Federal Aviation Administration Frangibility Guidebook

Version 1.0

Photo: Impact Testing of Approach Light System (ALS) Tower at MIRA Ltd Facility in the United Kingdom

U.S. Department of Transportation
Federal Aviation Administration

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16. Abstract

The Federal Aviation Administration (FAA) is responsible for the safe design and operation of our nation's airports and air transportation system. One area of concern is the proper selection and installation of frangible support structures that provide essential equipment to sustain the safe operation at each airport. Further definition and clarification is needed for manufacturers, suppliers, and airport authorities to comply with frangibility safety standards. The FAA developed this guidebook to assist in the compliance to these standards and provide additional clarification and direction for products currently governed by the National Cooperative Highway Research Program Report 350, "Recommended Procedures for the Safety Performance Evaluation of Highway Features" and the American Association of State Highway and Transportation Officials' "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals."

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LIST OF SYMBOLS AND ACRONYMS

C	Celsius
cm	Centimeter
F	Fahrenheit
fps	Frames per second
ft	Feet
ft lb	Foot pound (unit of work)
F_w	Force of wind
in.	Inch
kg	Kilogram
kHz	Kilo Hertz
kJ	Kilo Joule
kN	Kilo Newton
km/hr	Kilometers per hour
lb	Pound
lbf	Pounds-force (unit of force or weight)
lb-ft	Pound-feet (unit of torque)
m	Meter
mm	Millimeter
mph	Miles per hour
ms	Millisecond
m/s	Meters per second
N-m	Newton meters
AC	Advisory Circular
ACRP	Airport Cooperative Research Program
ALS	Approach lighting system
ANSI-TIA	American National Standards Institute/Telecommunications Industry Association
ASTM	American Society for Testing and Materials
EB	Engineering Brief
EMAS	Engineered Materials Arresting Systems
FAA	Federal Aviation Administration
FRP	Fiberglass-reinforced plastic
GRP	Glass-reinforced plastic
IAW	In accordance with
ICAO	International Civil Aviation Organization
ILS	Instrument landing system
LIR	Low-impact resistant
NCHRP	National Cooperative Highway Research Program
NRC	National Research Council
PAPI	Precision approach path indicator
REIL	Runway end identifier lights
ROFA	Runway object-free area
RSA	Runway safety area

SLIR	Small low-impact resistant structures
TRB	Transportation Research Board
TSA	Taxiway safety area
USA	United States of America
USAF	United States Air Force
UV	Ultraviolet

EXECUTIVE SUMMARY

In response to airport manager requests for direction in compliance with frangibility standards, the Federal Aviation Administration (FAA) initiated a project to define frangibility and develop a guidebook to assist airport managers in the area of frangibility. The research focused on impact testing and finite-element simulations to determine the critical areas of frangibility and how to comply. This research provided the initial version of a guidebook with the intent of future revisions as future studies and research programs are conducted.

This "Federal Aviation Administration Frangibility Guidebook" provides information for airfield product manufacturers both in the design of their products as well as the testing and qualification thereof. This guidebook is intended to be used by engineers, airport designers and consultants, airfield approval authorities, manufacturers, test facilities, and third-party certifiers. The focus of this guidebook is on products that are located within the runway safety area and the taxiway safety area. Frangible objects should be utilized throughout the airfield whenever possible.

The project that is the subject of this report was a part of the Airport Cooperative Research Program (ACRP), conducted by the Transportation Research Board (TRB) with the approval of the Governing Board of the National Research Council (NRC).

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the TRB and approved by the Governing Board of the NRC.

CHAPTER 1—INTRODUCTION

1. INTRODUCTION

The Federal Aviation Administration (FAA) is responsible for the safe design and operation of our nation's airports and air transportation system. One area of concern is the proper selection and installation of frangible support structures that provide essential equipment to sustain the safe operation at each airport. Further definition and clarification is needed for manufacturers, suppliers, and airport authorities to comply with frangibility safety standards.

2. PURPOSE AND SCOPE

This guidebook has been developed by the FAA to assist in the compliance to these standards and provide additional clarification and direction for products currently governed by the National Cooperative Highway Research Program (NCHRP) Report 350 [1], and the American Association of State Highway Transportation Officials (AASHTO) standard specifications [2]. This guidebook does not purport to address all safety problems associated with its use or all applicable standards and it is the responsibility of the user of this guidebook to determine the applicability of regulatory limitations before its use.

3. BACKGROUND

A Pan American World Airways, Boeing 747-121, N747PA, operating as Flight 845, struck the approach light system (ALS) structure at the departure end of Runway O1R while taking off from the San Francisco International Airport on July 30, 1971, at 15:29 Pacific Daylight Time. Two passengers were seriously injured by parts of the ALS structure that penetrated the passenger compartment, and 27 other passengers were injured during the evacuation after the aircraft had landed. The aircraft sustained major structural damage to the fuselage and empennage, and three of the four hydraulic systems were disabled. [1 and 2]

Following the FAA investigation, it was apparent that ALS structures could be designed to break way if struck by an airplane, reducing the risk to the aircraft and passengers. Research was conducted to develop and test more frangible ALS structures. This was the first of several tests conducted by the FAA from 1972 until 1979. Early tests focused on the aluminum structures, but soon researchers discovered the use of fiberglass materials for making a stiff structure with break-away joints. Multiple designs were tested until 1979, when the FAA settled on one design that has been used from then to the present. In addition to the development of frangible ALS structures, other frangible connections were developed as well, such as frangible couplings and fuse bolts.

Interest in frangibility began to spread internationally; in May 1983, the first meeting for the Frangible Aids Study Group was held in Montreal, Canada. Participants included both private industry and government representatives. Discussions focused on previous frangible studies that had been conducted and potential future studies that need to be accomplished. Two frangible ALS structures were in operation at this time: a glass-filament, reinforced, epoxy-resin structure in the United States of America (USA) and a low-mass, aluminum-tube structure in Sweden.

Over the next 10 years, the Frangibility Aids Study Group held five additional meetings, each presenting more data from tests performed on new structures. Organizations such as Netherlands Aerospace Centre, Exel of Norway, Latix of Sweden, Millard Towers, and Transport Canada, all contributed resources to study and test a variety of frangible structures. These organizations operated rather independently of each other, and therefore each test setup was quite different. There was no standard for the vehicle, the impactor, or the instrumentation used, and thus comparing data from one test to another was inconclusive. However, these tests provided valuable insight for establishing frangibility standards that could be used to regulate the types of products installed near commercial and military runways. From this data, the FAA generated Advisory Circulars (AC) 150/5220-23 [3] and AC 150/5345-45 [4] and the International Civil Aviation Organization (ICAO) produced "Aerodrome Design Manual, Part 6: Frangibility" [5], which provided information on how to design and test ALS structures to meet frangibility standards.

In recent years, the United States Air Force (USAF) and the FAA reexamined the topic of frangibility in hopes of answering some of the questions that continue to arise from the airfield community. Much of the focus for frangibility testing in the past has centered on the ALS structures; however, there are many other types of structures near runways, including the instrument landing system (ILS) glideslope tower, which pose significant risk to aircraft. The Joint Airfield Frangibility Study Group was formed with the main objective of establishing a standard test system that could be used to test all frangible airfield products as well as clarifying current standards. The test system was designed, built, and tested in 2014, and has since performed over 60 tests on airfield products including ALS structures, ILS glideslope towers, and smaller structures, such as the end-fire glideslope pedestal [6]. These tests, as well as historical data, were used as the basis for this guidebook. More research, testing, and case studies still remain to be completed, and as work progresses, this guidebook will be updated to reflect the latest developments.

4. HOW TO USE THIS GUIDEBOOK

This guidebook is designed to define and clarify current ACs produced by the FAA. Chapters 2 through 5 detail specific design and test considerations needed to define frangibility for that specific airfield product. These requirements vary based on the structure's height and intended use. Not all airfield structures are addressed in this guidebook, so the designers, manufacturers, and end users should use best engineering practices to determine the most applicable section to reference until further revisions of this guidebook are made.

CHAPTER 2—GENERAL COMMENTS ON FRANGIBLE CONNECTIONS

1. INTENT

AC 150/5300-13 [7] was established to provide guidance on the use of frangible connections implemented in support structures. This AC provides the FAA standards for airport design and refers to AC 150/5220-23 [3], which provides the standards for frangibility design. AC 150/5220-23 establishes general requirements for all airfield structures and refers to several other ACs for more specific requirements pertaining to those products.

2. FRANGIBILITY CONCEPTS

There are many variables that affect how a structure will react when impacted by an aircraft. From the information gathered from historical and recent testing [6], there are four main frangibility concepts that should be understood.

- Mass of structure
- Impact location relative to frangible connection
- Rigid vs soft impactor
- Design of structure

2.1 Mass of Structure

Recent case studies [6] indicate the mass of the structure is directly related to the amount of damage to the aircraft. Using finite-element simulations and comparing the impacts to a specific mast/tower where the mass per linear foot is changed, the resulting energy transfer to the aircraft increases and decreases according to the mass. These simulations also demonstrated that having a frangible connection at the base of a post versus having a rigid non-frangible connection made very little difference on the overall energy imparted to the impacting object, confirming the acceleration of the mass of the mast/tower causes the most damage to the aircraft. Simulations show the mass per linear foot should be at or below 2 pounds per foot (lb/ft) (3 kilograms per meter (kg/m)) [6].

2.2 Impact Location Relative to Frangible Connection

The distance from frangible connections can have a significant influence on the frangibility of the structure. The closer the impact occurs to the frangible connection, the faster the activation of the frangible design causing a reduction in the force and energy imparted to the aircraft. This applies both to intermittent connections along the structure as well as frangible connections at the base. Full-scale impact tests and finite-element simulations have shown that a properly installed frangible fuse bolt or coupling will not shear as designed when the mast/tower is impacted 3 feet (ft) (1 meter (m)) or more above the bolt/coupling. It is therefore important to have as many frangible connections on a structure as practicable.

2.3 Rigid vs Soft Impactor

Impactor rigidity changes the failure mode of the structure, which in turn affects the energy imparted to the aircraft. Depending on where the airfield structure impacts the aircraft, the rigidity changes. A rigid impact was thought to be a conservative test setup, but further testing has shown this not to be the case. Rigid impacts activate frangible connections much faster than a soft impactor does, reducing the total contact time between the obstacle and the aircraft. This changes the failure mode and reduces the overall energy imparted to the aircraft. Soft impactors absorb more energy, delaying the time to break the frangible structure, therefore increasing the contact time and transferring more energy to the aircraft. [6]

2.4 Design of Structure

Current airfield structures are primarily designed using steel, aluminum, or fiberglass-reinforced plastic (FRP) materials. The material chosen as well as the design of the frangible connections has an influence on the overall frangibility of the structure. Due to the large mass, per-length, steel structures generally are not frangible, posing a serious risk not only to small aircraft, but to large aircraft as well. Aluminum structures have less mass, but with no break-away joints, they pose a high risk of wrapping around the aircraft and potentially causing loss of control. This is due to the aluminum not yielding during an impact scenario. This problem is accentuated with an increase in mass located at the top of the structure, typically from lights or electronic equipment [8]. Some FRP structures exhibit the same wrap-around problems, but properly designed FRP mast/towers can tear through near the point of impact reducing the damage compared to aluminum structures of similar design. Having frangible joints is essential in all cases to allow a windowing effect during impact. When the structure breaks into segmented pieces, the amount of mass moved out of the way by the aircraft can be significantly reduced. This is referred to as windowing, and will produce the lowest energy transfer based on the current designs and test data available.

Other factors and variables were tested and studied, such as height of the tower, mass of the impactor, frangible mounts for airborne impacts, mass at the top of the structure that windows during impact, and impact speed. It was found that although these variables are important, they had a minimal effect on the potential damage to an aircraft as compared to the four listed above. [6]

3. IMPACT FORCE AND ENERGY

The force and energy discussed throughout these specifications are related to the force applied to the aircraft and the energy being transferred from the aircraft to the obstacle. The term energy can have many different forms and is clarified in section 3.2 of this chapter.

3.1 Impact Force

When an aircraft collides with an obstacle, there is a large dynamic force applied to both objects. For impacts at speeds of 87 miles per hour (mph) (140 kilometers per hour (km/hr)) (75.6 knots), the duration of the force can occur between less than 30 milliseconds (ms) (10 times faster than the blink of an eye), or as much as 100 ms, depending on the rigidity of the impactor and the stiffness of the test structure. The magnitude of the force is not as important as the duration. A large spike in force over a very small time frame may do little or no damage to the aircraft and have little or no effect on its loss of momentum; whereas the opposite, having a small force for a long period of time, may do significant damage and alter the flight path of the aircraft. Typically, the maximum force occurs at the initial impact and is referred to as the peak force. The maximum peak force is difficult to capture due to its short duration along with the vibrations initiated in the test system, making it highly unrepeatable.

3.2 Impact Energy

The generic term energy has been used as a defining criterion in frangibility specifications; however, it can be confusing. It is very difficult to give a comprehensive definition to energy due to its many forms. One form of energy closely related to these types of impacts is called work energy, which is a force applied to an object as it moves over a defined distance. For example, there is work energy applied on the obstacle as it is pushed out of the way by the aircraft; however, this work energy does not directly correlate to the energy loss of the aircraft due to the many other forms of energy transfer taking place, such as the crushing of the obstacle and the aircraft (plastic and elastic deformation and strain energy), friction energy, and vibration energy (dynamic ringing). There have been attempts to determine the energy transfer by use of the Conservation of Energy method[1]; however, measuring the change in velocity accurately enough is impractical. This method is highly sensitive to the velocity value and a small error in the velocity measurement can result in a large error in the energy value. Given the limitations of test equipment, the simplest method to determine the energy transfer is to integrate the force with respect to distance and multiply by the velocity. By assuming a constant velocity throughout the impact, this value becomes a multiplier of the impulse. To clarify the energy value (E_c) used throughout these specifications, the impulse value (I_x) is scaled up by multiplying it by the recorded velocity at the point of impact (V_x)

$$I_X(t) = \int_{t=0}^{t} F_X(t)\, dt$$

where $F_x(t)$ is the sum of force data from all load cells in the X-direction as a function of time.

$$E_C(t) = V_X \times I_X(t)$$

It is important to be aware of the limitations when calculating impact energy this way. It is considered work energy, and therefore distance is a key variable. In a perfectly elastic collision, both objects will travel the same distance while they remain in contact with each other creating a constant distance. This is not a perfectly elastic collision, and the distance is not a constant. Figure 1 shows an airplane wing hitting a pole. The work energy applied on the pole equals the force multiplied by the distance, or how far the pole is pushed while in contact with the wing.

[1] In physics and chemistry, the law of conservation of energy states that the total energy of an isolated system remains constant; it is said to be conserved over time. This law means that energy can neither be created nor destroyed; rather, it can only be transformed or transferred from one form to another.

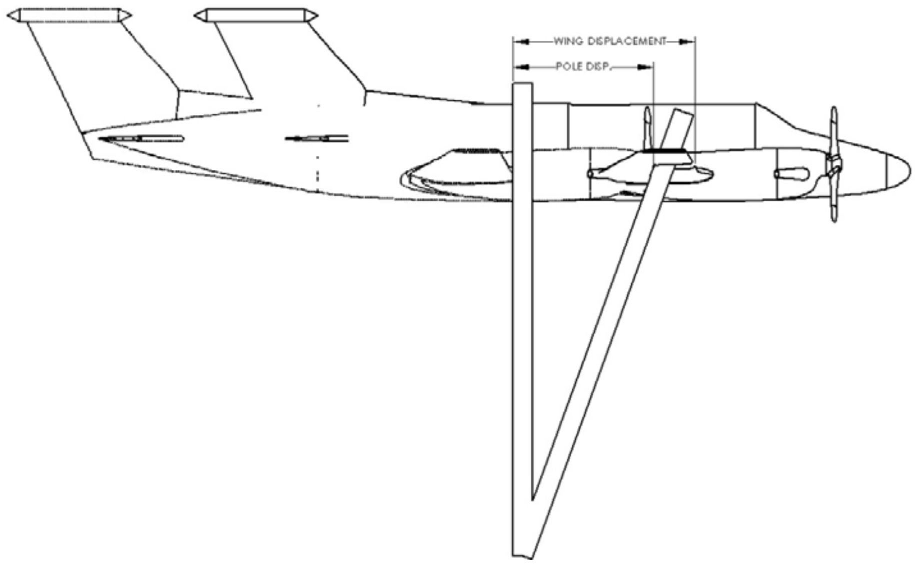


Figure 1. Error in Energy Calculation Due to Wing Crush

As figure 1 shows, there is a difference between the distance traveled by the wing and the pole. When performing tests on products, the force data and time data are based on the displacement of the test vehicle, which does not take into account how much the product may crush into the impactor. This inherently induces an error into the energy calculation, and that error will be different for every product [6].

Additionally, using this method to calculate energy can only be done in the direction of the impact. Energy pulling the wing down cannot be calculated since there is no way to measure the distance traveled along that path.

Measuring energy on a subscale test and simulation level does not often translate to the full-scale level and therefore is not valid for product approval. Measuring all other forms of energy during an impact is impractical; therefore, the test methods should be clearly defined to ensure all manufacturers follow the same methods for product approval.

4. PERFORMANCE STANDARDS

This section addresses performance standards for frangible connections incorporated in FAA advisory circulars.

4.1 Frangibility Requirements

Tests indicate that structures no taller than 40 ft (14 m) may be impacted by a grounded aircraft that is taxiing or during a runway overrun [4]. These structures may have some built-in frangible joints, but most likely they will rely on frangible connections at the base. Typical speeds for an aircraft on the ground are around 31 mph (50 km/hr) (26.9 knots). In the event of an accidental impact, the structure will collide with the landing gear or nose, the leading edge of the wing, or a combination of such. It is implied that the force and energy limits are applicable to all structures unless otherwise specified in an AC. Most sublevel ACs addressing frangibility only address static force requirements and not dynamic force requirements, which are very different [9 and 10]. However, AC 150/5345-45 [4] is the exception to this, because it only applies to tests for airborne impacts. The 13,000 pounds force (lbf) (58.0 kilo Newton (kN)) limit should therefore apply to all other structures except the low-impact resistant (LIR) structures. Testing has been performed on a variety of different structures, and recommended requirements for individual structures are given in the final report. [6]

A frangible point no greater than 3 inches (in.) (7.6 cm) above the surrounding grade is also specified for all structures, which applies to ground-borne impacts. The 3-in. (7.6-cm) rule is used by the Federal Highway Administration and is a good guide for allowing vehicles to pass over obstacles still firmly attached to the ground. There is no need for this requirement if the aircraft is airborne.

The frangibility requirements in AC 150/5220-23 [3] are not clearly listed in one location; therefore, these frangibility requirements and their approval methods are listed in table 1. These approval methods and related procedures are provided in sections for specific products.

Table 1. Frangibility Requirements

Requirement Number From AC 150/5220-23 [3]	Requirement	Approval Method
Para. 2.2, f, (1)	Effective failure mechanisms to allow the structure to break, distort, or yield and not wrap around.	Test
Para. 2.2, f, (2)	Low-mass segments of predictable size that will not present a hazardous secondary impact.	Test
Para. 3.2, c, (1), (a)	Withstand environmental and jet blast loads, but will break, distort, or yield when impacted by a 6600-lb (3000-kg) aircraft at 31 mph (50 km/hr or 26.9 knots) on the ground or airborne at 87 mph (140 km/hr or 75.6 knots).	Test
Para. 3.2, c, (1), (b)	Should not impose a peak force greater than 13,000 pounds force (lbf) (58.0 kN) or impart energy greater than 40,500 lb ft (55.0 kilo Joule (kJ)) to the aircraft during a contact period of 100 ms.	Test
Para. 3.2, c, (1), (c)	Provide a frangible point 3 in. (7.6 cm) or less above surrounding grade.	Inspection
Para. 3.2, a	Electrical cable and other components should not entangle with or wrap around the aircraft.	Test
Para. 3.2, h	Electrical cable should not rupture the conductor but disconnect at predetermined points.	Test

4.2 Environmental Requirements

Environmental requirements are, for the most part, specified in the individual ACs for each structure. General environmental requirements and their approval methods applicable to all structures are given in table 2.

Table 2. Environmental Requirements

Requirement Number From AC 150/5345-45 [4]	Requirement	Approval Method
Para. 3.3. Para. 4.2	Frangible connections should withstand wind, ice, and other environmental loads.	Analysis
Para. 3.3.1 Para. 3.3.6 Para. 3.11 Para. 4.2.4 Para. 4.2.6	Structure should be able to withstand direct loads and fatigue loads while minimizing vibration and deflection.	Analysis
Para. 3.4 Para. 3.5	Materials used should withstand and protect against temperature fluctuations, solar radiation, vibration, salt spray, humidity, and corrosion.	Test

4.3 Maintenance Requirements

When maintenance equipment for frangible structures is out of reach, some type of support equipment (such as a ladder, lift system, or stand) is required to access it. Occasionally, this support equipment requires maintenance and servicing. Maintenance requirements focus specifically on how support equipment might affect frangibility. Only a few maintenance requirements are mentioned, and some clarification may be helpful.

- In most cases, ladder systems will decrease the frangibility of the structure due to the additional mass as well as the strength of material required to support a climber. There may be some exceptions to this; however, approval can be granted for such systems. One example of an approval would be a lift or climbing system that attaches to the base of the structure and extends up to the equipment only when maintenance is required. When not in use, the system remains retracted and out of the area of possible collision from an air borne aircraft.

- Portable maintenance stands are good for maintaining frangible requirements because they can be moved out of the runway safety area (RSA) and taxiway safety area (TSA). However, portable stands sometimes can be difficult to transport or store when not in use.

- Permanently fixed maintenance stands may be necessary and designed with a focus on keeping the mass as low as possible with as many frangible connections as possible. Advancements in composites and plastics technology make these materials the preferred choice; therefore, in most cases, they are favored over any type of wood.

5. TYPES OF FRANGIBLE CONNECTIONS

Frangible connections should be designed to handle the operational and environmental design loads for the structure, but these connections can fracture or break at impact. Frangible connections work best when the structural member has low mass and high stiffness. This more effectively transfers the impact forces/energy to the connections, causing them to quickly separate, and allowing the aircraft to pass through. A wide variety of connections are currently in use on airfields, and others are continuing to be developed. Some connections were tested as part of the frangibility study, and others still need to be tested. Table 3 lists the known frangible connections along with the advantages and disadvantages of each.

Table 3. Types of Frangible Connections

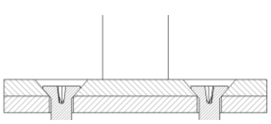
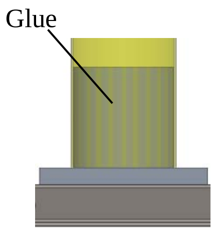
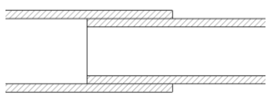
Frangible Connection	Illustration	Description	Advantages	Disadvantages
Fuse Bolt/ Neck-Down Bolts		Bolts designed to break at a specific tensile load by reducing the diameter at a point on the bolt shank. These connections are typically located between the structure and the foundation.	– Shear strength maintained – Predictable/ repeatable – Variety of different sizes available – Two products currently FAA approved	– Susceptible to fatigue failure and corrosion – Due to location, may not reach failure loads if impact occurs too far from connection
Special Material Bolts		Bolts engineered with specific materials to fail at a given load. Should have a certificate to guarantee compliance of physical properties.	– Eliminates the need for machining to reduce diameter	– Difficult to periodically inspect for corrosion or fatigue – No FAA-approved products
Frangible Couplings		Cylindrical couplings with a reduced circumference or cross-sectional area in a specific area to reduce strength at that point. Typically located between structure and foundation.	– Eliminates the need for heavy base plates on small posts, masts, and tubing – Variety of different sizes and types available	– Susceptible to fatigue failure and corrosion – Due to location, may not reach failure loads if impact occurs too far from connection – No FAA-approved products
Tear-Through Fasteners		Fasteners, such as countersunk rivets, designed to tear through the base material when dynamically loaded. Can be used with slip joints.	– Decrease mass being pushed by impactor – Good for tension or bending failure	– High-tolerance machining process – Extensive quality inspection – No FAA-approved products
Tear-Out Sections	None available	Gusset plates designed with notches that will tear out during a dynamic impact. Fasteners do not fail, but are used to pull out a section of the gusset plate.	– Decrease mass being pushed by impactor – Minimize deflection in the structure	– Susceptible to fatigue failure – High tolerance machining process – No FAA-approved products

Table 3. Types of Frangible Connections (Continued)

Frangible Connection	Illustration	Description	Advantages	Disadvantages
Glued Joints		Type of slip joint where adhesive is added to provide extra strength during normal use. Can be used at base of structure or throughout the structure.	– Variety of adhesives available with different strengths – Not susceptible to corrosion – Low maintenance	– Inconsistent failure based on application of adhesive and environmental conditions – No FAA-approved products
Friction Joints		Friction joints can supply high strength normal to sliding surface, but slip when force is applied parallel to surface.	– Designs can be simple and easy to install – Low maintenance	– Inconsistent failure based on impact scenario – Separation force may change over time with cyclic loading – No FAA-approved products
Swing-Away or Frangible Support Members		Support members incorporated into a structure providing stability. During an impact, these members will break or swing free, leaving it unstable.	– Provides high stability to structures requiring low amounts of deflection	– May require large amounts of mass to be moved by the impactor – No FAA-approved products

6. QUALIFICATION REQUIREMENTS

This section addresses qualification requirements for frangible connections.

6.1 Selection, Installation, Inspection, and Maintenance

AC 150/5220-23 [3] addresses two primary factors used in selecting frangible connections for supporting equipment in airfield safety areas. In summary, they are

- devices approved in accordance with (IAW) current ACs and this guidebook, and
- rated shear strength of connections that should not exceed frangibility design requirements.

Many of these frangible connections have no established standard test setup and can react very differently depending on the impact scenario to which it may be subjected. Based on historical research, testing, and computer simulations, shear strength does not apply proportionately to the force required to move an object out of the path of an aircraft [6]. Many factors have an effect, such as the mass, stiffness, distance from the frangible connection, and speed of impact. It has also been shown that dynamic forces are very different than static forces and result in very dissimilar results. Determining which frangible connection to use can often be narrowed through the use of computer simulation; however, it is recommended that the final design still be tested according to the current ACs and this guidebook. The following questions and answers can help guide the selection process when considering frangible connections. Further commentary is included with each item on the list as appropriate.

How large is the mass and height of the structure?
Mass might be the dominant factor, and the frangible connection will only make a small difference. In this case, it would not be as critical to choose a connection that has a small margin between the working load limit and the frangible load limit. A frangible connection on a structure with small mass will play a much larger role in keeping the impact forces low.

Can computer simulation be used?
For connections with standard metallic materials, such as fuse bolts and couplings, computer simulations are quite simple to perform and provide fairly accurate results. Composite materials, glued joints, and friction joints are more complex, but computer models can still provide a general understanding of the connection.

How many frangible connections are needed?
If there is one connection at the base, that would dictate a certain design verses multiple connections along the structure. Some connections are more effective in specific locations than others.

Will the frangible connections be located at the base or on the structure, above or below grade?
Location is important not only for the design but also for frangibility. Putting frangible connections near areas of expected impact makes a large difference. When possible, heavy metal base plates should be mounted below the 3 in. (7.6 cm) above-grade requirement.

Are there deflection requirements for the structure?
Certain frangible connections, such as guy rods, are better suited for supporting the structure. These types of connections add extra mass and should not be used if possible; however, they might be a good alternative to adding more mass to the main structure. In some cases, adding these connections can actually reduce the net mass of the structure.

Would the structure fall into a ground-borne or airborne impact?
Some structures may be subject to both tests, but if the structure is short and will only be impacted by an aircraft or vehicle that is already on the ground, then there would be no need to consider an airborne impact. Products between the heights of 20 to 40 ft (6 to 14 m) will need to be tested in both regimes. This should be considered in the design and selection of frangible connections.

What is the expected cost and maintenance?
This may be a concern and should be considered. If the structure is located in an area that is difficult to reach, lower maintenance connections may be a high priority. Maintenance can be costly if needed frequently. It also increases the risk of malfunction if maintenance schedules are not followed. Structures may fail in a wind storm or not break if hit by an aircraft due to improper maintenance.

What types of environmental conditions are expected?
Some connections will not do as well with high fatigue loading and therefore would not be suitable in high wind areas or frequent jet blast areas. Highly corrosive environments, such as high humidity or salt spray, would not be favorable for metallic connections. Fiberglass composites, plastics, or glued connections may be preferred for these areas, where dry areas with constant sunshine may not be ideal for these materials due to ultraviolet (UV) degradation.

6.2 Testing Categories

As explained in Paragraph 2.4.1 of AC 150/5220-23 [3], all products will need to meet the requirements in either ground-borne, airborne, or both testing categories. In the past, products that were likely to be hit by an aircraft on the ground were referred to the NCHRP report 350 [1] for testing procedures. This guidebook provides testing guidelines for ground impact tests.

CHAPTER 3—SMALL LOW-IMPACT RESISTANT STRUCTURES

1. INTRODUCTION

Chapter 3 includes FAA guidance on small low-impact resistant (SLIR) structures and adapts guidance from AC 150/5345-45 [4] for use with AC 150/5345-44 [9] and AC 150/5345-46 [10] and other small airfield fixtures with or without individual ACs.

2. INTENT

AC 150/5345-44 [9] focuses on the design requirements for runway and taxiway signs that can be hit by aircraft while transitioning from terminal to runway or during a runway excursion. AC 150/5345-46 [10] focuses on the design requirements for runway and taxiway lights that can be hit by an aircraft while transitioning from terminal to runway or during a runway excursion. The design requirements apply specifically to the structure supporting the taxiway and runway lights, signs, and other systems within the airfield environment. Testing requirements provide information for setting up and performing the standard test methods for FAA approval. It is recommended that full-scale testing be performed for all products seeking approval. Previous studies have shown subscale testing or static testing is not sufficient for determining frangibility of structures [6].

3. CLASSIFICATION

The current specifications divide ground structures into numerous classifications and modes of signs and lights. For example, Paragraphs 1.2.1 through 1.2.5 of AC 150/5345-44 [9] describe types, sizes, and classifications of signs; while Paragraphs 1.2.1 through 1.2.4 of AC 150/5345-46 [10] describe types, classes, modes, and styles of runway and taxiway lights. Specific classifications and modes of signs, lights, and airfield structures should be determined from the appropriate sections of the system-specific AC.

4. END-FIRE GLIDESLOPE

This section provides guidance from AC 150/5220-23 [3] and AC 150/5345-45 [4] as they pertain to structures similar to the end-fire glideslope (FAA-E-2970) antenna array [11]. No AC currently exists detailing the specific environmental or frangibility requirements for this system.

4.1 Design Requirements

The end-fire glideslope does not have a system-specific AC. All pertinent design requirements for the end-fire glideslope antenna structure are identified in this section. Additional information on LIR design and application may be found in AC 150/5345-45 [4] and 150/5220-23 [3]. Methods for product approval should be approved by an independent, third-party certification body (per AC 150/5345-53 [12]).

4.1.1 Fabrication, Assembly, and Installation.

Information and guidance on standards for fabrication, assembly, and installation (such as materials, hardware, finishes, wiring, packaging, shipping, and foundations) is detailed in subsections 4.1.1.1 through 4.1.1.6 of this chapter. Testing is not required for validation, but approval by inspection from a third-party certification body (per AC 150/5345-53 [12]) is required. All requirements listed in AC 150/5220-23 [3] and AC 150/5345-45, Sections 3.3, 3.4, 3.5, and 3.9 [4] related to this subject are presented in this section below.

4.1.1.1 Packaging and Shipping

The following is a list of packaging and shipping guidelines for fabrication, assembly, and installation standards.

- When packages are shipped, they should be supplied complete with all accessories, including mounting base, adjusting and connecting hardware, and installation instructions.
- Product manual should be provided that includes all necessary procedures for unpacking, assembly, installation, operation, recommended maintenance practices, and a complete parts list.
- Structures should be properly packaged to protect small parts and prevent damage and deterioration during shipment.
- Structures should be made in sections to provide easy shipment and handling.
- All containers should be clearly marked for content, type, class, and height of the structure.
- Components should be identified on the package labels if shipped in more than one container per American Society for Testing and Materials (ASTM) D3951 [13].

4.1.1.2 Fabrication

The following is a list of guidelines for fabrication standards for SLIR structures.

- LIR structures and members should not have sharp edges that could be hazardous during handling or any other irregularities that could interfere with fit and assembly.
- All bonding areas should be sandblasted and/or cleaned with a solvent before applying a structural adhesive.
- Exposed surfaces should be free from grease, oil, dirt, scale, flux, and chemicals that are deposited during the fabrication process.
- Drilled holes and cut edges of glass-reinforced plastic (GRP) members should be coated with the same material as the original resin.

4.1.1.3 Design and Assembly

The following is a list of guidelines for design and assembly standards for SLIR structures.

- Sections should be designed for rapid field assembly without the use of special tools or welding.
- Mass of structure should be minimized while meeting all other requirements. The mass per unit length should be 2 lb/ft (3 kg/m) or less.
- Manufacturer should supply equipment necessary to service the product.
- Structure should be designed for routing electrical wires in enclosed wireways to antenna and should be part of the frangible design.

4.1.1.4 Hardware

The following is a list of hardware guidelines for fabrication, assembly, and installation standards for SLIR structures.

- All stainless steel connecting hardware components should be 18-8 stainless steel.
- Aluminum, GRP, and carbon-steel hardware is permissible.
- All high-strength carbon-steel bolts, nuts, and hardened steel washers should be suitable for the application and should comply with ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17].
- All ferrous metal parts (non-stainless steel) should be hot-dip galvanized after fabrication per ASTM A123 [18]. Ferrous hardware (nuts, bolts, washers, and other minor items) should be galvanized by the hot-dip method conforming to ASTM A153 [19].

4.1.1.5 Materials

The following are material guidelines for fabrication, assembly, and installation of SLIR structures.

The materials used for LIR structures are critical components for compliance with all requirements. The materials specified in Section 3.4 of AC 150/5345-45 [4] are currently approved for use; however, new materials may be developed that will also be approved in the future. The materials chosen should have a high strength-to-weight ratio as well as the ability to withstand harsh environmental conditions.

Table 4 provides a reference for the materials and finishes specified in AC 150/5345-45. Aluminum materials are required to be anodized according to the current specification. In addition, AC 150/5345-45 requires structures (including aluminum structures) to be painted the color orange 12197, per FED-STD-595 [20]. Table 4 lists the acceptable procedures for painting anodized aluminum in accordance with references 14 through 26.

Documentation should be provided to a third-party certification body (per AC 150/5345-53 [12]) showing the materials used in the structure and the finishes applied (see chapter 4 §4.3 of this guidebook). Visual inspections will also be performed for verification.

Table 4. Materials and Finishes for SLIR Structures

Application From AC 150/5345-45 [4]	Material Description	Finish
Structures (Hardware) Para. 3.4.1 Para. 3.5.2 Para. 3.5.3	Aluminum 6061-T6, 6061-T6511 per AA ASD-1 [21]	All aluminum structures should be anodized IAW MIL-A-8625 [22] Type II, Class I Matte Finish Paint IAW AAMA 2603-98 [23] MIL-PRF-85285 [24] FED-STD-595 [20] MIL-P-85582 [25].
Structures Para. 3.5.2	Aluminum casting should be A356-T6 per AA ASD-1 [21].	All aluminum structures should be anodized IAW MIL-A-8625 [22] Type II, Class I Matte Finish Paint IAW AAMA 2603-98 [23] MIL-PRF-85285 [24] FED-STD-595 [20] MIL-P-85582 [25].
Structures Para. 3.5.1	Carbon steel	Hot-dipped galvanized per ASTM A 123 [18].
Hardware Para. 3.4.3	Stainless steel 18-8	None
Hardware Para. 3.4.4 Para. 3.5.1	Steel per ASTM A325 [14], A194 [15], A563 [16] and F436 [17]	Hot-dipped galvanized per ASTM A 153 [19]
Structures Para. 3.4.2 Para. 3.5.3	GRP	Paint IAW AAMA 2603-98 [23] MIL-PRF-85285 [24]
Accessories Para. 3.4.6	Rubber per ASTM D1149 [26]	None

4.1.1.6 Installation

Installation of LIR antenna structures should comply with the following requirements:

- Base of each structure should be secured to a foundation, normally concrete per AC 150/5345-45 Paragraph 3.13 [4] using approved frangible connections per AC 150/5220-23 Chapter 4 [3].

- Leveling of each structure should be by simple adjustments.

- Foundation should be flush with grade when possible but should comply with the 3-in. (7.6 cm) frangibility rule specified in AC 150/5220-23 Paragraph 3.2 [3] when located in the RSA or TSA.

- A copper lug sized for a #6 ground wire connection should be provided and secured to the structure base per AC 150/5345-45 Paragraph 3.14 [4].

- No electrical wires are allowed to be exposed, and they should be enclosed in wireways that are designed as part of the structure per AC 15/5345-45 Paragraph 3.15 [4].

4.1.2 Maintenance

Maintenance of airfield structures is costly and difficult when located in areas near a runway. LIR antenna structures should be designed to minimize maintenance to the greatest extent possible. Antenna structures should be designed for easy access to mounted equipment with no permanent climbing fixture installed that would increase mass and jeopardize frangibility per AC 150/5220-23 Paragraph 3.2.i [3]. The product should demonstrate the proper fit and function of all component parts and be accurately represented in the installation instructions.

4.1.3 Environmental

AC 150/5220-23 [3] does not address environmental factors. New products without a system-specific AC should be developed in accordance with AC 150/5345-45 Paragraph 3.3 [4]. In addition to the weather environment, the requirements for strength, durability, and frangibility should also be met. Aircraft safety depends on the structure's ability to yield or break if an accidental collision occurs. Minimum strength requirements have been established to provide a standard for all manufacturers per AC 15/5345-45 Paragraph 3.9 [4]. These requirements should be approved by means of analysis or testing as shown in table 5 in accordance with references 27 through 30.

Table 5. Environmental Design Requirements for SLIR Structures

Requirement Numbers From AC 150/5345-45 [4]	Description	Approval Method
Wind/Deflection Test Para. 3.3.1 Para. 4.2.4	Structures should be designed to withstand the following velocities (3-second gust per ANSI/TIA*-222, Annex L [27]): up to 75 mph (121 km/hr) (65.2 knots) with 0.5 in. (13 millimeters (mm)) of ice on all surfaces, 100 mph (161 km/hr) (86.9 knots) without ice. A static load calculated from a wind velocity of 60 mph (97 km/hr) (52.1 knots) (3 second gust) and 0.5 in. (13 mm) of ice should be applied perpendicular to the vertical axis of a Type L-891, Style 3 structure (maximum height) that is assembled and installed per actual use. The deflection of the structure should not exceed the values in AC 15/5345-45 Paragraph 3.11 [4]. Permanent deformation of the structure is not allowed.	Analysis
Temperature Para. 3.3.2	The structures, components and all necessary equipment should be designed to withstand temperatures from -67 degrees Fahrenheit (°F) (-55 degrees Celsius (°C)) to 131°F (55°C).	Test MIL-STD-810, Method 501.5, 502.5 [28]
Relative Humidity Para. 3.3.3	The structures, components and all necessary equipment should be designed to withstand any relative humidity from 5% to 100% including condensation.	Test MIL-STD-810, Method 507.3, Proc. II [28]
Sunshine Test (Solar Radiation) Para. 3.3.4 Para. 4.2.3	Structures, components, and equipment using plastic or nonmetallic exterior components should be subjected to a minimum of 56 radiation cycles. Any evidence or deterioration or GRP delamination is cause for rejection.	Test MIL-STD-810, Method 505.5, Para. 4.4.3, Proc. II [28] ASTM G155 [29] ASTM D2565 [30]
Salt Spray Test (Fog) Para. 3.3.5 Para. 4.2.2	Structures, components, and equipment should be designed to withstand exposure to a corrosive salt laden environment. Salt spray testing should be conducted on a section of structure mast, complete with all sections and hardware. Test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, pitting, corrosion (except for sacrificial coatings), or GRP delaminating is cause for rejection.	Test MIL-STD-810, Method 509.4, Para. 4.5.2, Proc. I [28]
Vibration Para. 3.3.6	The components of the LIR structure should be designed so that no component or combination of components (up to and including the entire structure) will vibrate at or near their resonant frequency and exceed the deflection requirements in Paragraph 3.11 when subjected to the wind load requirements in Paragraph 3.3.1 of reference 4.	Test MIL-STD-810 Method 514.6, Para. 4.4.1 Proc. 1, b. [28]

* ANSI-TIA—American National Standards Institute/Telecommunications Industry Association

4.1.4 Frangibility

The structure should be designed with the minimum mass possible while still meeting working loads and environmental requirements. AC 150/5220-23 [3] and Paragraph 3.9 of AC 15/5345-45 [4] delineate the concepts of frangibility for objects located in airfield safety areas. The structure and connections should be frangible when accidentally struck from any direction while causing minimal damage to an aircraft. Specific details for frangible design requirements are provided in table 6.

Table 6. Frangible Structure Design Requirements for SLIR Structures

Requirement Numbers From AC 150/5220-23 [3] and AC 150/5345-45 [4]	Description	Approval Method
AC 150/5220-23 Para. 2.2, f. (1) Para. 3.2, e AC 150/5345-45 Para. 3.1 Para. 3.9, a Para. 4.2.5.2, c, d, f	Effective failure mechanisms to allow the structure to break, distort, or yield and not wrap around.	Test Computer Simulation
AC 150/5220-23 Para. 2.2, f. (2), 3.3, e	Low-mass segments of predictable size that will not present a hazardous secondary impact.	Test
AC 150/5220-23 Para. 3.2, c. (1), (a) AC 150/5345-45 Para. 3.9,b Para. 4.2.4 Para. 4.2.6	Withstand environmental and jet blast loads, but will break, distort, or yield when impacted by a 6600-lb (3000-kg) aircraft at 31 mph (50 km/hr or 26.9 knots) on the ground or airborne at 87 mph (140 km/hr or 75.6 knots).	Test
AC 150/5220-23 Para. 3.2, c. (1), (b) AC 150/5345-45 Para. 3.9, c. Para. 4.2.5.2, a	Should not impose a peak force greater than 13,000 lbf (58.0 kN) or impart energy greater than 40,500 ft lb (55.0 kJ) to the aircraft during a contact period of 100 ms.	Test
AC 150/5220-23 Para. 3.2, c. (1), (c) AC 150/5345-45 Para. 3.9, f	Provide a frangible point 3 in. (7.6 cm) or less above surrounding grade and tested using the base mounting points connected to frangible connections.	Test
AC 150/5220-23 Para. 3.2, a AC 150/5345-45 Para. 3.9 d. 4.2.5.2, e	Electrical cabling should be designed to disconnect so as to not entangle with or impede the aircraft.	Test
AC 150/5220-23 Para. 3.2, h	Electrical cable should not rupture the conductor but disconnect at predetermined points.	Test

4.1.5 Test Requirements

AC 150/5345-45 Section 4 [4], highlighted in chapter 3 §4.1 of this guidebook, specifies design requirements to be inspected and/or testing for approval. The intent is to provide a test procedure that can be used as a standard for all parties seeking FAA approval for their products. This subsection provides the details for setup and execution of these tests as well as data processing and documentation.

4.1.6 Environmental Qualification Procedure and Test Setup

This section provides information for performing the standard environment tests required for FAA approval. Environmental test methods for product qualifications presented in ACs [4, 9, 10, and 31] reference MIL-STD-810 [28] for details on conducting each test (i.e., temperature, humidity, sunshine or solar radiation, and salt spray). The system-specific AC details which environmental tests are required to be performed on each system. An overview of basic environmental requirements extracted from system-specific ACs is presented here. It is recommended that if a system-specific AC exists, the required environmental test parameters for qualification should be verified there for all products seeking approval. If no system-specific AC exists, then AC 150/5345-45 Paragraphs 3.3 and 4.2 [4] should be used for product environmental requirements and qualification.

4.1.6.1 Visual Examination

The FAA-approved, third-party certification body (per AC 150/5345-53 [12]) will make all approvals required in this section. Visual inspections and analysis approval methods will be used for the construction, assembly, and installation requirements; hardware requirements; materials and finishing requirements; and maintenance requirements. Documentation (such as material specification sheets, painting, anodizing, or galvanizing certifications, and calculations for wind loading) should be provided to the third-party certification body.

4.1.6.2 Wind Test

The structures and all necessary equipment should be designed to withstand pressure loading (no permanent deformation) arising from the following wind velocities when installed with all applicable equipment attached. Structures should be designed to withstand the following velocities (3-second gust per ANSI/TIA-222, Annex L [27]): up to 75 mph (121 km/hr) (65.2 knots) with 0.5 in. (13 mm) of ice on all surfaces, 100 mph (161 km/hr) (86.9 knots) without ice. Using ANSI/TIA-222, calculate the design wind load on the structure (F_w) with and without ice. Using the highest force value, perform the wind test by pulling at the midpoint of the structure with a force equal to F_w (as shown in figure 9 in chapter 4 §2 of this guidebook). Verify that force level was achieved and that the structure did not sustain any permanent deformation.

4.1.6.3 Salt Spray Test

The salt spray test should be conducted on a section of the structure, complete with all accessory hardware per MIL-STD-810, Method 509.4 Paragraph 4.5.2, Procedure I [28]. The test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, rust, pitting, corrosion (except for sacrificial coatings), or GRP delamination is cause for rejection.

4.1.6.4 Sunshine (Solar Radiation) Test

The sunshine (solar radiation) test should be conducted per MIL-STD-810, Method 505.4 Paragraph 4.4.3, Procedure II [28], for all structures with plastic/nonmetallic exterior materials. The material should be subjected to a minimum of 56 radiation cycles. Any evidence of deterioration or GRP delamination is cause for rejection.

4.1.6.5 Temperature

The structure should be tested for both high- and low-operating temperature and should sustain no delamination, and there should be no damage to seals or other components. Structures should be tested in accordance with MIL-STD-810, Method 501.3 [28]. Operational temperature should be between 131°F (55°C) and -67°F (-55°C).

4.1.6.6 Humidity

For hot-humid conditions, the structure should be subjected to MIL-STD-810, the moisture resistance test, Method 507.3, Procedure II [28]. There should be no evidence of delamination, cracking, corrosion, or deterioration of any part of the structure after cycling has been completed.

4.1.7 Frangible Qualification Procedures and Test Setup

Paragraph 4.2.5 of AC 150/5345-45 [4] provides the requirements for testing frangible LIR structures. These requirements are best understood when divided into two categories: Test System and test qualification. The test system requirements explain how the test should be set up to create a standard method of testing for all manufacturers. The test qualification requirements explain how the product should perform during the test. These requirements are summarized and listed below.

4.1.7.1 Test System Requirements

Test system requirements for SLIR structures, a photograph of which is shown in figure 2, are as follows:

- Test vehicle should weigh approximately 6600 lb (3000 kg).
- Impact structure should be sufficiently rigid to minimize energy absorption and be designed such that vibration modes do not interfere with load cell data.
- A Piper Navajo nose gear or equivalent should be mounted to the front of the impact vehicle, directly in line with the structure being tested. Steel adaptor plates should be fabricated to transition between the two mounting points on the landing gear and the load cells. Mass of adaptor plates should be minimized yet sufficient to handle impact loads. This can be shown by analysis. Landing gear strut should be serviced according to the

manufacturer's recommendations and be fully operational. Steering horn should be locked in place to not allow the wheel to turn.

- Load cells should attach between the landing gear and the support structure, with one load cell at each landing gear attachment point as shown in figure 3. Load cells should be triaxial, meaning they are able to capture force data in the X, Y, and Z axes, as shown in figure 4 of this guidebook. Force data should be recorded for a minimum of 250 ms.

- Rigid impactor will represent the nose or wing of the aircraft and should be a semicircular mild steel tube, 3.28 ft (1 m) long, 9.8 in. (24.9 cm) diameter, with wall thickness of 0.5 in. (13 mm). The impactor should be supported by a rigid structure and located 43 in. (1 m) off the test track surface and 45.5 in. (115.6 cm) beyond the centerline of the landing gear. The mass of the impactor can significantly affect the data; therefore, it is recommended that the impactor be limited to 3.28 ft (1 m) in length (mounted with two load cells). If a longer impactor is required, a second impactor, with two load cells should be installed in line with the first.

- The test structure should be mounted as installed on the airfield according to the manufacturer's instructions.

- High-speed video cameras should be used to capture the collision that occurs between the impactor and the structure as well as the failure mode of the structure. A high-speed video capture rate of 1000 frames per second (fps) and minimum of 250 ms recorded time is required.

- A data acquisition system should be used to collect instrumentation data such as load cell and accelerometer data. Improvements in technology have made it possible to collect data at much higher rates. A minimum capture rate of 20 kilo Hertz (kHz) is required.

- For grounded aircraft tests, it is required to reach a test speed of 31 ±2.5 mph (50 ±4 km/hr) (26.9 ±2.2 knots). This speed should be recorded at the point of impact. However, current technology does not allow speed-recording devices to record data at 20 kHz, but closer to 100 Hz. This means there most likely will not be a data point right at the time of impact. Use linear interpolation to derive the speed at the point of impact. This is the value that will be used in calculating the energy as explained in chapter 2 §3 of this guidebook.

Figure 2. Impact Testing of End-Fire Glideslope at MIRA Ltd. Facility in the United Kingdom

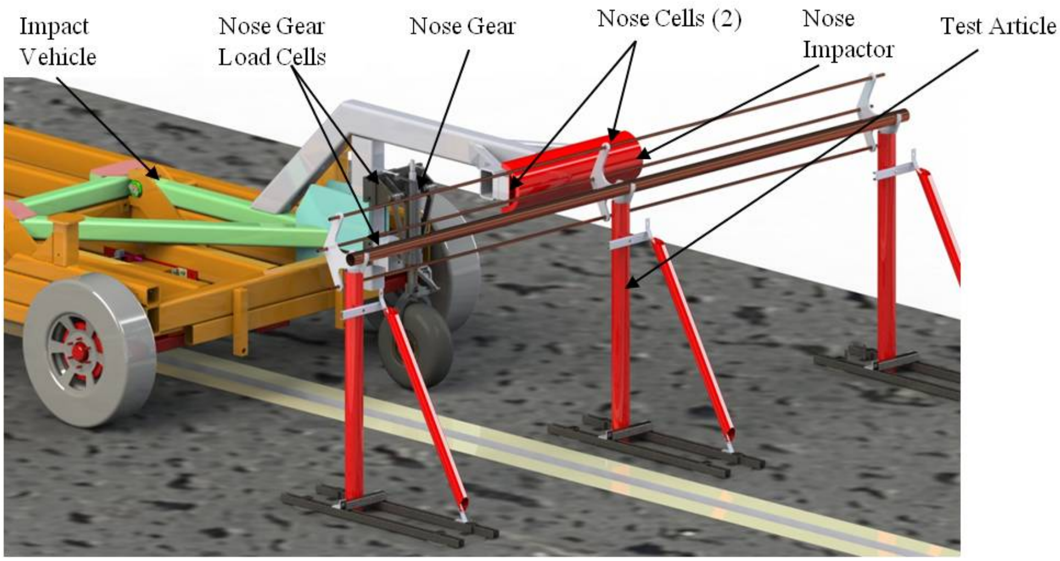


Figure 3. Ground Impact Test System With Frangible End-Fire Glideslope

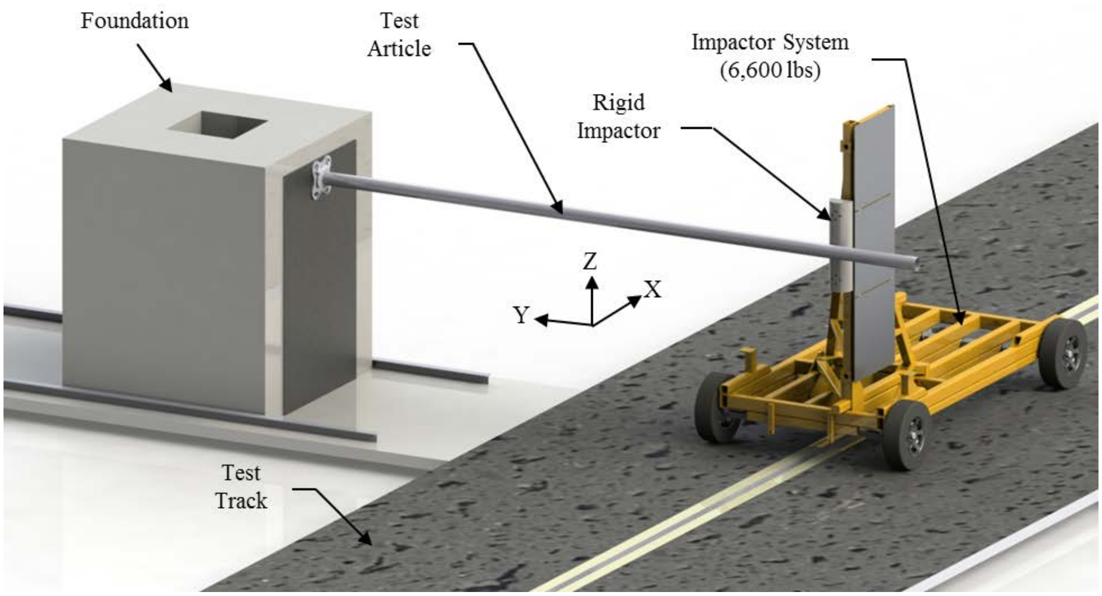


Figure 4. Full-Scale Test System With ALS Structure

4.1.7.2 Test Qualification Requirements

Test qualification requirements for SLIR structures are as follows:

- The LIR structure should not impose a peak force greater than 13,000 lbf (58.0 kN) on the impactor or the landing gear. Peak force is determined by the summation of data for either the impactor or landing gear load cells. This applies to the forces along the X axis, as shown in figure 4 of this guidebook. Force data cannot be filtered by anything lower than CFC600. Both raw and filtered data should be documented and reported to the third-party certifying body.

- Energy (*Ex*) is calculated by taking the integral of the force in the *x* direction (*Fx*) with respect to time from 0 to no less than 250 ms and multiplying it by the velocity at the point of impact (*Vx*). The maximum resultant energy value should not be greater than 40,566 ft lb (55.0 kJ).

$$E_x = V_x \int_{t_1}^{t_2} F_x \, dt$$

- No part of the landing gear can fail such that it would collapse and cause the fuselage or wings of the aircraft to contact the ground.

- Electrical cabling, or any other accessories on the structure, should not impede the failure of the structure and should not hinder the continued momentum of an aircraft. This should be observed using the high-speed video.

- Structure fragments resulting from the impact should not rebound in a direction that could cause additional damage to an actual aircraft (puncture the fuselage, tail surfaces, or windows etc.). This can be observed using high-speed video as well as computer simulations.

- All products should undergo full-scale testing witnessed by the third-party certifying body to receive FAA approval.

4.1.8 Data Collection and Documentation

Clear and consistent test data is critical for evaluating airfield structures for use on airfield RSAs and TSAs. All historical tests lack data in certain areas and render it impossible to establish a standard based on consistent data. Part of the research and testing done by the FAA in 2015 [6] was to determine what documentation is important. The following list of items should be provided to the FAA along with the test report when applying for product approval.

- Specification sheets for instrumentation such as data acquisition systems, sensors, converters, amplifiers, load cells, accelerometers, high-speed cameras, etc.

- Calibration records for all instrumentation

- Documentation of the effective sampling rate for raw data

- Raw data for load cells, accelerometers, and speed measurement devices

- Raw data plots (If data were filtered, those plots may also be provided. Energy plots should be included as well.)

- Speed at the point of impact (interpolated if necessary)

- High-speed video

- Measured point of impact from top of structure

- Mass and length of broken segments for windowing systems

- Basic dimensions of test system, description of operation, and location of instrumentation

- Final mass of test system

- Detailed drawing for the impactor and mounting of load cells

- Basic descriptions of frangible connections and locations on structure

- Structure material specification sheets and basic drawings for dimensions, location of equipment, and weight per linear foot (30.5 cm) of main structure

- Details (such as weight, size, and attachment method) on attached equipment, electrical cables, lights, etc.
- Details on foundation and connection to main structure, anchor bolts, fuse bolts, etc.
- Wind calculations as well as wind and deflection test results
- All other environmental test results (salt spray, sunshine, humidity, and temperature)
- Results for any computer simulations, including force and energy plots as well as simulation video

4.1.9 Evaluation Criteria (Qualification Requirements)

A test evaluation checklist of qualification requirements is provided in table 7.

Table 7. Test Evaluation Checklist for SLIR Structures

Item Number	Test Description	Test Value/Date	Pass/Fail
1	By examination, product meets fabrication and assembly requirements (chapter 3 §4.1.1 of this guidebook)		
2	By examination, product meets all installation requirements (chapter 3 §4.1.1.1 of this guidebook)		
3	By examination, product meets all hardware requirements (chapter 3 §4.1.1.4 of this guidebook)		
4	By examination, product meets all material requirements (chapter 3 §4.1.1.5 of this guidebook)		
5	By examination, product meets all maintenance requirements including the tilt/lowering test (chapter 3 §4.1.2 of this guidebook)		
Environmental Tests			
6	Wind test (chapter 3 §4.1.6.2 of this guidebook): certification and date of completion		
7	Deflection test (chapter 4 §3.2 of this guidebook): maximum deflection should be less than ±5.0°.		
8	Salt spray test (chapter 3 §4.1.6.3 of this guidebook): certification and date of completion		
9	Sunshine test (chapter 3 §4.1.6.4 of this guidebook): certification and date of completion		
10	Humidity test (chapter 3 §4.1.6.6 of this guidebook): certification and date of completion		
11	Temperature test (chapter 3 §4.1.6.5 of this guidebook): certification and date of completion		
12	Vibration analysis (chapter 4 §3.2 of this guidebook): show analysis		

Table 7. Test Evaluation Checklist for SLIR Structures (Continued)

Item Number	Test Description	Test Value/Date	Pass/Fail
Frangibility Tests			
14	Peak force (13,000 lbf (58.0 kN) unfiltered)		
15	Maximum energy (40,566 ft lb (55.0 kJ) unfiltered)		
16	Speed at impact (31 ±2.5mph) (50.3 ±4.1 km/hr) (26.9 ±2.2 knots)		
17	Location of impact (distance from nominal ±4 in.) (±10.2 cm)		
18	Failure mode		
19	Release of electrical cables		

5. RUNWAY AND TAXIWAY SIGNS

This section contains requirements relating to Runway and Taxiway Signs.

5.1 Design Requirements

This section focuses on frangible design elements from AC 150/5345-44 Paragraphs 3.2.5.3 and 3.2.6.4 [9]. Additional information on LIR design and application may be found in AC 150/5345-45 [4] and AC 150/5220-23 [3]. Pertinent design requirements are identified in this section. Per AC 150/5345-53 [12], methods should be approved by an independent, third-party certification body.

5.1.1 Fabrication, Assembly, and Installation Standards

This section provides information and guidance on standards for fabrication, assembly, and installation such as packaging and shipping, fabrication, design and assembly, and hardware. These requirements do not require testing for validation, but require approval by inspection from a third-party certification body (per AC 150/5345-53 [12]). Most requirements are associated with a military, federal, or ASTM specification to ensure the processes are completed in accordance with up-to-date standards and practices. Pertinent requirements detailed in AC 150/5345-44 [9] related to runway and taxiway signs are identified in this section.

5.1.1.1 Packaging and Shipping

Packaging and shipping requirements for runway and taxiway signs are addressed below.

- When packages are shipped, they should be supplied complete with all accessories, including mounting base, adjusting and connecting hardware, light covers (where required), and installation instructions.

- Product manual should be provided that includes all necessary procedures for unpacking, assembly, installation, operation, recommended maintenance practices, and a complete parts list.

- Structures should be properly packaged to protect small parts and prevent damage and deterioration during shipment.

- Structures should be made in sections to provide easy shipment and handling.

- All containers should be clearly marked for content, type, class, and height of the structure.

- Per ASTM D3951 [13], components should be identified on the package labels if shipped in more than one container.

5.1.1.2 Fabrication

Fabrication requirements for Runway and Taxiway Signs are addressed in this section.

- Signs should be constructed of lightweight, nonferrous materials for installation on a concrete pad.

- Runway and taxiway signs should not have sharp edges that could be hazardous during handling or any other irregularities that could interfere with fit and assembly.

- All required mounting hardware, except anchor bolts, should be supplied with each sign.

- Exposed surfaces should be free from grease, oil, dirt, scale, flux, and chemicals that are deposited during the fabrication process.

5.1.1.3 Design and Assembly

Design and assembly requirements for runway and taxiway signs are contained in this section.

- Signs should be designed for rapid field assembly without the use of special tools or welding.

- Mass of components should be minimized while meeting all other requirements.

- Manufacturer should supply equipment necessary to service the product.

- Design should permit maintenance of lamps without the use of specialized equipment.

- Structure should be designed for routing electrical wires in enclosed wireways to lamps and should be part of the frangible design.

5.1.1.4 Hardware

Hardware requirements for runway and taxiway signs are contained in this section.

- Aluminum, GRP, and carbon steel hardware is permissible.

- All stainless steel connecting hardware components should be 18-8 stainless steel.

- All high-strength carbon steel bolts, nuts and hardened steel washers should be suitable for the application and comply with ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17].

- All ferrous metal parts (non-stainless steel) should be hot-dip galvanized after fabrication per ASTM A123 [18]. Ferrous hardware (nuts, bolts, washers, and other minor items) should be galvanized by the hot-dip method conforming to ASTM A153 [19].

5.1.2 Maintenance

Maintenance of airfield structures is costly and difficult when located in areas near a runway or taxiway. Runway and taxiway signs should be designed to minimize maintenance to the greatest extent possible. Signs should be designed for easy access to internal components and mounted equipment. The product should demonstrate the proper fit and function of all component parts and be accurately represented in the installation and maintenance instructions.

5.1.3 Environmental

AC 150/5345-44 Paragraph 3.2 [9] delineates the environmental design requirements for signs. Certification procedures for signs, including environmental, are described in Section 4 of the AC. In addition to the weather environment, requirements for strength, durability, and frangibility should also be met per AC 150/5345-44 Paragraph 4.1.1.2 [9]. Aircraft safety depends on the structure’s ability to yield or break if an accidental collision occurs. Minimum strength requirements have been established to provide a standard for all manufacturers. These requirements should be approved by means of analysis or testing as shown in table 8.

Table 8. Environmental Design Requirements for Runway and Taxiway Signs

Requirement Numbers From AC 150/5345-44 [9]	Description	Approval Method
Temperature Para. 3.2.1 Para. 4.1.1.5 Para. 4.1.1.6 Para. 4.2.1.3 Para. 4.2.1.4	Class 1 operating from -4°F (-20°C) to 131°F (55°C) Storage/handling: exposure to any temperature from -67°F (-55°C) to 131°F (55°C) Class 2 operating from -40°F (-40°C) to 131°F (55°C) Storage/shipping: exposure to any temperature from -67°F (-55°C) to 131°F (55°C)	Test MIL-STD-810 Method 503.4, Proc. II, 502.4, Proc. II [28]
Wind Para. 3.2.2 Para. 4.1.1.2 Para. 4.2.1.2	See AC 150/5345-44 Paragraphs 1.2.5, 3.2.2, and 4.1.1.2 [9] for specific sign type and mode wind load requirements	Analysis
Rain Para. 3.2.3 Para. 4.1.1.4	Exposure to wind driven rain, snow, ice, and standing water	Test MIL-STD-810 Method 506, Par. 4.4.2, Proc. I [28]
Sunshine (Solar radiation) Para. 3.2.4 Para. 4.1.1.7 Para. 4.2.1.5	Structures, components, and equipment using plastic or nonmetallic components should withstand prolonged exposure to solar radiation.	Test MIL-STD-810, Method 505.4, Para. 4.4.2, Proc. II [28] ASTM G155 [29] ASTM D2565 [30]
Immersion Para. 4.1.1.8	A water immersion test should be conducted on the external sign power adapter unit after it is subjected to the high-temperature testing in Paragraph 4.1.1.6 of the AC [9].	Test MIL-STD-810 Method 512.4, Proc. I [28]

5.1.4 Frangibility

The structure should be designed with the minimum mass possible while still meeting working loads and environmental requirements. AC 150/5345-44 Paragraphs 3.2.5.3, 3.2.5.13, 3.2.6.4, 3.2.6.9, 4.1.1.2, and 4.2.1.2 [9] delineate numerous frangibility requirements for runway and taxiway signs. The structure should be frangible when accidentally struck from any direction while causing minimal damage to an aircraft. Specific details for frangible design requirements are provided in table 9.

Table 9. Frangible Structure Design Requirements for Runway and Taxiway Signs

Requirement Numbers From AC 150/5345-44 [9]	Description	Approval Method
Para. 3.2.5.3, a	Lighted sign mounting legs should incorporate a frangible groove 2 in. (51 mm) or less above base.	Inspection
Para. 3.2.5.3, b, c Para. 3.2.6.4, b, c Para. 4.1.1.2	Mode 2 and Mode 3 sign frangible points should meet wind load requirements delineated in AC 150/5345-44.	Test
Para. 3.2.5.8	Electrical cabling should be designed to disconnect so as to not entangle with or impede the aircraft.	Test
Para. 3.2.5.3 Para. 4.2.1.2	Structures should be tested using the base mounting points connected to frangible connections.	Test
Para. 3.2.5.13 Para. 3.2.6.9	Each frangible coupling should be permanently marked with the manufacturer's name (may be abbreviated) and the size of the sign for which the coupling is rated.	Inspection
Para, 3.2.5.3, a	Lighted sign-mounting legs should incorporate a frangible groove 2 in. (51 mm) or less above base.	Inspection
Para, 3.2.5.3, b, c Para. 3.2.6.4, b, c Para. 4.1.1.2	Mode 2 and Mode 3 sign frangible points should meet wind load requirements delineated in AC 150/5345-44.	Test

5.2 Test Requirements

Section 4 of AC 150/5345-44 [9] specifies designs to be inspected and/or tested for approval and are highlighted in chapter 3 §5.1 of this guidebook. Additional details as to how these tests should be performed are provided in this section. The intent is to provide a test procedure that can be used as a standard for all parties seeking FAA approval for their products. This section provides the details for setup and execution of these tests as well as data processing and documentation.

5.2.1 Environmental Qualification Procedure and Test Setup

This section provides information for performing the standard environment tests required for FAA approval. Environmental test methods for product qualifications presented in ACs reference MIL-STD-810 [28] for details on conducting each test (i.e., temperature, humidity, sunshine or solar radiation, and salt spray). The system-specific AC details which environmental tests are required to be performed on each system. An overview of basic environmental requirements extracted from system-specific ACs is presented here. It is recommended that if a system-specific AC exists, the required environmental test parameters for qualification should be verified there for all products seeking approval. If no system-specific AC exists, then AC 150/5345-45, Paragraphs 3.3 and 4.2 [4] should be used for product environmental requirements and qualification.

5.2.1.1 Visual Examination

The FAA-approved, third-party certification body (per AC 150/5345-53 [12]) will need to make all approvals required in chapter 3 §5.1 of this guidebook. Visual inspections and analysis approval methods will be used for the construction, assembly, and installation requirements; hardware requirements; materials and finishing requirements; and maintenance requirements. Documentation (such as material specification sheets, painting, anodizing, or galvanizing certifications, and calculations for wind loading) should be provided to the third-party certification body.

5.2.1.2 Wind Test

Runway and taxiway signs should be designed to withstand pressure loading (no permanent deformation) arising from the specified wind velocities when certified and installed in accordance with AC 150/5345-44 [9]. It should be verified that force level was achieved and the structure did not sustain permanent deformation.

5.2.1.3 Sunshine (Solar Radiation) Test

The sunshine (solar radiation) test should be conducted per MIL-STD-810, Method 505.4, Paragraph 4.4.2, Procedure II [28], for all structures with plastic/nonmetallic exterior materials. The material should be subjected to a minimum of 56 radiation cycles. Any evidence of deterioration or GRP delamination is cause for rejection.

5.2.1.4 Temperature

The structure should be tested for both high- and low-operating temperature and should sustain no delamination, and there should be no damage to seals or other components. Structures should be low-temperature tested in accordance with MIL-STD-810, Method 502.4, Procedure II [28] to 67°F (-55°C) and high-temperature tested in accordance with MIL-STD-810, Method 503.4, Procedure II to 131°F (55°C) as detailed in AC 150/5345-44, Paragraphs 4.1.1.5 and 4.1.1.6 [9].

5.2.1.5 Humidity

The structure should be subjected to the moisture-resistance test for hot-humid conditions per MIL-STD-810, Method 507.3, Procedure II [28]. There should be no evidence of delamination, cracking, corrosion, or deterioration of any part of the structure after cycling has been completed.

5.2.2 Frangible Qualification Procedures and Test Setup

Paragraph 4.2.5 of AC 150/5345-45 [4] provides the requirements for testing frangible LIR structures. These requirements are best understood when divided into two categories: test system and test qualification. The test system requirements explain how the test should be set up to create a standard method of testing for all manufacturers. The test qualification requirements explain how the product should perform during the test. These requirements are summarized and listed in sections 5.2.2.1 and 5.2.2.2 of this chapter.

5.2.2.1 Test System Requirements

Test system requirements for runway and taxiway signs are as follows:

- The test vehicle should weigh approximately 6600 lb (3000 kg).

- Impact structure should be sufficiently rigid to minimize energy absorption and be designed such that vibration modes do not interfere with load cell data.

- A Piper Aztec nose gear or equivalent should be mounted to the front of the impact vehicle, directly in line with the structure being tested. Steel adaptor plates should be fabricated to transition between the two mounting points on the landing gear and the load cells. The mass of adaptor plates should be minimized yet sufficient to handle impact loads. This can be shown by analysis. The landing gear strut should be serviced according to the manufacturer’s recommendations and be fully operational. The steering horn should be locked in place to not allow the wheel to turn.

- Load cells should attach between the landing gear and the support structure, with one load cell at each landing gear attachment point as shown in figure 5. Load cells should be triaxial, meaning they are able to capture force data in the X, Y, and Z axes, as shown in figure 4 of this guidebook. Force data should be recorded for a minimum of 250 ms.

- The rigid impactor will represent the nose or wing of the aircraft and should be a semicircular mild steel tube, 3.28 ft (1 m) long, 9.8 in. (24.9 cm) diameter, with wall thickness of 0.5 in. (13 mm). The impactor should be supported by a rigid structure and located 43 in. (1 m) off the test track surface and 45.5 in. (115.6 cm) beyond the centerline of the landing gear. The mass of the impactor can significantly affect the data; therefore, it is recommended that the impactor be limited to 3.28 ft (1 m) in length (mounted with two load cells). If a longer impactor is required, a second impactor, with two load cells should be installed in line with the first.

- The test structure should be mounted the same way it is done on the airfield, according to the manufacturer’s directions.

- High-speed video cameras should be used to capture the collision that occurs between the impactor and the structure, as well as the failure mode of the structure. To accomplish this, it is recommended to use a video capture rate of 1000 fps and be able to run the video for a minimum of 250 ms.

- A data acquisition system should be used to collect instrumentation data, such as load cell and accelerometer data. Improvements in technology have made it possible to collect data at much higher rates. It is recommended to collect the data at 20 kHz.

- For grounded aircraft tests, it is required to reach a test speed of 31 ±2.5 mph (50 ±4 km/hr) (26.9 ±2.2 knots). This speed should be recorded at the point of impact. However, current technology does not allow speed-recording devices to record data at 20 kHz, but closer to 100 Hz. This means that there most likely will not be a data point right at the time of impact. Linear interpolation should be used to derive the speed at the point of impact. This is the value that will be used in calculating the energy as explained in chapter 2 §3 of this guidebook.

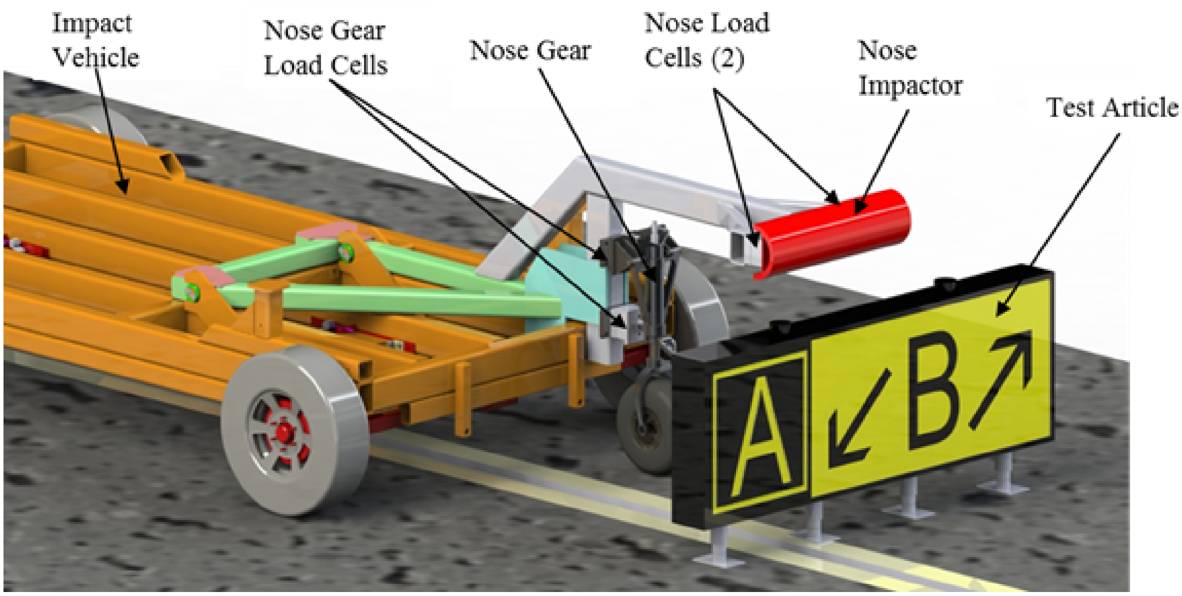


Figure 5. Ground Impact Test System With Frangible Navigation Sign

5.2.2.2 Test Qualification Requirements

Test qualification requirements for runway and taxiway signs are as follows:

- The LIR structure should not impose a peak force greater than 13,000 lbf (58 kN) on the impactor as recorded by the two load cells and the data summed together. This applies to the forces along the X axis, as shown in figure 4 of this guidebook. Force data cannot be filtered by anything lower than CFC600.

- Taking the integral of the force and multiplying it by the velocity at the point of impact, the resultant energy value should not be greater than 40,566 ft lb (55 kJ), during the time in which the structure is in contact with the impactor.

- No part of the landing gear can fail such that it would collapse and cause the fuselage or wings of the aircraft to crash to the ground.

- Electrical cabling (or any other accessories on the structure) should not impede the failure of the structure and should not appear to potentially hinder the continued momentum of an aircraft. This should be observed using the high-speed video.

- Structure fragments resulting from the impact should not rebound in a direction that could potentially cause additional damage to an actual aircraft (puncture the fuselage, tail surfaces, or windows, or cause a wind screen). This can be observed using high-speed video as well as computer simulations.

- All products should undergo full-scale testing to receive FAA approval.

5.2.3 Data Collection and Documentation

As emphasized in chapter 1 §3 of this guidebook, information about tests performed is critical to achieving a standard by which all tests can be compared. All historical tests lack data in certain areas and render it impossible to establish a standard. Part of the research and testing done by the FAA in 2015 [6] was to determine what documentation is important. The following items should be provided to the FAA along with the test report when applying for product approval.

- Specification sheets for instrumentation such as data acquisition systems, sensors, converters, amplifiers, load cells, accelerometers, high-speed cameras, etc.

- Calibration records for all instrumentation

- Documentation of the effective sampling rate for raw data

- Raw data for load cells, accelerometers, and speed measurement devices

- Raw data plots (If data were filtered, those plots may also be provided. Energy plots should be included as well.)

- Speed at the point of impact (interpolated if necessary)

- High-speed video

- Measured point of impact from top of structure

- Mass and length of broken segments for windowing systems

- Basic dimensions of test system, description of operation, and location of instrumentation

- Final mass of test system

- Detailed drawing for the impactor and mounting of load cells

- Basic description of frangible connection and locations on structure

- Structure material specification sheets and basic drawings for dimensions, location of equipment, and weight per linear foot (30.5 cm) of main structure

- Details (such as weight, size, and attachment method) on attached equipment, electrical cables, lights, etc.

- Details on foundation and connection to main structure, anchor bolts, fuse bolts, etc.
- Wind calculations as well as wind and deflection test results
- All other environmental test results (i.e., salt spray, sunshine, humidity, and temperature)
- Results for any computer simulations, including force and energy plots as well as simulation video

5.2.4 Evaluation Criteria (Qualification Requirements)

A test evaluation checklist of qualification requirements is provided in table 10.

Table 10. Test Evaluation Checklist for Runway and Taxiway Signs

Item Number	Test Description	Test Value/Date	Pass/Fail
1	By examination, product meets fabrication and assembly requirements (chapter 3 §5.1.1 of this guidebook)		
2	By examination, product meets all installation requirements (chapter 4 §3.1.2 of this guidebook)		
3	By examination, product meets all hardware requirements (chapter 3 §5.1.1.4 of this guidebook)		
4	By examination, product meets all material requirements (chapter 4 §3.1.1.5 of this guidebook)		
5	By examination, product meets all maintenance requirements including the tilt/lowering test (chapter 3 §5.1.2 of this guidebook)		
Environmental Tests			
6	Wind test (chapter 3 §5.2.1.2 of this guidebook): maximum deflection should be less than ± 2.0°.		
7	Deflection test (chapter 4 §3.2 of this guidebook): maximum deflection should be less than ± 5.0°.		
8	Salt spray test (chapter 4 §4.1.4 of this guidebook): certification and date of completion		
9	Sunshine test (chapter 3 §4.1.5 of this guidebook): certification and date of completion		
10	Humidity test (chapter 3 §4.1.7 of this guidebook): certification and date of completion		
11	Temperature test (chapter 3 §4.1.6 of this guidebook): certification and date of completion		
12	Vibration analysis (chapter 4 §3.2 of this guidebook): show analysis		

Table 10. Test Evaluation Checklist for Runway and Taxiway Signs (Continued)

Item Number	Test Description	Test Value/Date	Pass/Fail
Frangibility Tests			
14	Peak force (10,116 lbf (45.0 kN) unfiltered)		
15	Maximum energy (40,566 ft lb (55.0 kJ) unfiltered)		
16	Speed at impact (31 ±2.5mph) (50.3 ± 4 km/hr) (26.9 ±2.2 knots)		
17	Location of impact (distance from nominal ±4 in.) (±10.2 cm)		
18	Failure mode		
19	Release of electrical cables		

6. RUNWAY AND TAXIWAY LIGHT FIXTURES

This section addresses runway and taxiway light fixture requirements.

6.1 Design Requirements

This section focuses on frangible design elements from AC 150/5345-46, Paragraph 3.4.2 [10]. Additional information on LIR design and application may be found in AC 150/5345-45 [4] and AC 150/5220-23 [3]. Pertinent design requirements are identified in this section. Per AC 150/5345-53 [12], methods should be approved by an independent, third-party certification body.

6.1.1 Fabrication, Assembly, and Installation Standards

This section provides information and guidance on standards for fabrication, assembly, and installation, such as materials, hardware, finishes, wiring, packaging, shipping, and foundations. These requirements do not require testing for validation, but require approval by inspection from a third-party certification body (per AC 150/5345-53 [12]). Most requirements are associated with a military, federal, or ASTM specification to ensure the processes are completed in accordance with up-to-date standards and practices. All pertinent requirements detailed in AC 150/5345-46 [10] related to runway and taxiway lights have been identified in this section.

6.1.1.1 Packaging and Shipping

This section addresses packaging and shipping requirements for runway and taxiway light fixtures.

- Shipment packages should be supplied complete with all accessories, including: mounting base, adjusting and connecting hardware, light covers (where required), and installation instructions including durability information on pop-out yield (frangible) devices.

- A product manual should be provided that includes all necessary procedures for unpacking, assembly, installation, operation, recommended maintenance practices, and complete parts list.

- Structures should be properly packaged to protect small parts and prevent damage and deterioration during shipment.

- Structures should be made in sections to provide easy shipment and handling.

- All containers should be clearly marked for content, type, class, and height of the structure.

- Per ASTM D3951 [13], components should be identified on the package labels if shipped in more than one container.

6.1.1.2 Fabrication

This section addresses fabrication requirements for runway and taxiway light fixtures.

- All components should be suitable for the intended purpose and adequately protected against corrosion.

- LIR structures and members should not have sharp edges that could be hazardous during handling or any other irregularities that could interfere with fit and assembly.

- All bonding areas should be sandblasted and/or cleaned with a solvent before applying a structural adhesive.

- Exposed surfaces should be free from grease, oil, dirt, scale, flux, and chemicals that were deposited during the fabrication process.

- Drilled holes and cut edges of GRP members should be coated with the same material as the original resin.

6.1.1.3 Design and Assembly

This section addresses design and assembly requirements for runway and taxiway light fixtures.

- Sections should be designed for rapid field assembly without the use of special tools or welding.

- Mass of the structure should be minimized while meeting all other requirements. The mass per unit length should be 2 lb/ft (3 kg/m) or less.

- Manufacturer should supply equipment necessary to service the product.

- The design should permit maintenance of lights without the use of specialized equipment.

- During maintenance, the design should permit proper light mounting and not restrict the adjustment range of lamp holders.

- Upon maintenance completion, lights should be returned to their original horizontal and vertical alignments, and the structure should be securely locked into place.

- The structure should be designed for routing electrical wires in enclosed wireways to lamps with pull-apart connectors as part of the frangible design.

6.1.1.4 Hardware

This section addresses hardware requirements for runway and taxiway light fixtures.

- Aluminum, GRP, and carbon steel hardware is permissible.

- All stainless steel connecting hardware components should be 18-8 stainless steel.

- All high-strength carbon steel bolts, nuts, and hardened steel washers should be suitable for the application and IAW ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17].

- All ferrous metal parts (non-stainless steel) should be hot-dip galvanized after fabrication per ASTM A123 [18]. Ferrous hardware (nuts, bolts, washers, and other minor items) should be galvanized by the hot-dip method conforming to ASTM A153 [19].

6.1.2 Maintenance

Maintenance of airfield structures is costly and difficult when located in areas near a runway. LIR structures should be designed to minimize maintenance to the greatest extent possible. Structures should be designed for easy access to mounted equipment. The product should demonstrate the proper fit and function of all component parts and be accurately represented in the installation instructions.

6.1.3 Environmental

AC 150/5345-46 [10] delineates the environmental design requirements. In addition to the weather environment, requirements for strength, durability, and frangibility also should be met. Aircraft safety depends on the structure's ability to yield or break if an accidental collision occurs. Minimum strength requirements have been established to provide a standard for all manufacturers. These requirements should be approved by means of analysis or testing as shown in table 11.

Table 11. Environmental Design Requirements for Runway and Taxiway Light Fixtures

Requirement Numbers From AC 150/5345-46 [10]	Description	Approval Method
Temperature Para. 3.2, a, (1), (2) Para. 3.2, b Para. 4.6.1 Para. 4.6.2	Operating: exposure to any temperature from -40°F (-40°C) to 131°F (55°C) Storage/shipping: Exposure to any temperature from -67°F (-55°C) to 131°F (55°C) See AC 150/5345-46, Paragraphs 4.6.1 and 4.6.2 [10]	Test MIL-STD-810, Method 501.4, Procedure II [28]
Salt Spray (Fog) Para 3.2, c Para. 4.6.4	Structures, components, and equipment should be designed to withstand exposure to a corrosive salt-laden environment. Salt-spray testing should be conducted on a section of structure mast, complete with all sections and hardware. Test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, pitting, corrosion (except for sacrificial coatings), or GRP delaminating is cause for rejection.	Test MIL-STD-810, Method 509.4 Proc. I [28]
Wind Para. 3.2, d Para. 4.6.7	Exposure to wind velocities of 300 mph (482 km/hr) (260.7 knots) for all L-804, L-861, and L-862 fixtures, and 150 mph (241 km/hr) (130.4 knots) for all other elevated light fixtures. No plastic deformation should result from the wind-loading test.	Analysis
Rain Test (Precipitation) Para. 3.2, e Para. 4.6.3	Exposure to rain, snow, ice, and standing water.	Test MIL-STD-810, Method 506.4, Procedure I [28]
Sunshine (Solar Radiation) Para. 3.2, f Para. 4.6.6	Structures, components, and equipment using plastic or nonmetallic components should withstand prolonged exposure to solar radiation.	Test MIL-STD-810 [28] ASTM G155 [29] ASTM D2565 [30]

6.1.4 Frangibility

The structure should be designed with the minimum mass possible while still meeting working loads and environmental requirements. AC 150/5345-46, Paragraph 4.6.5 [10] delineates Yield Device requirements. The light unit and support structure should be frangible and offer minimal resistance when accidentally struck from any direction while causing minimal damage to an aircraft. Specific details for frangible design requirements are provided in table 12.

Table 12. Frangible Structure Design Requirements for Runway and Taxiway Light Fixtures

Requirement Numbers From AC 150/5345-46 [10]	Description	Approval Method
Para. 3.4.2.1, a Para. 4.6.5	Each elevated light fixture should have a yield point near the point or position where the light attaches to the base plate or mounting stake. Fixture should withstand a bending moment of 150 ft lb (203 Newton-meters (N-m)) without failure.	Test Computer Simulation
Para. 3.4.2.1, a, (1) Para. 4.6.5.	The yield point should separate cleanly from the mounting system before the bending moment reaches 500 ft lb (678 N-m).	Test
Para. 3.4.2.1.1, a Para. 4.6.5.	Each L-804 elevated light fixture should yield at a force less than 2100 ft lb (2847 N-m).	Test
Para.3.4.2.2, d Para. 4.4, d, e	When the base plate is bolted to an L-867 light base, it should withstand an evenly distributed static compressive load of 2500 lb (1134 kg) and a bending moment of 2500 ft lb (3389.50 N-m) for L-804 and 700 ft lb (949.07 N-m) for all other applications without damage or permanent deformation.	Test
Para. 3.4.2.3	Stake mounts should have a fitting attached at the top to receive a yield device	Inspection
Para. 3.7.2, e	At the yield point on elevated lights with frangible or pop-out devices, the electrical circuit should have a means of disconnecting (such as a plug and receptacle) to break the electrical circuit and allow the light fixture to separate cleanly.	Test
Para. 4.6.5, a	All tests, demonstrating compliance to the requirements of Paragraph 3.4.2.1 (3.4.2.1.1 for L-804) [10] should be performed with the light unit fully assembled at nominal height (14 in. or 355.60 mm) and mounted to a rigidly secured base plate.	Test

6.2 Test Requirements

AC 150/5345-46 Chapter 4 [10] specifies design requirements, which were highlighted in chapter 3 §6.1 of this guidebook, to be inspected and/or tested for approval. This section details how these tests should be performed. The intent is to provide a test procedure that can be used as a standard for all parties seeking FAA approval for their products. This section provides the details for setup and execution of these tests as well as data processing and documentation.

6.2.1 Environmental Qualification Procedure and Test Setup

This section provides information for performing the standard environment tests required for FAA approval. Environmental test methods for product qualifications are presented in ACs reference MIL-STD-810 [28] with details on conducting each test (temperature, humidity, sunshine or solar radiation, and salt spray). The system-specific AC details which environmental tests are required to be performed on each system. An overview of basic environmental requirements extracted from system-specific ACs is presented here. It is recommended that if a system-specific AC exists, the required environmental test parameters for qualification should be verified there for all products seeking approval. If no system-specific AC exists, then AC 150/5345-45, Paragraphs 3.3 and 4.2 [4] should be used for product environmental requirements and qualification.

6.2.1.1 Visual Examination

The FAA-approved, third-party certification body (per AC 150/5345-53 [12]) will need to make all approvals required in chapter 3 §6.1 of this guidebook. Visual inspections and analysis approval methods will be used for the construction, assembly, and installation requirements; hardware requirements; materials and finishing requirements; and maintenance requirements. Documentation (such as material specification sheets, painting, anodizing, or galvanizing certifications, and calculations for wind loading) should be provided to the third-party certification body.

6.2.1.2 Wind Test

The structures and all necessary equipment should be designed to withstand wind velocities to 150 mph (241 km/hr) (130.4 knots) with no part of the light, mounting system, or yield device damaged. The light may not sway more than 1 in. with the exception of the L-804 (minimum height of 14 in. (35.6 cm)), which should not sway more than 2 in.

6.2.1.3 Salt Spray Test

The salt spray test should be conducted on a section of the structure mast, complete with all accessory hardware per MIL-STD-810, Method 509.4, Paragraph 4.5.2, Procedure I [28]. The test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, rust, pitting, corrosion (except for sacrificial coatings), or GRP delamination is cause for rejection.

6.2.1.4 Sunshine (Solar Radiation) Test

The sunshine (solar radiation) test should be conducted per MIL-STD-810, Method 505.4, Paragraph 4.4.3, Procedure II [28] for all structures with plastic/nonmetallic exterior materials. The material should be subjected to a minimum of 56 radiation cycles. Any evidence of deterioration or GRP delamination is cause for rejection.

6.2.1.5 Temperature

The structure should be tested for both high- and low-operating temperature and should sustain no delamination; also there should be no damage to seals or other components. Structures should be tested in accordance with MIL-STD-810, Method 501.3 [28]. Operational temperature should be between 131°F (55°C) and -67°F (-55°C).

6.2.1.6 Humidity

For hot-humid conditions, the structure should be subjected to MIL-STD-810, the moisture resistance test, Method 507.3, Procedure II [28]. There should be no evidence of delamination, cracking, corrosion, or deterioration of any part of the structure after cycling has been completed.

6.2.2 Frangible Qualification Procedures and Test Setup

Paragraph 4.2.5 of AC 150/5345-45 [4] provides the requirements for testing frangible LIR structures. These requirements are best understood when divided into two categories: test system and test qualification. The test system requirements explain how the test should be set up to create a standard method of testing for all manufacturers. The test qualification requirements explain how the product should perform during the test. These requirements are summarized and listed below.

6.2.2.1 Test System Requirements

Test system requirements for runway and taxiway light fixtures are as follows:

- The test vehicle should weigh approximately 6600 lb (3000 kg).
- The impact structure should be sufficiently rigid to minimize energy absorption and be designed such that vibration modes do not interfere with load cell data.
- A Piper Aztec nose gear or equivalent should be mounted to the front of the impact vehicle, directly in line with the structure being tested. Steel adaptor plates should be fabricated to transition between the two mounting points on the landing gear and the load cells. Mass of the adaptor plates should be minimized yet sufficient to handle impact loads. This can be shown by analysis. The landing gear strut should be serviced according to the manufacturer's recommendations and be fully operational. The steering horn should be locked in place to not allow the wheel to turn.
- Load cells should attach between the landing gear and the support structure, with one load cell at each landing gear attachment point as shown in figure 6. Load cells should be triaxial, meaning they are able to capture force data in the X, Y, and Z axes, as shown in figure 4 of this guidebook. Force data should be recorded for a minimum of 250 ms.
- The rigid impactor will represent the nose or wing of the aircraft and should be a semicircular mild steel tube, 3.28 ft (1 m) long, 9.8 in. (24.90 cm) diameter, with wall thickness of 0.5 in. (13 mm). The impactor should be supported by a rigid structure and located 43 in. (1 m) off the test track surface and 45.5 in. (115.6 cm) beyond the centerline of the landing gear. The mass of the impactor can significantly affect the data; therefore, it is recommended that the impactor be limited to 3.28 ft (1 m) in length (mounted with two load cells). If a longer impactor is required, a second impactor, with two load cells should be installed in line with the first.

- The test structure should be mounted the same way it is done on the airfield, according to the manufacturer's directions.

- High-speed video cameras should be used to capture the collision that occurs between the impactor and the structure, as well as the failure mode of the structure. To accomplish this, it is recommended to use a video capture rate of 1000 fps and be able to run the video for a minimum of 250 ms.

- A data acquisition system should be used to collect instrumentation data such as load cell and accelerometer data. Improvements in technology have made it possible to collect data at much higher rates. It is recommended to collect the data at 20 kHz.

- For grounded aircraft tests, it is required to reach a test speed of 31 ±2.5 mph (50 ±4 km/hr) (26.9 ±2.2 knots). This speed should be recorded at the point of impact. However, current technology does not allow speed-recording devices to record data at 20 kHz, but closer to 100 Hz. This means there most likely will not be a data point right at the time of impact. Use linear interpolation to derive the speed at the point of impact. This is the value that will be used in calculating the energy as explained in chapter 2 §3 of this guidebook.

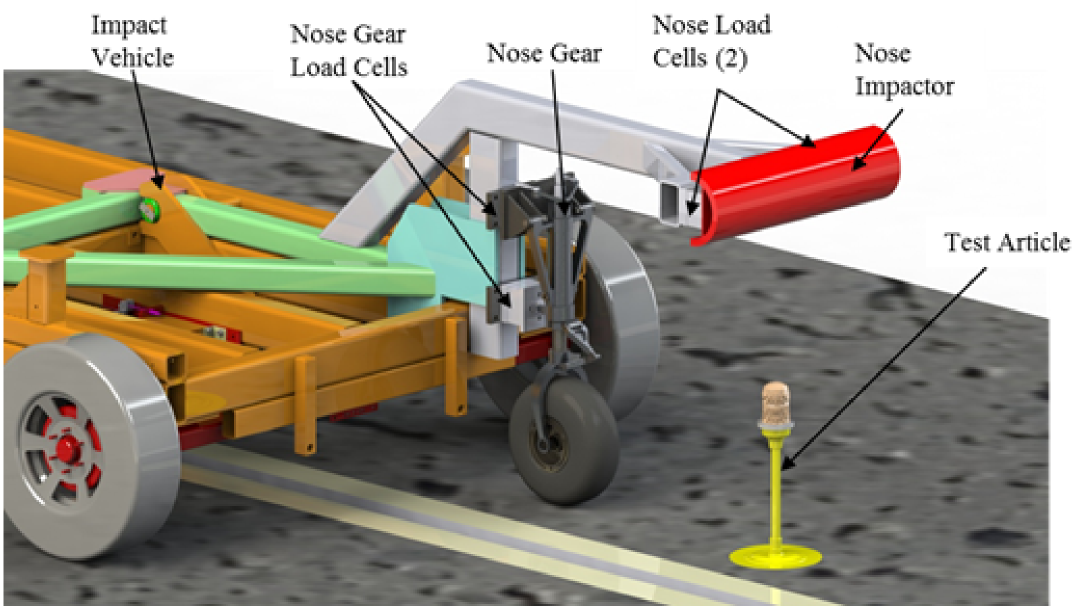


Figure 6. Ground Impact Test System With Frangible Light Fixture

<u>6.2.2.2 Test Qualification Requirements</u>

Test qualification requirements for runway and taxiway light fixtures are as follows:

- The LIR structure should not impose a peak force greater than 13,000 lbf (58.0 kN) on the impactor as recorded by the two load cells and the data summed together. This applies to the forces along the X axis, as shown in figure 4 of this guidebook. Force data cannot be filtered by anything lower than CFC600.

- Taking the integral of the force and multiplying it by the velocity at the point of impact, the resultant energy value should not be greater than 40,566 ft lb (55.0 kJ), during the time in which the structure is in contact with the impactor.

- No part of the landing gear can fail such that it would collapse and cause the fuselage or wings of the aircraft to crash to the ground.

- Electrical cabling, or any other accessories on the structure, should not impede the failure of the structure and should not appear to potentially hinder the continued momentum of an aircraft. This should be observed using the high-speed video.

- Structure fragments resulting from the impact should not rebound in a direction that could potentially cause additional damage to an actual aircraft (puncture the fuselage, tail surfaces, or windows, or cause a wind screen). This can be observed using high-speed video as well as computer simulations.

- All products should undergo full-scale testing to receive FAA approval.

6.2.3 Data Collection and Documentation

As emphasized in chapter 1 §3 of this guidebook, information about tests performed is critical to achieving a standard by which all tests can be compared. All historical tests lack data in certain areas. Part of the research and testing done by the FAA in 2015 [6] was to determine what documentation is important. The following list of items should be provided to the FAA along with the test report when applying for product approval.

- Specification sheets for instrumentation such as data acquisition systems, sensors, converters, amplifiers, load cells, accelerometers, high-speed cameras, etc.

- Calibration records for all instrumentation

- Documentation of the effective sampling rate for raw data

- Raw data for load cells, accelerometers, and speed measurement device

- Raw data plots (If data were filtered, those plots may also be provided. Energy plots should be included as well.)

- Speed at the point of impact (interpolated if necessary)

- High-speed video

- Measured point of impact from top of structure

- Mass and length of broken segments for windowing systems

- Basic dimensions of test system, description of operation, and location of instrumentation

- Final mass of test system
- Detailed drawing for the impactor and mounting of load cells
- Basic description of frangible connection and locations on structure
- Structure material specification sheets and basic drawings for dimensions, location of equipment, and weight per linear foot (30.5 cm) of main structure
- Details (such as weight, size, and attachment method) on attached equipment, electrical cables, lights, etc.
- Details on foundation and connection to main structure, anchor bolts, fuse bolts, etc.
- Wind calculations as well as wind and deflection test results
- All other environmental test results (salt spray, sunshine, humidity, and temperature)
- Results for any computer simulations, including force and energy plots as well as simulation video

6.2.4 Evaluation Criteria (Qualification Requirements)

Table 13 provides a test evaluation checklist of qualification requirements.

Table 13. Test Evaluation Checklist for Runway and Taxiway Light Fixtures

Item Number	Test Description	Test Value/Date	Pass/Fail
1	By examination, product meets fabrication and assembly requirements (chapter 3 §6.1.1 of this guidebook)		
2	By examination, product meets all installation requirements (chapter 4 §3.1.2 of this guidebook)		
3	By examination, product meets all hardware requirements (chapter 3 §6.1.1.4 of this guidebook)		
4	By examination, product meets all material requirements (chapter 4 §3.1.1.5 of this guidebook)		
5	By examination, product meets all maintenance requirements including the tilt/lowering test (chapter 3 §6.1.2 of this guidebook)		
Environmental Tests			
6	Wind test (chapter 3 §6.2.1.2 of this guidebook): maximum deflection should be less than ±2.0°.		
7	Deflection test (chapter 4 §3.2 of this guidebook): maximum deflection should be less than ±5.0°.		
8	Salt spray test (chapter 3 §6.2.1.3 of this guidebook): certification and date of completion		

Table 13. Test Evaluation Checklist for Runway and Taxiway Light Fixtures (Continued)

Item Number	Test Description	Test Value/Date	Pass/Fail
Environmental Tests			
9	Sunshine test (chapter 3 §6.2.1.4 of this guidebook): certification and date of completion		
10	Humidity test (chapter 3 §6.2.1.6 of this guidebook): certification and date of completion		
11	Temperature test (chapter 3 §6.2.1.5 of this guidebook): certification and date of completion		
12	Vibration analysis (chapter 4 §3.2 of this guidebook): show analysis		
Frangibility Test			
14	Peak force (13,000 lbf (58.0 kN) unfiltered)		
15	Maximum energy (40,566 ft lb (55.0 kJ) unfiltered)		
16	Speed at impact (31 ±2.5mph) (50.3 ±4 km/hr) (26.9 ±2.2 knots)		
17	Location of impact (distance from nominal ±4 in.) (±10.2 cm)		
18	Failure mode		
19	Release of electrical cables		

7. PRECISION APPROACH PATH INDICATORS AND RUNWAY END INDENTIFIER LIGHTS

This section addresses requirements for precision approach path indicators (PAPIs) and runway end identifiers lights (REILs).

7.1 Design Requirements

This section focuses on PAPI frangible design elements from AC 150/5345-28, Sections 3 and 4 [31]. Additional information on LIR design and application may be found in AC 150/5345-45 [4] and AC 150/5220-23 [3]. Pertinent design requirements are identified in this section. Methods should be approved by an independent, third-party certification body (per AC 150/5345-53 [12]).

7.1.1 Fabrication, Assembly, and Installation Standards

This section provides information and guidance on standards for fabrication, assembly, and installation such as materials, hardware, finishes, wiring, packaging, shipping, and foundations. These requirements do not require testing for validation, but require approval by inspection from a third-party certification body (per AC 150/5345-53 [12]). Most requirements are associated with a military, federal, or ASTM specification to ensure the processes are completed in accordance with up-to-date standards and practices. All pertinent requirements detailed in AC 150/5345-28 [31] related to PAPI and REIL light systems have been identified in this section.

7.1.1.1 Packaging and Shipping

This section addresses packaging and shipping requirements for PAPIs and REILs.

- Package shipments should be supplied complete with all accessories, including: mounting base, adjusting and connecting hardware, light covers (where required), and installation instructions.

- A product manual should be provided that includes all necessary procedures for unpacking, assembly, installation, operation, recommended maintenance practices, and a complete parts list.

- Structures should be properly packaged to protect small parts and prevent damage and deterioration during shipment.

- Structures should be made in sections to provide easy shipment and handling.

- All containers should be clearly marked for content, type, class, and height of the structure.

- Per ASTM D3951 [13] components should be identified on the package labels if shipped in more than one container.

7.1.1.2 Fabrication

This section addresses fabrication requirements for PAPIs and REILs.

- LIR structures and members should not have sharp edges that could be hazardous during handling or any other irregularities that could interfere with fit and assembly.

- All bonding areas should be sandblasted and/or cleaned with a solvent before applying a structural adhesive.

- Exposed surfaces should be free from grease, oil, dirt, scale, flux, and chemicals that are deposited during the fabrication process.

- Drilled holes and cut edges of GRP members should be coated with the same material as the original resin.

7.1.1.3 Design and Assembly

This section addresses design and assembly requirements for PAPIs and REILs.

- Sections should be designed for rapid field assembly without the use of special tools or welding.

- Mass of the structure should be minimized while meeting all other requirements. The mass-per-unit length should be 2 lb/ft (3 kg/m) or less.

- Should supply equipment necessary to service the product.
- Design should permit maintenance of lights without the use of specialized equipment.
- During maintenance, design should permit proper light mounting and not restrict the adjustment range of lamp holders.
- At the completion of maintenance, the lights should be returned to their original horizontal and vertical alignments and structure securely locked into place.
- Structure should be designed for routing electrical wires in enclosed wireways to lamps and should be part of the frangible design.

7.1.1.4 Hardware

This section addresses hardware requirements for PAPIs and REILs.

- Aluminum, GRP, and carbon steel hardware is permissible.
- All stainless steel connecting hardware components should be 18-8 stainless steel.
- All high-strength carbon steel bolts, nuts and hardened steel washers should be suitable for the application and comply with ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17].
- All ferrous metal parts (nonstainless steel) should be hot-dip galvanized after fabrication per ASTM A123 [18]. Ferrous hardware (nuts, bolts, washers, and other minor items) should be galvanized by the hot-dip method conforming to ASTM A153 [19].

7.1.2 Maintenance

Maintenance of airfield structures is costly and difficult when located in areas near a runway. LIR structures should be designed to minimize maintenance to the greatest extent possible. Structures should be designed for easy access to mounted equipment. The product should demonstrate the proper fit and function of all component parts and be accurately represented in the installation instructions.

7.1.3 Environmental

AC 150/5345-28 [31] delineates the environmental design requirements for these specific systems. In addition to the weather environment, requirements for strength, durability, and frangibility should also be met. Aircraft safety depends on the structure's ability to yield or break if an accidental collision occurs. Minimum strength requirements have been established to provide a standard for all manufacturers. These requirements should be approved by means of analysis or testing as shown in table 14.

Table 14. Environmental Design Requirements for PAPIs and REILs

Requirement Numbers From AC 150/5345-28 [31]	Description	Approval Method
Temperature Para. 3.2 Para. 4.2 Para. 4.3	Class I - from -31°F (-35°C) to 131°F (55°C). Class II - from -67°F (-55°C) to 131°F (55°C) Storage/Handling: exposure to any temperature from -67°F (-55°C) to 131°F (55°C).	Test MIL-STD-810, Method 501.4, Procedure II [28]
Relative Humidity Para. 3.3	Structures, components, and equipment should be designed to withstand relative humidity from up to 100% including condensation.	Test MIL-STD-810, Method 507.3, Proc. II [28]
Sand and Dust Para. 3.4	The PAPI equipment should operate when exposed to windborne sand and dust particles.	Test MIL STD 810 B - G 510.5 Proc. I and II [28]
Wind-blown Rain Para. 3.5 Para. 4.4	The PAPI equipment should operate when exposed to wind-blown rain from any direction as well as snow, ice, and standing water.	Test MIL-STD 810 Method 506.4 [28]
Wind Para. 3.6 Para. 4.6	The PAPI equipment should be designed for exposure to wind velocities of 100 mph (86.9 knots) (161 km/hr) from any direction.	Analysis
Salt Spray (Fog) Para. 3.7 Para. 4.5	The PAPI equipment should operate when exposed to a salt laden atmosphere with relative humidity up to 100%.	Test MIL-STD-810, Method 509.4 Proc. I [28]
Sunshine (Solar Radiation) Para. 3.8	The PAPI equipment should operate when exposed to solar radiation with ambient temperatures stated in AC 150/5345-28 Paragraph 3.2, Temperature [31].	Test MIL-STD-810 [28] ASTM G155 [29] ASTM D2565 [30]

7.1.4 Frangibility

The general concept of a frangible structure is to be designed with the minimum mass possible while still meeting working loads and environmental requirements. The structure should be frangible when accidentally struck from any direction while causing minimal damage to an aircraft. Specific details for frangible design requirements for PAPI and REIL lights are found in; FAA Drawing C-6046 [32] per AC 150/5220-23 [3] and table 15.

Table 15. Frangible Structure Design Requirements for PAPIs and REILs

Requirement Numbers From AC 150/5220-23 [3]	Description	Approval Method
Para. 2.2, f, (1)	Effective failure mechanisms to allow the structure to break, distort, or yield and not wrap around.	Test
Para. 2.2, f, (2)	Low mass segments of predictable size that will not present a hazardous secondary impact.	Test
Para. 3.2, c, (1), (a)	Withstand environmental and jet blast loads, but will break, distort, or yield when impacted by a 6600-lb (3000-kg) aircraft at 31 mph (26.9 knots) (50 km/hr) on the ground or airborne at 87 mph (75.6 knots) (140 km/hr).	Test
Para. 3.2, c, (1), (b)	Should not impose a peak force greater than 13,000 lbf (58.0 kN) or impart energy greater than 40,500 ft lb (55.0 kJ) to the aircraft during a contact period of 100 ms.	Test
Para. 3.2, c, (1), (c)	Provide a frangible point 3 in. or less above surrounding grade.	Observation
Para. 3.2, a	Electrical cable and other components should not entangle with or wrap around the aircraft.	Test
Para. 3.2, h	Electrical cable should not rupture the conductor but disconnect at predetermined points.	Test

7.2 Test Requirements

AC 150/5345-28 Section 4 [31] specifies design requirements to be inspected and/or tested for approval and are highlighted in chapter 3 §7.1 of this guidebook. More detail as to how these tests should be performed will be provided in this section. The intent is to provide a test procedure that can be used as a standard for all parties seeking FAA approval for their products. This section provides the details for setup and execution of these tests as well as data processing and documentation.

7.2.1 Environmental Qualification Procedure and Test Setup

AC 150/5345-28 [31] provides information for performing the standard environment tests required for FAA approval. Environmental test methods for product qualifications presented in ACs reference MIL-STD-810 [28] for details on conducting each test (i.e., temperature, humidity, sunshine or solar radiation, and salt spray). The system-specific AC details which environmental tests are required to be performed on each system. An overview of basic environmental requirements extracted from system-specific ACs is presented here. It is recommended that if a system-specific AC exists, the required environmental test parameters for qualification should be verified there for all products seeking approval. If no system-specific AC exists, then AC 150/5345-45, Paragraphs 3.3 and 4.2 [4] should be used for product environmental requirements and qualification.

7.2.1.1 Visual Examination

The FAA-approved, third-party certification body (per AC 150/5345-53 [12]) will need to make all approvals required in chapter 3 §7.1 of this guidebook. Visual inspections and analysis approval methods will be used for the construction, assembly, and installation requirements; hardware requirements; materials and finishing requirements; and maintenance requirements. Documentation (such as material spec sheets, painting, anodizing, or galvanizing certifications, and calculations for wind loading) should be provided to the third-party certification body.

7.2.1.2 Wind Test

The structures and all necessary equipment should be designed to withstand pressure loading (no permanent deformation) arising from the following wind velocities when installed with all lighting equipment attached. Structures should be designed to withstand exposure to wind velocities of 100 mph (161 km/hr) (86.9 knots). Verify that force level was achieved and the structure was not damaged in any way.

7.2.1.3 Deflection Test

The purpose of the deflection test is to demonstrate that the structure is sufficiently rigid to meet the requirements in Paragraph 3.11 of AC 150/5345-45 [4]. The test will require equipment to perform a static bend test, which can be done in conjunction with the wind test. Measuring the vertical axis of the structure, verify that the maximum deflection angle is less than ±2°.

7.2.1.4 Salt Spray Test

The salt spray test should be conducted on a section of the structure mast, complete with all accessory hardware per MIL-STD-810, Method 509.4, Paragraph 4.5.2, Procedure I [28]. The test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, rust, pitting, corrosion (except for sacrificial coatings), or GRP delamination is cause for rejection.

7.2.1.5 Sunshine (Solar Radiation) Test

The sunshine (solar radiation) test should be conducted per MIL-STD-810, Method 505.4, Paragraph 4.4.3, Procedure II [28], for all structures with plastic/nonmetallic exterior materials. The material should be subjected to a minimum of 56 radiation cycles. Any evidence of deterioration or GRP delamination is cause for rejection.

7.2.1.6 Temperature

The structure should be tested for both high- and low-operating temperature and should sustain no delamination; also there should be no damage to seals or other components. Structures should be tested in accordance with MIL-STD-810, Method 501.3 [28]. Operational temperature should be between 131°F (55°C) and -67°F (-55°C).

7.2.1.7 Humidity

The structure should be subjected to the moisture-resistance test for hot-humid conditions per MIL-STD-810, Method 507.3, Procedure II. [28] There should be no evidence of delamination, cracking, corrosion, or deterioration of any part of the structure after cycling has been completed.

7.2.2 Frangible Qualification Procedures and Test Setup

Paragraph 4.2.5 of AC 150/5345-45 [4] provides the requirements for testing frangible LIR structures. These requirements are best understood when divided into two categories: test system and test qualification. The test system requirements explain how the test should be structured to create a standard method of testing for all manufacturers. The test qualification requirements explain how the product should perform during the test. These requirements are summarized and listed below in sections 7.2.2.1 and 7.2.2.2 of this chapter.

7.2.2.1 Test System Requirements

Test system requirements for PAPIs and REILs are as follows:

- Test vehicle should weigh approximately 6600 lb (3000 kg).
- The impact structure should be sufficiently rigid to minimize energy absorption and be designed such that vibration modes do not interfere with load cell data.
- A Piper Aztec nose gear or equivalent should be mounted to the front of the impact vehicle, directly in line with the structure being tested. Steel adaptor plates should be fabricated to transition between the two mounting points on the landing gear and the load cells. The mass of adaptor plates should be minimized yet sufficient to handle impact loads. This can be shown by analysis. The landing gear strut should be serviced according to the manufacturer’s recommendations and be fully operational. The steering horn should be locked in place to not allow the wheel to turn.
- Load cells should attach between the landing gear and the support structure, with one load cell at each landing gear attachment point as shown in figure 7. Load cells should be triaxial, meaning they are able to capture force data in the X, Y, and Z axes, as shown in figure 4 of this guidebook. Force data should be recorded for a minimum of 250 ms.
- The rigid impactor will represent the nose or wing of the aircraft and should be a semicircular mild steel tube, 3.28 ft (1 m) long, 9.8 in. (24.9 cm) diameter, with wall thickness of 0.5 in. (13 mm). The impactor should be supported by a rigid structure and located 43 in. (1 m) off the test track surface and 45.5 in. (115.5 cm) beyond the centerline of the landing gear. The mass of the impactor can significantly affect the data; therefore, it is recommended that the impactor be limited to 3.28 ft (1 m) in length (mounted with two load cells). If a longer impactor is required, a second impactor, with two load cells should be installed in line with the first.

- The test structure should be mounted the same way it is done on the airfield, according to the manufacturer's directions.

- High-speed video cameras should be used to capture the collision that occurs between the impactor and the structure, as well as the failure mode of the structure. To accomplish this, it is recommended to use a video capture rate of 1000 fps and be able to run the video for a minimum of 250 ms.

- A data acquisition system should be used to collect instrumentation data, such as load cell and accelerometer data. Improvements in technology have made it possible to collect data at much higher rates. It is recommended to collect the data at 20 kHz.

- For grounded aircraft tests, it is required to reach a test speed of 31 ±2.5 mph (50 ±4 km/hr) (26.9 ±2.2 knots). This speed should be recorded at the point of impact. However, current technology does not allow speed-recording devices to record data at 20 kHz, but closer to 100 Hz. This means that there most likely will not be a data point right at the time of impact. Use linear interpolation to derive the speed at the point of impact. This is the value that will be used in calculating the energy as explained in chapter 2 §3 of this guidebook.

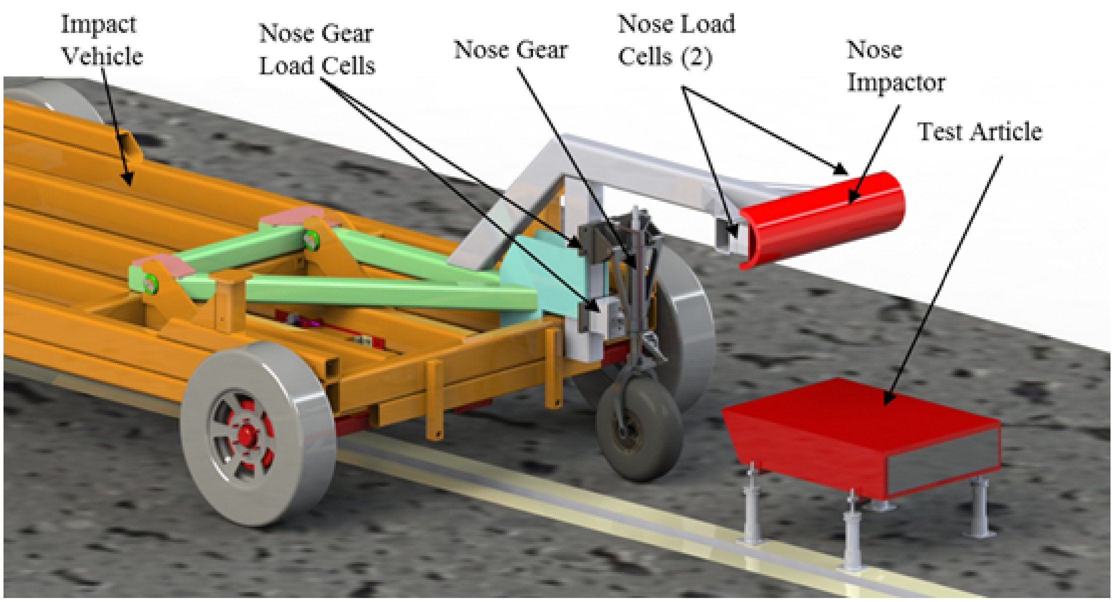


Figure 7. Ground Impact Test System With Frangible LIR Structure

<u>7.2.2.2 Test Qualification Requirements</u>

Test qualification requirements for PAPIs and REILs are as follows:

- The LIR structure should not impose a peak force greater than 13,000 lbf (58.0 kN) on the impactor as recorded by the two load cells and the data summed together. This applies to the forces along the X axis, as shown in figure 4 of this guidebook. Force data cannot be filtered by anything lower than CFC600.

- Taking the integral of the force and multiplying it by the velocity at the point of impact, the resultant energy value should not be greater than 40,566 ft lb (55.0 kJ), during the time in which the structure is in contact with the impactor.

- No part of the landing gear can fail such that it would collapse and cause the fuselage or wings of the aircraft to crash to the ground.

- Electrical cabling (or any other accessories on the structure) should not impede the failure of the structure and should not appear to potentially hinder the continued momentum of an aircraft. This should be observed using the high-speed video.

- Structure fragments resulting from the impact should not rebound in a direction that could potentially cause additional damage to an actual aircraft (puncture the fuselage, tail surfaces, or windows, or cause a wind screen). This can be observed using high-speed video as well as computer simulations.

- All products should undergo full-scale testing to receive FAA approval.

7.2.3 Data Collection and Documentation

As emphasized in chapter 1 §3 of this guidebook, information about tests performed is critical to achieving a standard by which all tests can be compared. All historical tests lack data in certain areas and render it impossible to establish a standard. Part of the research and testing done by the FAA in 2015 [6] was to determine what documentation is important. The following items should be provided to the FAA along with the test report when applying for product approval.

- Specification sheets for instrumentation such as data acquisition systems, sensors, converters, amplifiers, load cells, accelerometers, high-speed cameras, etc.

- Calibration records for all instrumentation

- Documentation of the effective sampling rate for raw data

- Raw data for load cells, accelerometers, and speed measurement devices

- Raw data plots. (If data were filtered, those plots may also be provided. Energy plots should be included as well.)

- Speed at the point of impact (interpolated if necessary)

- High-speed video

- Measured point of impact from top of structure

- Mass and length of broken segments for windowing systems

- Basic dimensions of test system, description of operation, and location of instrumentation

- Final mass of test system
- Detailed drawing for the impactor and mounting of load cells
- Basic description of frangible connection and locations on structure
- Structure material specification sheets and basic drawings for dimensions, location of equipment, and weight per linear foot (30.5 cm) of main structure
- Details (such as weight, size, and attachment method) on attached equipment, electrical cables, lights, etc.
- Details on foundation and connection to main structure, anchor bolts, fuse bolts, etc.
- Wind calculations as well as wind and deflection test results
- All other environmental test results (salt spray, sunshine (solar radiation), humidity, and temperature)
- Results for any computer simulations, including force and energy plots as well as simulation video

7.2.4 Evaluation Criteria (Qualification Requirements)

A test evaluation checklist of qualification requirements is provided in table 16.

Table 16. Test Evaluation Checklist for PAPIs and REILs

Item Number	Test Description	Test Value/Date	Pass/Fail
1	By examination, product meets fabrication and assembly requirements (chapter 3 §7.1.1 of this guidebook)		
2	By examination, product meets all installation requirements (chapter 4 §3.1.2 of this guidebook)		
3	By examination, product meets all hardware requirements (chapter 3 §7.1.1.4. of this guidebook)		
4	By examination, product meets all material requirements (chapter 4 §3.1.1.5 of this guidebook)		
5	By examination, product meets all maintenance requirements including the tilt/lowering test (chapter 3 §7.1.2 of this guidebook)		

Table 16. Test Evaluation Checklist for PAPIs and REILs (Continued)

Item Number	Test Description	Test Value/Date	Pass/Fail
	Environmental Tests		
6	Wind test (chapter 3 §7.2.1.2 of this guidebook): maximum deflection should be less than ±2.0°.		
7	Deflection test (chapter 3 §7.2.1.3 of this guidebook): maximum deflection should be less than ±5.0°.		
8	Salt spray test (chapter 3 §7.2.1.4 of this guidebook): certification and date of completion		
9	Sunshine test (chapter 3 §7.2.1.5 of this guidebook): certification and date of completion		
10	Humidity test (chapter 3 §7.2.1.7 of this guidebook): certification and date of completion		
11	Temperature test (chapter 3 §7.2.1.6 of this guidebook): Certification and date of completion		
12	Vibration analysis (chapter 4 §3.2 of this guidebook): show analysis		
	Frangibility Tests		
14	Peak force (13,000 lbf (58.0 kN) unfiltered)		
15	Maximum energy (40,566 ft lb (55.0 kJ) unfiltered)		
16	Speed at impact (31 ±2.5mph) (50.3 ± 4.1 km/hr) (26.9 ±2.2 knots)		
17	Location of impact (distance from nominal ±4 in.) (±10.2 cm)		
18	Failure mode		
19	Release of electrical cables		

8. WIND CONES

This section addresses wind cone requirements.

8.1 Design Requirements

This section focuses on frangible design elements from AC 150/5345-27 [33]. Additional information on LIR design and application may be found in AC 150/5345-45 [4] and AC 150/5220-23 [3]. Pertinent design requirements are identified in this section. Methods should be approved by an independent, third-party certification body (per AC 150/5345-53 [12]).

8.1.1 Fabrication and Assembly

This section provides information and guidance on standards for fabrication, assembly, and installation such as materials, hardware, finishes, wiring, packaging, shipping, and foundations. These requirements do not require testing for validation, but require approval by inspection from a third-party certification body (per AC 150/5345-53 [12]). Most requirements are associated with a military, federal, or ASTM specification to ensure the processes are completed in accordance with up-to-date standards and practices. All requirements listed in AC 150/5345-27 [33] related to wind cones are identified in this section.

8.1.1.1 Packaging and Shipping

Packaging and shipping requirements for wind cones are as follows:

- Fabric windsocks should be made so it takes the shape of a truncated cone when filled with air. Windsocks also should allow for water drainage and be treated for water repellency.

- All exposed metal parts of the wind cone assembly should be given one primer, one body, and one finish coat of colorfast orange paint.

- Product manual should be provided that includes all necessary procedures for unpacking, assembly, installation, mounting foundation, anchor bolt requirements, operation, recommended maintenance practices, a complete parts list, and wiring diagram for lighted wind cones.

- Wind cone assemblies should be supplied complete with all accessories, including: mounting base, adjusting and connecting hardware, light covers (where required), and installation instructions.

- Structures should be properly packaged to protect small parts and prevent damage and deterioration during shipment.

- Structures should be made in sections to provide easy shipment and handling.

- All containers should be clearly marked for content, type, class, and height of the structure.

- Per ASTM D3951 [13], components should be identified on the package labels if shipped in more than one container.

8.1.1.2 Fabrication

Fabrication of wind cones should be as follows:

- LIR structures and members should not have sharp edges that could be hazardous during handling or any other irregularities that could interfere with fit and assembly.

- The fabric windsock should be made so it takes the shape of a truncated cone when it is filled with air. The windsock should be reinforced at all points that are subject to abrasion by flexing against the metal framework. Also, the windsock should be designed to allow removal and replacement without the use of special tools or stitching.

- The fabric windsock should be constructed to allow water drainage out of the basket assembly area.

- Exposed surfaces should be free from grease, oil, dirt, scale, flux, and chemicals that were deposited during the fabrication process.

- Drilled holes and cut edges of GRP members should be coated with the same material as the original resin.

8.1.1.3 Design and Assembly

Design and assembly of wind cones should be as follows:

- Sections should be designed for rapid field assembly without the use of special tools or welding.

- Mass of structure should be minimized while meeting all other requirements. The mass per unit length should be 2 lb/ft (3 kg/m) or less. Vendor should supply equipment necessary to service the product.

- Design should permit maintenance of lights without the use of specialized equipment.

- During maintenance, design should permit proper light mounting and not restrict the adjustment range of lamp holders.

- At the completion of maintenance, the lights should be returned to their original horizontal and vertical alignments and structure securely locked into place.

- The structure should be designed for routing electrical wires in enclosed wireways to lamps and should be part of the frangible design.

8.1.1.4 Hardware

Wind cone hardware requirements are as follows:

- Aluminum, GRP, and carbon steel hardware is permissible.

- All stainless steel connecting hardware components should be 18-8 stainless steel.

- All high-strength carbon steel bolts, nuts and hardened steel washers should be suitable for the application and comply with ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17].

- All ferrous metal parts (non-stainless steel) should be hot-dip galvanized after fabrication per ASTM A123 [18]. Ferrous hardware (nuts, bolts, washers, and other minor items) should be galvanized by the hot-dip method conforming to ASTM A153 [19].

8.1.2 Maintenance

Maintenance of airfield structures is costly and difficult when located in areas near a runway. LIR structures should be designed to minimize maintenance to the greatest extent possible.

Structures should be designed for easy access to mounted equipment. The product should demonstrate the proper fit and function of all component parts and be accurately represented in the installation instructions.

8.1.3 Environmental

AC 150/5345-27 [33] delineates the environmental design requirements. In addition to the weather environment, requirements for strength, durability, and frangibility should be met. Aircraft safety depends on the structure's ability to yield or break if an accidental collision occurs. Minimum strength requirements have been established to provide a standard for all manufacturers. These requirements should be approved by means of analysis or testing as shown in table 17.

Table 17. Environmental Design Requirements for Wind Cones

Requirement Numbers From AC 150/5345-27 [33]	Description	Approval Method
Temperature Para. 3.1, a	Any ambient temperature between -67°F (-55°C) to 131°F (55°C)	Test MIL-STD-810, Method 501.4, Procedure II [28]
Wind Para. 3.1, b	Wind velocities up to 75 knots (140 km/hr or 86 mph)	Analysis

8.1.4 Frangibility

Frangible structure design goals require structures to be designed with the minimum mass possible while still meeting working loads and environmental requirements. The structure should be frangible when accidentally struck from any direction while causing minimal damage to an aircraft. Specific details for frangible design requirements are provided in table 18.

Table 18. Frangible Structure Design Requirements for Wind Cones

Requirement Numbers From AC-150/5345-27 [33], AC 150/5220-23 [3], AC 150/5345-45 [4]	Description	Approval Method
AC 150/5220-23 Para. 2.2, f, (1) Para 3.2, e AC 150/5345-45 Para. 3.1 Para. 3.9, a Para. 4.2.5.2, c, d, f	Effective failure mechanisms to allow the structure to break, distort, or yield, and not wrap around.	Test Computer Simulation

Table 18. Frangible Structure Design Requirements for Wind Cones (Continued)

Requirement Numbers From AC-150/5345-27 [33], AC 150/5220-23 [3], AC 150/5345-45 [4]	Description	Approval Method
AC 150/5345-27 Para. 3.3 AC 150/5220-23 Para. 2.2, f, (2) Para. 3.3, e	Low-mass segments of predictable size that will not present a hazardous secondary impact.	Test
AC 150/5345-27 Para. 3.4.1 Para. 3.4.2 AC 150/5220-23 Para. 3.2, c, (1), (a) AC 150/5345-45 Para. 3.9, b Para. 4.2.4 Para. 4.2.6	For Type L-806, the frangible support should withstand a moment of 350 lb-ft (475 N-m) without damage and fail before a moment of 700 lb-ft (950 N-m) is reached by a force parallel to and 6 ft (1.8 m) above the surface to which the support is attached or withstand environmental and jet blast loads, but will break, distort, or yield when impacted by a 6600-lb (3000-kg) aircraft at 31 mph (50 km/hr or 26.9 knots) on the ground or air borne at 87 mph (140 km/hr or 75.6 knots). For Type L-807, the support should withstand without damage a moment of not less than 3200 lb-ft (4340 N-m) when the force is applied parallel to and 16 ft (4.8 m) above the surface to which the support is attached. This support may be used only where allowed by airport design standards published in AC 150/5300-13 [7].	Test
AC 150/5220-23 Para. 3.2, c, (1), (b) AC 150/5345-45 Para. 3.9, c Para. 4.2.5.2, a	Should not impose a peak force greater than 13,000 lbf (58.0 kN) or impart energy greater than 40,500 ft lb (55.0 kJ) to the aircraft during a contact period of 100 ms.	Test
AC 150/5220-23 Para. 3.2, c. (1), (c) AC 150/5345-45 Para. 3.9, f	Provide a frangible point 3 in. or less above surrounding grade and tested using the base mounting points connected to frangible connections.	Test
AC 150/5220-23 Para. 3.2, a AC 150/5345-45 Para. 3.9, d Para. 4.2.5.2, e	Electrical cabling should be designed to disconnect so as not to entangle with or impede the aircraft.	Test
AC 150/5220-23 Para. 3.2, h	Electrical cable should not rupture the conductor, but disconnect at predetermined points.	Test

8.2 Test Requirements

AC 150/5345-27 Section 4 [33] specifies design requirements to be inspected and/or tested for approval and were highlighted in chapter 3 §8.1 of this guidebook. More detail in performing tests is provided in this section. The intent is to provide a test procedure that can be used as a standard for all parties seeking FAA approval for their products. This section provides the details for setup and execution of tests as well as data processing and documentation.

8.2.1 Environmental Qualification Procedure and Test Setup

This section provides information for performing the standard environment tests required for FAA approval. Environmental test methods for product qualifications presented in ACs reference MIL-STD-810 [28] for details on conducting each test (i.e., temperature, humidity, sunshine or solar radiation, and salt spray). The system-specific AC details which environmental tests are required to be performed on each system. An overview of basic environmental requirements extracted from system-specific ACs is presented here. It is recommended that if a system-specific AC exists, the required environmental test parameters for qualification should be verified there for all products seeking approval. If no system-specific AC exists, then AC 150/5345-45, Paragraphs 3.3 and 4.2 [4] should be used for product environmental requirements and qualification.

8.2.1.1 Visual Examination

The FAA-approved, third-party certification body (per AC 150/5345-53 [12]) will need to make all approvals required in chapter 3 §8.1 of this guidebook. Visual inspections and analysis approval methods will be used for the construction, assembly, and installation requirements; hardware requirements; materials and finishing requirements; and maintenance requirements. Documentation (such as material specification sheets, painting, anodizing, or galvanizing certifications, and calculations for wind loading) should be provided to the third-party certification body.

8.2.1.2 Wind Test

The structures and all necessary equipment should be designed to withstand pressure loading (no permanent deformation) arising from the following wind velocities when installed with all lighting equipment attached. Structures should be designed to withstand the following velocities up to 75 knots (140 km/hr or 86 mph). Using ANSI/TIA-222 [27], calculate the design wind load on the structure (F_w). See AC 150/5345-26, Paragraph 4.2.3 [34] for support rigidity requirements. Verify that force level was achieved and the structure was not damaged in any way.

8.2.1.3 Salt Spray Test

The salt spray test should be conducted on a section of the structure mast, complete with all accessory hardware per MIL-STD-810, Method 509.4, Paragraph 4.5.2, Procedure I [28]. The test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, rust, pitting, corrosion (except for sacrificial coatings), or GRP delamination is cause for rejection.

8.2.1.4 Sunshine (Solar Radiation) Test

The sunshine (solar radiation) test should be conducted per MIL-STD-810, Method 505.4, Paragraph 4.4.3, Procedure II [28], for all structures with plastic/nonmetallic exterior materials. The material should be subjected to a minimum of 56 radiation cycles. Any evidence of deterioration or GRP delamination is cause for rejection.

8.2.1.5 Temperature

The structure should be tested for both high- and low-operating temperature and should sustain no delamination; also there should be no damage to seals or other components. Structures should be tested in accordance with MIL-STD-810, Method 501.3 [28]. Operational temperature should be between 131°F (55°C) and –67°F (–55°C).

8.2.1.6 Humidity

For hot-humid conditions, the structure should be subjected to the moisture resistance test in accordance with MIL-STD-810, Method 507.3, Procedure II [28]. There should be no evidence of delamination, cracking, corrosion, or deterioration of any part of the structure after cycling has been completed.

8.2.2 Frangible Qualification Procedures and Test Setup

Paragraph 4.2.5 of AC 150/5345-45 [4] provides the requirements for testing frangible LIR structures. These requirements are best understood when divided into two categories: test system and test qualification. The test system requirements explain how the test should be set up to create a standard method of testing for all manufacturers. The test qualification requirements explain how the product should perform during the test. These requirements are summarized and listed below.

8.2.2.1 Test System Requirements

Test system requirements for wind cones are as follows:

- Test vehicle should weigh approximately 6600 lb (3000 kg).
- The impact structure should be sufficiently rigid to minimize energy absorption and be designed such that vibration modes do not interfere with load cell data.
- A Piper Aztec nose gear or equivalent should be mounted to the front of the impact vehicle, directly in line with the structure being tested. Steel adaptor plates should be fabricated to transition between the two mounting points on the landing gear and the load cells. Mass of the adaptor plates should be minimized yet sufficient to handle impact loads. This can be shown by analysis. The landing gear strut should be serviced according to the manufacturer's recommendations and be fully operational. The steering horn should be locked in place to not allow the wheel to turn.

- Load cells should attach between the landing gear and the support structure, with one load cell at each landing gear attachment point as shown in figure 8. Load cells should be triaxial, meaning they are able to capture force data in the X, Y, and Z axes, as shown in figure 4 of this guidebook. Force data should be recorded for a minimum of 250 ms.

- Rigid impactor will represent the nose or wing of the aircraft and should be a semicircular mild steel tube, 3.28 ft (1 m) long, 9.8 in. (24.90 cm) diameter, with wall thickness of 0.5 in. (13 mm). The impactor should be supported by a rigid structure and located 43 in. (1 m) off the test track surface and 45.5 in. (115.6 cm) beyond the centerline of the landing gear. The mass of the impactor can significantly affect the data; therefore, it is recommended that the impactor be limited to 3.28 ft (1 m) in length (mounted with two load cells). If a longer impactor is required, a second impactor, with two load cells should be installed in line with the first.

- The test structure should be mounted the same way it is done on the airfield, according to the manufacturer's directions.

- High-speed video cameras should be used to capture the collision that occurs between the impactor and the structure, as well as the failure mode of the structure. To accomplish this, it is recommended to use a video capture rate of 1000 fps and be able to run the video for a minimum of 250 ms.

- A data acquisition system should be used to collect instrumentation data, such as load cell and accelerometer data. Improvements in technology have made it possible to collect data at much higher rates. It is recommended to collect the data at 20 kHz.

- For grounded aircraft tests, it is required to reach a test speed of 31 ±2.5 mph (50 ±4 km/hr) (26.9 ±2.2 knots). This speed should be recorded at the point of impact. However, current technology does not allow speed-recording devices to record data at 20 kHz, but closer to 100 Hz. This means there most likely will not be a data point right at the time of impact. Use linear interpolation to derive the speed at the point of impact. This is the value that will be used in calculating the energy as explained in chapter 2 §3 of this guidebook.

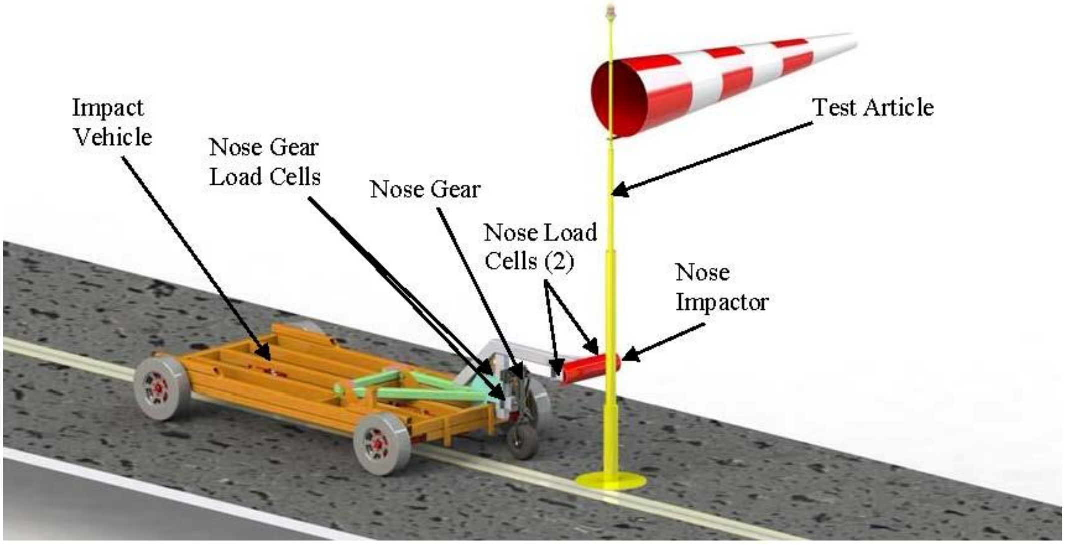


Figure 8. Ground Impact Test System With Frangible Wind Cone Structure

8.2.2.2 Test Qualification Requirements

Test qualification requirements for wind cones are as follows:

- The LIR structure should not impose a peak force greater than 13,000 lbf (58.0 kN) on the impactor as recorded by the two load cells and the data summed together. This applies to the forces along the X axis, as shown in figure 4 of this guidebook. Force data cannot be filtered by anything lower than CFC600.

- Taking the integral of the force and multiplying it by the velocity at the point of impact, the resultant energy value should not be greater than 40,566 ft lb (55.0 kJ), during the time in which the structure is in contact with the impactor.

- No part of the landing gear can fail such that it would collapse and cause the fuselage or wings of the aircraft to crash to the ground.

- Electrical cabling, or any other accessories on the structure, should not impede the failure of the structure and should not appear to potentially hinder the continued momentum of an aircraft. This should be observed using the high-speed video.

- Structure fragments resulting from the impact should not rebound in a direction that could potentially cause additional damage to an actual aircraft (puncture the fuselage, tail surfaces, or windows, or cause a wind screen). This can be observed using high-speed video as well as computer simulations.

- All products should undergo full-scale testing to receive FAA approval.

8.2.3 Data Collection and Documentation

As emphasized in chapter 1 §3 of this guidebook, information about tests performed is critical to achieving a standard by which all tests can be compared. All historical tests lack data in certain areas and render it impossible to establish a standard. Part of the research and testing done by the FAA in 2015 [6] was to determine what documentation is important. The following list of items should be provided to the FAA along with the test report when applying for product approval.

- Specification sheets for instrumentation such as data acquisition systems, sensors, converters, amplifiers, load cells, accelerometers, high-speed cameras, etc.
- Calibration records for all instrumentation
- Documentation of the effective sampling rate for raw data
- Raw data for load cells, accelerometers, and speed measurement devices
- Raw data plots. (If data were filtered, those plots may also be provided. Energy plots should be included as well.)
- Speed at the point of impact (interpolated if necessary)
- High-speed video
- Measured point of impact from top of structure
- Mass and length of broken segments for windowing systems
- Basic dimensions of test system, description of operation, and location of instrumentation
- Final mass of test system
- Detailed drawing for the impactor and mounting of load cells
- Basic description of frangible connection and locations on structure
- Structure material specification sheets and basic drawings for dimensions, location of equipment, and weight per linear foot (30.5 cm) of main structure
- Details (such as weight, size, and attachment method) on attached equipment, electrical cables, lights, etc.
- Details on foundation and connection to main structure, anchor bolts, fuse bolts, etc.
- Wind calculations as well as wind and deflection test results
- All other environmental test results (salt spray, sunshine, humidity, and temperature)

- Results for any computer simulations, including force and energy plots as well as simulation video

8.2.4 Evaluation Criteria (Qualification Requirements)

A test evaluation checklist of qualification requirements is provided in table 19.

Table 19. Test Evaluation Checklist for Wind Cones

Item Number	Test Description	Test Value/Date	Pass/Fail
1	By examination, product meets fabrication and assembly requirements (chapter 3 §8.1.1 of this guidebook)		
2	By examination, product meets all installation requirements (chapter 4 §3.1.2 of this guidebook)		
3	By examination, product meets all hardware requirements (chapter 3 §8.1.1.4 of this guidebook)		
4	By examination, product meets all material requirements (chapter 4 §3.1.1.5 of this guidebook)		
5	By examination, product meets all maintenance requirements including the tilt/lowering test (chapter 3 §8.1.2 of this guidebook)		
Environmental Tests			
6	Wind test (chapter 3 §8.2.1.2 of this guidebook): maximum deflection should be less than ±2.0°		
7	Deflection test (chapter 4 §3.2 of this guidebook): maximum deflection should be less than ±5.0°		
8	Salt spray test (chapter 3 §8.2.1.3 of this guidebook): certification and date of completion		
9	Sunshine test (chapter 3 §8.2.1.4 of this guidebook): certification and date of completion		
10	Humidity test (chapter 3 §8.2.1.6 of this guidebook): certification and date of completion		
Environmental Tests			
11	Temperature test (chapter 3 §8.2.1.5 of this guidebook): certification and date of completion		
12	Vibration analysis (chapter 4 §3.2 of this guidebook): show analysis		
Frangibility Tests			
14	Peak force (13,000 lbf (58.0 kN) unfiltered)		
15	Maximum energy (40,566 ft lb (55.0 kJ) unfiltered)		
16	Speed at impact (31 ±2.5mph) (50.3 ±4.1 km/hr) (26.9 ±2.2 knots)		
17	Location of impact (distance from nominal ±4 in.) (±10.2 cm)		
18	Failure Mode		
19	Release of electrical cables		

9. JET BLAST DEFLECTORS

This section addresses jet blast deflector requirements.

9.1 Design Requirements

Jet blast deflectors are designed to divert or deflect jet blast or propeller wash. Jet blast deflectors should be strong enough to resist the pressures generated by engine thrust; therefore, by nature of their environment, they are not frangible. Jet blast deflectors should be designed and installed with enough structural rigidly to resist and deflect jet blast up and away from defined zones on an airport. Airports should be designed to minimize the need of any jet blast deflectors in the RSA/Runway Object Free Area (ROFA) and TSA environments and have their use confined as much as possible to maintenance and congested areas as required. According to Engineering Brief (EB) 79A [35], jet blast deflectors are not fixed-by-function. However, metal blast deflectors that are placed too close to a localizer may interfere with its navigation signal to aircraft and maybe have to be placed within the RSA. Nonmetallic jet blast deflectors, such as those made of fiberglass or other plastic polymers, do not interfere with localizer signals. Additionally, fiberglass and plastic blast deflectors provide greater frangibility than metal deflectors.

Therefore, any jet blast deflector located within the RSA/ROFA needs to be entirely made of fiberglass or low-mass plastic, including the frangible bolts at the base of the deflector. The point of frangibility should be made no higher than 3 in. above grade, subject to its determination process. Pertinent design requirements are identified in this section and are based on AC 150/5220-23 [3], AC 150/5345-45 [4], and EB-79A [35].

9.1.1 Fabrication, Assembly, and Installation Standards

This section provides information and guidance on standards for fabrication, assembly, and installation such as materials, hardware, finishes, wiring, packaging, shipping, and foundations. The selection of the blast deflector design will be influenced by several things, including the location, purpose, aircraft fleet, height, etc. Several types of blast deflector designs are readily available from various manufacturers. Blast deflectors located inside the ROFA should be made entirely of fiberglass or low-mass plastic, including the frangible bolts at the base of the deflector.

9.1.1.1 Packaging and Shipping

Packaging and shipping of jet blast deflectors should be as follows:

- Shipments should be packaged complete with all accessories, including: mounting base, adjusting and connecting hardware, light covers (where required), and installation instructions.

- A product manual should be provided that includes all necessary procedures for unpacking, assembly, installation, operation, recommended maintenance practices, and a complete parts list.

- Structures should be properly packaged to protect small parts and prevent damage and deterioration during shipment.
- Structures should be made in sections to provide easy shipment and handling.
- All containers should be clearly marked for content, type, class, and height of the structure.
- Per ASTM D3951 [13], components should be identified on the package labels if shipped in more than one container.

9.1.1.2 Fabrication

Fabrication of jet blast deflectors should meet the following guidelines:

- Blast deflector members should not have sharp edges that could be hazardous during handling or any other irregularities that could interfere with fit and assembly.
- All bonding areas should be sandblasted and/or cleaned with a solvent before applying a structural adhesive.
- Exposed surfaces should be free from grease, oil, dirt, scale, flux, and chemicals that are deposited during the fabrication process.
- Drilled holes and cut edges of FRP members should be coated with the same material as the original resin.

9.1.1.3 Design and Assembly

Design and assembly of jet blast deflectors should meet the following guidelines:

- Sections should be designed for rapid field assembly without the use of special tools or welding.
- Mass of structure should be minimized while meeting all other requirements.
- The manufacturer should supply equipment necessary to service the product.
- Structure should be designed for routing electrical wires in enclosed wireways to lamps and should be part of the design.

9.1.1.4 Hardware

Jet blast deflector hardware should meet the following guidelines:

- Aluminum, GRP, and carbon steel hardware is permissible.
- All stainless steel connecting hardware components should be 18-8 stainless steel.

- All high-strength carbon steel bolts, nuts and hardened steel washers should be suitable for the application and comply with ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17].

- All ferrous metal parts (non-stainless steel) should be hot-dip galvanized after fabrication per ASTM A123 [18]. Ferrous hardware (nuts, bolts, washers, and other minor items) should be galvanized by the hot-dip method conforming to ASTM A153 [19].

- Any jet blast deflector placed within the RSA should be made entirely of fiberglass or low-mass plastic, including the frangible bolts at the base of the deflector.

9.1.2 Maintenance

Maintenance of airfield structures is costly and difficult when located in areas near a runway. Jet blast deflector structures should be designed to minimize maintenance to the greatest extent possible. Structures should be designed for easy access to mounted equipment. The product should demonstrate the proper fit and function of all component parts and be accurately represented in the installation instructions.

9.1.3 Environmental

AC 150/5345-45 Section 4 [4] delineates general environmental design requirements. In addition to weather environment, requirements for strength, durability, and frangibility should also be met. Aircraft safety depends on the structure's ability to yield or break if an accidental collision occurs. Minimum strength requirements have been established to provide a standard for all manufacturers. These requirements should be approved by means of analysis or testing, as shown in table 20.

Table 20. Environmental Design Requirements for Jet Blast Deflectors

Requirement Numbers From AC 150/5345-45 [4]	Description	Approval Method
Wind Para. 3.3.1 Para. 4.2.4	Structures should be designed to withstand the following velocities (3-second gust, per ANSI/TIA-222, Annex L [27]): up to 75 mph (65.2 knots) (121 km/hr) with 0.5 in. (13 mm) of ice on all surfaces, 100 mph (86.9 knots) (161 km/hr) without ice. Permanent deformation of the structure is not allowed.	Analysis
Temperature Para. 3.3.2	The structures, components, and all necessary equipment should be designed to withstand temperatures from -67°F (-55°C) to 131°F (55°C).	Test MIL-STD-810, Method 501.5, 502.5 [28]
Relative Humidity Para. 3.3.3	The structures, components, and all necessary equipment should be designed to withstand any relative humidity from 5%-100% including condensation.	Test MIL-STD-810, Method 507.3, Proc. II [28]

Table 20. Environmental Design Requirements for Jet Blast Deflectors (Continued)

Requirement Numbers From AC 150/5345-45 [4]	Description	Approval Method
Sunshine Test (Solar Radiation) Para. 3.3.4 Para. 4.2.3	Structures, components, and equipment using plastic or nonmetallic exterior components should be subjected to a minimum of 56 radiation cycles. Any evidence or deterioration or GRP delamination is cause for rejection.	Test MIL-STD-810, Method 505.5, Para. 4.4.3, Proc. II [28] ASTM G155 [29] ASTM D2565 [30]
Salt Spray Test (Fog) Para. 3.3.5 Para. 4.2.2	Structures, components, and equipment should be designed to withstand exposure to a corrosive salt-laden environment. Salt spray testing should be conducted on a section of structure mast, complete with all sections and hardware. Test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, pitting, corrosion (except for sacrificial coatings), or GRP delaminating is cause for rejection.	Test MIL-STD-810, Method 509.4, Para. 4.5.2, Proc. I [28]
Vibration Para. 3.3.6	The components of the LIR structure should be designed so that no component or combination of components (up to and including the entire structure) will vibrate at or near their resonant frequency and exceed the deflection requirements in Paragraph 3.11 when subjected to the wind load requirements in Paragraph 3.3.1 of the AC.	Test MIL-STD-810 Method 514.6, Para. 4.4.1 Proc. 1, b. [28]

9.1.4 Frangibility

The structure should be designed with the minimum mass possible while still meeting working loads and environmental requirements. According to EB-79A [35], any jet blast deflector placed with the RSA should be entirely made of fiberglass or low-mass plastic, including the frangible bolts at the base of the deflector. The point of frangibility should be made no higher than 3 in. above grade, subject to its determination process.

9.2 Test Requirements

AC 150/5345-45 Section 4 [4] specifies design requirements, highlighted in chapter 3 §9.1 of this guidebook, are required to be inspected and/or tested for approval. More detail as to how these tests should be performed will be provided in this section. The intent is to provide a test procedure that can be used as a standard for all parties. This section provides the details for setup and execution of these tests as well as data processing and documentation.

9.2.1 Environmental Qualification Procedure and Test Setup

This section provides information for performing the standard environment tests required for FAA approval. Environmental test methods for product qualifications presented in ACs reference MIL-STD-810 [28] for details on conducting each test (i.e., temperature, humidity, sunshine or solar radiation, and salt spray). The system-specific AC details which environmental tests are required to be performed on each system. An overview of basic environmental requirements extracted from system-specific ACs is presented here. It is recommended that if a system-specific AC exists, the required environmental test parameters for qualification should be verified there for all products seeking approval. If no system-specific AC exists, then AC 150/5345-45, Paragraphs 3.3 and 4.2 [4] should be used for product environmental requirements and qualification.

9.2.1.1 Visual Examination

The FAA-approved, third-party certification body (per AC 150/5345-53 [12]) will need to make all approvals required in chapter 3 §9.1 of this guidebook. Visual inspections and analysis approval methods will be used for the construction, assembly, and installation requirements; hardware requirements; materials and finishing requirements; and maintenance requirements. Documentation (such as material specification sheets, painting, anodizing, or galvanizing certifications, and calculations for wind loading) should be provided to the third-party certification body.

9.2.1.2 Wind Test

The structures and all necessary equipment should be designed to withstand pressure loading (no permanent deformation) arising from the following wind velocities when installed with all equipment attached. Structures should be designed to withstand the following velocities (3-second gust per ANSI/TIA-222, Annex L [27]): up to 75 mph (121 km/hr) (65.2 knots) with 0.5 in. (13 mm) of ice on all surfaces, 100 mph (161 km/hr) (86.9 knots) without ice. Using ANSI/TIA-222 [27], calculate the design wind load on the structure (F_w) with and without ice. Using the highest force value, perform the wind test by pulling at the midpoint of the structure with a force equal to F_w. Verify that the force level was achieved and that the structure was not damaged in any way.

9.2.1.3 Deflection Test

The purpose of the deflection test is to demonstrate that the structure is sufficiently rigid to meet the requirements in Paragraph 3.11 of AC 150/5345-45 [4]. The test will require equipment to perform a static bend test, which can be done in conjunction with the wind test. The methods defined in ANSI/TIA-222, Paragraph 2.6 [27] can be used to determine the wind load design using a wind velocity of 60 mph (97 km/hr) (52.1 knots) with 3-second gusts and 0.5 in. (13 mm) of ice. The calculated force should then be applied to the structure at the midpoint, using a load cell to measure the force. Measuring the vertical axis of the structure, verify that the maximum deflection angle is less than ±2°.

9.2.1.4 Salt Spray Test

The salt spray test should be conducted on a section of the structure mast, complete with all accessory hardware per MIL-STD-810, Method 509.4, Paragraph 4.5.2, Procedure I [28]. The test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, rust, pitting, corrosion (except for sacrificial coatings), or GRP delamination is cause for rejection.

9.2.1.5 Sunshine (Solar Radiation) Test

The sunshine (solar radiation) test should be conducted per MIL-STD-810, Method 505.4, Paragraph 4.4.3, Procedure II [28], for all structures with plastic/nonmetallic exterior materials. The material should be subjected to a minimum of 56 radiation cycles. Any evidence of deterioration or GRP delamination is cause for rejection.

9.2.1.6 Temperature

The structure should be tested for both high- and low-operating temperature and should sustain no delamination; also there should be no damage to seals or other components. Structures should be tested in accordance with MIL-STD-810, Method 501.3 [28]. Operational temperature should be between 131°F (55°C) and -67°F (-55°C).

9.2.1.7 Humidity

For hot-humid conditions, the structure should be subjected to the moisture resistance test according to MIL-STD-810, Method 507.3, Procedure II [28]. There should be no evidence of delamination, cracking, corrosion, or deterioration of any part of the structure after cycling has been completed.

9.2.2 Evaluation Criteria (Qualification Requirements)

A test evaluation checklist of qualification requirements is provided in table 21.

Table 21. Test Evaluation Checklist for Jet Blast Deflectors

Item Number	Test Description	Test Value/Date	Pass/Fail
1	By examination, product meets fabrication and assembly requirements (chapter 3 §9.1.1 of this guidebook).		
2	By examination, product meets all installation requirements (chapter 4 §3.1.2 of this guidebook).		
3	By examination, product meets all hardware requirements (chapter 3 §9.1.1.4 of this guidebook).		
4	By examination, product meets all material requirements (chapter 4 §3.1.1.5 of this guidebook).		
5	By examination, product meets all maintenance requirements including the tilt/lowering test (chapter 3 §9.1.2 of this guidebook).		

Table 21. Test Evaluation Checklist for Jet Blast Deflectors (Continued)

Item Number	Test Description	Test Value/Date	Pass/Fail
Environmental Tests			
6	Wind test (chapter 3 §9.2.1.2 of this guidebook): maximum deflection should be less than ±2.0°		
7	Deflection Test (chapter 3 §9.2.1.3 of this guidebook): maximum deflection should be less than ±5.0°		
8	Salt spray test (chapter 3 §9.2.1.4 of this guidebook): certification and date of completion		
9	Sunshine test (chapter 3 §9.2.1.5 of this guidebook): certification and date of completion		
10	Humidity test (chapter 3 §9.2.1.7 of this guidebook): certification and date of completion		
11	Temperature test (chapter 3 §9.2.1.6 of this guidebook): certification and date of completion		
12	Vibration analysis (chapter 4 §3.2 of this guidebook): show analysis		

CHAPTER 4—APPROACH LIGHTING SYSTEMS

1. INTENT

This section provides guidance for AC 150/5345-45 [4], which provides the specifications for ALSs. The AC focuses on the design requirements for medium to tall LIR structures (ALSs) that could be hit by an in-flight airplane. To simplify these requirements, this chapter is divided into two parts:

- Design Requirements—section 3 of this chapter, which provides guidance for AC 150/5345-45, Section 3 “Requirements.” This section applies specifically to the structure supporting the ALSs.

- Qualification and Test Requirements—section 4 of this chapter, which provides guidance for AC 150/5345-45, Section 4 “Qualification Requirements.” This section also provides information for setting up and carrying out the standard test methods for FAA approval.

It is recommended that full-scale testing be performed for all products seeking approval. Neither subscale nor static testing provides accurate information as to how a structure will respond in a dynamic impact situation.

2. CLASSIFICATION

AC 150/5345-45 [4] includes four classifications for frangible LIR structures intended for use with ALSs:

- L-891 Style 1—support structures that range from 6 ft 1 in. to 21 ft 1 in.;

- L-892 Style 2—support structures that range from 21 ft 2 in. to 30 ft 0 in.;

- L-891 Style 3—support structures that range from 30 ft 1 in. to 40 ft 0 in.;

- and Type L-892, which applies to elevations above 40 ft 1 in., a 20-ft for which a frangible tower should be mounted on a rigid steel tower.

Section 1.1 of AC 150/5345-45 [4] currently divides the ALS structures into two types of structures based on height. The L-891 applies to any structure with a height between 6 ft 1 in. (1.85 m) and 40 ft (12.19 m). (The L-891 has three different styles; however, these have no relevance to the design and test requirements.) The L-892 applies to support structures that are 40 ft 1 in. (12.21 m) and taller. These will subsequently be referred to as ground borne and airborne, respectively.

Both testing categories may apply to ALS, glideslope, or runway distance remaining sign structures based on the height of the individual structure. Figure 9 shows how each testing category is determined.

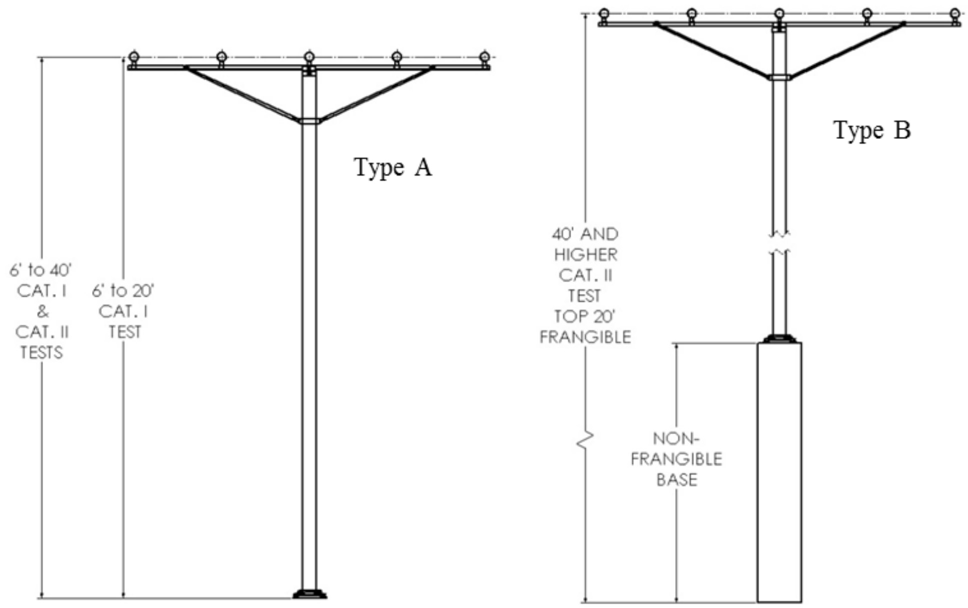


Figure 9. Test Categories for Ground-Borne (Type A) and Airborne (Type B) ALS Structures Based on Height

3. DESIGN REQUIREMENTS

To provide a straightforward approach to designing and approving LIR structures, all design requirements identified in Section 3 of AC 150/5345-45 [4] are organized here into three specific sections: Fabrication, Assembly, and Installation (chapter 4 §3.1); Environmental (chapter 4 §3.2); and Frangibility (chapter 4 §3.3). Methods are clearly defined and should be approved by an independent, third-party certification body (per AC 150/5345-53 [12]).

3.1 Fabrication, Assembly, and Installation

This section provides information and guidance on standards for fabrication, assembly, and installation including packaging and shipping, fabrication, design and assembly, hardware, and materials. These requirements do not require testing for validation, but require approval by inspection from the third-party certification body (per AC 150/5345-53 [12]). Most requirements are associated with a military, federal, or ASTM specification to ensure the processes are completed in accordance with up-to-date standards and practices.

3.1.1 Fabrication and Assembly

Fabrication and assembly should be conducted according to the information in this guidebook presented below.

3.1.1.1 Packaging and Shipping

Packaging and shipping requirements for ALSs are as follows:

- Shipment of packages should be supplied complete with all accessories, including mounting base, adjusting and connecting hardware, light bars (where required), and installation instructions.
- A product manual should be provided that includes all necessary procedures for unpacking, assembly, installation, operation, recommended maintenance practices, and a complete parts list.
- Structures should be properly packaged to protect small parts and prevent damage and deterioration during shipment.
- Structures should be made in sections to provide easy shipment and handling.
- All containers should be clearly marked for content, type, class, and height of the structure.
- Per ASTM D3951 [13], components should be identified on the package labels if shipped in more than one container.

3.1.1.2 Fabrication

Fabrication requirements for ALSs should be as follows:

- LIR structures and members should not have sharp edges that could be hazardous during handling or any other irregularities that could interfere with fit and assembly.
- All bonding areas should be sandblasted and/or cleaned with a solvent before applying a structural adhesive.
- Exposed surfaces should be free from grease, oil, dirt, scale, flux, and chemicals that were deposited during the fabrication process.
- Drilled holes and cut edges of GRP members should be coated with the same material as the original resin.

3.1.1.3 Design and Assembly

Design and assembly of ALSs should be as follows:

- Sections should be designed for rapid field assembly without the use of special tools or welding.
- Mass of the structure should be minimized while meeting all other requirements. Recommended target for mass per unit length is 2 lb/ft (3 kg/m).

- Designer/manufacturer/installer should supply equipment necessary to service the structure, either by lowering and raising equipment and hardware as required based on height, or by some other means.

- Design should permit maintenance of lights without the use of additional equipment, such as man-lift machines or large ladders.

- During maintenance, design should permit lights to be aligned horizontally, permit proper mounting, and not restrict the adjustment range of lamp holders.

- At the completion of maintenance, the lights should be returned to their original horizontal and vertical alignments, and the structure should be locked securely into place.

- The structure should be designed for routing electrical wires in enclosed wireways to lamps and should be part of the frangible design.

3.1.1.4 Hardware

Hardware includes equipment, mounts, lamps, lamp fixtures, nuts and bolts, etc. Requirements for hardware are as follows:

- All PAR-56 lamp-attaching hardware and lamp supports for the LIR structure should be compatible with the requirements in FAA-E-982 [36] and FAA Drawing D-6155-23 [37]. Lamp and holder should weigh 6.5 lb (3 kg) ±10%.

- All PAR-38 lamp-attaching hardware and lamp supports should be per the requirements in FAA-E-2325E (superseded by E-2980) [38]. Lamp and holder should weigh 2.75 lb (1.25 kg) ±10%.

- All high-strength carbon steel bolts, nuts and hardened steel washers should be suitable for the application and comply with ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17].

- All ferrous metal parts (non-stainless steel) should be hot-dip galvanized after fabrication per ASTM A123 [18]. Ferrous hardware (nuts, bolts, washers, and other minor items) should be galvanized by the hot-dip method conforming to ASTM A153 [19].

3.1.1.5 Materials

The materials used for LIR structures are critical components for compliance with all requirements. The materials specified in Paragraph 3.4 of AC 150/5345-45 [4] are currently approved for use; however, new materials may be developed that will also be approved in the future. The materials chosen should have a high strength-to-weight ratio as well as the ability to withstand harsh environmental conditions. Aluminum and steel materials have been used extensively in the past; however, technological advances in fiberglass and other composites have shown these materials to be more effective in meeting the requirements.

Studies and computer simulations were conducted to see the effects of an aircraft colliding with a steel tower. The forces were found to be extremely high, up to 10 times higher than GRP structures [39]. Aluminum towers also have been studied extensively and unless well-designed frangible joints are implemented, the aluminum structures tend to wrap around the wing (impactor) and pull down with significant force. GRP structures can also wrap around and pull on the impactor if no joints are implemented; however, it is common to implement these joints into LIR structures. Several designs already exist and have been tested.

Table 22 provides a reference for all materials and finishes specified in AC 150-5345-45 [4]. As a point of clarification, aluminum materials are required to be anodized according to the current specification. Some structures (including aluminum structures) are also required to be painted the color orange 12197, per FED-STD-595 [21]. There are procedures for painting anodized aluminum, and multiple paint procedures are acceptable. For this reason, several materials and finishes are listed in table 22.

Table 22. Materials and Finishes for ALSs

Application From AC 150/5345-45 [4]	Material Description	Finish
Structures (Hardware) Para. 3.4.1 Para. 3.5.2 Para. 3.5.3	Aluminum 6061-T6, 6061-T6511 per AA ASD-1 [21]	All aluminum structures should be anodized IAW MIL-A-8625 Type II, Class I [22] Matte Finish Paint IAW AAMA 2603-98 [23] MIL-PRF-85285 [24] FED-STD-595 [20] MIL-P-85582 [25]
Structures Para. 3.5.2	Aluminum casting should be A356-T6 per AA ASD-1 [21]	All aluminum structures should be anodized IAW MIL-A-8625 Type II, Class I [22] Matte Finish Paint IAW AAMA 2603-98 [23] MIL-PRF-85285 [24] FED-STD-595 [20] MIL-P-85582 [25]
Structures Para. 3.5.1	Carbon steel	Hot-dipped galvanized per ASTM A 123 [18]
Hardware Para. 3.4.3	Stainless steel 18-8	None
Hardware Para. 3.4.4 Para. 3.5.1	Steel per ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17]	Hot-dipped galvanized per ASTM A 153 [19]
Structures Para. 3.4.2 Para. 3.5.3	GRP	Paint IAW AAMA 2603-98 [23] MIL-PRF-85285 [24]
Accessories Para. 3.4.6	Rubber per ASTM D1149 [26]	None

Documentation should be provided to the third-party certification body (per AC 150/5345-53 [12]) showing the materials used in the structure and the finishes applied (see AC 150/5345-45, paragraph 3.4 and subparagraphs [4]). Visual inspections will also be performed for verification.

3.1.2 Installation

Installation of ALS structures should comply with the following requirements:

- Base of each ground-borne structure should be secured to a foundation using an approved frangible connection. Airborne structures should be attached using hardware sufficient for the expected loads and does not require the use of frangible connections.

- Leveling of each structure should be achievable by simple adjustments.

- Foundation should be flush with grade when possible; and when located in the RSA or TSA, should comply with the 3 in. (7.6 cm) frangibility rule specified in AC 150/5220-23 [3].

- A copper lug sized for a #6 ground wire connection should be provided and secured to the structure base.

- Two #12 wires should be supplied for each lamp and enclosed in wireways designed to be part of the structure. No electrical wires are allowed to be exposed.

- If the ALS is installed in an Engineered Materials Arresting System (EMAS) location, two points of frangibility should be incorporated. The first point should be 3 in. above grade level and the second should be 3 in. above the EMAS surface. The frangible point at the EMAS surface should be part of the composite material, and use of fuse bolts at the EMAS surface is not permitted. Figure 10 shows an example installation.

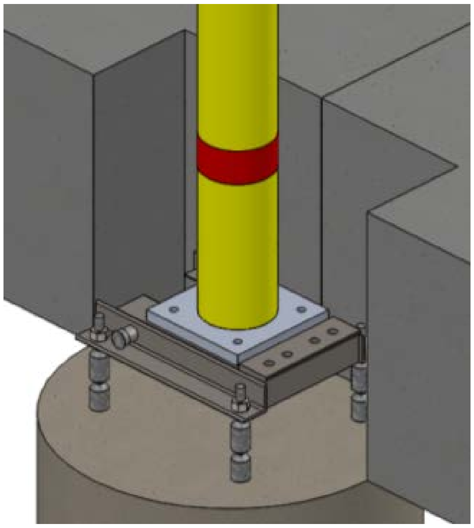


Figure 10. Example of ALS Installed in an EMAS

3.1.3 Maintenance

Maintenance on airfield structures can be costly and sometimes difficult to achieve when located in areas near the runway. LIR structures should be designed to minimize maintenance as much as possible. As discussed in the Fabrication and Assembly section (chapter 4 §3.1.1), structures should be designed to easily access mounted equipment by some means provided with the structure. Use of man lifts or other similar equipment should not be required.

To meet this requirement, a demonstration should be provided, as stated in AC 150/5345-45, Paragraph 4.2.7 [4]. The manufacturer should assemble and erect a structure designed to tilt or lower per the assembly instructions. The structure should demonstrate the proper fit and function of all component parts and the proper raising and lowering of the structure. Before raising or lowering of any structure, the manufacturer should install an equivalent weight for each lamp or flasher on the crossbar. The demonstration should prove to the satisfaction of the third-party certification body (per AC 150/5345-53 [12]) that maintenance specialists can safely perform all maintenance tasks.

3.2 Environmental

Designing LIR structures requires a delicate balance between strength/durability and frangibility. Mission requirements should be met, which include standing up to environmental forces, while safety depends on the structures ability to yield or break if an accidental collision occurs. Minimum strength requirements have been established to provide a standard for all manufacturers. These requirements should be approved by means of analysis or testing according to Section 3 of AC 150/5345-45 [4], as shown in table 23.

Water can cause the degradation of coatings; therefore, knowledge of how a coating resists water is helpful for assessing how it will perform in actual service. Failure in tests at 100 % relative humidity may be caused by a number of factors including a deficiency in the coating itself, contamination of the substrate, or inadequate surface preparation. This practice is therefore useful for evaluating coatings alone or complete coating systems.

Table 23. Environmental Tests and Approval Methods for ALSs

Requirement Numbers. From AC 150/5345-45 [4]	Description	Approval Method
Wind Para. 3.3.1	Structures should be designed to withstand 3-second gusts up to 75 mph (121 kmhr) (65.2 knots) with 0.5 in. (13 mm) of ice on all surfaces or 100 mph (161 km/hr) (86.9 knots) without ice.	Analysis Test (guidebook chapter 4 §4.1.2)
Temperature Para. 3.3.2	Structures, components, and equipment should be designed to withstand temperatures from -67°F (-55°C) to 131°F (55°C).	Test (guidebook chapter 4 §4.1.6)
Relative Humidity Para. 3.3.3	Structures, components, and equipment should be designed to withstand relative humidity from 5% to 100% including condensation.	Test (guidebook chapter 4 §4.1.7)
Sunshine (Solar Radiation) Para. 3.3.4	Structures, components, and equipment using plastic or nonmetallic components should withstand prolonged exposure to solar radiation.	Test (guidebook chapter 4 §4.1.5) MIL-STD-810 [28] ASTM G155 [29] ASTM D2565 [30]
Salt Spray Para. 3.3.5	Structures, components, and equipment should be designed to withstand exposure to a corrosive salt laden environment. Salt spray testing should be conducted on a section of structure mast, complete with all sections and hardware. Test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, pitting, corrosion (except for sacrificial coatings), or GRP delaminating is cause for rejection.	Test (guidebook chapter 4 §4.1.4) MIL-STD-810, Method 509.4, Para. 4.5.2, Proc. I [28]
Vibration Para. 3.3.6	Components, assemblies, and structure should be designed so as to not vibrate at or near their resonant frequency and exceed the deflection requirements when subjected to the maximum wind load.	Analysis
Deflection Para. 3.11	Structure should be rigid enough to prevent the light beam from deflecting more than ±2° in the vertical axis and ±5° in the horizontal axis when subjected to a wind velocity of 60 mph (97 km/hr) (52.1 knots) (3 second gust) and coated with 0.5 in. (13 mm) of ice.	Test (guidebook chapter 4 §4.1.3)

3.3 Frangibility

According to AC 150/5345-45 Section 3.9 [4], the general concept for frangible structure design is this: the structure should be designed with the minimum mass possible while still meeting working loads and environmental requirements, and be frangible when accidentally struck from any direction, causing minimal damage to an aircraft. Specific details for frangible design requirements are provided in table 24 and are important to consider during the design process. Details for testing procedures are given in chapter 4 §4.2 of this guidebook.

Table 24. Frangible Structure Design Requirements and Approval Methods for ALSs

Requirement Numbers From AC 150/5220-23 [3] and AC 150/5345-45 [4]	Description	Approval Method
AC 150/5220-23 Para. 2.2, f, (1) Para. 3.2, e AC 150/5345-45 Para. 3.1, 3.9, a Para. 4.2.5.2, c, d, f	Effective failure mechanisms to allow the structure to break, distort, or yield and not wrap around. Structure should be designed to break, yield, or distort and not entangle or otherwise limit the safe maneuverability of the aircraft.	Test Computer simulation
AC 150/5220-23 Para. 2.2, f, (2) Para. 3.3, e AC 150/5345-45 Para. 4.2.5.1, d	Low mass segments of predictable size that will not present a hazardous secondary impact. Structure should be designed to be frangible subjected to a collision by a 6613.8-lb (3000-kg) airborne aircraft traveling at 75.6 knots (87 mph) (140 km/hr).	Test
AC 150/5220-23 Para. 3.2, c, (1), (a) AC 150/5345-45 Para. 3.9, b Para. 4.2.4 Para. 4.2.6	Withstand environmental and jet blast loads, but will break, distort, or yield when impacted by a 6600-lb (3000-kg) aircraft at 31 mph (26.9 knots) (50 km/hr) on the ground or airborne at 87 mph (75.6 knots) (140 km/hr). During the collision, the structure should not exert a force greater than 10,116 lbf (45 kN) and a maximum energy imparted to the aircraft of 40,566 ft lb (55 kJ) peak during structural contact period of 100 ms.	Test
AC 150/5220-23 Para. 3.2, c. (1), (c) AC 150/5345-45 Para. 3.9, f	Provide a frangible point 3 in. (7.6 cm) or less above surrounding grade and tested using the base mounting points connected to frangible connections. If the ALS is installed in an EMAS location, two points of frangibility should be incorporated. The first point should be 3 in. above grade level and the second should be 3 in. above the EMAS surface. The frangible point at the EMAS surface should be part of the composite material and use of fuse bolts at the EMAS surface is not permitted. An example installation is pictured in figure 8 of this guidebook.	Test
AC 150/5220-23 Para. 3.2, a AC 150/5345-45 Para. 3.9 d Para. 4.2.5.2, e	Electrical cabling should be designed to disconnect so as to not entangle with or impede the aircraft.	Test
AC 150/5220-23 Para. 3.2, h	Electrical cable should not rupture the conductor but disconnect at predetermined points.	Test

4. QUALIFICATION AND TEST REQUIREMENTS

Most AC 150/5345-45 Section 4 [4] design requirements should be inspected and/or tested for approval, as described in chapter 4 §3 of this guidebook. More detail as to how these tests should be performed will be provided in this section. The intent is to provide clear test procedures that can be used as a standard for all parties seeking FAA approval for their products. This section provides the details as to how to setup and perform these tests including proper data processing and documentation.

4.1 Environmental Qualification Procedures and Test Setup

Section 4.2 of AC 150/5345-45 [4] provides information for performing the standard environment tests required for FAA approval. Environmental test methods for product qualifications presented in ACs reference MIL-STD-810 [28] for details on conducting each test (temperature, humidity, sunshine or solar radiation, and salt spray). The system-specific AC details of which environmental tests are required to be performed on each system is presented here. It is recommended that if a system-specific AC exists, it should be used to verify the required environmental test parameters for qualification for all products seeking approval. If no system-specific AC exists, then AC 150/5345-45, Paragraphs 3.3 and 4.2 [4] should be used for product environmental requirements and qualification.

4.1.1 Visual Examination

Per AC 150/5345-53 [12], the FAA-approved, third-party certification body will make all approvals required in chapter 4 §4.1 of this guidebook. Visual inspections and analysis approval methods will be used for the construction, assembly, and installation requirements; hardware requirements; materials and finishing requirements; and maintenance requirements. Documentation such as material specification sheets, painting, anodizing, or galvanizing certifications, and calculations for wind loading should be provided to the third-party certification body.

4.1.2 Wind Test

The structures and all necessary equipment should be designed to withstand pressure loading (no permanent deformation) arising from the following wind velocities when installed with all lighting equipment attached (3-second gust per ANSI/TIA-222, Annex L [27]): up to 75 mph (121 km/hr) (65.2 knots) with 0.5 in. (13 mm) of ice on all surfaces, 100 mph (161 km/hr) (86.9 knots) without ice. Using ANSI/TIA-222, calculate the design wind load on the structure (F_w) with and without ice. Using the resulting highest force value, perform the wind test by pulling at the midpoint of the structure with a force equal to F_w, as shown in figure 9. Verify that force level was achieved, that the structure was not damaged, and it returned to its original position.

4.1.3 Deflection Test

The purpose of the deflection test is to demonstrate that the structure is sufficiently rigid to meet the requirements in Paragraph 3.11 of AC 150/5345-45 [4]. The test will require equipment to perform a static bend test and can be done in conjunction with the wind test. Use the methods defined in ANSI/TIA-222, Section 2.6 [27] to determine the design wind load using a wind velocity of 60 mph (97 km/hr) (52.1 knots) with 3-second gusts and 0.5 in. (13 mm) of ice. The calculated force should then be applied to the structure at the midpoint, using a load cell to measure the force, as shown in figure 11. Measuring the vertical axis of the structure, verify that the maximum deflection angle is less than ±2°.

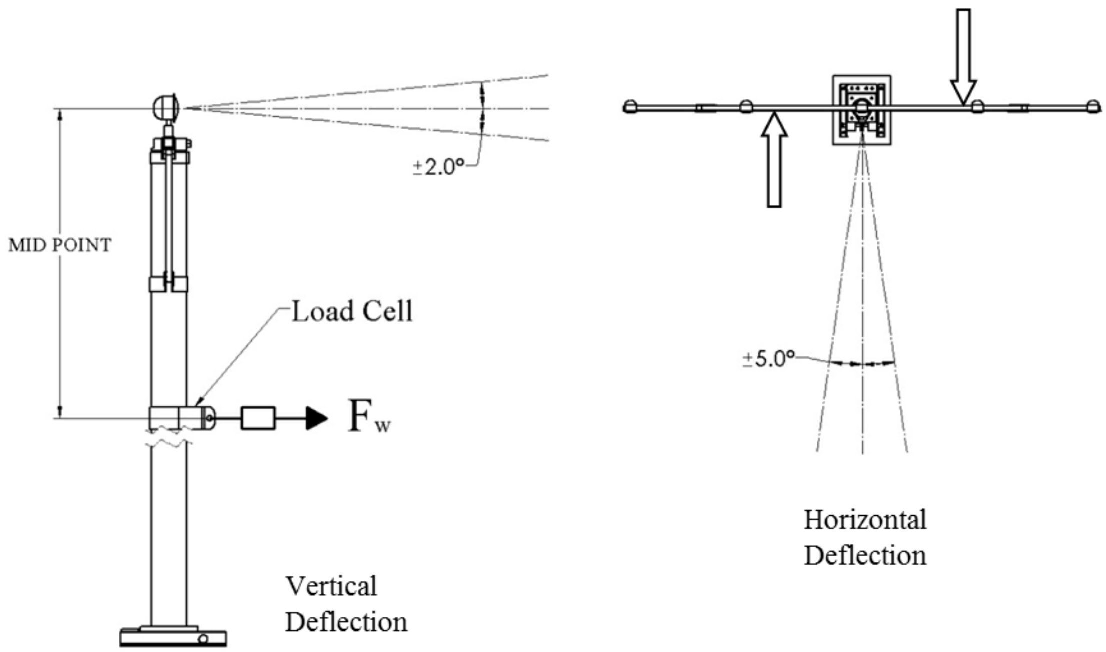


Figure 11. Wind and Deflection Test for ALS Structures

Wind forces may also cause deflection in the horizontal axis. Typically, wind forces are evenly distributed along the cross arm; but it may be possible that in a wind gust, a force may cause rotation about the center axis of the structure. To determine this force, calculate the wind force along the cross arm using a wind velocity of 60 mph (97 km/hr) (52.1 knots) with 3-second gusts and 0.5 in. (13 mm) of ice (include surface area of equipment mounted on cross arm). Divide the force by 4 and apply to the midpoint of each half of the cross arm in opposite directions, as shown in figure 9. The light-beam axis should not deflect more than ±5° in the horizontal plane.

4.1.4 Salt Spray Test

The salt spray test should be conducted on a section of the structure mast, complete with all accessory hardware per MIL-STD-810, Method 509.4, Paragraph 4.5.2, Procedure I [28]. The test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, rust, pitting, corrosion (except for sacrificial coatings), or GRP delamination is cause for rejection.

4.1.5 Sunshine (Solar Radiation) Test

The sunshine (solar radiation) test should be conducted per MIL-STD-810, Method 505.4, Paragraph 4.4.3, Procedure II [28] for all structures with plastic/nonmetallic exterior materials.

The material should be subjected to a minimum of 56 radiation cycles. Any evidence of deterioration or GRP delamination is cause for rejection.

4.1.6 Temperature

The structure should be tested for both high- and low-operating temperature and should sustain no delamination; also there should be no damage to seals or other components. Structures should be tested in accordance with MIL-STD-810, Method 501.3 [28]. Operational temperature should be between 131°F (55°C) and -67°F (-55°C).

4.1.7 Humidity

For hot-humid conditions, the structure should be subjected to the moisture resistance test per MIL-STD-810 [28], Method 507.3, Procedure II. There should be no evidence of delamination, cracking, corrosion, or deterioration of any part of the structure after cycling has been completed.

4.2 Frangible Qualification Procedures and Test Setup

Paragraph 4.2.5 of AC 150/5345-45 [4] provides the requirements for testing a frangible ALS structure. These requirements are best understood when divided into two categories: test system and test qualification. The test system requirements relate to how the test should be set up so as to create a standard method of testing for all manufacturers. The test qualification requirements relate to how the product should perform during the test. These requirements are summarized and listed below.

4.2.1 Airborne Testing for Structures Between 20 - 40 ft (6 - 12 m)

This section addresses airborne testing requirements for ALS structures.

4.2.1.1 Test System Requirements

Test system requirements for ALS structures are as follows:

- Test vehicle should weigh approximately 6600 lb (3000 kg).
- Impact structure should be sufficiently rigid to minimize energy absorption and be designed such that vibration modes do not interfere with load cell data.
- Load cells should attach between the rigid impactor and the support structure, with only two allowed for each impactor as shown in figure 10, and mounted as close as possible to the ends of the impactor to ensure all of the impact occurs between the load cells. Load cells should be triaxial, meaning they are able to capture force data in the X, Y, and Z axes, as shown in figure 4 of this guidebook. AC 150/5345-45 requires the data to be recorded for at least 100 ms; however, testing has shown that certain impact scenarios may take longer than that. Therefore, it is recommended that all data be recorded for a minimum of 250 ms.

- The rigid impactor should be a semicircular mild steel tube, 3.28 ft (1 m) long, 9.8 in. (24.9 cm) in diameter, with wall thickness of 1.0 in. (25 mm). The mass of the impactor can significantly affect the data; therefore, it is recommended that the impactor be limited to 3.28 ft (1 m) in length (mounted with two load cells). If a longer impactor is required, a second impactor with two load cells should be installed in line with the first (see figure 12).

- High-speed video cameras should be used to capture the collision that occurs between the impactor and the structure, as well as the failure mode of the structure. To accomplish this, it is recommended to use a video capture rate of 1000 fps and be able to run the video for a minimum of 250 ms.

- A data acquisition system should be used to collect instrumentation data such as load cell and accelerometer data. Improvements in technology have made it possible to collect data at much higher rates. AC 150/5345-45 requires 10 kHz as a minimum; however, for all future testing, it is recommended to collect the data at 20 kHz to be consistent with current testing procedures.

- For ALS structures, it is required to reach a test speed of 87 ±2.5 mph (140 ±4 km/hr) (75.6 ±2.2 knots). This speed should be recorded at the point of impact. Current technology does not allow speed-recording devices to record data at 20 kHz, but closer to 100 Hz. This means that there most likely will not be a data point right at the time of impact. Therefore, it is recommended to use linear interpolation to derive the speed at the point of impact. This is the value that will be used in calculating the energy, as explained in chapter 2 §3 of this guidebook.

- The impact location should be 3.28 ft. ±3.0 in. (1.0 m ±10 cm) from the top. The top of the structure is defined by the end of the main mast of the structure.

- All ALS test structures should be 20 ft (6 m) in length to standardize the test setup. Structures can be mounted vertically or horizontally.

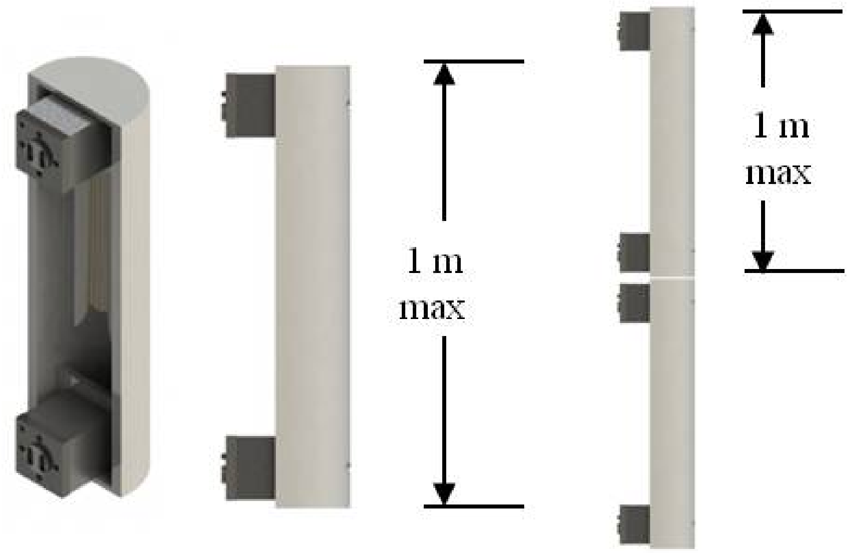


Figure 12. Single and Multiple Impactor Setups

4.2.1.2 Test Qualification Requirements

Test qualification requirements for LIR structures are as follows:

- The LIR structure should not impose a peak force greater than 10,116 lbf (45.0 kN) on the impactor as recorded by the two load cells and the data summed together. This applies to the forces along the X axis, as shown in figure 4 of this guidebook. Force data cannot be filtered by anything lower than CFC600.

- Taking the integral of the force and multiplying it by the velocity at the point of impact, the resultant energy value should not be greater than 40,566 ft lb (55.0 kJ), during the time in which the structure is in contact with the impactor.

- The failure mode of the structure should be fracturing, windowing, or bending. This means that the structure should either break somewhere near the point of impact allowing the impactor to pass through the pieces on either side, or the structure should push out of the way without wrapping around the wing and pulling it down. The force pulling the wing down has not been defined as a requirement, but testing and research is being done in this area.

- If part of the structure wraps around the impactor and remains engaged, it should separate from the foundation and/or other parts of the structure. It should have a mass no greater than 2 lb/ft (3 kg/m) and not be longer than 3 ft (1 m).

- Electrical cabling or any other accessories on the structure should not impede the failure of the structure and should not appear to potentially hinder the continued flight of an aircraft. This should be observed using the high-speed video.

- Structure fragments resulting from the impact should not rebound in a direction that could potentially cause additional damage to an actual aircraft (puncture the fuselage, tail surfaces, or windows, or cause a wind screen). This can be observed using high-speed video as well as computer simulations.

- All products should undergo full-scale testing to receive FAA approval.

4.2.2 Ground-Borne Testing for Structures Less Than 40 ft (12 m)

This section addresses ground-borne testing requirements for ALS structures.

4.2.2.1 Test System Requirements

Test system requirements for ALS structures are as follows:

- Test vehicle should weigh approximately 6600 lb (3000 kg).

- The impact structure should be sufficiently rigid to minimize energy absorption and be designed such that vibration modes do not interfere with load cell data.

- A Piper Aztec nose gear or equivalent should be mounted to the front of the impact vehicle, directly in line with the structure being tested. Steel adaptor plates should be fabricated to transition between the two mounting points on the landing gear and the load cells. Mass of adaptor plates should be minimized yet sufficient to handle impact loads. This can be shown by analysis. The landing gear strut should be serviced according to the manufacturer's recommendations and be fully operational. The steering horn should be locked in place to not allow the wheel to turn.

- Load cells should attach between the landing gear and the support structure, with one load cell at each landing gear attachment point, as shown in figure 13. Load cells should be triaxial, meaning they are able to capture force data in the X, Y, and Z axes, as shown in figure 4 of this guidebook. Force data should be recorded for a minimum of 250 ms.

- The rigid impactor will represent the nose or wing of the aircraft and should be a semicircular mild steel tube, 3.28 ft (1 m) long, 9.8 in. (24.9 cm) diameter, with wall thickness of 0.5 in. (13 mm). The impactor should be supported by a rigid structure and located 43 in. (1 m) off the test track surface and 45.5 in. (115.6 cm) beyond the centerline of the landing gear. The mass of the impactor can significantly affect the data; therefore, it is recommended that the impactor be limited to 3.28 ft (1 m) in length (mounted with two load cells). If a longer impactor is required, a second impactor, with two load cells should be installed in line with the first.

- The test structure should be mounted the same way it is done on the airfield, according to the manufacturer's directions.

- High-speed video cameras should be used to capture the collision that occurs between the impactor and the structure, as well as the failure mode of the structure. To accomplish this, it is recommended to use a video capture rate of 1000 fps and be able to run the video for a minimum of 250 ms.

- A data acquisition system should be used to collect instrumentation data such as load cell and accelerometer data. Improvements in technology have made it possible to collect data at much higher rates. It is recommended to collect the data at 20 kHz.

- For grounded aircraft tests, it is required to reach a test speed of 31 ±2.5 mph (50 ±4 km/hr) (26.9 ±2.2 knots). This speed should be recorded at the point of impact. Current technology does not allow speed-recording devices to record data at 20 kHz, but closer to 100 Hz. This means that there most likely will not be a data point right at the time of impact. Therefore, it is recommended to use linear interpolation to derive the speed at the point of impact. This is the value that will be used in calculating the energy as explained in chapter 2 §3 of this guidebook.

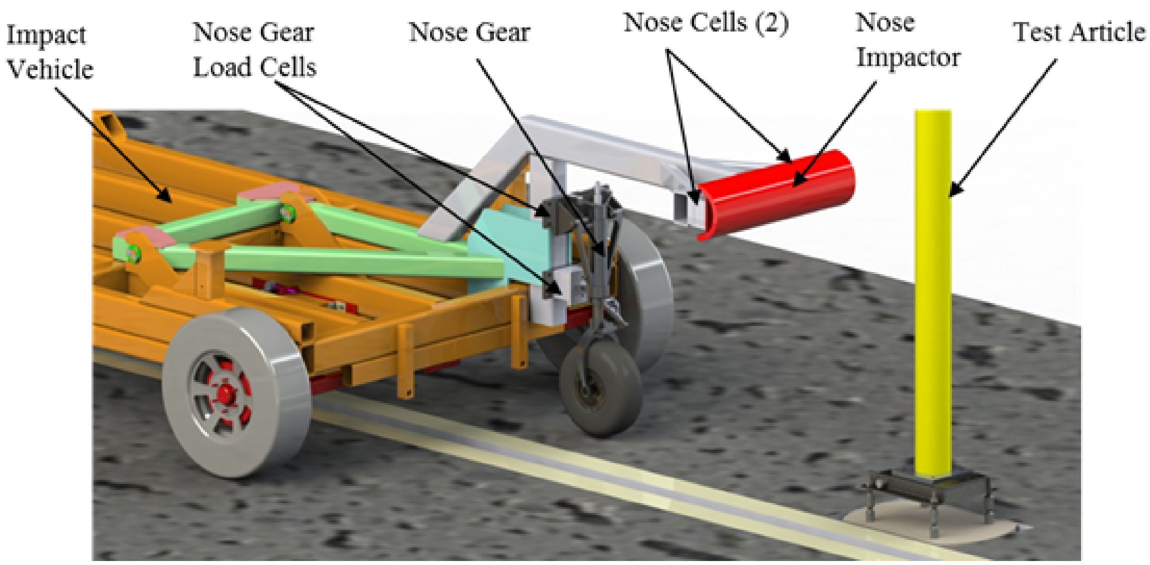


Figure 13. Ground Impact Test System With Frangible Structure Less Than 40-ft High

4.2.2.2 Test Qualification Requirements

Test qualification requirements for frangible LIR structures are as follows:

- The LIR structure should not impose a peak force greater than 13,000 lbf (58.0 kN) on the impactor as recorded by the two load cells and the data summed together. This applies to the forces along the X axis, as shown in figure 4 of this guidebook. Force data cannot be filtered by anything lower than CFC600.

- Taking the integral of the force and multiplying it by the velocity at the point of impact, the resultant energy value should not be greater than 40,566 ft lb (55.0 kJ), during the time in which the structure is in contact with the impactor.

- No part of the landing gear can fail such that it would collapse and cause the fuselage or wings of the aircraft to crash to the ground.

- Electrical cabling or any other accessories on the structure should not impede the failure of the structure and should not appear to potentially hinder the continued momentum of an aircraft. This should be observed using the high-speed video.

- Structure fragments resulting from the impact should not rebound in a direction that could potentially cause additional damage to an actual aircraft (puncture the fuselage, tail surfaces, or windows, or cause a wind screen). This can be observed using high-speed video as well as computer simulations.

- All products should undergo full-scale testing to receive FAA approval.

4.3 Data Collection and Documentation

As emphasized in the chapter 1 §3 of this guidebook, information about tests performed is critical to achieving a standard by which all tests can be compared. All historical tests lack data in certain areas and render it impossible to establish a standard. Part of the research and testing done by the FAA in 2015 [6] was to determine what documentation is important. The following list of items should be provided to the FAA along with the test report when applying for product approval.

- Specification sheets for instrumentation such as data acquisition systems, sensors, converters, amplifiers, load cells, accelerometers, high-speed cameras, etc.

- Calibration records for all instrumentation

- Documentation of the effective sampling rate for raw data

- Raw data for load cells, accelerometers, and speed measurement devices

- Raw data plots (If data were filtered, those plots may also be provided. Energy plots should be included as well.)

- Speed at the point of impact (interpolated if necessary)

- High-speed video

- Measured point of impact from top of structure

- Mass and length of broken segments for windowing systems

- Basic dimensions of test system, description of operation, and location of instrumentation

- Final mass of test system
- Detailed drawing for the impactor and mounting of load cells
- Basic description of frangible connection and locations on structure
- Structure material specification sheets and basic drawings for dimensions, location of equipment, and weight per linear foot (30.5 cm) of main structure
- Details (such as weight, size, and attachment method) on attached equipment, electrical cables, lights, etc.
- Details on foundation and connection to main structure, anchor bolts, fuse bolts, etc.
- Wind calculations as well as wind and deflection test results
- All other environmental test results (salt spray, sunshine, humidity, and temperature)
- Results for any computer simulations, including force and energy plots as well as simulation video

4.4 Evaluation Criteria (Qualification Requirements)

The criteria established in AC 150/5345-45 [4] provide a standard for frangibility testing for ALS structures. As technology and economic conditions improve, higher levels of safety performance should be expected. The frangibility criteria are no different, and over time, these values will likely change to help improve airfield safety.

Often, it can be difficult to keep track of all the requirements that need to be met during testing. Table 25 provides a checklist that can be used to evaluate the criteria and verify that all requirements have been approved. Column 3 in table 25 can be used to record actual test values. When no specific value is associated with that test, the date of completion can be recorded.

Table 25. Test Evaluation Checklist for ALSs

Item Number	Test Description	Test Value/Date	Pass/Fail
1	By examination, product meets fabrication and assembly requirements (chapter 4 §3.1.1 of this guidebook)		
2	By examination, product meets all installation requirements (chapter 4 §3.1.2 of this guidebook)		
3	By examination, product meets all hardware requirements (chapter 4 §3.1.1.4 of this guidebook)		
4	By examination, product meets all material requirements (chapter 4 §3.1.1.5 of this guidebook)		
5	By examination, product meets all maintenance requirements including the tilt/lowering test (chapter 4 §3.1.3 of this guidebook)		

Table 25. Test Evaluation Checklist for ALSs (Continued)

Item Number	Test Description	Test Value/Date	Pass/Fail
Environmental Tests			
6	Wind test (chapter 4 §4.1.2 of this guidebook): Maximum deflection should be less than ±2.0°.		
7	Deflection test (chapter 4 §4.1.3 of this guidebook): maximum deflection should be less than ±5.0°.		
8	Salt spray test (chapter 4 §4.1.4 of this guidebook): certification and date of completion		
9	Sunshine test (chapter 4 §4.1.5 of this guidebook): Certification and date of completion		
10	Humidity test (chapter 4 §4.1.7 of this guidebook): certification and date of completion		
11	Temperature test (chapter 4 §4.1.6 of this guidebook): certification and date of completion		
12	Vibration analysis (chapter 4 §3.2 of this guidebook): show analysis		
Frangibility Tests			
13	Airborne peak force (10,116 lbf [45.0 kN] unfiltered)		
14	Ground-borne peak force (13,000 lbf [58.0 kN] unfiltered)		
15	Maximum energy (40,566 ft lb [55.0 kJ] unfiltered)		
16	Airborne speed at impact (87 ±2.5 mph) (140 ± 4 km/hr) (75.6 ± 2.2 knots)		
17	Ground-borne speed at impact (31 ±2.5 mph [50 ±4 km/hr] [26.9 ±2.2 knots])		
18	Location of impact (3.28 ft. ±3.0 in. [1.0 m ±10 cm] from top of structure for airborne or above ground for ground borne).		
19	Failure mode		
20	Release of electrical cables		

CHAPTER 5—THE ILS GLIDESLOPE TOWER

1. INTENT

The ILS glideslope (sometimes referred to as glide path) towers are the largest structures located within the RSA and TSA. AC 150/5300-13 [7] states that ILS glideslope towers should be located outside the RSA; however, this is not always possible due to terrain or lack of real estate. A study of USAF airfields showed that 24% of ILS towers are located inside the RSA. It is unknown as to how many commercial airfields have the same problem, but as cities continue to expand and space becomes a higher priority, it is possible that shrinking real estate around airfields will force more of these towers into the RSA. Due to the size and mass of these structures and their equipment, this poses a significant threat to aircraft and passengers.

Currently, there is little information for the designing and testing of ILS glideslope towers. ICAO has produced the following commentary:

> …structures located within the graded portion of the runway strip not meeting the frangibility requirement, such as an existing non-frangible ILS glide path antenna, should be replaced by a frangible structure, if practicable, and relocated within the non-graded portion of the runway strip. (ICAO Aerodrome Design Manual, Part 6, Paragraph 2.2.8 [5])

No testing criteria have been developed, and as stated in the ICAO manual, current requirements for ALS structures may be too restrictive for large structures. (ICAO Aerodrome Design Manual, Part 6, Paragraph 5.1.5 [5])

New technology has brought about advancements in both materials and in computer simulations, making it possible to make larger structures more frangible. The intent of this section is to provide guidance for designing and testing ILS glideslope towers. Note that these detailed requirements have not been adopted into an AC specific to the ILS glideslope tower; however, where applicable, AC 150/5220-23 [3] should apply. This information only provides guidance for building safer towers.

2. THE ILS TOWER

Several configurations exist for ILS glideslope towers, yet they are all similar in several ways. The towers are approximately 50 ft (15.2 m) tall and consist of 3 or 4 main masts with lattice supports. Most towers in the USA installed at both commercial and military airports are made of steel and would not be considered frangible. The USAF initiated a research program [39] to develop and test a composite frangible tower that could be used on their airfields around the world. The USAF program focused on two main objectives. The first objective was to develop a universal high-speed impact test setup configured to test large structures such as the ILS glideslope tower. The second objective was to design a composite ILS glideslope tower that significantly improved the frangible characteristics compared to steel towers. Their research has been shared with the FAA to develop this section of the guidebook. This information is not authoritative, but instead provides guidance for producing a frangible ILS glideslope tower.

2.1 Design Requirements

Currently, no AC has been established describing the specific design requirements for the ILS glideslope tower. The FAA Order 6750.16D [40] details installation locations and terrain considerations for the ILS glideslope tower, but no physical design requirements are listed. Through the USAF development program, the design requirements for the ILS glideslope tower are described below.

2.1.1 Fabrication, Assembly, and Installation

This section provides information and guidance on standards for fabrication, assembly, and installation, such as packaging and shipping, fabrication, design and assembly, hardware, and materials.

2.1.1.1 Packaging and Shipping

The following is a list of packaging and shipping guidelines for fabrication, assembly, and installation standards.

- Shipping should be packaged complete with all accessories, including mounting base, adjusting and connecting hardware, antenna bars (where required), and installation instructions.
- A product manual should be provided that includes all necessary procedures for unpacking, assembly, installation, operation, recommended maintenance practices, and a complete parts list.
- Structures should be properly packaged to protect small parts and prevent damage and deterioration during shipment.
- Structures should be made in sections to provide easy shipment and handling.
- All containers should be clearly marked for content, type, class, and height of the structure.
- Per ASTM D3951 [13], components should be identified on the package labels if shipped in more than one container.

2.1.1.2 Fabrication

The following is a list of guidelines for fabrication standards.

- ILS structures and members should not have sharp edges that could be hazardous during handling or any other irregularities that could interfere with fit and assembly.
- All bonding areas should be sandblasted and/or cleaned with a solvent before applying a structural adhesive.

- Exposed surfaces should be free from grease, oil, dirt, scale, flux, and chemicals that are deposited during the fabrication process.

- Drilled holes and cut edges of GRP members should be coated with the same material as the original resin.

2.1.1.3 Design and Assembly

The following is a list of guidelines for design and assembly standards.

- Sections should be designed for field assembly.

- Mass of the structure should be minimized while meeting all other requirements.

- The design should permit maintenance of equipment using a system that can be removed from the safety zone when not in use, such as bucket trucks or extension ladders. All systems should meet or exceed OSHA 1910 Subparts D, F, and I [41] requirements for safety.

- During maintenance, the design should permit access to the antennas and other equipment, permit proper mounting, and not restrict the adjustment range of antennas.

- The structure should be designed for routing electrical wires in enclosed wireways to equipment and should be part of the frangible design.

- Signal cable and down conductor assemblies should include frangible connectors as part of the design.

2.1.1.4 Hardware

Hardware includes: equipment, mounts, antennas, antenna fixtures, bolts, nuts, hardened flat washers, obstruction lights, etc. Requirements for hardware are as follows:

- Antenna mounts should be sufficiently rigid to meet antenna deflection requirements while minimizing mass.

- Each air terminal should have two down conductors creating separate paths to the ground loop, and one equipment ground is required for each tower to comply with NFPA 780 [42]. Pull-apart connectors for the down conductor cable have been developed and tested for this application and should be used where the cables pass a frangible tower connection or a minimum of every 13 ft (4 m), whichever is fewest. The specially designed connectors comply with resistance limitations for down conductors in NFPA 780 [42] and will separate with negligible force during an impact to the structure on which it is installed. Each connector is designed for 20 years of continued use in all weather conditions [8].

- Obstruction lights should be installed at the top of the tower and be visible in all directions. Pull-apart connectors for the power cables similar to the down conductor connectors described above have been developed and should be used where frangible applications require.

- All stainless steel connecting hardware components should be 18-8 stainless steel. Aluminum, FRP, and carbon steel hardware is permissible. All high-strength steel bolts, nuts, and hardened washers should be suitable for the application and comply with ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17]. Ferrous (non-stainless) hardware should be galvanized by the hot-dip method conforming to ASTM A153 [19].

- Any ILS glideslope placed within the RSA should be entirely made of fiberglass or low-mass plastic.

2.1.1.5 Materials

Steel is the most common material used for ILS glideslope towers in the USA. These towers are not considered frangible and should not be located inside the RSA. Current siting criteria require the location of the ILS glideslope tower to be outside of the RSA; however, due to limited real estate or terrain constraints the installation of the tower within the RSA is allowed if entirely made of fiberglass or low-mass plastic. AC 150/5345-45 [4] specifies allowable materials that can be used in the construction of an LIR support structure. These materials can also be used in the design and construction of larger structures like the ILS glideslope tower. These materials and finishes are described in table 26.

Table 26. Materials and Finishes for ILS Glideslope Towers

Application	Material Description	Finish
Structures Hardware	Aluminum 6061-T6, 6061-T6511 per AA ASD1 [21]	All aluminum structures should be anodized IAW MIL-A-8625 Type II, Class I [22] Matte Finish Paint IAW AAMA 2603-98 [23] MIL-PRF-85285 [24] FED-STD-595 [20] MIL-P-85582 [25]
Structures	Aluminum casting should be A356-T6 per AA ASD1 [21].	All aluminum structures should be anodized IAW MIL-A-8625 Type II, Class I [22] Matte Finish Paint IAW AAMA 2603-98 [23] MIL-PRF-85285 [24] FED-STD-595 [20] MIL-P-85582 [25]

Table 26. Materials and Finishes for ILS Glideslope Towers (Continued)

Application	Material Description	Finish
Structures	Carbon steel	Hot-dipped galvanized per ASTM A123 [18]
Hardware	Steel per ASTM A325 [14], ASTM A194 [15], ASTM A563 [16], and ASTM F436 [17]	Hot-dipped galvanized per ASTM A153 [19]
Hardware	Stainless steel 18-8	None
Structures	GRP	Paint IAW AAMA 2603-98 [23] MIL-PRF-85285 [24]
Accessories	Rubber per ASTM D1149, Method B [26]	None
Hardware Covers	Plastic(s)	
Adhesive	Epoxy, glue	

2.1.2 Installation

Installation of ILS glideslope towers should comply with the following requirements:

- Base of tower should be secured to a foundation using properly sized anchor bolts. Full-scale testing has shown fuse bolts do not add to the frangibility design of large structures and therefore are not required to secure the tower to the foundation

- Leveling of each structure should be by simple adjustments with standard tools.

- Foundation should be flush with grade.

- A grounding ring of copper-braided cable should surround the tower foundation and attach to the two copper down conductors for sufficient lightning protection per NFPA 780 [42]. The grounding ring should also connect to a ground wire attached to the equipment.

- An obstruction light should be installed per AC 70/7460-1 [43]. Pull-apart connectors for the power cable are available and should be used where applicable.

2.1.3 Maintenance

Maintenance on airfield structures can be costly and sometimes difficult to achieve when located in areas near the runway. ILS glideslope towers should be designed to minimize maintenance as much as possible. Access to the equipment on these towers can be difficult and has typically required the use of lifts or other similar equipment or a fixed ladder on the tower. Some research has been done on using an extension ladder that can retract below the frangibility area [8]. Other options may become available in the future.

2.2 Environmental

Designing frangible structures requires a balance between strength, durability, and frangibility.

Mission requirements should be met, which include withstanding environmental forces, while frangibility safety depends on the structures ability to yield or break if an accidental collision occurs. Currently, no AC details environmental requirements for the ILS glideslope tower, and these requirements will vary by location. According to ANSI/TIA-222 [27] most of the USA wind speed requirements are below 100 mph (161 km/hr) (86.9 knots) other than areas along the Gulf Coast and Atlantic Coast lines. Additionally, AC 150/5345-45 [4] details environmental requirements (such as wind speed, sunshine, temperature, humidity, and salt spray) that are applicable to ILS glideslope towers. ILS glideslope towers should be built to stand for at least 20 years with minimal maintenance required on the structure itself. Coatings should be able to withstand sunshine (solar radiation) degradation and corrosion during that time. Table 27 provides a list of environmental requirements and suggested approval methods.

Table 27. Environmental Tests and Suggested Approval Methods for ILS Glideslope Towers

Requirement Numbers From AC 150/5345-45 [4]	Description	Approval Method
Wind Para. 3.3.1	Structures should be designed to withstand 3-second gusts up to 75 mph (121 km/hr) (65.2 knots) with 0.5 in. (13 mm) of ice on all surfaces or 100 mph (161 km/hr) (86.9 knots) without ice.	Analysis Test (guidebook chapter 5 §3.1.2)
Temperature Para. 3.3.2	Structures, components, and equipment should be designed to withstand temperatures from -67°F (-55°C) to 131°F (55°C).	Test (guidebook chapter 5 §3.1.6)
Relative humidity Para. 3.3.3	Structures, components, and equipment should be designed to withstand relative humidity from 5% to 100% including condensation.	Test (guidebook chapter 5 §3.1.7)
Sunshine (solar radiation) Para. 3.3.4	Structures, components, and equipment using plastic or nonmetallic components should withstand prolonged exposure to solar radiation.	Test (guidebook chapter 5 §3.1.5) MIL-STD-810 [28] ASTM G155 [29] ASTM D2565 [30]
Salt spray Para. 3.3.5	Structures, components, and equipment should be designed to withstand exposure to a corrosive salt laden environment. Salt spray testing should be conducted on a section of structure mast, complete with all sections and hardware. Test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, pitting, corrosion (except for sacrificial coatings), or GRP delaminating is cause for rejection.	Test (guidebook chapter 5 §3.1.4) MIL-STD-810, Method 509.4, Para. 4.5.2, Proc. I [28]
Vibration Para. 3.3.6	Components, assemblies, and structure should be designed so as to not vibrate at or near their resonant frequency and exceed the deflection requirements when subjected to the maximum wind load.	Analysis

2.3 Frangibility

ILS glideslope towers are not fixed-by-function; however, due to terrain limitations the towers may have to be placed within the RSA. Fiberglass and plastic towers provide greater frangibility than metal towers. Therefore, any ILS glideslope tower placed within the RSA should be entirely made of fiberglass or low-mass plastic. The point of frangibility should be no higher than 3 in. above grade, subject to its determination process.

3. QUALIFICATION AND TEST REQUIREMENTS

Design requirements are required to be inspected and/or tested for approval and were identified in chapter 5 §2.1 of this guidebook. More detail of how these tests should be performed will be provided in this section. The intent is to provide clear test procedures that form a standard for all parties seeking to develop and test a frangible ILS glideslope tower. This section provides the details as to how to setup and carry out these tests, including proper data processing and documentation. Currently, no ACs include comprise these requirements.

3.1 Environmental Qualification Procedures and Test Setup

Chapter 5 §3.1 addresses environmental qualification procedures and test setup requirements for ILS glideslope towers.

3.1.1 Visual Examination

Visual inspections and analysis approval methods are required for the construction, assembly, and installation; hardware; materials and finishing; and maintenance. Documentation such as material specification sheets, painting, anodizing, or galvanizing certifications, and calculations for wind loading should be provided.

3.1.2 Wind Test

The structures and all necessary equipment should be designed to withstand pressure loading (no permanent deformation) arising from the following wind velocities when installed with all equipment attached. Structures should be designed to withstand the following velocities (3-second gust per ANSI/TIA-222, Annex L [27]): up to 75 mph (121 km/hr) (65 knots) with 0.5 in. (13 mm) of ice on all surfaces, 100 mph (161 km/hr) (86.9 knots) without ice. Using ANSI/TIA-222, calculate the design wind load on the structure (F_w) with and without ice. Using the resulting highest force value, perform the wind test by pulling at the midpoint of the structure with a force equal to F_w, as shown in figure 14. Verify that force level was achieved, that the structure was not damaged, and returned to its original position upon releasing the force.

3.1.3 Deflection Test

The deflection test is required to demonstrate that the structure is sufficiently rigid to meet the equipment manufacturer's requirements. Use the methods defined in ANSI/TIA-222, Section 2.6 [27] to determine the design wind load using a wind velocity of 60 mph (97 km/hr) (52.1 knots) with 3-second gusts and 0.5 in. (13 mm) of ice. The calculated force should then be applied to the structure at the midpoint, using a load cell to measure the force, as shown in figure 14. Measuring the displacement of the top antenna, verify that the maximum deflection is less than 3 in. (7.6 cm). Perform this test in both the X and Y axes.

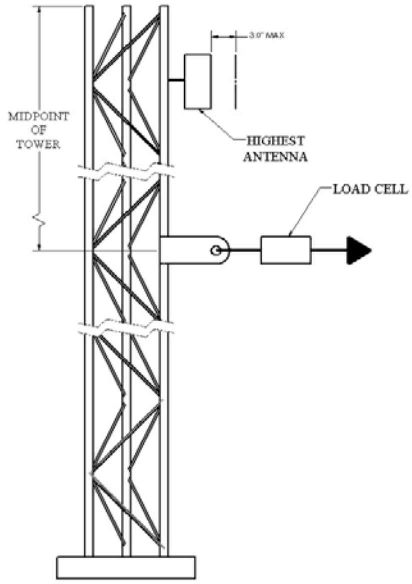


Figure 14. Wind and Deflection Test for ILS Glideslope Towers

3.1.4 Salt Spray Test

The salt spray test should be conducted on a section of the structure mast, complete with all accessory hardware per MIL-STD-810, Method 509.4, Paragraph 4.5.2, Procedure I [28]. The test duration should be 48 hours exposure and 48 hours drying. Any evidence of damage, rust, pitting, corrosion (except for sacrificial coatings), or GRP delamination is cause for rejection.

3.1.5 Sunshine (Solar Radiation) Test

The sunshine (solar radiation) test should be conducted per MIL-STD-810, Method 505.4, Paragraph 4.4.3, Procedure II [28], for all structures with plastic/nonmetallic exterior materials. The material should be subjected to a minimum of 56 radiation cycles. Any evidence of deterioration or GRP delamination is cause for rejection.

3.1.6 Temperature

The structure should be tested for both high- and low-operating temperature and should sustain no delamination; also, there should be no damage to seals or other components. Structures should be tested in accordance with MIL-STD-810, Method 501.3 [28]. Operational temperature should be between 131°F (55°C) and -67°F (-55°C).

3.1.7 Humidity

For hot-humid conditions, the structure should be subjected to the moisture resistance test per MIL-STD-810, Method 507.3, Procedure II [28]. There should be no evidence of delamination, cracking, corrosion, or deterioration of any part of the structure after cycling has been completed.

3.2 Evaluation Criteria (Qualification Requirements)

Table 28 provides an example checklist that can be used to evaluate the criteria and verify that all requirements have been approved. Column 3 can be used to record actual test values or when no specific value is associated with that test, the date of completion can be recorded.

Table 28. Test Evaluation Checklist for ILS Glideslope Towers

Item Number	Test Description	Test Value/Date	Pass/Fail
1	By examination, product meets fabrication and assembly requirements (chapter 5 §2.1.1 of this guidebook)		
2	By examination, product meets all installation requirements (chapter 5 §2.1.2 of this guidebook)		
3	By examination, product meets all hardware requirements (chapter 5 §2.1.1.4 of this guidebook)		
4	By examination, product meets all material requirements (chapter 5 §2.1.1.5 of this guidebook)		
5	By examination, product meets all maintenance requirements including the tilt/lowering test (chapter 5 §2.1.3 of this guidebook)		
Environmental Tests			
6	Wind test (chapter 5 §3.1.2 of this guidebook): maximum deflection should be less than ±2.0°.		
7	Deflection test (chapter 5 §3.1.3 of this guidebook): maximum deflection should be less than ±5.0°.		
8	Salt spray test (chapter 5 §3.1.4 of this guidebook): certification and date of completion		
9	Sunshine test (chapter 5 §3.1.5 of this guidebook): certification and date of completion		
10	Humidity test (chapter 5 §3.1.7 of this guidebook): certification and date of completion		
11	Temperature test (chapter 5 §3.1.6 of this guidebook): certification and date of completion		
12	Vibration analysis (chapter 5 §2.2 of this guidebook): show analysis		

CHAPTER 6—CONCLUSIONS

This "Federal Aviation Administration Frangibility Guidebook" provides information for airfield product manufacturers both in the design of their products as well as the testing and qualification thereof. This guidebook is intended to be used by engineers, airport designers and consultants, airfield approval authorities, manufacturers, test facilities, and third-party certifiers. The focus of this guidebook is on products that are located within the runway safety areas and the taxiway safety areas. The guidebook references FAA Advisory Circulars and specifications, which directly relate to specific structures required to comply with FAA frangibility requirements. This includes Small Low-Impact Resistant Structures, Approach Lighting Systems, and ILS Glideslope Towers.

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