Lesson Plan – Design of Electric Engines for General Aviation Aircraft

https://polytechnic.purdue.edu/aircraft-electric-propulsion

Title:	Introduction to the standard specification for Design of Electric Engines for General Aviation Aircraft, ASTM F3338-21
Instructional Goal:	The goal of the four sets of lessons in this module is to increase student knowledge of the relationship between electric or hybrid-electric aircraft propulsion technologies and the applicable standards related to design and airworthiness. This module focuses on design requirements for electric engines for General Aviation (GA) aircraft. The companion website is divided into three areas: Materials, Assessments, and Resources. The Materials section contains four videos: introduction, terminology, requirements and ratings, and endurance and durability testing. The Assessments section of the website contains multiple choice assessments and answer keys for each of the four videos in the materials section. There are four goals for students in this module: Identify the major requirements for the design of electric engines. (ASTM F3338-24 is the revision published in Sept 2024. Please check for updated versions of this standard and for associated changes) Identify the connections between F3338 and Title 14 CFR Part 23 Airworthiness Standards. Identify the basic tests for certification (ASTM F3338-24, 5.21). Determine connections to FAA regulations found in Title 14 CFR Part 33, Part 35, and FAA Advisory Circulars.
Learning Standards:	N/A
Performance Objectives:	Given a list of multiple systems or tests, the student shall correctly identify which systems or tests are located in ASTM F3338. Given a particular system, the student shall correctly identify the appropriate tests required in ASTM F3338 or other standards.

Given a specific aircraft or engine system, the student shall be able to locate appropriate Federal Aviation Administration (FAA) Advisory Circular(s).

Given a list of terms, the student shall correctly identify the appropriate definition.

Instructional Resources: Access to FAA and ASTM documentation.

ASTM F3338-24 Standard Specification for Design of Electric Engines for General Aviation Aircraft

FAA regulations found in Title 14 CFR Part 23 AIRWORTHINESS STANDARDS: NORMAL CATEGORY AIRPLANES

FAA regulations found in Title 14 CFR Part 33 AIRWORTHINESS STANDARDS: AIRCRAFT ENGINES

FAA regulations found in Title 14 CFR Part 35 AIRWORTHINESS STANDARDS: PROPELLERS

ASTM F3060 Standard Terminology for Aircraft

SAE J245 Engine Rating Code – Spark Ignition

IEC 60034 Rotating Electrical Machines - Part 1: Rating and Performance

IEC 60349 Electric traction - Rotating electrical machines for rail and road vehicles - Part 1: Machines other than electronic converter-fed alternating current motors

Student Characteristics: Post-secondary adults.

Delivery Method: Online or in-person

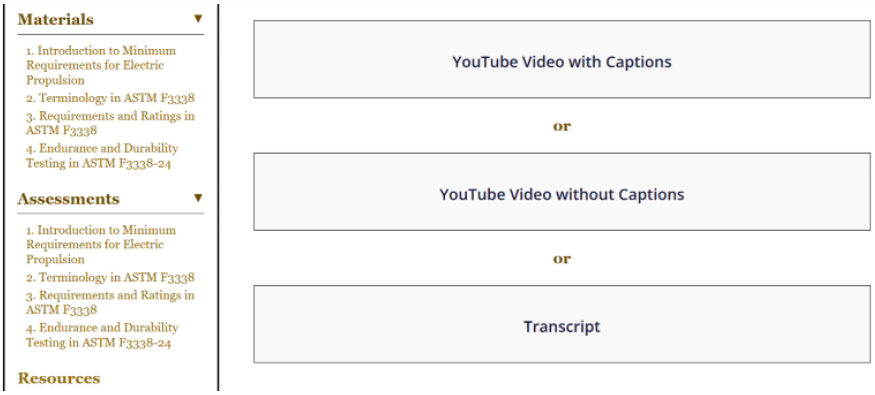
Lesson Outline

Introduction:

The purpose of this module is to familiarize students with available industry standards related to the design of electric engines for general aviation aircraft. The student will be provided with multiple resources such as videos, assessments, and activities. The videos are an introduction and do not replace in-depth study of the standards or regulations. The videos should be previewed by the instructor to determine how the video may be used in one of more classes. Depending on the course objectives, these materials may be adjusted to fit the needs of courses in technical, engineering, and general science or design courses.

Content:

See the associated website for instructional videos, assessments, and activities. The transcription for each of the videos is on the website in the Materials section. By clicking on each of the videos, the viewer may select from three options of video and transcript as shown in this figure.



Closing:

This module introduces the student to the use of standards for the design of electric engines for general aviation aircraft. It is not a comprehensive module on the design process, design requirements, or testing procedures.

Assignments/Activities: These are sample ideas for student activities and assignments that may be completed in class or as homework, and either by one student or in groups. The activities are not designed to be appropriate for all courses at all levels. Based on the instructional level and goals of the course, the instructor may choose to modify these activities, and/or develop their own activities.

Students will create a list of electric aircraft currently certificate or underdevelopment. For each aircraft, the student will identify the engine or aircraft type options, and the country of origin. The student will summarize their findings in a table of information (engine, aircraft type options, and country of origin) with citations and a reference list.
Students will identify the associated Advisory Circulars for one of the aircraft identified in A.
Students will define *critical parts* and *life-limited parts* based on ASTM F3338. The students will explain the differences between these two terms.
Students will review ASTM F3338 for all references to safety analysis, create a diagram of the connections among the analyses, and write and/or present a summary of their findings.
After viewing the videos and doing a number of activities, the students will develop and provide a list of questions that remain in their minds related to testing and airworthiness for electric propulsion. A quick exercise would be to develop a list of these questions (using brainstorming techniques, or one idea on a sticky note for each student, or a group activity) and then ask questions about how the students might go about finding answers to these questions. The instructor may share the final list with the class. This exercise may provide a way for instructors and students to connect these questions to other courses in their degree curriculum.

Assessment: See the four sets of assessment questions on the website. Any one of the assignments may be an option for a summative assessment.

Answer Key:

1.Introduction to Minimum Requirements for Electric Propulsion

Q1: Why does ASTM F3338-24 not cover all possible engine configurations?

A. Because it is meant to be used alongside other supporting documents

Q2: What is the role of the FAA in electric engine design approval in the U.S.?
B. It serves as the civil aviation authority and issues design guidance

Q3: What advantage does electric propulsion offer, as described in the video?
A. Reduced noise and no exhaust emissions

Q4: Which of the following is not one of the potential uses for electric aircraft mentioned in the video?
C. Military combat operations

Q5: What is significant about Pipistrel's Vellis Electro?
C. It is the first type-certificated electric aircraft for pilot training

Q6: What did the FAA grant in March 2024 regarding electric aircraft?
A. An LSA airworthiness exemption for flight training

Q7: Why are FAA "special conditions" being created for some electric engines?
B. Because no standard certification yet exists for all electric engines

Q8: How did the FAA establish the "special conditions" for certifying electric engines?
B. By combining Part 33 standards with F338-18 technical criteria

Q9: What milestone did Joby Aviation achieve in 2022?
A. They received their FAA Part 135 air carrier certificate

Q10: As of 2025, what is one ongoing challenge for electric engine certification in the U.S.?
C. Absence of comprehensive certification requirements for all electric engines

2. Terminology in ASTM F3338

Q1: Why is a common understanding of terminology important in aviation, according to the video?
A. It fosters teamwork and avoids confusion

Q2: How does the video define the role of an electric engine in aircraft?
B. It converts electric power into mechanical thrust for propulsion

Q3: What is the main difference between an electric engine and a motor, as explained in the video?
B. A motor produces rotational power; an engine provides aircraft propulsion

Q4: What does “rated maximum continuous power” refer to in ASTM F3338?
C. Brake power available for unrestricted use

Q5: How long can “rated takeoff power” be used, as defined in the video?
A. No more than five minutes

Q6: Which of the following is an example of non-periodic duty in aircraft systems?
B. Constant-speed propeller adjusting pitch during flight

Q7: What characterizes periodic duty in aviation systems?
C. One or more constant loads for specific durations

Q8: What’s the function of deicing boots as discussed in the context of duty types?
B. Example of periodic duty due to fixed operating cycle

Q9: Which term best describes how the load behaves across operating ranges in periodic duty?
A. Constant for defined durations

Q10: How does ASTM F3338 reference external standards?
C. It calls out other standards like SAE J245 when needed

3. Requirements and Ratings in ASTM F3338

Q1: What kind of information must be included for safe engine operation?
A. Things like maximum torque, temperature, and vibration limits

Q2: What factors influence how long and how hard an electric engine can run safely?
B. Duty cycle involving power, speed, torque, and time

Q3: How does the video say power ratings can be visually represented?
B. Using time-sequenced graphs or pre-defined duty profiles

Q4: What real-world example does the video use when discussing “overspeed”?

A. The rotor must not break apart even if spinning faster than normal

Q5: What kind of electric engine parts need to be taken out after a certain number of hours or flights?
C. Life limited parts like bearings with low-cycle fatigue

Q6: Which part is mentioned as critical, but not necessarily life limited, in electric engines?
A. The propeller

Q7: What does the safety analysis process aim to do in electric engine design?
B. Identify what could go wrong and reduce hazard risks

Q8: What kind of events can block cooling systems in electric aircraft?
C. Bird strikes, hail, or ice

Q9: What must happen if there's structural damage to a cooling system?
C. It should not lead to any hazardous engine behavior

Q10: What is the takeaway message about engine safety and design?
B. That safety must be ensured in real conditions like failure and ingestion

4. Endurance and Durability Testing in ASTM F3338-24

Q1: What is the primary goal of endurance and durability testing for electric engines?
A. To ensure no unsafe condition develops during the engine's life or between overhauls

Q2: What does vibration testing aim to confirm?
B. That any vibration encountered is within acceptable limits

Q3: What must be proven during the over torque test?
A. That the engine can keep running without maintenance at over torque levels

Q4: What is a key requirement of the over temperature test?
C. Operation until steady-state plus one hour, with magnets within limits

Q5: What is the main purpose of calibration tests?
B. To establish power characteristics across operational ranges

Q6: What types of functions are included in operation testing?

C. Powering on, idling, accelerating, and over speeding

Q7: What does the power response test assess?
B. The engine's ability to increase from minimum to peak power without damage

Q8: When are rotor locking tests performed?
B. If the engine has a rotor-locking feature that must be tested under torque

Q9: What happens during the teardown inspection?
A. The engine is fully disassembled and inspected post-testing

Q10: What is the focus of containment testing?
C. Assessing energy and path of any fragments from rotating component failures