DO-160G, *Environmental Conditions and Test Procedures for*

³ https://my.rtca.org/NC__Product?id=a1B36000001IcjTEAS

Airborne Electronic/Electrical Equipment and Instruments.⁴ Accordingly, proposed special condition 10(e) would require magniX to document the environmental limits to which the system has been qualified in the engine installation instructions.

Proposed special condition no. 10(f) would require magniX to evaluate various control system failures to assure that these failures will not lead to unsafe conditions. The FAA issued Advisory Circular, AC 33.28-3, *Guidance Material For 14 CFR § 33.28, Engine Control Systems*, on May 23, 2014.⁵ Paragraph 6-2 of this AC provides applicants with guidance on defining an engine control system failure when showing compliance with the requirements of 14 CFR 33.28. AC 33.28-3 also includes objectives for the integrity requirements, criteria for a loss of thrust (or power) control (LOT/LOPC) event, and an acceptable LOT/LOPC rate. As with other topics within these proposed special conditions, the failure rates that apply to electric engines were not established when the FAA issued this AC.

The phrase “in the full-up configuration” used in proposed 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 proposed special condition no. 10(f)(4) means failures or malfunctions leading to events in the intended

⁴ https://my.rtca.org/NC__Product?id=a1B36000001IcnSEAS

⁵ https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_33_28-3.pdf

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.

Proposed special condition no. 10(g) would require magniX to conduct a safety assessment of the control system to support the safety analysis in special condition no. 17. This control safety assessment provides failures and rates of these failures that can be used at the aircraft safety assessment level.

Proposed special condition no. 10(h) requires magniX to provide appropriate protection devices or systems to ensure that engine operating limitations will not be exceeded in-service.

Proposed special condition no. 10(i) is necessary to ensure 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 proposed special condition no. 10(i) is based on the FAA's determination that there are no reasonable means for the engine controller to determine the validity of any in-range signals from this system. In many cases, the engine control system can detect a faulty signal from the aircraft. 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 proposed special condition no. 10(i) means the controllers should be self-sufficient and isolated from other aircraft systems or provide redundancy that enables it 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 unacceptable effects on thrust or power, hazardous engine effects, or inability to comply with the operation demonstrations in proposed special condition no. 25.

The term “accommodated” in the context of “detected and accommodated” referenced in proposed special condition 10(i)(2) is to assure that once a fault has been detected, that the system continues to function safely.

Proposed special condition no. 10(j) would require magniX 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: Proposed special condition no. 11 would require magniX to comply with 14 CFR 33.29(a), (e), (f), and (g), which set certain requirements for the connection and installation of instruments to monitor engine performance. The remaining requirements in section 33.29 apply only to technologies used in reciprocating and turbine aircraft engines.

Instrument connections (wires, wire insulation, potting, grounding, connector designs) present opportunities for unsafe features to be present on the aircraft. Proposed special condition no. 11 would require the safety analysis to include potential hazardous effects from failure of instrument connections to function properly. The outcome of this analysis might identify the need for design enhancements or additional Instructions for Continued Airworthiness (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 not appropriate for the magniX magni250 and magni500 model engines. However, the FAA proposes that a stress analysis particular to these electric engines is necessary.

Proposed special condition no. 12 would require a mechanical, thermal, and electrical stress analysis to show there is 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: Proposed special condition no. 13 would require magniX 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 engineering plan referenced in proposed special condition no. 13(b)(1) would require magniX to establish activities for managing documents, practices, and procedures that govern key design criteria essential to part airworthiness. The engineering plan would be required to contain methods for verifying the characteristics and qualities assumed in the design data using methods that are suitable for the part criticality. The engineering plan flows information from engineering to manufacturing about the criticality of key attributes that affect the airworthiness of the part. The plan also includes a reporting system that flows problematic issues that develop in engines while they operate in service so the design process can address them. For example, the effect of

environmental influences on engine performance might not be consistent with the assumptions used to design the part. The impact of ice slab ingestion on engine parts might not be fully understood until the engine ingests the specific ice quantities and shapes that the airplane sheds. During the pre-certification activities, magniX must ensure the engineering plan is complete, available, and acceptable to the Administrator before the engine is certified.

The term “low-cycle fatigue” referenced in proposed 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 term “manufacturing definition” referenced in proposed special condition no. 13(b)(2) is the collection of data required to translate documented engineering design criteria into physical parts and verify that the parts comply with the properties established by the design data. Since engines are not intentionally tested to failure during a

certification program, there are inherent expectations for performance and durability guaranteed by the documents and processes used to execute production and quality systems required by § 21.137. These systems limit the potential manufacturing outcomes to parts that are consistently produced within design constraints.

The manufacturing plan and service management plan ensure essential information from the engineering plan, such as the design characteristics that ensure 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 has provisions for enhanced detection and reporting of service-induced anomalies that can cause the part to fail before it reaches its life limit or service limit. Anomalies can develop in service from improper handling, unforeseen operating conditions, and long-term environmental effects. The service management plan ensures important information that might affect the assumptions used to design a part is incorporated into the design process to remove unforeseen potential unsafe features from the engine.

Lubrication System: Proposed special condition no. 14 would require magniX to ensure the lubrication system is designed to function properly between scheduled maintenance intervals and prevent contamination of the engine bearings. This proposed condition would also require magniX to demonstrate the unique lubrication attributes and functional capability of the magni250 and magni500 model 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 magniX magni250 and magni500 model engines. For example, these engines do not have a crankcase or lubrication oil sump. The 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, proposed special condition no. 14 incorporates only certain requirements from the part 33 regulations.

Power Response: Proposed special condition no. 15 would require the design and construction of the magni250 and magni500 model engines to enable an increase (1) from the minimum power setting to the highest-rated power without detrimental engine effects, and (2) from the minimum obtainable power while in-flight and on the ground to the highest-rated power within a time interval for safe operation of the aircraft.

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 engine to provide thrust, maintain rotor speeds below burst thresholds, and temperatures below limits have the potential for detrimental effects to the aircraft. Similar detrimental effects are possible in the magni250 and magni500 model 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: Proposed special condition no. 16 would require magniX to design the magni250 and magni500 model 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 magniX magni250 and magni500 model engines consists of the rotors, shafts, magnets, bearings, and wire windings that convert electrical energy to shaft torque. This rotating system must continue to rotate after the power source to the engine is shut down. The safety concerns associated with this proposed special condition are substantial asymmetric aerodynamic drag that can cause aircraft instability, loss of control, and reduced efficiency, and result in a forced landing or inability to continue safe flight.

Safety Analysis: Proposed special condition no. 17 would require magniX to comply with 14 CFR 33.75(a)(1), (a)(2), and (a)(3), 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 proposed special condition would require magniX 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. 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.

Ingestion: Proposed special condition no. 18 would require magniX to ensure that these engines will not experience unacceptable power loss or hazardous engine effects from ingestion. The associated regulation for turbine engines, 14 CFR 33.76, is based on potential damage from birds being ingested into the turbine engine that has an inlet duct, which directs air into the engine for combustion, cooling, and thrust. In contrast, these electric engines do not use an inlet for those purposes.

An “unacceptable” power loss, as used in proposed special condition no. 18(a), is one in which 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 Systems: Proposed special condition no. 19 would require magniX to ensure that liquid systems used for lubrication or cooling of engine components are designed and constructed to function properly. Also, if a liquid system is not self-contained, the interfaces to that system would be required to be defined in the engine installation manual. Liquid 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: Proposed special condition no. 20 would require magniX to ensure (1) the engine 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) the engine design undergoes a vibration survey.

The vibration demonstration is a survey that characterizes the vibratory attributes of the engine and verifies 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: Proposed special condition no. 21 would require magniX to demonstrate that the engine is capable of continued operation without the need for maintenance if it experiences a certain amount of overtorque.

The electric engine proposed by magniX 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, there is a small delay, or latency, in the engine response time. While the engine dwells in this time interval, it can continue to apply torque until the command to reduce the torque is applied by the engine control. The amount of overtorque the FAA permits during operation depends on how well the applicant demonstrates the engine's capability to remain operational without the need for maintenance action. Therefore, this special condition is necessary.

Calibration Assurance: Proposed special condition no. 22 would require magniX 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 proposed 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 proposes that the methods used for accomplishing those tests

for turbine engines is not the best approach for electric engines. The calibration tests in § 33.85 have provisions applicable to ratings that are not relevant to the magniX magni250 and magni500 model engines. Proposed special condition no. 22 would allow magniX 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 proposed special condition applies the calibration requirement to both the endurance and durability tests.

Endurance Demonstration: Proposed special condition no. 23 would require magniX 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, to determine if the test is sufficient to show the engine design will not exhibit unacceptable effects in-service, such as significant performance deterioration, operability restrictions, engine power loss or instability, when it is run for sustained periods at extreme operating conditions.

Temperature Limit: Proposed special condition no. 24 would require magniX to ensure the engine can endure operation at its temperature limits plus an acceptable margin. An “acceptable margin,” as used in the proposed special condition, is the amount of temperature above that required to prevent the least-capable engine allowed by the type design from failing due to temperature-related causes when operating at the most extreme thermal conditions.

Operation Demonstration: Proposed special condition no. 25 would require 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 magniX magni250 and magni500 model engines can achieve without incurring hazardous effects. They are requisite capabilities of the type design that qualify the engine for installation into aircraft and 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 magniX 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 in a test cell. These effects could result from elevated inlet cowl temperatures, extreme aircraft maneuvers, flowstream distortion, and hard landings. An engine that is run in a test facility could demonstrate more capability for some operating characteristics than it will when operating on an aircraft and potentially decrease the engine ratings and operating limits. Therefore, the installed performance defines the engine performance capabilities.

Durability Demonstration: Proposed special condition no. 26 would require magniX to subject the engine to a durability demonstration. The durability demonstration must show that each part of the engine is designed and constructed to minimize the development of any unsafe condition of the system between overhaul periods or between engine replacement intervals if overhaul is not defined. Durability is the ability of an engine, in the fully deteriorated state, to continue generating rated power or thrust, retain adequate operating margins, and retain sufficient efficiency that enables the aircraft to reach its destination. The amount of deterioration an engine can experience is restricted

by operating limitations and managed by the 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, magniX will use different test effects to establish overhaul periods or engine replacement intervals if no maintenance is specified.

System and Component Tests: Proposed special condition no. 27 would require magniX to show that the systems and components of the engine would 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) establishes a need for temperature limits and additional testing where the endurance test does not fully expose internal components to thermal conditions that verify the desired operating limits. A safety concern for electric engines is extreme temperatures. The FAA proposes that the § 33.87 endurance test might not be the best way to achieve the highest thermal conditions for all the electronic components of electric engines because heat is generated differently in electronic systems than it is in turbine engines. There are also additional safety considerations that need to be addressed in the test. Therefore, proposed special condition no. 27 would be a performance-based requirement that allows magniX to determine how to challenge the electric engine and to determine the appropriate limitations that correspond to the technology.

Rotor Locking Demonstration: Proposed special condition no. 28 would require 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 functionality of certain flight systems before takeoff. The proposed magniX engine installations are not limited to vehicles 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 proposed special condition does not define “reliable” rotor locking, but would allow magniX to classify the hazard (major/minor) and assign the appropriate quantitative criteria that meet the safety objectives required by § 33.75.

Teardown Inspection: Proposed special condition no. 29 would require magniX to perform either a teardown evaluation or a non-teardown evaluation based on the criteria provided in proposed special condition no. 29(a) or (b).

Proposed 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 magniX’s are constructed in an integrated fashion that precludes the possibility of tearing them down without destroying them. Sections 33.55 and 33.93 do not contain similar requirements because reciprocating and turbine engines can be disassembled for inspection.

Containment: Proposed special condition no. 30 would require the engine to provide containment features that protect against likely hazards from rotating components unless magniX can show, by test or validated analysis, that 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 condition would require magniX to assume a rotor burst could occur and provide case features that will contain the failed rotors. In addition, magniX must also determine the effects of subsequent damage precipitated by the main rotor failure and characterize any fragments that are released forward or aft of the containment features. The fragment energy levels, trajectories, and size must be 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 the rotating parts that are built into them.

Operation with a Variable Pitch Propeller or Fan: Proposed special condition no. 31 would require magniX to conduct functional demonstrations, including feathering, negative torque, negative thrust, and reverse thrust operations, as applicable, based on the propeller or fan's variable pitch functions that are planned for use on these electric engines, with a representative propeller. The tests prescribed in § 33.95, for engines operating with variable pitch propellers, are based on the operating characteristics of turbine engines, which include thrust response times, engine stall, propeller shaft overload, loss of thrust control, and hardware fatigue. The electric engines proposed by

magniX have different operating characteristics that substantially affect their susceptibility to these and other potential failures. Since magniX's proposed electric engines may be installed with a variable pitch propeller, the proposed special condition associated with the operation with a variable pitch propeller or fan is necessary.

General Conduct of Tests: Proposed special condition no. 32 would require magniX to (1) include scheduled maintenance in the engine ICA before certification; (2) include any maintenance, in addition to the scheduled maintenance, that was needed during the test to satisfy the requirement; and (3) conduct any additional tests that the Administrator finds necessary 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 unplanned test stoppages to address engine issues that prevent the engine from completing the tests in proposed 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 the 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 magniX 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 in order to comply with the certification requirements.

These proposed 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 for reciprocating and turbine aircraft engines.

Applicability

As discussed above, these proposed special conditions are applicable to the magniX magni250 and magni500 model engines. Should magniX 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 magniX magni250 and magni500 model engines. It is not a rule of general applicability.

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 Proposed Special Conditions

Accordingly, the Federal Aviation Administration (FAA) proposes the following special conditions as part of the type certification basis for magniX USA, Inc., magni250 and magni500 model engines. The applicant must also comply with the certification procedures set forth in 14 CFR part 21.

1. Applicability.

Unless otherwise noted in these special conditions, the design must comply with the airworthiness standards for aircraft engines set forth in 14 CFR part 33, except those airworthiness standards specifically and explicitly applicable only to reciprocating and turbine aircraft engines.

2. Engine ratings and operating limits.

In addition to § 33.7(a), the design must comply with the following:

Ratings and operating limitations must be established and included in the type certificate data sheet based on:

- (a) Power, torque, speed, and time for:
 - (1) Rated maximum continuous power; and
 - (2) Rated maximum temporary power and associated time limit.
- (b) The duty cycle and the rating at that duty cycle. The manufacturer must declare the duty cycle or cycles in the engine certificate data sheet.

3. Materials.

The engine design must comply with 14 CFR 33.15.

4. Fire protection.

The engine design must comply with 14 CFR 33.17.

In addition, high-voltage electrical wiring interconnect systems must be protected against arc-faults. 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 Instructions for Continued Airworthiness (ICA).

6. Engine cooling.

The engine design and construction must comply with 14 CFR 33.21. In addition, if cooling is required to satisfy the safety analysis as described in special condition no. 17, the cooling system monitoring features and usage must be documented in the engine installation manual.

7. Engine mounting attachments and structure.

The engine mounting attachments and related engine structure must comply with 14 CFR 33.23.

8. Accessory attachments.

The engine must comply with 14 CFR 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). Compliance with this paragraph must be shown by test, validated analysis, or a combination of both. Applicable assumed 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 tests, validated analysis, or a combination of both.

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

10. Engine control systems.

(a) Applicability.

The requirements of this paragraph apply to any system or device 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 the engine does not experience any unacceptable operating characteristics or exceed any of its operating limitations.

(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 tests, 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 demonstrations, validated analysis, or a combination thereof, must be demonstrated by the system and component tests in special condition no. 27.

(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 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 result in hazardous engine effects; and

(4) Not have any likely failure or malfunction that lead to local events in the intended aircraft installation.

(g) 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.

(h) Protection systems.

The design and function of the engine control devices and systems, together with engine instruments, operating instructions and maintenance instructions, must ensure that engine operating limitations 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), 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.

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, as defined in special condition no. 17(d)(2), the unacceptable transmission of erroneous data, or continued engine operation in the absence of the control function.

11. Instrument connection.

The applicant must comply with 14 CFR 33.29(a), (e), (f), and (g). In addition, as part of the system safety assessment of special condition no. 10(g), 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.

12. Stress analysis.

(a) A mechanical, thermal, and electrical stress analysis must show there is a sufficient design margin to prevent unacceptable operating characteristics.

(b) Maximum stresses in the engine must be determined by tests, 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 part* means a rotor and major structural static part whose failure can result in a hazardous engine effect due to a low-cycle fatigue (LCF) mechanism or any LCF driven mechanism coupled with creep. 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) The applicant must establish the integrity of each critical part or life-limited part by providing the following three plans to the Administrator for approval:

(1) An engineering plan that establishes and maintains that the combination of loads, material properties, environmental influences, and operating conditions, including the effects of engine parts influencing these parameters, are sufficiently well-known and predictable by validated analysis, test, or service experience. The engineering plan must ensure each critical part or life-limited part is withdrawn from service at an approved life before hazardous engine effects can occur. The engineering plan must establish activities to be executed both pre- and post-certification. magniX must perform appropriate damage tolerance assessments to address the potential for failure from material, manufacturing, and service-induced anomalies within the approved life of the part. The approved life must be published in the mandatory ICA.

(2) A manufacturing plan that identifies the specific manufacturing definition (drawings, procedures, specifications, etc.) necessary to consistently produce critical or life-limited parts with the attributes required by the engineering plan.

(3) A service management plan that defines in-service processes for maintenance and repair of critical or life-limited parts that maintain attributes consistent with those required by the engineering plan. These processes must become part of the mandatory ICA.

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 by particle debris.

(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.

The design and construction of the engine must enable an increase—

(a) From the minimum power setting to the highest-rated power without detrimental engine effects; and

(b) From the minimum obtainable power while in-flight and while on the ground to the highest-rated power within a time interval for safe operation of the aircraft.

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 specified in special condition no. 17(d)(2).

17. Safety analysis.

(a) The applicant must comply with § 33.75(a)(1), (a)(2), and (a)(3) using the failure definitions in special condition no. 17(d).

(b) If the failure of such elements is likely to result in hazardous engine effects, then the applicant may show compliance by reliance on the prescribed integrity requirements of § 33.15, special condition no. 9, or special condition no. 13, as determined by analysis. The failure of such elements and associated prescribed integrity requirements must be stated in the safety analysis.

(c) The applicant must comply with 14 CFR 33.75(d) and (e) using the failure definitions in special condition no. 17(d) of this special condition.

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

(1) An engine failure in which the only consequence is the inability to dispatch the aircraft will be regarded as a minor engine effect.

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

Electrocution of crew, passengers, operators, maintainers, or others.

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

18. Ingestion.

(a) Ingestion from likely sources (foreign objects, birds, ice, rain, hail) must not result in unacceptable power loss, or in hazardous engine effects as defined by special condition

no. 17(d)(2).

(b) If the design of the engine relies on features, attachments, or systems that may be supplied by the installer for the prevention of unacceptable power loss or hazardous engine effects following potential ingestion, then the features, attachments, or systems must be documented in the engine installation manual.

19. Liquid systems.

(a) Each liquid 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 liquid system used for lubrication or cooling of engine components is not self-contained, the interfaces to that system must be defined in the engine installation manual.

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 proposed engine design must undergo a vibration survey to establish that the vibration characteristics of those components that may be 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, or electromagnetic. 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 tests, validated analysis, or a combination thereof, that the engine is capable of continued operation after operating at the maximum engine overtorque condition without maintenance action.

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.

23. Endurance demonstration.

The applicant must subject the engine to an endurance demonstration acceptable to the Administrator to demonstrate the limit capabilities of the engine. The endurance demonstration elevates and decreases the engine's power settings, and dwells at the power settings for durations that produce the extreme physical conditions the engine experiences at rated performance levels, operational limits, and at any other conditions or power settings 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 at each rated condition to the Administrator. The demonstration must be repeated for all declared duty cycles and associated ratings.

25. Operation demonstration.

The engine design must demonstrate safe operating characteristics, including but not limited to, power cycling, 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 the development of any unsafe condition of the system between overhaul periods, or between engine replacement intervals if 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.

27. System and component tests.

The applicant must show that systems and components will perform their intended functions in all declared environmental and operating conditions.

28. Rotor locking demonstration.

If shaft rotation is prevented by a means to lock the rotor(s), the engine must demonstrate reliable rotor locking performance and that no hazardous effects will occur.

29. Teardown inspection.

The applicant must comply with either (a) or (b) as follows:

(a) Teardown evaluation.

(1) After the endurance and durability demonstrations have been completed, the

engine must be completely disassembled. Each engine component must be within service limits and eligible for continued operation in accordance with the information submitted for showing compliance with § 33.4, *Instructions for Continued Airworthiness*.

(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 limits that were established and recorded at the beginning of the endurance and durability demonstrations.

(b) Non-Teardown evaluation.

If a teardown is not performed for all engine components, then the life limits for these components must be established based on the endurance and durability demonstrations.

30. Containment.

The engine must provide containment features that protect against likely hazards from rotating components as follows—

(a) The design of the case surrounding rotating components must provide for the containment of the rotating components in the event of failure unless the applicant shows that the rotor has a margin to burst that would justify no need for containment features.

(b) If the margin to burst shows the case must have containment features in the event of failure, the case must provide for the containment of the failed rotating components.

The applicant must define by test, validated analysis, or combination thereof, and document in the installation manual the energy level, trajectory, and size of any fragments released from damage caused by the main rotor failure that pass forward or aft of the surrounding case.

31. Operation with a variable pitch propeller or fan.

The applicant must conduct functional demonstrations including feathering, negative torque, negative thrust, and reverse thrust operations, as applicable, with a representative propeller. These demonstrations may be conducted as part of the endurance and durability demonstrations.

32. General conduct of tests.

(a) Maintenance of the engine may be made during the tests in accordance with the service and maintenance instructions contained in the proposed ICA.

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

(1) The frequency of the service is excessive;

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

(3) Major repairs are needed; or

(4) Replacement of a part is found necessary during the tests or as the result of findings from the teardown inspection.

(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.

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