DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 33

[Docket No. FAA–2020–0894; Special Conditions No. 33–022–SC]

Special Conditions: magniX USA, Inc., magni350 and magni650 Model Engines; Electric Engine Airworthiness Standards

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Final special conditions.

SUMMARY: These special conditions are issued for the magniX USA, Inc., (magniX), magni350 and magni650 model engines, which 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. This design feature is 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 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 October 27, 2021.

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SUPPLEMENTARY INFORMATION:

Background

On April 18, 2019,[1] magniX applied for a type certificate for its magni350 and magni650 model electric engines.[2] The FAA has not previously type certificated an engine that primarily uses electrical technology for propulsion of the aircraft. Electric propulsion technology is substantially different from the technology used in previously certificated aircraft engines that operate using aviation fuel; therefore, these engines introduce new safety concerns that need to be addressed in the certification basis.

As noted in the Notice of Proposed Special Conditions, the FAA used technical criteria from ASTM F3338–18, *Standard Specification for Design of Electric Propulsion Units for General Aviation Aircraft,*[3] along with engine information from magniX and other information, to develop these special conditions. These special conditions establish a level of safety that is equivalent to the level of safety 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 magni350 and magni650 model 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.,* 14 CFR part 33) do not contain adequate or appropriate safety standards for the magni350 and magni650 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. 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 Feature

The magni350 and magni650 model engines will incorporate the following novel or unusual design feature:

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

Discussion

14 CFR Part 33 Developed for Aircraft Engines That Operate Using Aviation Fuel

Aircraft engines make use of an energy source to drive mechanical systems that provide propulsion for the aircraft. The turbine and reciprocating aircraft engines certified under part 33 use aviation fuel as an energy source. The technology that the FAA anticipated in the development of 14 CFR part 33 converts oxygen and fuel to generate energy through an internal combustion system, which generates heat and mass flow of combustion products for turning shafts 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 engine manufacturers use in designing and manufacturing aircraft engines. These technologies involve chemical, thermal, and mechanical systems. Therefore, the existing engine regulations in 14 CFR part 33 address certain chemical, thermal, and mechanically induced failures specific to air and fuel combustion systems operating with cyclically loaded high-speed, high-temperature, highly-stressed components.

magniX's Electric Engines Are Novel or Unusual

The FAA's current airworthiness standards for aircraft engines, 14 CFR part 33, date back to 1964.[4] The FAA based these airworthiness standards on aircraft engines that operate using aviation fuel; such engines have mechanical systems that provide propulsion for aircraft. However, the magniX magni350 and magni650 model engines have a novel or unusual design feature which uses an electrical energy source instead of aviation fuel to drive the mechanical systems. The electric engine is exposed to chemical, thermal, and mechanical operating conditions that are unlike those observed in internal-combustion systems. Therefore, 14 CFR part 33 does not contain adequate safety standards for the magniX magni350 and magni650 model engines' novel or unusual design feature.

The two models of electric engine that have been proposed by magniX will use electrical power instead of air and fuel combustion to propel the aircraft. These electric engines will be designed, manufactured, and controlled differently than aircraft engines that operate using aviation fuel. They will be built with an electric motor, controller, and high-voltage systems that draw energy from electrical storage or

[1] The Notice of Proposed Special Conditions, published on November 19, 2020 (85 FR 73644), inaccurately indicated June 4, 2019, as magniX's type certificate application date.

[2] magniX submitted a comment which notified the FAA that the magniX engine model numbers were changed from magni250 and magni500 to magni350 and magni650, respectively. The model number change does not represent a change in the certification requirements of the engine.

[3] *https://www.astm.org/DATABASE.CART/HISTORICAL/F3338-18.htm.*

[4] 29 FR 7452.

generating systems. The magniX motor, in both models, 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 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.[5] The high-voltage system is a combination of wires and 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 aircraft engines that operate using aviation fuel. For example, high-voltage transmission lines, electromagnetic fields, magnetic materials, and high-speed electrical switches form the electric engine's physical properties. However, this technology also exposes the aircraft to potential failures that are not common to aircraft engines that operate using aviation fuel, which could adversely affect safety.

magniX's Electric Engines Require a Mix of 14 CFR Part 33 Standards and Special Conditions

Although magniX's proposed electric engines incorporate a novel or unusual design feature that the FAA did not envisage during the development of its existing 14 CFR part 33 airworthiness standards, these engines share some basic similarities, in configuration and function, to engines that use the combustion of fuel and air, and therefore they require similar provisions to prevent common hazards (*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 electric engines. This probability creates a need to develop special conditions to ensure the engine's safety and reliability.

14 CFR part 33 does not fully address aircraft engines like magniX's, which use 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 14 CFR part 33, subparts B through G, apply to aircraft engines that operate using aviation fuel. Subpart B applies to reciprocating and turbine aircraft engines. Subparts C and D apply to reciprocating aircraft engines. Subparts E through G apply to turbine aircraft engines. As such, subparts B through G do not adequately address 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 primarily use electrical technology to propel the aircraft.

Discussion of Special Conditions and Comments

The FAA issued Notice of Proposed Special Conditions No. 33–19–01–SC (the Notice) for these proposed engines. This document was published in the **Federal Register** on November 19, 2020 (85 FR 73644). The FAA received comments from eleven organizations and two individuals.

The organizations that commented were Wisk Aero (Wisk), Rolls-Royce North America (Rolls-Royce), GE Aviation (GE), Ampaire Inc. (Ampaire), Textron Aviation (Textron), Associacao Das Industrias Aeroespaciais Do Brasil (AIAB), Safran Electrical & Power (Safran), Airbus Commercial Aircraft (Airbus), magniX USA, Inc. (magniX), Transport Canada Civil Aviation (TCCA), and European Union Aviation Safety Agency (EASA).

The following summarizes each special condition proposed by the FAA; the pertinent comments, and the FAA's response, including whether the FAA made any changes in these final special conditions.

Special Condition No. 1, Applicability

The FAA proposed that 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.

Comment Summary: TCCA commented that proposed Special Condition no. 1 could be read in different ways regarding which sections of 14 CFR part 33 apply directly to electric engines and that applicants might disagree when assessing the appropriate airworthiness requirements for their engine designs. TCCA also suggested a manner in which to reformat this special condition.

FAA Response: These special conditions are not intended for all electric engine projects, only for the two models of engine proposed by magniX. Addressing the 14 CFR, part 33 applicability portion of the comment, 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 the magni350 and magni650 model engines are not reciprocating or turbine engines, subparts B through G of part 33 are not applicable to these engines unless these special conditions expressly require compliance, as set forth herein. The FAA did not change the special condition as a result of this comment.

Comment Summary: TCCA requested that Special Condition no. 1 include an additional requirement. TCCA asked that the FAA require the applicant to specify, within the engine installation manual, the electrical bonding for the installation of the engine and its control system. TCCA explained that proper bonding is required to protect the engine and the control system from the effects of lightning and electrostatic electricity, noting that 14 CFR 33.5(a) does not explicitly require electrical bonding instructions to be included in the engine installation manual.

FAA Response: Special Condition no. 10(e) addresses environmental limits for the magniX engines, which include electromagnetic interference, high-intensity radiated fields, and lightning. The assessments that verify environmental limits account for the effects of electrical bonding. A special condition for electrical bonding is not required to establish proper electrical bonding. Special Condition no. 1 mandates compliance with § 33.5(a), which addresses all physical and functional interfaces with the aircraft, including TCCA's recommendation to specify electrical bonding details in the engine installation instructions. The FAA made no changes to the special condition as a result of this comment.

Comment Summary: Wisk stated the inclusion of the high voltage and high current electrical system within the system covered by the engine OEM introduces aspects of 14 CFR 23.2525 that have not typically been addressed by engine OEMs before. Wisk added that consideration within the proposed SC for these aspects would ensure a safer product during the development, flight test, and service lifecycle. Wisk proposed the FAA consider applying § 23.2525(a) and (b), and possibly other relevant regulations to the components between the controller and motor in the engine system.

FAA Response: The requirements Wisk identifies in their comment apply to system power generation, storage, and distribution. These special conditions

[5] Sometimes this entire system is referred to as an inverter. Throughout this document, the controller and inverter will be referred to as the controller.

apply only to the magniX engine designs, which do not include the power systems addressed in 14 CFR 23.2525. These power systems are normally approved as part of the airplane. Therefore, any other relevant part 23 airplane requirements would also be addressed during the airplane certification program. The FAA did not change this special condition as a result of this comment.

Comment Summary: Wisk acknowledged that the high voltage and current electrical system is analogous to the traditional fuel system. As such, omitting regulations that are equivalent to all, or parts of 14 CFR 33.67 from these special conditions may result in a loss of a critical interface boundary, resulting in a lack of clear ownership between the airframe and engine OEM. Wisk requested that the FAA clarify within the proposed SC the analogous aspects of § 33.67 for the interface between the engine controller and the airframe electrical system as it relates to voltage and current.

FAA Response: 14 CFR 33.67 includes requirements for features that do not exist in the magniX engine electrical system. However, the analogous aspects of § 33.67 are included Special Condition no. 2, which requires magniX to establish and declare ratings and operating limits based on power-supply requirements for the engine. Therefore, Special Condition no. 2 addresses Wisk's comment. The FAA did not change this special condition as a result of this comment.

Special Condition No. 2, Engine Ratings and Operating Limits

The FAA proposed that 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 shaft horsepower, torque, speed, and duty cycle(s). The duty cycle is an engine rating that declares a performance capability for the load(s) that will be imposed on the engine, including, if applicable, starting, no-load and rest, and de-energized periods, including their durations or cycles and sequence in time.

Comment Summary: Wisk recommended that the FAA expand the ratings and operating limits required by Special Condition no. 2 to include maximum temperature, maximum and minimum voltage, current, and power; and, if applicable, coolant and/or lubrication temperatures & pressures for safe operation.

FAA Response: It is not necessary to impose voltage and current limits to ensure that these magniX engines achieve the same level of safety intended by 14 CFR part 33. The FAA has changed final Special Condition no. 2 to add temperature and power (power-supply) requirements to the engine ratings and operating limits.

Comment Summary: Wisk stated that proposed Special Condition no. 2(a)(1) (Rated Maximum Continuous Power) should not have a time limit as it is continuous. Wisk suggested deleting the word ''time'' from proposed Special Condition no. 2(a).

FAA Response: The FAA agrees that the power at the ''Rated Maximum Continuous Power'' rating is not time limited. The FAA has modified final Special Condition no. 2 to remove the time constraint from the rating.

Comment Summary: Wisk suggested that the FAA specify coolant and lubrication temperatures and pressures for safe operation.

FAA Response: The FAA does not agree with Wisk's suggestion. A special condition is not required for coolant and lubrication (operating) temperatures. Special Condition nos. 6 (Engine cooling) and 14 (Lubrication system) address Wisk's suggestion. No changes were made to this special condition as a result of Wisk's comment.

Comment Summary: Rolls-Royce commented that, by placing a duty cycle on the engine's type certificate data sheet, proposed Special Condition no. 2 would be overly prescriptive when compared to the FAA's requirements for aircraft engines that operate using aviation fuel. Rolls-Royce stated that Special Condition no. 2(b) should be removed, and the FAA should require the applicant to define a duty cycle in the Airworthiness Limitations Section of the Operating Manual.

FAA Response: The magni350 and magni650 electric engines have different operating characteristics than conventional reciprocating or turbine engines. The performance capability of electric engine designs is defined, in part, by a duty cycle. Therefore the FAA did not change this special condition as a result of this comment.

Comment Summary: GE recommended that the FAA modify Special Condition no. 2 to require the applicant to list the engine's cooling fluid as an engine operating limitation, similar to 14 CFR 33.7(b)(3), which requires, for reciprocating engines, established ratings and operating limitations related to oil grade or specification.

FAA Response: The FAA agrees with the comment and has modified final Special Condition no. 2 to require a cooling fluid grade or specification as an operating limit.

Comment Summary: Ampaire commented that the term ''power,'' as used in proposed Special Condition no. 2, is not the most relevant metric for electric machinery and power electronics. Ampaire stated that it understood ''power,'' as used in that condition, to be the electrical power output delivered by the magniX engine. Ampaire recommended that the FAA change the requirement to specify current and voltage.

FAA Response: The FAA does not agree with the comment. As used in Special Condition no. 2, ''power'' describes the mechanical shaft horsepower supplied by the engine to propel the aircraft and not the electrical power delivered by the engine. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: Ampaire asked that the FAA include more details from ASTM F3338–18, such as those listed in sections 5.3.1–5.3.8, EPU Operating Limitations and Ratings, in Special Condition no. 2.

FAA Response: The FAA does not agree with the comment. ASTM F3338–18 contains technical criteria that the FAA used in developing these special conditions. The airworthiness requirements for these engines include paragraphs from the ASTM specification and from 14 CFR part 33. The FAA made no changes to the special condition as a result of this comment.

Comment Summary: Textron recommended that the FAA add engine temperature to the ratings and operating limits mandated by Special Condition no. 2.

FAA Response: The FAA agrees with the comment. The FAA has changed final Special Condition no. 2 to add temperature to the engine ratings and operating limits.

Comment Summary: Textron stated the term ''speed,'' as used in Special Condition no. 2(a), could be misleading and mistaken for aircraft speed or gearbox output-shaft speed. Textron stated the term ''speed'' should instead be ''RPM.''

FAA Response: The FAA does not agree with the comment. Engine speed is typically measured in units that describe a rate of mechanical rotation. In Special Condition no. 2, the word ''speed,'' used in the context of ''rotational speed,'' applies to the output-shaft rotation rate. The applicant can express engine speed using various units, so the measurement unit of the engine shaft rotation does not need to be prescribed in Special Condition no. 2. The FAA did not change the special condition based on the comment.

Comment Summary: Textron recommended that the FAA add rated takeoff power to the required engine ratings and operating limits in Special Condition no. 2.

FAA Response: The FAA agrees and has added ''rated takeoff power'' to the engine ratings and operating limits in final Special Condition no. 2.

Comment Summary: TCCA suggested that the engine ratings and operating limits not be limited to those proposed in Special Condition no. 2(a). TCCA recommended adding a statement that requires magniX to include any other ratings or limitations that are necessary for the safe operation of the engine.

FAA Response: The engine ratings and operating limits that Special Condition no. 2 requires are based on existing aircraft engine technologies. However, electric engine technology is new to aviation. The FAA has modified Special Condition no. 2 to require additional ratings if they are determined to be necessary for the safe operation of the engine.

Comment Summary: TCCA asked why the FAA did not mandate that the applicant comply with 14 CFR 33.7(d) within Special Condition no. 2. Similarly, AIAB commented that Special Condition no. 2 should mandate compliance with 14 CFR 33.7(d), since the electric motor can be affected by the accuracy of the engine control system and instrumentation.

FAA Response: The FAA does not agree with the comment. Special Condition no. 1 requires that the proposed design complies with §§ 33.7(a), 33.7(d), as those requirements are not expressly and explicitly applicable only to reciprocating and turbine engines. The FAA did not change Special Condition no. 2 as a result of these comments.

Comment Summary: TCCA stated that Special Condition no. 2, as proposed, provided requirements ''in addition to § 33.7(a),'' and then proceeds to replace all of the § 33.7 details with Special Condition no. 2 requirements. TCCA stated the replacement of § 33.7 with Special Condition no. 2, as proposed, removes the determination by the FAA, as well as the concept of ''any other information found necessary for the safe operation of the engine.'' TCCA indicated that § 33.7, combined with § 33.8, should be referenced in the special condition to provide the essential cornerstone for establishing aircraft performance based on installed rated power.

FAA Response: The FAA does not agree with the comment. Special Condition no. 1 requires that the proposed design complies with §§ 33.7(a), 33.7(d), and 33.8. Special Condition no. 2 provides requirements in addition to those in § 33.7(a). The concern stated by TCCA is remedied by the inclusion of §§ 33.7(a), 33.7(d), and 33.8 within Special Condition no. 1. No change was made to this special condition as a result of the comment.

Comment Summary: Regarding the reference to ''duty cycle'' in proposed Special Condition no. 2(b), and the rating (singular) at that duty cycle, TCCA recommended that the FAA clarify whether the duty cycle corresponds to a flight cycle, a series of flights, or an engine test cycle.

FAA Response: The term duty cycle in Special Condition no. 2 is an engine rating that declares a performance capability for the load(s) that will be imposed on the magniX engines. These capabilities are determined by tests that may include starting, no-load and rest, de-energized periods and their durations (or cycles), and sequence. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA commented that proposed Special Condition no. 2 omitted consideration of electric engines' capability to regenerate electrical power. TCCA recommended that the special conditions provide design, construction, and testing that demonstrate this new capability, while acknowledging that this issue is partially addressed by Special Condition no. 31 (Operation with a variable pitch propeller).

FAA Response: Although electric engines are capable of regenerating electrical power, these special conditions apply only to the magniX engine designs, which are not intended to provide electrical power to an aircraft. Therefore the FAA did not change these special conditions as a result of this comment.

Comment Summary: TCCA suggested that the Special Condition no. 10 should be modified to include the following: ''If any electrical power is supplied from the aircraft to the engine control system for powering on and operating the engine, the need for and the characteristics of this electrical power, including transient and steady-state voltage limits, must be identified and declared in the engine installation manual.''

FAA Response: The FAA modified Special Condition no. 2 as a result of Wisk's comment and TCCA's comment for Special Condition no. 10. The change requires the applicant to establish ratings and operating limits for power-supply requirements, which include voltage and current, to be included in the type certificate data sheet.

Comment Summary: TCCA stated that Special Condition nos. 2(a)(1) and 2(a)(2) address power and time limits and asked if the limits are based on an expected power supply and whether the power supply will be part of the baseline configuration. TCCA recommended including another special condition explaining how the power-supply characteristics will be addressed in the declaration of power ratings and operational limits.

FAA Response: The term ''power,'' as used in Special Condition nos. 2(a)(1) and 2(a)(2), refers to engine shaft horsepower. Special Condition no. 2 has been modified to include the terms ''shaft power'' and ''rated takeoff power.''

Comment Summary: TCCA suggested that the FAA modify Special Condition no. 2 to require the propeller overspeed limit to be defined in the engine installation manual for situations involving propeller control malfunctions. TCCA recommended that the FAA add a special condition that requires a ''get-home'' capability.

FAA Response: The FAA does not agree with the comment. The propeller has its own type certificate, documented ratings, and operating limits, including an overspeed limit. These engines will also have their own ratings and operating limits, including an overspeed limit. Propeller overspeed protection will be managed using the engine and propeller installation manuals' declared ratings and operating limits. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA recommended incorporating the following text to the special conditions: ''Each selected rating must be for the lowest power that all engines of the same type may produce under the conditions used to determine that rating at all times between overhaul periods or other maintenance.''

FAA Response: Special Condition no. 1 includes a requirement for magniX to comply with 14 CFR 33.8, so the existing requirement in part 33 is applicable to these engines. Special Condition no. 29 (Teardown inspection) requires the engine to 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.* Therefore, these special conditions address the recommendation by TCCA. The FAA made no changes to the special condition as a result of the comment.

Special Condition No. 3, Materials

The FAA proposed that Special Condition no. 3 would require the design of these engines 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.

Comment Summary: Textron highlighted the potential hazards from certain electronic components, such as aging electrolytic capacitors. Textron recommended that the FAA require periodic testing of electrolytic capacitors to determine an appropriate replacement interval to avoid hazardous effects at altitude such as breakdown, corona, flashover, creep, strike distance, and cooling.

FAA Response: These special conditions address the hazards that may result from failure or malfunction of electronic components. Special Condition no. 27 (System and component tests) is a performance-based requirement in which the applicant must show that systems and components will perform their intended functions in all declared environmental and operating conditions. This requirement addresses all types of component failures, including those referenced in Textron's comment. Special Condition no. 13 (Critical and life-limited parts) requires the applicant to 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, including electronic parts and components. Special Condition no. 10(g) (Engine control systems) requires the applicant to conduct a control system safety assessment to identify the hazards resulting from control system failures and malfunctions, such as those in Textron's comment. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: TCCA recommended that these special conditions address the potential for manufacturing errors by appending the following text: ''In addition, manufacturing methods and processes must be such as to produce sound structure and mechanisms, and electrical systems that retain the design properties under assumed service conditions declared in the engine installation manual. This includes the effects of deterioration over time, *e.g.,* corrosion.''

FAA Response: The 14 CFR part 33 airworthiness requirement for materials (§ 33.15) applies to these engines. The existing part 33 materials requirement is adequate and appropriate for the certification basis for these engines. The FAA made no changes to the special condition as a result of the comment.

Special Condition No. 4, Fire Protection

The FAA proposed that Special Condition no. 4 would require the design of these engines 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 special condition proposed to 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 to thousands of amps and are highly variable in strength and duration.

Comment Summary: GE proposed that the special conditions include a provision for non-protected electrical wiring interconnects that requires the applicant to conduct an analysis to show that arc faults do not cause hazardous engine effects. GE stated that if electrical wiring interfaces with aircraft parts or components, the potential for arc faults should be communicated to the aircraft manufacturer. In addition, GE recommended that the FAA require the applicant to declare potential arc faults in the engine installation manual.

FAA Response: This special condition has provisions to prevent arc faults in high-voltage wire interconnecting systems from causing hazardous engine effects. Additionally, Special Condition no. 17 (Safety analysis) will have the effect of requiring magniX to account for the intended aircraft application in the engine installation manual. 14 CFR 33.5(c), ''*Instruction manual for installing and operating the engine,*'' applies to the two magniX engines. These requirements will generate the recommended documentation, such as installation instructions. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA stated that no special conditions provide standards for the electrical connectors supplied with the motor. TCCA requested clarification of the FAA's intent.

FAA Response: The special condition is a performance-based requirement, which allows flexibility for magniX to design and substantiate components (such as connectors) that they use in their engine design. The FAA made no changes to the special condition as a result of the comment.

Special Condition No. 5, Durability

The FAA proposed that Special Condition no. 5 would require the engine design and construction to ensure safe engine operation between maintenance intervals, overhaul periods, and mandatory actions described in the applicable ICA.

Comment Summary: Textron noted that the proposed wording of Special Condition no. 5 matched the intent of 14 CFR 33.19(a) but omitted the requirements of § 33.19(b). Textron suggested that Special Condition no. 5 include the following: ''Each component of the propeller-blade pitch control system which is part of the engine type design must meet the requirements of §§ 35.21, 35.23, 35.42 and 35.43.''

TCCA provided a similar comment, asking why § 33.19(b) was omitted and seeking its inclusion in Special Condition no. 5.

FAA Response: These special conditions apply only to the two magniX engine designs, which do not include a propeller-blade pitch control system. The FAA made no changes to the special condition as a result of the comments.

Comment Summary: TCCA recommended that the FAA include the requirements from 14 CFR 33.5(b) into these special conditions, as the controller may include propeller control functions.

FAA Response: These special conditions apply only to the proposed magniX engine designs, which do not include propeller controls and controllers. In addition, Special Condition no. 1 mandates compliance with § 33.5(b), *Instruction manual for installing and operating the engine,* which addresses this comment. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA stated the requirements from 14 CFR 33.4 are missing from these special conditions, but noted that including all instructions for off-wing maintenance that were contained in the ICA, would not be appropriate.

FAA Response: These special conditions are not intended for all electric engine certification projects. As

provided in Special Condition no. 1, § 33.4, *Instructions for continued airworthiness,* and its appendix, apply to the magniX engines. The FAA made no changes to the special condition as a result of the comment.

Special Condition No. 6, Engine Cooling

The FAA proposed that Special Condition no. 6 would require the engine design and construction to comply with 14 CFR 33.21. That regulation requires the engine design and construction to provide necessary cooling under conditions in which the airplane is expected to operate and would otherwise be applicable only to reciprocating and turbine aircraft engines. Additionally, this special condition proposed to require the applicant to document the cooling system monitoring features and usage in the engine installation manual, if cooling is required to satisfy the safety analysis described in 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.

Comment Summary: GE suggested that Special Condition no. 6 is redundant to Special Condition no. 17 (Safety analysis) because it includes 14 CFR 33.75(d) *Safety analysis,* and should be deleted.

FAA Response: The FAA does not agree with the suggested change. The reference to § 33.75(d) in Special Condition no. 17 does not explicitly address cooling systems that are necessary for the engine to comply with the safety analysis. Special Condition no. 6 requires additional information about the cooling system that is not specified in § 33.75(d). The FAA made no change to Special Condition no. 6 as a result of this comment.

Comment Summary: Ampaire suggested that, given certain assumptions, the electric engine manufacturer may need to specify cooling limits that cannot be exceeded at the aircraft and engine interface to ensure safe operation.

FAA Response: The FAA does not agree with the comment. These special conditions are applicable only to the magniX magni350 and magni650 model engines. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: Rolls-Royce stated that the cooling system monitoring and documentation requirements in proposed Special Condition no. 6 are already covered in 14 CFR 33.29(h), ''Instrument connection.'' Rolls-Royce recommended that the FAA modify § 33.29(h) to include a statement of applicability to electric engines.

TCCA recommended adding, ''The cooling system monitoring must be made available to enable the flight crew or the automatic control system to monitor the functioning of the engine cooling system.''

FAA Response: The FAA does not agree to amend 14 CFR 33.29(h) as a result of Rolls-Royce's comment, as these special conditions are of particular applicability to the magni350 and magni650 model engines only. However, as a result of Rolls-Royce's and TCCA's comments that recommend applying cooling system monitoring to the magniX engines, the FAA has added paragraph (b) to final Special Condition no. 11 to incorporate the requirements of 14 CFR 33.29(h), except for those provisions specifically applicable to turbine aircraft engines.

Comment Summary: TCCA recommended adding, ''If aspects of the engine cooling system require the installer to ensure that the temperature limits are met, those limits must be specified in the installation manual.''

FAA Response: The FAA does not agree with TCCA's comment. Special Condition no. 24 requires magniX to establish a temperature limit. If the temperature limit is necessary for the safe operation of the engine, these special conditions require the limit to be documented in the installation manual. Therefore, a special condition is not needed to mandate information specified in TCCA's comment.

Comment Summary: TCCA recommended adding, ''Any reliance placed upon the assumed installed conditions, or installation requirements must be declared in the instructions for installation.''

FAA Response: The FAA does not agree with TCCA's comment. Special Condition no. 1 requires magniX to comply with 14 CFR 33.5. Therefore, these special conditions already require the information specified in TCCA's comment to be documented in the instructions for installing the engine.

Comment Summary: TCCA recommended adding ''magniX must prepare and make available to the Agency prior to the issuance of the type certificate, and to the installer at the time of delivery of the engine, approved instructions for installing and operating the engine.''

FAA Response: The FAA does not agree with TCCA's comment. Special Condition no. 1 requires magniX to comply with 14 CFR 33.4, which requires magniX to prepare Instructions for Continued Airworthiness in accordance with appendix A to that part. Appendix A requires the Instructions for Continued Airworthiness include instructions for installing and operating the engine. Special Condition no. 1 also mandates compliance with 14 CFR 33.5, which requires magniX to prepare and make available to the Administrator, prior to the issuance of the type certificate, and to the owner at the time of delivery of the engine, approved instructions for installing and operating the engine. The FAA made no changes to the special condition as a result of the comment.

Special Condition No. 7, Engine Mounting Attachments and Structure

The FAA proposed that Special Condition no. 7 would require these engines to comply with 14 CFR 33.23, which requires the applicant to define 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.

Comment Summary: Textron stated that a propeller could be a much higher percentage of the total propulsion system mass in electric systems than for reciprocating or turbine engine propulsion systems and suggested that an electric motor's rotating components can be nearly instantly coupled to the non-rotating components due to FOD, internal failure, rotor growth, and commutation errors. Textron proposed additional requirements to Special Condition no. 7 related to sudden stoppage and bearing protection to ensure the engine mounting system can absorb the load or mitigate the effect of the load on aircraft.

FAA Response: The FAA does not agree with the comment. The certification basis for the proposed engines includes 14 CFR 33.23, *Engine mounting attachments and structure,* which is a performance-based requirement. The regulation doesn't specify how maximum and ultimate loads are determined because these load conditions are determined by magniX. Also, Special Condition no. 2 requires magniX to establish a torque limit and Special Condition no. 21 requires magniX to establish a maximum overtorque limit. These requirements address the conditions described in Textron's comment. magniX's engines must be designed to accommodate the load at these limit values. These special conditions address high engine mount load conditions, including the conditions described in Textron's comment, except for loads from the

failure considerations that are normally addressed by Special Condition no. 17 (Safety Analysis). The FAA made no changes to the special condition as a result of the comment.

Comment Summary: Textron recommended adding a requirement for bearing protection that states, ''Engine bearings must be protected from rotor voltage or a periodic replacement interval shall be determined as defined in Special Condition no. 13.''

FAA Response: The FAA agrees with the technical content of this comment, but there is no requirement in these special conditions to add rotor shaft grounding technology in the magniX engines. Bearings could experience accelerated wear-out from ungrounded shafts, but the failure should not present a safety issue because the failure is predictable with sufficient testing. Requirements such as § 33.4, *Instructions for Continued Airworthiness,* Special Condition no. 3 (Materials), Special Condition no. 5 (Durability), Special Condition no. 13 (Critical and life-limited parts), and Special Condition no. 29 (Teardown inspection) will all have a role in managing the consequences of potential bearing wear from electrical effects. magniX may assess the impact to product support at the predicted bearing replacement frequency and decide to include rotor shaft grounding technology.

Comment Summary: TCCA recommended that the FAA add a requirement to this special condition, requiring the applicant to demonstrate that the engine mounts and mounting features are fireproof if flammable fluids are used within the engine.

FAA Response: The FAA does not agree with the comment. The fire protection requirements in 14 CFR 33.17 apply to the magniX engines. The FAA made no changes to the special condition as a result of the comment.

Special Condition No. 8, Accessory Attachments

The FAA received no comments for Special Condition no. 8, and it is adopted as proposed. It requires the engine 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.

Special Condition No. 9, Overspeed

The FAA proposed that Special Condition no. 9 would require magniX to establish by test, validated analysis, or a combination of both, that: (1) The rotor overspeed not result in a burst, rotor growth, or damage that results in a hazardous engine effect; (2) rotors possess sufficient strength margin to prevent burst; and (3) operating limits of the engine not be exceeded in-service.

Comment Summary: GE stated that proposed Special Condition no. 9(c) was duplicative of Special Condition no. 10(b) and (h) (Engine control systems), and requested the special condition be removed.

FAA Response: The FAA does not agree with the comment. The special conditions referenced by GE accomplish different safety objectives. Special Condition no. 9(c) requires that the engine must not exceed the rotor speed operational limitations that could affect rotor structural integrity. This requirement results in an overspeed limit. Special Condition no. 10(b) requires the engine control system must ensure 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. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: Ampaire stated that Special Condition no. 9 (Overspeed) should include more information from ASTM F3338–18.

FAA Response: The FAA does not agree with the comment. ASTM F3338–18 section 5.9, EPU Rotor Overspeed, contains technical criteria that the FAA used in developing these special conditions. It also contains information that the applicant can use to propose means of compliance to these special conditions. The FAA did not change this special condition as a result of this comment.

Comment Summary: Textron recommended that the FAA modify Special Condition no. 9, paragraphs (a) and (c), replacing ''speed'' with ''RPM.'' Textron reasoned that the term ''speed'' could be misleading.

FAA Response: The units used for rotational speed in the limitations section of the engine manual can be expressed using various units. The FAA recognizes that ''rpm'' is used in 14 CFR 33.88, *Engine overtemperature test* and § 33.201, *Design and test requirements for Early ETOPS eligibility,* but speed units are not specified in all regulations that mention engine rotor speed. Therefore, the FAA will maintain the term ''speed'' in these special conditions. The FAA did not change this special condition as a result of this comment.

Comment Summary: TCCA stated that proposed Special Condition no. 9 suggested that the controller will provide the engine overspeed protection and commented that the FAA should ensure that the overspeed protection will function as intended when exposed to high-intensity radiated fields (HIRF), lightning environments, and threats. TCCA stated that verification of this protection might require the electric motor and engine control system to be included in the test setup when conducting the HIRF and lightning transient system tests and recommended that these special conditions clarify this topic in the discussion section of these special conditions.

FAA Response: This special condition is a performance-based requirement, and test details will be established as part of the demonstration of compliance. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA recommended that the FAA modify ''Rotors must possess'' as stated in Special Condition no. 9(b), to ''Rotors, including any integral fan rotors used for cooling, must possess.''

FAA Response: These special conditions are not generally applicable to all electric engines; they apply only to the applicant's proposed engines. The magniX engines do not use integral fan rotors to cool the engine. The FAA did not change this special condition as a result of the comment.

Special Condition No. 10, Engine Control Systems

The FAA proposed that Special Condition no. 10 would impose several requirements.

Special Condition no. 10(a) proposed that the requirements of that special condition apply to any engine system or device that controls, limits, monitors, or protects engine operation and is necessary for the continued airworthiness of the engine.

Special Condition no. 10(b) proposed to require that an engine control system ensure that the engine does not experience any unacceptable operating characteristics (such as unstable speed or torque control) or exceed any of its operating limits.

Special Condition no. 10(c) proposed to require magniX to systematically design, develop, and verify the software and complex electronic hardware, including programmable logic devices. RTCA DO–254, *Design Assurance Guidance for Airborne Electronic*

Hardware, dated April 19, 2000,[6] distinguishes between complex and simple electronic hardware.

Special Condition no. 10(d) proposed to require the applicant to substantiate all functional aspects of the control system to show that it performs its intended functions throughout the declared operational envelope.

Special Condition no. 10(e) proposed to require the system and component tests in Special Condition no. 27 to demonstrate the control will function as intended at environmental limits that magniX cannot otherwise substantiate. These limits include temperature, vibration, HIRF, and other limits addressed in RTCA DO–160G, *Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments*[7] (DO–160G) or other appropriate industry standards for airborne environmental-conditions testing, such as Mil-STD–810 ''Environmental Engineering Considerations and Laboratory Tests,'' Mil-STD–202 ''Test Method Standard for Electronic and Electrical Component Parts,'' Mil-461 ''Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment,'' and those listed in Advisory Circular 21–16G, RTCA Document DO–160 versions D, E, F, and G, ''Environmental Conditions and Test Procedures for Airborne Equipment,'' Special Condition no. 10(e) also requires magniX to document the environmental limits to which the system has been qualified in the engine installation manual.

Special Condition no. 10(f) proposed to require the engine control system not to exceed a maximum rate of Loss of Power Control (LOPC) for the aircraft types that will use the magniX engines, be single-fault tolerant in the full-up configuration, not have any single failure that results in hazardous engine effects, and not have any likely failure or malfunction that lead to local events in the intended installation.

The FAA issued Advisory Circular AC 33.28–3, *Guidance Material For 14 CFR 33.28, Engine Control Systems,* on May 23, 2014.[8] Paragraph 6–2 of this AC provides applicants with guidance about defining an engine control system failure when showing compliance with the requirements of § 33.28. It also explains the safety objectives of the requirements, provides criteria for a loss of thrust control (LOTC)/LOPC events for reciprocating and turbine engines. However, the guidance in AC 33.28–3 may not have sufficient information to identify failure modes and establish acceptable LOTC/LOPC rates for the magniX electric engines because electric engines did not exist when the FAA issued this AC.

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

The term ''local events'' used in Special Condition no. 10(f)(4) means failures or malfunctions that could lead to hazardous effects such as fire, overheat, or failures causing damage to engine control system components.

Special Condition no. 10(g) proposed to require magniX to conduct a system safety assessment to support the safety analysis in Special Condition no. 17.

Special Condition no. 10(h) proposed to require that the design and function of the engine control devices and systems, together with the engine instruments, operating instructions, and maintenance instructions, ensure that engine operating limits will not be exceeded in-service.

Special Condition no. 10(i) proposed to protect the airplane and engine from single failures relating to the aircraft-supplied data by mandating that the control system is able to detect and accommodate such failures, and not result in a hazardous engine effect.

The term ''independent,'' as it is used in ''fully independent engine systems,'' means that the controllers should be either self-sufficient and isolated from other aircraft systems or provide redundancy. In the case of loss, interruption, or corruption of aircraft-supplied data, the engine must continue to function without hazardous engine effects.

The term ''accommodated'' means that when a fault has been detected, the system must continue to function safely.

Special Condition no. 10(j) proposed to require magniX to show that the loss, malfunction, or interruption of the control system electrical power source will not result in a hazardous engine effect, the unacceptable transmission of erroneous data, or continued engine operation in the absence of the control function.

Comment Summary: Rolls-Royce asked that the FAA clarify the requirements contained in Special Condition nos. 10(f)(1) and (f)(2). The commenter expressed concern that the single fault tolerance requirement in Special Condition no. 10(f)(2) would be applied to both historical electrical elements of the engine control system and to the new high-voltage electrical/electronic elements required to motivate an electric motor. Rolls-Royce commented that it was possible the wording of this condition would be extended to cover loss of power (LOP) events due to the difficulties of establishing the boundary between the control and the motor drive in an electric engine. Rolls-Royce asked the FAA to modify this special condition to clarify that the degree of fault tolerance in the high-voltage electrical/electronic elements will be governed by the LOP reliability requirement of Special Condition no. 10(f)(1), and not the single fault tolerance requirement of LOPC of Special Condition no. 10(f)(2). AIAB articulated a similar concern and recommended the FAA delete Special Condition no. 10(f)(2) in these final special conditions. AIAB stated a loss of thrust control (LOTC)/LOPC event could be considered minor in aircraft with distributed propulsion, and therefore may not require electrical redundancy.

FAA Response: The comments from Rolls-Royce and AIAB describe the potential dependency between the electric engine safety analysis and certain aircraft configurations, and the potential effect the aircraft design could have on the need for engine design redundancy. However, magniX designed these engines for certain aircraft configurations that do not have special flight control capabilities, which is why the LOPC and single fault tolerance criteria from 14 CFR part 33 are adopted in these special conditions. The FAA also included ''suitable for the intended aircraft application'' in Special Condition no. 10(f)(1), and ''as determined by the Administrator'' in Special Condition no. 10(f)(2) ''Engine control system failures'' to constrain the use of these engines to aircraft that are designed with compatible engine safety assumptions. Therefore, the FAA did not change these special conditions as a result of this comment.

Comment Summary: TCCA commented that the FAA's introductory text to proposed Special Condition no. 10(e), ''Environmental limits,'' indicated that the environmental limits are addressed in DO–160G. However, TCCA suggested that some of the test specifications, methods, and categories in DO–160G might not be adequate for high-voltage systems such as the high-voltage components of this engine. TCCA suggested that the FAA modify Special Condition no. 10(e) to require

[6] *https://my.rtca.org/NC__Product?id=a1B36000001IcjTEAS.*

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

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

that the applicant establish and demonstrate the environmental limits of the engine for those circumstances when the standards in DO–160G may not be adequate.

FAA Response: These special conditions are applicable to this applicant's project and are not generally applicable requirements. As such, the FAA will evaluate the approach that the applicant proposes to substantiate the compliance of their design's high-voltage systems. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: TCCA noted that in the introduction to proposed Special Condition no. 10(f), the FAA stated that ''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'' [referring to AC 33.28–3]. TCCA stated that the referenced FAA guidance document might not have sufficient data to allow an applicant to substantiate the selected failure modes and failure rates applicable to the electrical engine and associated high-voltage systems. TCCA recommended that the FAA clarify the statement in the discussion and note that the applicant has the responsibility to substantiate the failure modes and rates to show compliance to these special conditions.

FAA Response: The FAA added clarification to the discussion of Special Condition no. (10)(f).

Comment Summary: TCCA asked the FAA to clarify whether the engine cockpit controls are part of the configuration discussed in Special Condition no. 10. TCCA also recommended that the FAA require the applicant to conduct a human error assessment to mitigate the effects of crew mistakes due to electric engine cockpit controls if they are different from conventional engine cockpit controls.

FAA Response: The engine cockpit controls are not part of the engine configuration. No changes to these final special conditions are required to address TCCA's comment.

Comment Summary: TCCA requested that Special Condition no. 10(a) use similar wording as 14 CFR 33.28(a). TCCA stated that such wording could affect the applicant's understanding of the requirement because the proposed words indicate Special Condition no. 10(a) could also be applicable to a system or a device that is not part of the engine type design.

FAA Response: In these final special conditions, the FAA has modified Special Condition no. 10(a) to incorporate the purpose of 14 CFR 33.28(a).

Comment Summary: TCCA stated proposed Special Condition no. 10(j) requires that the loss, malfunction, or interruption of the electrical power to the engine control system not result in a hazardous engine effect, the unacceptable transmission of erroneous data, or continued engine operation in the absence of the control function. TCCA stated that this special condition does not require the engine control system to be capable of resuming normal operation when the electrical power returns to a normal state. TCCA commented that the electrical power source could be subject to transients resulting in a temporary effect on the output power and shut down the control system and/or engine. TCCA explained once the temporary transients cease, the engine control system should be capable of resuming normal operation when the power characteristics return to the normal range (similar to the requirements of (14 CFR) 33.28(i)(4). TCCA proposed adding a subparagraph to Special Condition no. 10(j) to require, ''Voltage transients outside the power-supply voltage limitations declared in SC 10(j)(2) must meet the requirements of SC no. 10(j)(1). The engine control system must be capable of resuming normal operation when electrical power returns to within the declared limits.''

FAA Response: A special condition is not required to specify requirements for voltage transients that are outside the power-supply voltage limitations declared in Special Condition no. 10(j)(2), ''Engine control system electrical power'' because exceedances to these limitations are addressed by Special Condition no. 10(h), ''Protection systems.'' Special Condition no. 10(j)(1) corresponds to 14 CFR 33.28(i), which includes the additional requirement TCCA recommended. The FAA added, ''The engine control system must be capable of resuming normal operation when aircraft-supplied power returns to within the declared limits'' to Special Condition no. 10(j)(1) as a result of this comment.

Comment Summary: TCCA stated Special Condition no. 10 is similar to the current 14 CFR 33.28 requirement. TCCA suggested modifying Special Condition no. 10 to state, ''The engine design must comply with 14 CFR 33.28.''

FAA Response: 14 CFR 33.28 is applicable to reciprocating and turbine aircraft engines. The airworthiness regulations in 14 CFR 33.28 do not contain adequate or appropriate safety standards for the magni350 and magni650 model engines because of a novel or unusual design feature (use of electrical energy source instead of aviation fuel to drive the mechanical systems). Section 33.28 contains design requirements that do not apply to the proposed engines. The FAA did not change these special conditions as a result of this comment.

Comment Summary: TCCA recommended that Special Condition no. 10(j) require the applicant to define and declare, in the engine installation manual, the characteristics of the electrical power supplied to the engine control system, as required by 14 CFR 33.28(i)(3).

FAA Response: The FAA has added a subparagraph to Special Condition no. 10(j) ''Engine control system electrical power,'' which requires magniX to identify and declare the characteristics of any electrical power supplied from the aircraft to the engine control system for starting and operating the engine, including transient and steady-state voltage limits, and any other characteristics necessary for the safe operation of the engine in the engine installation manual.

Comment Summary: TCCA recommended that Special Condition no. 10 require a means to shut the engine down rapidly.

FAA Response: Special Condition no. 17(d)(2) incorporates 14 CFR 33.75(g)(2)(vii), which includes, as a hazardous engine effect, the complete inability to shut the engine down. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: TCCA commented that the proposed special conditions do not address the emerging issue of cybersecurity. Since the FAA is currently addressing this issue with an issue paper, TCCA recommended incorporating the issue paper into Special Condition no. 10 by reference.

TCCA also recommended that the FAA address cybersecurity by adding a special condition that states, ''Information system security protection. Engine control systems, including networks, software, and data, must be designed and installed so that they are protected from intentional unauthorized electronic interactions (IUEI) that may result in adverse effects on the safety of the aircraft. The security risks and vulnerabilities must be identified, assessed, and mitigated as necessary. The applicant must make procedures and instructions for continued airworthiness (ICA) available that ensure that the security protections of the engine controls are maintained.''

FAA Response: The FAA does not agree with the comment. A special condition for cybersecurity is not

needed for the magniX engine design. Cybersecurity issues are not specific to these magniX engines and will be addressed by other compliance determinations. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: Wisk stated that the change in wording from 14 CFR 33.28 from ''Operating limits'' to ''Operating limitations'' could have uncertain impacts, as ''limits'' are typically parametric-based and mostly achievable by a control system if so required. Wisk noted that operating limitations are more aligned to what is found in an airplane flight manual, so this expands the scope of what the control system may be expected to do.

FAA Response: The FAA has changed ''operating limitations'' to ''operating limits'' in Special Condition no. 10(b).

Comment Summary: Wisk asked what the FAA meant by ''be single fault tolerant, as determined by the Administrator'' in proposed Special Condition no. 10(f)(2).

FAA Response: The term ''single fault tolerant'' describes an engine control system's ability to experience single failures and not result in a hazardous engine effect while operating without any fault conditions present and in all dispatchable configurations. Special Condition no. 10(f)(2) requires the engine control system to be single fault tolerant for electrical, electrically detectable, and electronic failures involving LOPC events. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: Wisk asked that the FAA clarify the meaning of ''local events'' as used in proposed Special Condition no. 10(f)(4) ''Engine control system failures.''

FAA Response: The term ''local events'' used in Special Condition no. 10(f)(4) means failures or malfunctions that could lead to hazardous effects such as fire, overheat, or failures causing damage to engine control system components. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: Wisk suggested that the FAA not impose proposed Special Condition no. 10(g), ''System safety assessment.'' Wisk stated that the condition was unnecessary and could lead to uncertainty because 14 CFR 33.75(a), *Safety analysis,* is more rigorous. Wisk suggested incorporating § 33.75(a)(1) into Special Condition no. 10, or linking Special Condition no. 17 to Special Condition no. 10(g).

FAA Response: Special Condition no. 17 (Safety Analysis), incorporates 14 CFR 33.75(a)(1), which requires the applicant to analyze the engine, including the control system, to assess the likely consequences of all failures that can reasonably be expected to occur. Special Condition no. 10, which is adopted as proposed, contains a separate requirement for the engine control, including the frequency of occurrence of faults or failures. The linkage requested by Wisk between the engine safety analysis and control system safety assessment exists in these special conditions. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: Wisk stated they understood the initial intent of § 33.28(i) around engine controllers being reliant on electrical power for function, whereby fuel was used for the production of useful thrust/power. Wisk commented that by stating the engine control must accommodate any 'malfunction' of the electrical supply forces the engine control to accommodate overvoltage, overcurrent, etc., that may drive unnecessary cost and weight on the engine manufacturer. Wisk recommended consideration is given to the high-voltage electrical source used for thrust/power generation such that it is treated more like fuel, which is under the control of the airframe OEM.

FAA Response: Special Condition no. 10(j) does not require the magniX engine controller to accommodate malfunctions of the electrical supply. The special condition requires the engine control system to be designed such that a loss, malfunction, or interruption of the control system electrical power source will not result in hazardous engine effects. However, Special Condition no. 2 requires magniX to establish and declare ratings and operating limits based on power-supply requirements for the engine, which addresses the suggestion proposed by Wisk. The FAA did not change this special condition as a result of this comment.

Comment Summary: Ampaire asked the FAA to incorporate additional information from ASTM F3338–18 section 5.10, EPU Controls, into Special Condition no. 10(g), system safety assessment, and Special Condition no. 10(h), protection systems.

FAA Response: ASTM F3338–18 contains technical criteria that the FAA incorporated in these special conditions. It also contains information that the applicant can use to develop a means of compliance to these special conditions. The FAA did not change these special conditions as a result of this comment.

Comment Summary: AIAB proposed that the FAA mandate compliance with 14 CFR 33.28(h)(2). AIAB stated that the accommodation strategy could depend on the aircraft that use the engines because the aircraft's response to a change to thrust or power will determine if the accommodation strategy is acceptable. AIAB asked that the FAA require the applicant to evaluate the effects of aircraft-supplied data failures and document them in the engine installation manual.

FAA Response: As a result of this and other comments, the FAA modified Special Condition no. (10)(g) by adding, ''The intended aircraft application must be taken into account to assure the assessment of the engine control system safety is valid.'' Therefore, the applicant's fault accommodation strategies will need to account for the aircraft's capabilities. If the accommodation strategy meets any criteria in 14 CFR 33.5, that regulation will prompt magniX to document the details in the Instruction manual for installing and operating the engine. The FAA has changed the special condition to include additional requirements for aircraft-supplied data consistent with the recommendation.

Comment Summary: An anonymous commenter inquired if these special conditions would address electromagnetic interference potential, which, the commenter states, has caused issues with onboard radios and equipment.

FAA Response: Special Condition no. 10(e), Environmental limits, addresses potential engine effects from HIRF and lightning, as well as electromagnetic compatibility between the engine and aircraft systems. This special condition also requires the applicant to document the environmental limits to which the system has been qualified and the electromagnetic emissions from the engine. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: Textron stated the proposed Special Condition no. 10(h) matches the requirements of § 33.28(f)(1), but the requirements of § 33.28(f)(2) and (f)(3) are not included. Textron also stated there is no obvious reason why the same requirements for overspeed protection would not also apply to an electric engine, so those requirements should be added to the proposed special condition.

FAA Response: These special conditions are applicable only to the magniX magni350 and magni650 model engines. Special condition 10(h) ensures the magniX operating limits will not be exceeded in-service. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: Textron recommended that the FAA add the following to the end of Special Condition no. 10(b), ''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.'' Textron reasoned that 14 CFR 33.28(c) addresses failures resulting in changes to the operation of the engine and that regulatory requirements should be applicable to electric engines.

FAA Response: Special Condition no. 10 (Engine control systems) addresses the potential for all control system failures and failure effects, including failure or malfunction during control system transitions during a rotor overspeed. However, in these final special conditions, the FAA has changed Special Condition no. 10(b) as a result of this comment to include 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.

Special Condition No. 11, Instrument Connection

The FAA proposed that Special Condition no. 11 would require magniX to comply with 14 CFR 33.29(a), (e), (f), and (g), and, as part of the required system safety assessment, assess the possibility and subsequent effect of incorrect fit of instruments, sensors, or connectors.

Comment Summary: Wisk referred to the statement, ''In addition, as part of the system safety assessment of Special Condition no. 10(g)'' and recommended that the FAA replace the citation in Special Condition no. 11 with reference to Special Condition no. 17 or 14 CFR 33.75(a)(1).

FAA Response: Special Condition no. 10(g) requires a separate safety assessment for the engine control system. The engine control system safety assessment is not addressed by Special Condition no. 17 or 14 CFR 33.75(a)(1), which requires an engine-level safety analysis. The engine-level safety analysis does not go into enough detail to address the effects of control system failures and malfunctions. The FAA did not modify this special condition as a result of this comment.

Comment Summary: Textron stated, Special Condition no. 11 mandates compliance with 14 CFR 33.29(f), thereby requiring the applicant to assess the possibility and subsequent effects of incorrect fit of instruments, sensors, or connectors. Textron considered this requirement to repeat the assessments required by Special Condition no. 10(g) (Engine control systems). For this reason, Textron recommended removing the provisions in Special Condition no. 11 that are adopted by reference to § 33.29(f).

FAA Response: Special Condition no. 10(g) corresponds to § 33.28(e), which requires an engine control systems safety assessment. However, § 33.29(f) requires that, as part of the System Safety Assessment of § 33.28(e), the applicant must assess the possibility and subsequent effect of incorrect fit of instruments, sensors, or connectors. Therefore, Special Condition no. 11 does not repeat the requirements in Special Condition 10(g). After reviewing Textron's comment, the FAA removed reference to § 33.29(f) because the content of that regulation is captured within Special Condition no. 11(a). The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA recommended that the FAA add a provision requiring that instrument or sensor connections be designed or labeled to ensure a correct connection.

FAA Response: The FAA does not agree with the comment. Special Condition no. 11 applies 14 CFR 33.29(a) to the magniX engines, so this special condition already requires that the connections meet the criteria specified in TCCA's comment. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA recommended adding the following to Special Condition no. 11: ''Any instrumentation on which the Safety Analysis (see special condition no. 17) depends must be specified and declared mandatory in the engine installation manual.''

FAA Response: The certification basis for the proposed engines includes 14 CFR 33.5(a)(6), 33.5(c), and Special Condition no. 17(c), which encompasses § 33.75(d) and § 33.75(e). These requirements will achieve the desired results recommended in this comment. The FAA did not change these special conditions as a result of this comment.

Special Condition No. 12, Stress Analysis

14 CFR 33.62 requires a stress analysis be performed on each turbine engine. The requirement is applicable only to turbine engines and turbine engine components, and therefore, is not appropriate for the magni350 and magni650 Model engines. The FAA proposed this special condition due to the need for a stress analysis of similar components used in these proposed engines.

The FAA proposed that Special Condition no. 12 would require a mechanical, thermal, and electromagnetic stress analysis that showed a sufficient design margin to prevent unacceptable operating characteristics. Also, the condition proposed to require the applicant to 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.

Comment Summary: Wisk asked the FAA to clarify this special condition by declaring the types of failure effects that the special condition addresses. Wisk stated that Special Condition no 12 refers to ''unacceptable operating characteristics'' and that this term, coupled with Special Condition no. 9, may leave a gap where no analysis is required for static structural components (mounts, casings, etc.), which would not affect operating characteristics but could still be hazardous.

FAA Response: The corresponding 14 CFR part 33 airworthiness requirement for this special condition is § 33.62 *Stress analysis.* The corresponding part 33 airworthiness requirement for Special Condition no. 9 (Overspeed) is § 33.27, *Turbine, compressor, fan, and turbosupercharger rotor overspeed.* These special conditions are intended to apply similar requirements to the magniX engines but with additional provisions to account for electric engine technology. The additional analysis suggested in Wisk's comment is already required by Special Condition no. 13 (Critical and life-limited parts). It requires a stress analysis of static engine parts, so no changes were made to this special condition as a result of this comment.

Comment Summary: TCCA recommended that the FAA require the applicant to provide an analysis of electromagnetic stresses.

FAA Response: The FAA concurs with this comment. The FAA has modified Special Condition no. 11 to require the analysis to assess the impact of electromagnetic interference on stress.

Comment Summary: TCCA recommended adding, ''The sufficient design margin must be established in the means of compliance'' to Special Condition no. 12(a).

FAA Response: Design margin is already required by Special Condition no. 12 (Stress Analysis), which will require magniX to develop the compliance documents suggested by

TCCA. In addition, design margins are also required by Special Condition nos. 9 (Overspeed), 12 (Stress Analysis), 19 (Liquid Systems), 24 (Temperature Limit), and 30 (Containment). No changes have been made to this special condition as a result of this comment.

Special Condition No. 13, Critical and Life-Limited Parts

The FAA proposed that 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.

Special Condition no. 13 corresponds to 14 CFR 33.70, *Engine life-limited parts,* which is a complex requirement. Accordingly, additional information is provided in this discussion. In this context, the engineering plan referenced in Special Condition no. 13(b)(1) requires magniX to establish activities for managing documents, practices, and procedures that govern essential design criteria essential to part airworthiness. The engineering plan contains methods for verifying the characteristics and qualities assumed in the design data. The methods must be suitable for the part criticality. The engineering plan communicates information from engineering to manufacturing about the criticality of design features that affect airworthiness. In accordance with 14 CFR 21.137, *Quality system,* the plan must include a reporting system that flows problematic issues that develop while operating in-service so the applicant's design process can address them. The engineering plan is established during pre-certification activities and executed during post-certification activities.

For example, the effect the environment has on engine performance might not be consistent with the design assumptions. The impact of ice slab ingestion on engine parts might not be fully understood until the engine response is evaluated during testing the specific ice quantities and shapes that the airplane sheds.

The term ''low-cycle fatigue,'' as 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 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,'' as referenced in Special Condition no. 13(b)(2), means the collection of data required to translate documented engineering-design criteria into physical parts and verify that the parts comply with the design data properties. Because FAA regulations do not require parts to fail during a certification program, the documents and processes have outcome expectations, required by 14 CFR 21.137, *Quality system* and 14 CFR 21.138, *Quality manual,* to result in parts with the integrity and reliability assumed in the design data. These production and quality systems limit the potential manufacturing outcomes to parts that are consistently produced within physical 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 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 reaching its life-limit or service limit. Abnormalities 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 design process's assumptions is incorporated into the design process to remove unforeseen potential unsafe features from the engine.

Comment Summary: Wisk stated it is more appropriate to use ''The Applicant'' than the Company name ''magniX'' in Special Condition no. 12(b)(1). Wisk recommended changing the reference to the engine manufacturer reference from ''magniX'' to ''the applicant.''

FAA Response: The FAA understands Wisk's comment to be relevant to Special Condition no. 13(b)(1) because Special Condition no. 12(b)(1) does not exist. These special conditions are not applicable to all electric engine manufacturers. As stated in this preamble, these special conditions apply to the magniX magni350 and magni650 model engines. No change to this special condition is necessary as a result of this comment.

Comment Summary: Textron recommended that the post-certification activities described in the Discussion section of the proposed special conditions be included in the text of Special Condition no. 13.

FAA Response: The Discussion for this special condition is based on its similarity to 14 CFR 33.70, *Engine life-limited parts.* No change to this special condition is necessary as a result of this comment.

Comment Summary: An individual commenter suggested there might be unique questions regarding low-cycle fatigue (LCF) of components used in electric engines. The commenter explained that if the core rotor speed is low, the risk of a rotor burst might not be significant. However, a core rotor assembly that uses windings or embedded permanent magnets (if applicable) may have some LCF/thermal/electrical (refer to corona effect on motor windings) cycling challenges and the electrically powered electronics driving the motor. The individual also stated that they have learned through experience about the significance of thermal effects resulting from a broad range of operating conditions, especially during quick power transients.

FAA Response: Special Condition no. 13 requires magniX to determine the parts and components that should be classified designed, manufactured and managed throughout their service life as critical or life-limited parts. Therefore, Special Condition no. 13 provides the requirements for magniX to address the unique issues that arise when identifying and managing life-limited and critical electric engine parts. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: TCCA stated that 14 CFR 33.70 is similar enough to proposed Special Condition no. 13 that the FAA should replace the proposed special condition with reference to the 14 CFR part 33 requirement and modify it. EASA suggested the FAA remove the

term ''Critical Parts'' from this special condition.

FAA Response: Section 33.70 prescribes a mandatory replacement interval for turbine engine parts that are likely to fail from fatigue if they are not removed from service. The failure can cause a hazardous engine effect. Section 33.70 does not address parts that have a different primary failure mode than fatigue but can still fail in a way that causes a hazardous engine condition. Electric engine technology operates using electromagnetic technology and physical properties that are different than those of turbine engines. This is why the special condition has requirements for ''critical'' parts. Therefore, there is a need for a special condition that addresses failures of parts and components caused by the properties related to the novel technology used in these proposed engines. Further, the FAA currently uses the term ''critical parts'' to describe certain parts approved under 14 CFR part 21 subpart K, *Parts Manufacturer Approval* and in 14 CFR part 35, *Airworthiness Standards: Propellers.* The use of the term ''critical parts'' in these special conditions is consistent with the FAA's use of the term as it applies to conventional engines. The FAA did not change these special conditions as a result of these two comments.

Comment Summary: TCCA asked that these special conditions define ''primary failure'' as failures that are not the result of a prior failure of another part or system.

FAA Response: The term ''primary failure'' is used in 14 CFR 33.70, and this special condition is based on the requirements in that section. The FAA did not change these special conditions as a result of this comment, but the suggested clarification is adopted in the discussion to Special Condition no. 17.

Comment Summary: AIAB proposed that the FAA require the assumptions used by the applicant in the life-limited parts analysis to be declared in the engine installation manual, should the FAA certify the engine with no associated aircraft.

FAA Response: Final Special Condition nos. 10(g) and 17(e) require magniX to account for the intended aircraft application for the engine safety analysis and engine control systems safety assessment to be valid, so there will be no need to account for engines with no associated aircraft. Special Condition no. 13, Critical and life-limited parts, requires magniX to show, by 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. The assumptions used by magniX in the life-limited parts analysis are design data that provide information for compliance to Special Condition no. 13. The installers and operators of the magniX engines do not use these assumptions, and therefore, the assumptions do not need to be included in the installation manual. The FAA made no changes to this special condition as a result of this comment.

Special Condition No. 14, Lubrication System

The FAA proposed that Special Condition no. 14 would require that the lubrication system of these engines be designed to function properly between scheduled maintenance intervals and prevent engine bearing and lubrication system contamination. The FAA also proposed to require magniX to demonstrate the unique lubrication attributes and functional capability of the magni350 and magni650 Model engines.

Comment Summary: Wisk recommended removing the reference to ''particle debris'' from Special Condition no. 14(b), and replacing it with ''The lubrication system must be designed to prevent unacceptable contamination of the engine bearings.''

FAA Response: The FAA has changed Special Condition no. 14 to specify the lubrication system must prevent any unacceptable contamination of the engine bearings. The FAA has changed the special condition as a result of this comment.

Comment Summary: TCCA recommended that Special Condition no. 14 require magniX to declare, in the engine installation manual, any reliance upon assumed installation conditions or installation requirements.

FAA Response: Special Condition no. 1 requires magniX to comply with14 CFR 33.5, *Instruction manual for installing and operating the engine.* Section 33.5(a)(5) includes the additional requirement recommended by TCCA. The FAA made no changes to the special condition as a result of the comment.

Special Condition No. 15, Power Response

The FAA proposed that Special Condition no. 15 would require the design and construction of these engines and their control systems 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 the safe operation of the aircraft.

Comment Summary: Wisk recommended including the engine control system as part of the engine in these requirements. They suggest adding ''and its control system'' to this special condition to read, ''The design and construction of the engine and its control system must enable an increase.''

FAA Response: The FAA has modified Special Condition no. 15 in these final special conditions to incorporate ''including its control system'' in response to the comment.

Comment Summary: Ampaire recommended that the FAA add a requirement to these special conditions that correspond to ASTM F3338–18, section 5.20.9.

FAA Response: The FAA added Special Condition no. 15(c) in the final special condition, which incorporates criteria from ASTM F3338–18, section 5.20.9.

Comment Summary: Textron commented that electrical motors could produce significantly more torque than reciprocating or turbine engines. Textron said that unregulated application of torque could be detrimental to the flight characteristics of the aircraft or the structural components of the aircraft. Textron recommended supplementing this special condition with the following requirement: ''(c) of torque without detrimental engine or aircraft effects. Aircraft components must be designed to withstand the unregulated application of torque, or the application of torque should be controlled to ensure aircraft structural integrity or aircraft aerodynamic characteristics are not exceeded.''

FAA Response: The FAA agrees that electric engines produce torque differently than turbine engines. The potential for high torque values is attributable to the novel technology used in magniX's proposed engines. Therefore, final Special Condition no. 15 has changed to include a requirement that prevents engine torque from causing detrimental aircraft effects.

Comment Summary: TCCA recommended that the FAA revise Special Condition no. 15(b), from ''a time interval for the safe operation of the aircraft'' to ''a time interval that is determined to be safe for aircraft operation.''

FAA Response: The FAA finds that the recommended revision would be beneficial and consistent with the

change the FAA made to Special Condition no. 10(g) and the addition to Special Condition no. 17(e), which requires magniX to take into account the intended aircraft application in the engine installation manual. The FAA has changed final Special Condition no. 15(b) in the manner requested by this comment.

Comment Summary: TCCA recommended that the special condition should state the power-lever movement interval, and that response times in 14 CFR 33.73 should apply to the magniX engines, unless magniX substantiates different values for the power-lever movement interval and response times for the aircraft that will use the engines. TCCA also recommended adapting the existing § 33.73 requirement to remove the condition only applicable to the turbine engine, such as surge, stall.

FAA Response: The FAA does not agree with the comment. These special conditions are applicable only to the magniX engines. Special Condition no. 10 (Engine control systems) and Special Condition no. 17 (Safety analysis) require magniX to account for the aircraft that can use these engines. Therefore, the required power-lever movement interval and response times account for the aircraft safety objectives. Also, Special Condition no. 15 was developed to be a performance-based version of § 33.73, so all requirements of § 33.73 are not part of the special condition. The FAA did not change these special conditions as a result of this comment.

Special Condition No. 16, Continued Rotation

The FAA proposed that Special Condition no. 16 would prohibit any hazardous engine effects to result from the continued rotation of engine rotating systems that the design allows to rotate after the engine is shut down.

Comment Summary: Textron stated that there is potential for electric engines to regenerate electric energy from continuing to freely rotate after the engine is shut down, and recommended an additional requirement to prevent hazardous electrical bus effects.

FAA Response: These special conditions apply only to the subject magniX engines, which are not intended to regenerate or otherwise direct electrical power to the aircraft. The FAA made no changes to the special condition as a result of the comment.

Special Condition No. 17, Safety Analysis

The FAA proposed that Special Condition no. 17 would require magniX to comply with 14 CFR 33.75(a)(1), (a)(2), and (a)(3), which require an applicant to conduct a safety analysis of the engine, and which would otherwise apply only to applications for turbine aircraft engines. Additionally, the proposed special conditions would require magniX to assess its engine design to determine the likely consequences of all failures that can reasonably be expected to occur, and state, in the safety analysis, the failure of such elements and associated prescribed integrity requirements.

As used in Special Condition no. 17, a primary failure is a manner in which a part fails if the engine is installed in the expected aircraft configurations and operated in accordance with operating conditions assumed in the design data such as the expected performance cycles, engine limits, and operating environments, and maintained using the declared instructions for continued airworthiness. A primary failure is not the result of the prior failure of another part or system.

Some engine parts can fail suddenly in their primary failure from prolonged exposure to the physical conditions in a normal engine environment, such as temperature, vibration, and stress. The probability of failure cannot be sensibly estimated in numerical terms, and failure will likely result in a hazardous engine effect. As a result, 14 CFR 33.70, *Engine life-limited parts,* and 14 CFR 33.75, *Safety analysis,* do not allow these parts to be managed by on-condition or probabilistic means. Therefore, requirements such as life limits, scheduled inspections, and inspection techniques are mandated to ensure the essential attributes are preserved throughout the part's service life. For example, if the number of engine cycles to failure is predictable and can be associated with specific design characteristics, such as material properties, then the applicant can manage the engine part with life limits.

The safety analysis requires magniX to identify hazards that are applicable to the electric technology used in their engine design. All the engine hazards that apply to turbine engines also apply to the magniX electric engines, in addition to possible exceedances of any new engine limits pursuant to Special Condition no. 2 (Engine ratings and operating limits) to prevent failure of electronic components that have a direct impact on safety.

The outcome of the safety analysis partially depends on the aircraft types that will use these engines. Therefore, final Special Condition nos. 17(e) and 10(g) require magniX to account for the intended aircraft application in the engine installation manual to ensure the magniX engine is installed only in aircraft with compatible safety assumptions. The term ''intended aircraft application'' means the aircraft that are expected to operate with the magniX engines.

Comment Summary: Regarding Special Condition no. 17(d)(3), Wisk recommended that the FAA classify a loss of partial thrust, or a thrust variation of a small amount, as a ''major effect'' which should be only considered when the impact is relevant at the aircraft level. Wisk also stated that the applicable 14 CFR part 23, 25, 27, and 29 regulations establish appropriate LOTC/LOPC classifications, so a special condition for 14 CFR 33.75 appears unnecessary. Wisk recommended that Special Condition no. 17(d)(1) use the existing words of § 33.75(g)(1), which state, ''An engine failure in which the only consequence is partial or complete loss of thrust or power (and associated engine services) from the engine will be regarded as a minor engine effect.''

FAA Response: The FAA does not agree with the comment. These special conditions are not generally applicable to electric engines. The requirements only apply to the magniX magni350 and magni650 model electric engines. The safety analysis classifies engine failures, including LOTC/LOPC. The classification LOTC/LOPC events partially depends on the aircraft types that will use these engines, so the existing engine reliability requirements and accepted partial power levels in 14 CFR part 23, 25, 27, and 29 aircraft are not directly applicable without further review of the engine and aircraft capabilities. In addition, Special Condition no. 10(f)(1) requires the LOPC rate to be suitable for the intended aircraft application; and Special Condition no. 10, including 10(f)(2), requires the Administrator to determine the need for design redundancy relating to LOPC events to ensure the magniX engine LOPC rate is compatible with the aircraft safety objectives. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: GE directed attention to the integrity requirements listed in Special Condition no. 17(b). The requirement addresses elements (engine parts, components, and systems) that can fail and are likely to result in hazardous engine effects. GE stated that the integrity requirements in Special Condition no. 17(b) are not complete and may not achieve a level of safety equivalent to that established in 14 CFR 33.75, *Safety analysis,* and 33.70, *Engine life-limited parts.* GE recommended adding a statement that requires magniX to include any other

necessary requirements to achieve the safety analysis goals. EASA provided a similar comment and recommendation.

FAA Response: In response to these comments, the FAA has changed final Special Condition no. 17(b) to ensure all the applicable integrity requirements are applied to magniX engine parts that can fail and are likely to result in hazardous engine effects.

Comment Summary: GE commented that the definitions of ''major'' and ''minor'' engine effects, as mentioned in Special Condition nos. 17(d)(1), 17(d)(2), and 17(d)(3) are ambiguous, leaving a wide gap in the failure types that could be classified as hazardous or major engine effects. GE also commented that there is no probability requirement for major engine effects like there is in 14 CFR 33.75(a)(4). GE recommended that the FAA clarify the definitions of major and minor engine effects, and include a probability requirement to ensure a level of safety commensurate with the current regulations.

FAA Response: These special conditions are not generally applicable to all electric engines. They apply only to these proposed magniX engines. The FAA acknowledges many possible outcomes to the engine safety analysis, including the failure classifications. Failure classification and probabilities for the engine and certain electronic components are still needed, but the failure classifications and reliability thresholds will account for the aircraft's capabilities. Special Condition no. 17 does not specify the engine failure effects that could be classified as major because aircraft's capabilities can affect the failure classification.

As a result of this comment, the FAA modified final Special Condition nos. 17(d)(1) and 17(d)(3) to clarify the differences between major and minor engine failure effects. The FAA also added final Special Condition no. 17(e) to account for the potential influence aircraft capabilities may have on the engine safety analysis.

Comment Summary: Ampaire recommended adding criteria from the industry standard ASTM F3338–18, sections 5.18.1 through 5.18.6, to Special Condition no. 17.

FAA Response: ASTM F3338–18 contains technical criteria that the FAA incorporated in these special conditions. It also contains information that the applicant can use to develop a means of compliance to these special conditions. The FAA did not change these special conditions as a result of this comment.

Comment Summary: Textron stated that electrical-component manufacturers typically do not know how their components will be used or the implications to safety when changes are made to the design and manufacturing process. Textron recommended modifying Special Condition no. 17(c) to state: ''In addition, if electrical components of a safety system are outside the control of the engine manufacturer, then the manufacturer must implement a component tracking system to monitor component revisions, change of manufacture, counterfeit parts, and component end of life (EOL).''

FAA Response: Textron's comment identified a need for engine-level configuration control. The FAA acknowledges that a product's end-user could affect the intended engine configuration through parts manufacturer approvals and supplemental type certificates. However, the FAA imposed Special Condition no. 1, which mandates magniX's compliance with14 CFR 33.5(a)(5), 33.5(c), and 33.75 (d) to manage non-OEM engine configurations. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: Safran noted that Special Condition no. 17(a) requires magniX to comply with 14 CFR 33.75(a)(3), which establishes a fixed numerical value of 10^{-7} per flight hour for ''extremely remote;'' a number that might exceed the aircraft safety objectives. For example, ''extremely remote'' for a part 23/Level 1 aircraft application is rated at 10^{-5} per flight hour, not 10^{-7}. EASA shared Safran's concern and recommended that the FAA use the EASA SC E–18 [9] to establish engine safety objectives that are proportional to the safety objectives of the intended aircraft when they are equipped with the magniX engines.

FAA Response: Both comments presume the general applicability of the proposed special conditions. These special conditions apply only to magniX's two proposed engine models. The aircraft that will use the magniX engines do not include Part 23/Level 1 aircraft. However, the FAA acknowledges that acceptable engine failure rates could vary depending on the aircraft's configuration and capabilities. Therefore, the FAA removed reference to § 33.75(a)(3) from Special Condition no. 17(a). Also, The FAA changed final Special Condition no. 10(g) and added Special Condition no. 17(e) to require magniX to account for the intended aircraft application.

Comment Summary: TCCA stated the term ''electrocution'' is defined as ''to kill with electricity'' and recommended that the FAA change the term ''electrocution'' in this special condition to ''electric shock'' or ''injury from electric shock.''

FAA Response: The FAA does not agree with the comment. The term ''electrocution,'' as used in these special conditions, is consistent with the risk of serious injury or fatality caused by electric shock.

Comment Summary: TCCA asked the FAA to explain why proposed Special Condition no. 17 did not include the requirement for major failure rates in 14 CFR 33.75(a)(4).

FAA Response: To account for the potential dependency between the electric engine safety analysis and the aircraft capabilities, the FAA did not prescribe failure rates for major engine failures. Special Condition no. 10(g) and Special Condition no. 17(e) require magniX to account for the intended aircraft application. magniX will still need to classify major failures for the engine and certain electronic components, but the failure rates will account for aircraft capabilities. The FAA has changed the special condition as a result of this comment.

Comment Summary: TCCA asked the FAA to consider requiring the applicant's safety analysis to analyze uncontrollable high thrust and potential physical separation of the engine from the aircraft.

FAA Response: The FAA understands TCCA's reference to ''uncontrollable'' high thrust to mean a higher thrust than the commanded thrust or a thrust that is above a limit value. Special Condition no. 10(f)(1) requires a maximum LOPC rate for the intended aircraft that will use the magniX engines, and magniX will need to show how they comply with those rates. Special Condition no. 17(d)(2) requires magniX to comply with 14 CFR 33.75(g)(2)(v), which addresses the physical separation of the engine from the aircraft. The FAA did not change this special condition as a result of this comment.

Comment Summary: TCCA suggested that the FAA require magniX to show that a cooling loss will not result in a hazardous engine effect or that blockage cannot lead to a cooling failure. TCCA's comment was directed to Special Condition no. 18 in the context of protecting the cooling inlet from ingestion.

FAA Response: In response to TCCA's comment, the FAA has included a requirement in Special Condition no.

[9] *https://www.easa.europa.eu/sites/default/files/dfu/sc_e-18_electric_propulsion_units_for_cs-23_normal-category_aeroplanes_u.pdf.*

17(d)(2)(ii) to prevent hazardous engine effects from cooling blockage.

Comment Summary: EASA commented that the special condition has no proposed safety objectives for major failure conditions. EASA recommended that the FAA use the approach of EASA SC E–19 [10] that requires the propulsion system to have a level of safety that allows the intended aircraft to meet its safety objectives defined in the aircraft type certification basis.

FAA Response: There are many possible outcomes to the magniX engine safety analysis, including the failure classifications. Failure classification and probabilities for the engine and certain electronic components are needed, but the failure classifications and reliability thresholds will account for aircraft capabilities. The FAA has changed final Special Condition no. 10(g) and added Special Condition no. 17(e) to require magniX to account for the intended aircraft application.

The additions to Special Condition nos. 10(g) and 17(e) allow for the aircraft safety objectives to be considered when establishing the engine failure classifications and failure rates.

Comment Summary: EASA noted the reference to Special Condition no. 9 in Special Condition no. 17(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 14 CFR 33.15, Special Condition no. 9, or Special Condition no. 13, as determined by analysis.''

EASA stated that proposed Special Condition no. 9 is insufficient for hazardous failure conditions. EASA said that a rotor growth margin is a design margin, but it does not preclude any other failure root cause of a failure, such as a production issue. EASA suggested that the FAA change these special conditions to remove this possibility.

FAA Response: The FAA agrees with the comment. There might be a need to consider additional integrity requirements to account for the potential root causes for failures of the magniX electric engine parts. The FAA has changed final Special Condition 17(b) to add ''such as'' before the list of integrity requirements.

Special Condition No. 18, Ingestion

The FAA proposed that Special Condition no. 18 would require magniX to ensure that these engines will not experience unacceptable power loss or hazardous engine effects from ingestion. For example, the current bird-ingestion airworthiness regulation for turbine engines, 14 CFR 33.76, is based on potential damage from birds entering a turbine engine with an inlet duct that directs air into the engine for combustion, cooling, and thrust. In contrast, these electric engines do not use an inlet duct for those purposes. Instead, the electric engine inlet duct is primarily used to streamline the air entering the inlet for efficient cooling of internal engine components.

An ''unacceptable'' power loss, as stated in Special Condition no. 18(a), refers to a situation in which the power or thrust required for safe flight of the aircraft becomes unavailable to the pilot. The specific amount of power loss necessary for a 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 the aircraft's safe operation.

This special condition also requires magniX to declare the ingestion sources that are not evaluated in the engine installation manual.

Comment Summary: Textron recommended that this special condition quantify the ingestion threats in a manner similar to the way they are quantified for turbine engines in 14 CFR 33.76, *Bird ingestion,* § 33.77, *Foreign object ingestion—ice,* and § 33.78, *Rain and hail ingestion.* The commenter suggested that bird numbers and sizes, ice, rain, and hail concentrations should be provided.

FAA Response: The FAA does not agree with Textron's recommendation. A special condition is not required to quantify ingestion threats. The FAA did not change this special condition as a result of this comment.

Comment Summary: Airbus stated that while detailed means of compliance (test, analysis, etc.) need not be part of this special condition, the FAA should specify the ingestion conditions, such as icing environments, that magniX must consider in showing compliance.

FAA Response: The FAA has changed final Special Condition no. 18 to require ingestion sources, that are not evaluated by magniX, to be declared in the engine installation manual.

Comment Summary: Textron recommended that this special condition include a provision to prevent the accumulation of ferromagnetic material in the air-cooled passages, and to prevent blockages and short circuits between the rotor and the stator for non-sealed engines.

FAA Response: The FAA does not agree with this comment. The special condition requires magniX to consider ingestion of material originating from outside the engine, not from within it. The potential for ferromagnetic contamination of engine bearings from sources within the engine would not likely meet the requirements established in these special conditions, such as Special Condition nos. 5 (Durability) and 7 (Safety Analysis). The contamination is more likely a consequence of an engine failure or inadequate maintenance. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: EASA stated rain conditions are a normal flight condition, even in VFR, and should be distinguished from other ingestion phenomena. EASA recommended incorporating EASA Special Condition E–18 issue 2: ''operation under rain conditions must not result in any abnormal operation (*i.e.,* shutdown, power loss, erratic operation, power oscillations, failures . . .) throughout the EPU operating range.''

FAA Response: The FAA has modified Special Condition no. 18 in response to this comment to require the magniX engine to operate safely in rain environments. The word ''rain'' was removed from Special Condition no. 18(a). The following special conditions were added: Special Condition no. 18(b), which provides that rain ingestion must not result in an abnormal operation such as shutdown, power loss, erratic operation, or power oscillations throughout the engine operating range, and Special Condition no. 18(d), which requires the applicant to declare, in the engine installation manual, ingestion sources that are not evaluated.

Comment Summary: EASA asked the FAA to verify the proposed Special Condition no. 18 might result in a limitation that could be established at the aircraft-level for operation in icing conditions.

FAA Response: These special conditions are not intended for all electric engine certification projects. They are intended for the magni350 and magni650 electric engines. magniX intends to pursue a type certificate for their electric engine. If magniX elects to omit likely sources of ingestion (foreign objects, birds, ice, hail) from their evaluations, Special Condition no. 18(d) requires magniX to declare ingestion sources that are not evaluated in the engine installation manual, except for rain. Special Condition no. 18(b) was added as a result of EASA's comment to implement performance requirements in

[10] *https://www.easa.europa.eu/document-library/product-certification-consultations/final-special-condition-sc-e-19-electric.*

rain conditions. No changes were made to this special condition as a result of this comment.

Special Condition No. 19, Liquid Systems

The FAA proposed that 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, the FAA proposed that, if a magniX engine liquid system is shared with an aircraft liquid system, the interfaces between the engine and aircraft systems must be defined in the engine installation manual.

Comment Summary: Wisk recommended that these special conditions address the risk of a liquid system freezing after an engine shutdown and preserve the ability for engine restart.

FAA Response: These special conditions already account for the concerns expressed by Wisk. Special Condition no. 19 requires magniX to ensure the liquid system operates appropriately in all atmospheric conditions in which the engine is expected to operate. The FAA did not change Special Condition no. 19 as a result of this comment.

Comment Summary: Rolls-Royce noted that the FAA did not propose to require the design to comply with 14 CFR 33.64, *Pressurized engine static parts.* The commenter stated that it anticipated electric engine configurations with pressurized cooling systems and pressurized lubrication systems and recommended that this requirement be included in these special conditions.

FAA Response: These special conditions are not generally applicable to all electric engines and apply only to these proposed magniX electric engines. However, magniX may choose to pressurize the liquid systems in their engines. Therefore, the FAA has changed final Special Condition no. 19 to require magniX to account for pressurized static engine parts.

Comment Summary: Textron recommended that these special conditions require that the engine installation manual prescribe the cooling and lubricating fluids used on these engines.

FAA Response: The FAA has modified Special Condition no. 19 in these final special conditions to require magniX to list eligible lubricants and coolants in the engine installation manual.

Comment Summary: Textron recommended that the FAA add a requirement that prevents magnetically attracted engine debris from accumulating in passages that could block or limit coolant flow.

FAA Response: The potential for magnetic debris in the magniX engine liquid cooling system would likely be a consequence of an engine failure or inadequate maintenance. If this were a characteristic of the type design, the magniX engines would not likely meet the requirements established in these special conditions, such as Special Condition nos. 5 (Durability) and 7 (Safety Analysis). The FAA did not change Special Condition no. 19 as a result of this comment.

Comment Summary: TCCA noted the possibility that the magniX electric engine liquid system might rely on aircraft systems. In that case, TCCA recommended that these special conditions require that reliance be declared in the engine installation manual.

FAA Response: Special Condition no. 1 requires magniX to comply with 14 CFR 33.5, *Instruction manual for installing and operating the engine.* The requirements in §§ 33.5(a)(5) and 33.5(c) address the safety concern raised in this comment. The FAA did not change Special Condition no. 19 due to this comment.

Special Condition No. 20, Vibration Demonstration

The FAA proposed that 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.

Comment Summary: Wisk recommended that the FAA incorporate the requirements from 14 CFR 33.83(f), *Vibration test,* instead of proposed Special Condition no. 20(b), when the installation can be assessed by analysis to match an approved engine installation because the existing 14 CFR part 33 regulation does not appear to require a vibration survey.

FAA Response: This special condition combines the requirements of §§ 33.63, *Vibration,* and 33.83, *Vibration test.* Special Condition no. 20(a) corresponds to § 33.63, Subpart E, which has provisions for the design and construction of the electric engine. Special Condition no. 20(b) corresponds to § 33.83, Subpart F, which applies to the block tests. This § 33.83, *Vibration test,* reference explains why a vibration survey is specified in Special Condition no. 20(b) and not in 20(a). In addition, the special condition requires magniX engines to undergo a vibration survey using test, validated analysis, or a combination of both. Therefore, this special condition addresses Wisk's comment. The FAA did not change this special condition as a result of this comment.

Comment Summary: Ampaire suggested the terminology used in the title of proposed Special Condition no. 20 described a ''vibration demonstration,'' and the term used in the ASTM document referred to the requirement as a ''test'' (ref. ASTM F3338–18, section 5.20.4).

FAA Response: A demonstration is a test, but this special condition also allows validated analysis to show compliance. A test is required to validate an analysis, so the requirement is grounded in a test. The FAA did not change this special condition as a result of this comment.

Comment Summary: TCCA stated that paragraph (a) of proposed Special Condition no. 20 is similar to 14 CFR 33.83(b), which has a demonstration element. TCCA asked that the FAA clarify when to use representative propeller loads during engine testing. TCCA also recommended the FAA add clarification within Special Condition no. 20 to explain when propeller loads are required during the engine demonstrations.

FAA Response: Special Condition no. 20 has a demonstration element. Special Condition no. 20(a) corresponds to 14 CFR 33.63 in Subpart E, *Design and Construction; Turbine Aircraft Engines,* and Special Condition no. 20(b) corresponds to § 33.83 in Subpart F, Block Tests; Turbine Aircraft Engines. TCCA's comment also relates to Special Condition no. 31, Operation with a variable pitch propeller, which corresponds to § 33.95, *Engine-propeller systems tests.* As a result of TCCA's comment, the FAA modified final Special Condition no. 31 to enable magniX to run their engines with a variable pitch propeller during the operation demonstration.

Comment Summary: TCCA recommended that the FAA add a requirement for magniX to evaluate the vibration effects from sustained engine unbalance to protect the engine and aircraft from vibration effects caused by engine failures that result in windmilling or propeller pitch or propeller feathering issues. TCCA recommended adding a paragraph that states, ''The effects on vibration characteristics of excitation forces caused by fault conditions must be evaluated by test or analysis, or by reference to previous experience and

shown not to result in a hazardous engine effect.''

FAA Response: Special Condition no. 16 (Continued rotation) corresponds to 14 CFR 33.74, which precludes hazardous engine effects from continued rotation of engine main rotating systems after the engine is shut down for any reason while in flight. This includes the effects of vibration from failures that result in a rotor unbalance. Therefore, Special Condition no. 16 addresses the failure effects TCCA identified in their comment. The FAA did not change these special conditions as a result of this comment.

Comment Summary: TCCA recommended requiring an evaluation of vibration effects that result from excitation forces caused by fault conditions or to address these effects by reference to experience with engine failures that did not result in a hazardous engine effect. TCCA also recommended addressing the vibration effects from sustained engine unbalance.

FAA Response: Special Condition no. 16 (Continued rotation) precludes hazardous engine effects from continued rotation after the engine is shut down for any reason while in flight, including fault conditions. These special conditions are applicable to the magniX engines, which are new to aviation. Therefore, engine experience is not relevant to the magniX engine certification project. The FAA did not change this special condition as a result of this comment.

Special Condition No. 21, Overtorque

The FAA proposed that Special Condition no. 21 would require magniX to demonstrate that the engine is capable of continuous operation without the need for maintenance if it experiences a certain amount of overtorque.

Comment Summary: TCCA suggested that the FAA add the teardown inspection requirement of Special Condition no. 29 for each engine part or individual groups of components after conducting the overtorque test.

FAA Response: The additional requirement suggested by TCCA corresponds to 14 CFR 33.84(a)(2), *Engine overtorque test.* The engines proposed by magniX may require a transient maximum overtorque rating. The FAA has changed final Special Condition no. 21 to require compliance to Special Condition no. 29 (Teardown inspection) after conducting an overtorque test.

Special Condition No. 22, Calibration Assurance

The FAA received no comments for Special Condition no. 22, and it is adopted as proposed. It requires 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 methods used for accomplishing those tests for turbine engines are 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 magni350 and magni650 model engines. Special Condition no. 22 allows 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, this special condition applies the calibration requirement to both the endurance and durability tests.

Special Condition No. 23, Endurance Demonstration

The FAA proposed that Special Condition no. 23 would require magniX to subject the engine to an endurance demonstration test, acceptable to the Administrator, to demonstrate the engine capabilities at the declared limits.

The FAA proposed to evaluate the extent to which the test exposes the engine to failures that could occur when the engine is operated at its rated values, to 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 run for sustained periods at extreme operating conditions.

Comment Summary: Rolls-Royce stated that the second sentence of the proposed special condition contained a typographical error and suggested that it should read, ''The endurance demonstration elevates and increases the engine's power settings, and dwells at the power settings for durations that produce the extreme physical conditions. . . .'' Rolls-Royce recommended replacing ''decreases'' with ''increases'' in the special condition.

FAA Response: Final Special Condition no. 23 has been changed. The FAA considered the change proposed by Rolls-Royce and changed the term ''elevates'' to ''increases.''

Comment Summary: TCCA recommended that the FAA add the following three sentences to Special Condition no. 23: (1) ''The severity of the demonstration should consider the design and intended use of the engine, and include the demonstration of safe operation under all operational limits to be applied during service operation of the engine.'' (2) ''When approval is sought for Normal Transient engine exceedances, it must be substantiated that the engine is capable of operation at the maximum engine transient condition of the affected engine parameter(s) without maintenance action.'' (3) ''When approval is sought for Inadvertent Transient engine exceedances, it must be substantiated that the engine is capable of operation at the maximum engine transient condition of the affected engine parameter(s) without maintenance action other than to correct any failure that led to the exceedances.''

FAA Response: The FAA does not agree to include the additions recommended by TCCA. Regarding TCCA sentence (1), adding a definition for severity in this special condition is unnecessary because this special condition is intended to achieve the same objectives as 14 CFR 33.87, *Endurance test,* but for the magniX electric engines. The test will be different for the magniX engines because those engines use electrical technology for propulsion. Whether the engine is turbine or electric, the endurance test achieves a severity that demonstrates the engine is safe to operate at its certificated limits.

Regarding TCCA sentence (2), Special Condition no. 32 requires the engine and its components to be within serviceable limits, safe for continued operation, and capable of operating at declared ratings while remaining within limits upon completing all demonstrations and testing specified in these special conditions. If the magniX engine ratings include maximum transients, the engines must demonstrate that they operate safely during the maximum transients and meet the post-test engine requirements specified in these special conditions.

Regarding TCCA sentence (3), Special Condition no. 23 is intended to assess the magniX engine's capabilities. It is not intended to show the engine can accommodate failures and malfunctions that lead to inadvertent transients that exceed the engine's certificated limits. Special Condition no. 17 (Safety analysis) addresses potential effects

from exceeding maximum limits and transients. Results from the safety analysis are used to decide how to manage the consequences of all failures that can reasonably be expected to occur.

Special Condition No. 24, Temperature Limit

The FAA proposed that 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 this 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.

Comment Summary: Textron recommended that the FAA require the applicant to consider environmental conditions and that the engine temperature limit be substantiated at the worst-case environmental conditions to ensure the engine cooling system performance is adequate when the engine operates at the declared temperature limit.

FAA Response: The FAA has changed final Special Condition no. 24 with a requirement for magniX to account for operating environments when they establish a value for the engine temperature limit.

Comment Summary: TCCA recommended that Special Condition no. 24 include the following footnote: ''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.'' TCCA also recommended that Special Condition no. 24 includes: ''Upon completion of the demonstration, the engine must be within serviceable limits.''

FAA Response: The FAA does not agree with this comment. The following special conditions already incorporate the technical criteria proposed by TCCA:

Special Condition no. 1 requires magniX to comply with 14 CFR 33.8, *Selection of engine power and thrust ratings,* for the proposed engines. Section 33.8(b) requires that each selected rating must be for the lowest power or thrust that all engines of the same type may be expected to produce under the conditions used to determine that rating. This requirement will address the temperature margins required for the least (thermally) capable engine the type design allows.

Special Condition no. 32(c) (General conduct of tests) has provisions that require the engine and its components to be within serviceable limits, safe for continued operation, and capable of operating at the declared ratings without exceeding limits after completing the tests identified in these special conditions.

Special Condition no. 24 requires the engine design to demonstrate its capability to endure operation at its temperature limit plus an acceptable margin.

Special Condition no. 12 (Stress analysis) includes a requirement for a thermal stress analysis to show a sufficient design margin to prevent unacceptable operating characteristics and hazardous engine effects.

Therefore, Special Condition nos. 12, 24, 32(c), and § 33.8 address TCCA's recommendation. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: EASA commented that the temperature limit is a new requirement compared to the requirements in 14 CFR part 33, EASA CS–E's,[11] and the technical criteria in ASTM F3338–18. EASA stated that the applicant demonstrates operation up to the limits as part of the endurance test. EASA further commented that the engine's serviceability after the endurance test is sufficient proof that the engine has been designed and manufactured with margins compared to the limits declared in the engine installation manual. Therefore EASA recommended removing this requirement from this special condition.

FAA Response: The FAA does not agree with this comment. The FAA included a temperature limit because it is directly related to a primary failure mechanism associated with the novel technology used in magniX's proposed electric engine designs. The FAA did not change this special condition as a result of this comment.

Special Condition No. 25, Operation Demonstration

The FAA proposed that Special Condition no. 25 would require that the engine demonstrate safe operating characteristics throughout its declared flight envelope and operating range. The engine performance data magniX will use to certify each engine must account for installation loads and effects.

Comment Summary: Ampaire stated that the terminology used in the proposed special condition uses the term ''demonstration,'' and the term used in the ASTM document refers to the requirement as a ''test'' (ref. ASTM F3338–18, section 5.20.8).

FAA Response: As used in these special conditions, a demonstration is a test, but the special condition also allows validated analysis to show compliance. A test is required to validate an analysis, so the requirement is always grounded in a test. The FAA made no changes to the special condition as a result of this comment.

Comment Summary: Ampaire suggested that in-flight restart characteristics are a critical capability of electric engines and recommended that the FAA require this capability as part of the engine demonstration test. Airbus and TCCA also recommended that the FAA require a demonstration of in-flight restart capability. In addition, TCCA recommended that the special conditions require these demonstrations to be conducted with a representative propeller.

FAA Response: The FAA does not agree with the comments. Engine in-flight restart capabilities are established at the aircraft level in accordance with 14 CFR 23.2425(b), 25.903(e), 27.903(d), and 29.903(e). These regulations also require installed engines to have a restart capability within the aircraft's flight envelope. Therefore, a requirement for magniX to verify the in-flight restart capability of their engines during the engine certification program is not within the bounds of these special conditions. No changes were made to final Special Condition no. 25 as a result of this comment.

Comment Summary: TCCA asked if a gearbox assembly is considered as a single ''part'' of the engine.

FAA Response: A gearbox assembly is not considered to be a single part of the magniX engine. Gearboxes used in the magniX engines are treated as an engine accessory. The 14 CFR part 33 requirements imposed by Special Condition no. 1 that address engines with gearboxes and apply to magniX engines are 14 CFR 33.3, 33.5, 33.25, and Appendix A33.3. The special conditions that correspond to 14 CFR part 33 requirements that address gearboxes used in the magniX engines are Special Condition nos. 2, 15, 20, 22, 23 and 26. No changes were made to these special conditions as a result of TCCA's comment.

Special Condition No. 26, Durability Demonstration

The FAA proposed that Special Condition no. 26 would require magniX to subject the engine to a durability

[11] *https://www.easa.europa.eu/certification-specifications/cs-e-engines.*

demonstration. The durability demonstration must show that each part of the engine is 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.

Comment Summary: TCCA commented that these special conditions do not contain a modified 14 CFR 33.4 description of ICA for the intended electric engine applications. TCCA suggested that ICA should represent all the instructions required for the magniX engines to remain airworthy, but that instructions for off-wing maintenance instructions in the ICA would not be appropriate.

FAA Response: These special conditions are not intended for all electric engine certification projects. As required by Special Condition no. 1, magniX must comply with § 33.4, *Instructions for Continued Airworthiness,* and its appendix. These requirements are appropriate to address the maintenance requirements for these proposed engine designs. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA recommended adding 14 CFR 33.19(b), *Propeller pitch control design requirements,* to Special Condition no. 26, with an opt-out option if the magniX engines do not have propeller-blade pitch control systems.

FAA Response: These special conditions apply to the magni350 and magni650 model engines. These magniX engines do not have a propeller-blade pitch control system. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA recommended revising this special condition to state, ''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 and subsystem between overhaul periods or between engine components/parts replacement intervals. . . .''

FAA Response: magniX's proposed engines must meet Special Condition no. 29 (Teardown inspection) requirements after completing the durability demonstration specified in this special condition. In addition, magniX must meet the requirements of Special Condition no. 32 (General conduct of tests). These special conditions, in combination with the demonstration tests required by these magniX special conditions, achieve the objectives identified by this comment. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: TCCA suggested that the FAA modify Special Condition no. 26 in a manner that results in the following revision: ''This test must simulate the conditions in which the engine is expected to operate in-service, including typical start-stop cycles and scheduled maintenance actions and must be of sufficient duration in order to provide confidence in the durability of the engine.''

FAA Response: The FAA does not agree with the comment. The required durability demonstration provides information for compliance to 14 CFR 33.4, *Instructions for continued airworthiness,* which is imposed by Special Condition no. 1. If maintenance is required to complete the test, the specific maintenance actions could become part of the mandatory ICA. The discussion for Special Condition no. 32 contains more information about maintenance conducted during a test. Special Condition no. 32 (General conduct of tests) has criteria that permit some maintenance to be accomplished during the test without incurring additional mandatory ICA. The FAA agrees that the test duration can provide confidence in the engine's durability. However, whether the test duration is long or short, magniX will develop a maintenance plan based on the test that magniX creates for their program, in accordance with § 33.4. The FAA made no changes to the special condition as a result of the comment.

Special Condition No. 27, System and Component Tests

The FAA proposed that Special Condition no. 27 would require magniX to show that the engine's systems and components would perform their intended functions in all declared engine environments and operating conditions.

Comment Summary: TCCA recommended that the FAA require magniX to establish temperature limits for each component that requires temperature-controlling provisions in the aircraft installation to assure satisfactory functioning, reliability, and durability.

FAA Response: Other special conditions address TCCA's concern. Special Condition no. 2 (Engine ratings and operating limits) requires magniX to establish a temperature limit that is necessary for safe operation of the engine. Whether or not a temperature limit is established for a component depends on the outcome of Special Condition no. 17 (Safety analysis), which examines the consequence of engine failure from high-temperature. If cooling is required to satisfy Special Condition no. 17 (Safety analysis), the cooling system monitoring features and usage are documented in accordance with § 33.5(c), *Safety analysis instructions.* The FAA did not change this special condition as a result of this comment.

Comment Summary: TCCA recommended that the FAA require magniX to establish voltage and current limits ''for each component that requires voltage or current controlling provisions, or both, in the aircraft installation to assure satisfactory functioning, reliability, and durability.''

FAA Response: Other special conditions address TCCA's concern. Regarding voltage and current limits, Special Condition no. 2 requires magniX to establish ratings and operating limitations based on power-supply requirements for the engine. Whether or not voltage and current limits are established for a component depends on the outcome of Special Condition no. 17 (Safety analysis), which examines the consequence of the component's failure from high temperature. The FAA did not change this special condition as a result of this comment.

Special Condition No. 28, Rotor Locking Demonstration

The FAA proposed that Special Condition no. 28 would require the engine to demonstrate reliable rotor locking performance and that no hazardous engine effects will occur if the engine uses a rotor locking device to prevent shaft rotation.

Comment Summary: Wisk stated that this special condition does not contain a requirement that ensures the rotor lock feature cannot be enabled with a motor power set and also that its inadvertent activation is sufficiently unlikely that no major engine effect can occur. Wisk recommended that the FAA clarify if the term ''hazardous'' is being used in the context of system safety or in general terms.

Textron also requested that the FAA clarify the definition of ''hazardous effects'' and use that term consistently and recommended the following be added to Special Condition no. 28: ''. . . that no hazardous effects as specified in Special Condition no. 17(d)(2) will occur.''

FAA Response: If magniX implements a rotor locking device in their engine design, Special Condition no. 28 will ensure the device exhibits reliable rotor locking performance and will not cause hazardous engine effects to preserve system safety. Special Condition no. 17 (Safety analysis) examines the

consequence of accidental rotor locking while the aircraft is in-flight and classifies the failure as either hazardous or major. The magniX engine will need to meet the requirements of this special condition and those of the safety analysis, which provide protection from inadvertent rotor locking.

The FAA clarified the terms ''hazardous'' and ''hazardous engine effects'' as they are used in Special Condition no. 28 by adding a reference to Special Condition no. 17(d)(2). The FAA changed final Special Condition no. 28 as a result of this comment.

Comment Summary: Textron requested that Special Condition no. 28 require magniX to consider the potential hazards from an automatic rotor locking system. Textron stated that if the engine is shut down during flight, and the locking device is automatic, the flight crew needs to have a means to remove the locking device and restart the engine without creating a hazard. The commenter recommended adding the following to Special Condition no. 28: ''(b) When the locking device is in place, an indication shall be provided so that the crew will be able to retract the device while in flight.''

FAA Response: The FAA does not agree with the comment. magniX verifies rotor lock performance and reliability using the tests required by Special Condition no. 28. Typically, only rotorcraft have cockpit indications for locking devices. Those rotorcraft cockpit indications for locking devices are for main rotor transmissions, which are aircraft-level components. If an engine lock position indication is required to meet the aircraft safety objectives, the devices that notify the crew are part of the aircraft safety system. The FAA did not change these special conditions as a result of this comment.

Comment Summary: TCCA commented that this special condition should allow additional techniques to verify rotor locking performance. TCCA also suggested that the special condition requires a demonstration of reliable rotor ''unlocking'' performance.

FAA Response: Final Special Condition no. 28 has been changed to add rotor unlocking performance to the demonstration. However, allowing the use of a validated analysis would render the demonstration optional.

Special Condition No. 29, Teardown Inspection

The FAA proposed that Special Condition no. 29 would require magniX to perform either a teardown evaluation or a non-teardown evaluation based on the criteria of Special Condition no. 29(a) or (b).

The FAA proposed that Special Condition no. 29(a) would require that the engine be disassembled after the endurance and durability demonstrations to verify each component remained within its service limits and in a condition for continued operation in accordance with § 33.4, *Instructions for Continued Airworthiness.*

The FAA proposed that Special Condition no. 29(b) would require magniX, for ''non-teardown evaluations,'' to establish life limits based on endurance and durability demonstrations.

In final Special Condition no. 29(b), magniX is required, for non-teardown evaluations, to account for engines, sub-assemblies, and components that cannot be disassembled without destroying the components. If teardown and inspection are not accomplished for components or assemblies after testing, the maintenance requirements for the engine are contingent on the demonstrated capabilities exhibited during the certification tests.

Comment Summary: GE recommended that the FAA clarify how life limits will be established if magniX cannot complete the teardown inspection of parts or components after the endurance and durability demonstrations. GE stated that the life limits should be documented in the engine's airworthiness limitations or the engine's ICA. TCCA also requested clarification about how life limits are established for parts and components that are not torn down after testing.

FAA Response: Special Condition no. 29 can have an effect on life limits. In the foregoing discussion of this condition, the FAA provided additional information to clarify how maintenance (such as life limits) is established for parts and components that are not torn down and inspected after testing. Also, the FAA changed final Special Condition no. 29 to require life limits resulting from this special condition to be documented in the ICA, in accordance with 14 CFR 33.4.

Comment Summary: Textron recommended that the FAA require inspections of electrical components in the controller after the endurance and durability demonstrations. Textron stated that, at a minimum, the FAA should require inspection of the controller's fasteners, heat transfer components, dissimilar metallic junctions, and age or use affected electrical components.

FAA Response: The preamble of these special conditions explains that the magniX engine consists of an electric motor, controller, and high-voltage systems. Special Condition no. 29(a) requires the engine to be completely torn down and inspected. Special Condition no. 29(b) contains provisions for engine components that are not disassembled for inspection. The FAA did not change these special conditions as a result of this comment.

Comment Summary: An individual commenter suggested potential long-term issues with main bearing lubrication related to grease life. The commenter stated that these issues might not be evident after completing a certification program.

FAA Response: In response to this comment, the FAA has changed final Special Condition no. 29(b) to require a life limit for the bearing lubricant if the bearing is not disassembled after testing. The FAA has changed the special condition as a result of this comment.

Comment Summary: TCCA recommended that the FAA mandate additional tests if the teardown inspection shows that part replacement is necessary.

FAA Response: The FAA does not concur with the comment. Special Condition nos. 32(b) and (b)(4) (General conduct of tests) already have the requested provisions for additional testing of parts that require replacement during a test or based on their condition at teardown inspection. The FAA made no changes to the special condition as a result of the comment.

Comment Summary: EASA commented that this Special Condition no. 29(b) was proposed to define the life limits of the tested components based on the endurance and durability tests. EASA stated this special condition was not aligned with ASTM F3338–18 and asked the FAA to elaborate on whether the selected limit is the highest or lowest one and how limits are compared if they are based on different test conditions.

FAA Response: ASTM F3338–18, section 5.22.1.5 establishes life limits for an electric engine based on the length of an endurance test if the engine is not torn down for inspection after the test. These special conditions require individual life limits to be established, based on endurance and durability demonstrations if individual components are not torn down and inspected after the tests. This special condition is consistent with the ASTM document EASA referenced in their comment. Because these special conditions apply to the magniX engine, the life limits will be based on the test conditions magniX uses to assess their engines. The FAA made no changes to

the special condition as a result of the comment.

Comment Summary: TCCA recommended that Special Condition no. 29 apply the non-teardown requirement to those components that need additional testing in accordance with §§ 33.53(a), *Engine system and component tests* or 33.91(a), *Engine system and component tests.* TCCA commented that, as the special condition is currently worded, some might apply the requirement only to internal engine parts. TCCA also requested that the FAA modify the special condition to require some post-test assessments for non-torn down components. TCCA also asked that the FAA clarify the requirement that ''then the life limits for these components must be established based on the endurance and durability demonstrations.'' TCCA contended that, as this requirement is currently worded, magniX could interpret it to mean that all internal parts of the electric engine would not need to be examined, including (Non-Destructive Testing) NDT, especially if there is no overhaul.

FAA Response: Special Condition no. 27 ensures that magniX addresses electric engine components that cannot be torn down for inspection. If the condition of these parts is questionable, then the requirements in Special Condition nos. 32(b) and 32(b)(4) can be applied for additional data to substantiate the life limit. These special conditions address TCCA's comments. The FAA did not change the special condition as a result of this comment.

Special Condition No. 30, Containment

The FAA proposed that 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. 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.

Comment Summary: Textron stated that the wording in Special Condition no. 30(a) relating to the required burst margin for the rotor is vague. Textron suggested that the FAA incorporate the following change to Special Condition no. 30(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 margin to rotor burst unconditionally rules out the possibility of a rotor burst.''

FAA Response: The FAA agrees with the proposed change and has modified Special Condition no. 30(a) to incorporate Textron's suggestion.

Comment Summary: Airbus stated that experience with electrical generators has shown that axial ejection of debris might induce severe damage to surroundings. Airbus stated that an axial containment demonstration is feasible for electric engines and generators, and therefore should be required by the FAA. Airbus said that this special condition should require magniX to show full containment capability, eliminating the need to identify forward- and aft-ejected debris in the engine installation manual. Airbus recommended that the FAA modify Special Condition no. 30(a) to state, ''The design of the engine must provide for axial and radial containment of the rotating components . . .'' Airbus also recommended the FAA modify Special Condition no. 30(b) to state, ''If the margin to burst shows the case must have containment features in the event of failure, the case must provide axial and radial containment of the failed rotating components.''

FAA Response: These special conditions apply only to the magniX engine designs. Special Condition no. 30(b) is similar to § 33.94(a), *Blade containment and rotor unbalance tests,* and § 33.19(a), *Durability,* except this special condition includes the engine rotors. This special condition allows magniX to approach containment like turbine engines or provide full containment, as suggested in the comment. If a magniX engine design cannot contain the rotors, life limits will be applied in accordance with Special Condition no. 13 (Critical and life-limited parts). Therefore the FAA did not change this special condition as a result of this comment.

Comment Summary: EASA stated that the intent of the proposed Special Condition no. 30(b) is not clear, since that paragraph requests the case to provide containment of the failed rotating component while requesting that the applicant define the energy level, the trajectory, and the size of the released fragments. EASA asked the FAA to rewrite Special Condition no. 30(b) to be differentiated from Special Condition no. 30(a). EASA commented that Special Condition no. 30(b) should be dedicated to those cases where containment is not ensured.

FAA Response: Special Condition no. 30(b) provides a level of protection similar to that provided by FAA regulations that manage turbine engine blade failures, except it includes the engine rotors. It precludes the release of high-energy debris radially outward of the rotors. If the magniX engines qualify for the provisions in Special Condition no. 30(b), fragments resulting from rotor damage, and that travel forward or aft of the containment plane, must have their energy levels and trajectories defined. The magniX engine configuration and declared containment capabilities would determine if compliance with Special Condition no. 30(b) is required. The FAA made no change to this special condition as a result of this comment.

Special Condition No. 31, Operation With a Variable Pitch Propeller

The FAA proposed that 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. Also, since these electric engines may be installed with a variable pitch propeller, the special condition associated with the operation with a variable pitch propeller or fan is necessary.

Comment Summary: TCCA commented that, in addition to the propeller control, there is a risk that an electric engine controller could fail and result in reverse engine rotation. TCCA suggested that the FAA add a special condition that considers and minimizes the potential for engine controller failures that could result in reverse engine rotation.

FAA Response: The FAA does not agree with the comment. Section 33.75(g)(2) provides a list of hazardous engine effects. The list includes thrust in the opposite direction. Special Condition no. 17(d)(2) defines hazardous engine effects as those in § 33.75(g)(2), with several additions specifically applicable to these electric engines. These special conditions address the failure described in the comment.

Comment Summary: TCCA recommended revising the Special Condition no. 31 text to read, ''. . . with a representative propeller or fan. These demonstrations may be conducted in a manner acceptable to the Administrator as part . . .''.

FAA Response: The FAA has modified final Special Condition no. 31 to allow the Administrator to determine if a test is acceptable.

Special Condition No. 32, General Conduct of Tests

The FAA proposed that 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 additional tests that the Administrator finds necessary, warranted by the test results.

The term ''excessive,'' as it is used in proposed Special Condition nos. 32(b)(1) and (2), describes the frequency of unplanned engine maintenance and the frequency of unplanned test stoppages that are needed to address engine issues that prevent the engine from completing the tests. Deciding if unplanned maintenance or test stoppages are excessive requires an objective assessment of the reasons for the test interruptions. For example, magniX may not be able to simulate a realistic engine operating environment and may need to integrate test-enabling equipment to achieve the test goals. The test facility equipment may fail or cause an engine to fail during a test. Therefore, unplanned maintenance might not affect the certification test results, but if the FAA considers the maintenance or test stoppages to be ''excessive,'' additional testing or unforeseen ICA may be required to comply with the certification requirements.

Comment Summary: Rolls-Royce stated that it supports the clarifications in Special Condition no. 32(b) with the understanding that the term ''excessive'' in Special Condition nos. 32(b)(1) and 32(b)(2) allows for the rectification of some failures while the test continues. Rolls-Royce suggested that aircraft engines that operate using aviation fuel, operating at the extreme physical conditions required by the endurance tests, sometimes suffer a failure that is unrelated to the test conditions. The ability to review the failure with the FAA, rectify the failure, and continue the test is an important aspect of conducting these tests.

FAA Response: The FAA's assessment of whether unplanned service and maintenance during testing are ''excessive'' could include a variety of factors, such as the causes of the stoppage, the effects of test facility equipment, difficulties in simulating a realistic engine operating environment, and whether the engine requires modifications to complete the test. The applicant could also show that unplanned maintenance did not affect the certification test results. The FAA did not change this special condition as a result of this comment.

Comment Summary: TCCA commented that these special conditions do not address the emerging issue of single event effects, which the FAA is currently addressing via issue papers. TCCA recommended incorporating those issue papers into the special condition.

FAA Response: The FAA does not agree with the comment. The issue paper that TCCA referenced is applicable to engines that operate at high altitudes and high latitudes. Special Condition nos. 10 and 17 require magniX to account for the intended aircraft application. If magniX engines can operate at high altitudes and high latitudes, they could apply the referenced issue paper to the certification program. The FAA made no changes to these special conditions as a result of this comment.

Comment Summary: TCCA recommended that the FAA clarify the requirement in Special Condition no. 32(a) by including a reference to 14 CFR 33.4, *Instructions for continued airworthiness.*

FAA Response: The FAA has modified the special condition to add the requested reference to § 33.4 to clarify that magniX must provide the service and maintenance instructions in accordance with the ICA.

Applicability

As discussed above, these special conditions are applicable to the magniX magni350 and magni650 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 magni350 and magni650 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 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 magniX USA, Inc., (magniX), magni350 and magni650 model engines. The applicant must also comply with the certification procedures set forth in title 14, Code of Federal Regulations (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 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 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 § 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 structures 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 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 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.

(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;

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

(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 the assessment of the engine control system safety is valid.

(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 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.

(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, 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. 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 and declare, in the engine installation manual, the characteristics of any electrical power supplied from the aircraft to the engine control system for starting and operating the engine, 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 14 CFR 33.29(a), (e), and (g).

(a) 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.

(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, thermal, and electromagnetic stress analysis must show a sufficient design margin to prevent unacceptable operating characteristics and hazardous engine effects.

(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 part* means a rotor and major structural static part, the failure of which can result in a hazardous engine effect due to 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) 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 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. In addition to the activities that must be completed prior to certification, including a reporting system that flows, back to magniX, problematic issues that develop in engines while they operate in-service, to be addressed by the design process. 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 for the manufacturer to consistently produce critical or life-limited parts with the design attributes required by the engineering plan.

(3) A service-management plan 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 be 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 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

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

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

(b) 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 safe for aircraft operation; and

(c) From the minimum torque to the highest-rated torque without detrimental engine or aircraft effects to ensure aircraft structural integrity or aircraft aerodynamic characteristics are not exceeded.

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) and (a)(2) 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 such as § 33.15, Special Condition no. 9, Special Condition no. 13, or combinations thereof, as applicable. The failure of such elements and associated prescribed integrity requirements 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.

(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 meeting its certificated performance requirements and the intended functions in a manner consistent with § 33.28(b)(1)(i), § 33.28(b)(1)(iii) and § 33.28 (b)(1)(iv), and the engine complies with the operability requirements such as Special Condition no. 15 (Power response), Special Condition no. 25 (Operation demonstration), and Special Condition no. 31 (Operation with a variable pitch propeller), 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 are required for the engine to operate within temperature limits.

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

(e) The intended aircraft application must be taken into account to assure the analysis of the engine system safety is valid.

18. Ingestion

(a) Ingestion from likely sources (foreign objects, birds, ice, hail) must not result in hazardous engine effects defined by Special Condition no. 17(d)(2), or unacceptable power loss.

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

(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 following potential ingestion, then the features, attachments, or systems must be documented in the engine installation manual.

(d) Ingestion sources that are not evaluated must be declared 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.

(c) The applicant must establish by test, validated analysis, or a combination of both that all static parts subject to significant gas or liquid 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) 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 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 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 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 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.

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 engine's limit capabilities.

The endurance demonstration must include increases and decreases of the engine's power settings, and dwellings 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 to the Administrator the margin at each rated condition. The demonstration must be repeated for all declared duty cycles and associated ratings, and operating environments, that 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.

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 locking the rotor(s), the engine must demonstrate:

(a) Reliable rotor locking performance;

(b) Reliable unlocking performance; and

(c) That no hazardous engine effects, as specified in Special Condition no. 17(d)(2), 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 and lubricant 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 established and recorded limits 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 and lubricants must be established based on the endurance and durability demonstrations and documented in the ICA in accordance with § 33.4.

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 margin to rotor burst precludes the possibility of a rotor burst.

(b) If the margin to burst shows that 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 a combination thereof, and document in the engine installation manual, 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 case.

31. Operation With a Variable Pitch Propeller

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 in a manner acceptable to the Administrator as part of the endurance, durability, and operation 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 submitted in compliance with § 33.4.

(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 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.

Issued in Kansas City, Missouri, on September 10, 2021.

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