Concerns with Baseline Fire Barrier Recommendations of FAA AC 20-135

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Abstract

FAA AC 20-135 defines “Fireproof” as “the capability of a material or component to withstand, as well as or better than steel, a 2000°F (±150°F) for 15 minutes minimum, while still fulfilling its design purpose.”

Further, paragraph 6.d.(6) states:

“The following minimum thickness materials are considered acceptable for use in firewalls or shrouds for non-structural/non load-carrying applications, without being subjected to additional fire tests:

(i) Stainless steel sheet, .015 inch thick.
(ii) Mild steel sheet protected against corrosion, .018 inch thick.
(iii) Titanium sheet, .016 inch thick.
(iv) Monel metal sheet, .018 inch thick
(v) Steel or copper base alloy firewall fittings/fasteners.”

The implied interpretation of this requirement is that, if these materials make up a firewall, the flame will not penetrate and the fire will remain contained away from the rest of the aircraft.

However, when some standard fire barrier materials were tested against the fire challenge represented by the FAA’s Next Generation Burner, the resultant backside (or non-fire side) temperatures far exceeded the autoignition temperature of turbine engine fuel well before 15 minutes exposure requirement. The consequence of these test results is that, if there is a flammable mixture on the non-fire side of the barrier, even though the firewall itself may stay intact, ignition outside the containment area is possible, allowing the fire to spread beyond the firewall to the rest of the aircraft. Even assuming that there is no flammable material on the non-fire side of the firewall, thermal damage to aircraft structure and systems outside the firewall is a significant possibility.

Introduction

Federal Aviation Adminsitration Advisory Circular No. 20-135, POWERPLANT INSTALLATION AND PROPULSION SYSTEM COMPONENT FIRE PROTECTION TEST METHODS, STANDARDS AND CRITERIA, has been used for many years as the design standard for both military and civilian applications. The Joint Services Specification Guide (JSSG) for Air Vehicle Subsystems, JSSG 2009, mirrors many of the requirements of AC 20-135 where it addresses fire protection in Appendix G. However, the common image of an aircraft fire zone, an engine nacelle hanging from a wing (Figure 1) is changing with evolving design practices, especially for modern military aircraft configurations. To isolate the traditional type of fire zone, the designer simply has to prevent the fire from penetrating the confines of the nacelle for the required 15 minutes. The backside (non-fire side) temperature of the firewall for this nacelle is rarely a concern due to the surrounding open airflow that cools the exterior of the nacelle with fuel-free air.

Figure 1. Wing Mounted Engine Nacelles on 747

Photo from: Airline world - WordPress.com

Photo from: Global Engine Nacelle Market 2019: Industry Growth, Size, Share and Analysis 2025

In the case of an aircraft designed with internal or “buried” engines (Figure 2), or an internal Auxiliary Power Unit (APU) (Figure 3), the cooling, fuel-free airflow that surrounded the engine nacelle is not available.

Figure 2 Examples of Internally Mounted Engines - F/A-18E/F & B-2

Photo: Photo: US Navy - Released

Photo: B-2 Stealth Bomber (@Whiteman AFB) | Twitter

Figure 3 Internal APU Bay

Photo: 747 APU – slate.com

Photo: uaminc.blogspot.com

These internally installed engines and APU's are surrounded by structure and, in all likelihood, other aircraft compartments or bays adjacent to the structure. In these cases, as the temperature of the non-fire side of the bare firewall approaches the temperature of the flame being contained on the other side, hardware can be adversely affected, causing structures and systems contained in bays on the other side of the firewall can be compromised or fail, or even worse, ignite a fire outside the contained fire zone.

Zone Designations

During the initial stages of design of a military air vehicle, the various internal compartments or bays are given one of four fire-related designations: Fire Zone, Flammable Leakage Zone, Flammable Zone, or Ignition Zone. These zones are defined as:

Fire Zone[1]:
"Compartments which contain flammable fluid components with potential leakage, and, potential ignition sources, if the following applies:

(a) One "single failure" can cause a fire or explosion. A combustor and turbine compartment is in this category if it contains external flammable fluid lines with leakage potential as well as an unprotected engine case hot enough to ignite the flammable fluid, or when a combustor burn through can cause leakage from the flammable fluid lines.
(b) A dual failure is needed to cause ignition, but the flammable fluid components and potential ignition sources are not sufficiently separated and shielded, or are present in high concentration, so that contact of flammable fluid and vapor with ignition sources by gravity, ventilation airflow or squirt is likely. Accessory sections of engines are, and hydraulic and fuel service centers may be in this category."

Engine bays and APU bays are examples of this type of zone.

Flammable Leakage Zones[2]
"These are zones where flammable fluid or vapor leakage may occur from contained or adjacent lines and equipment or directly adjacent fuel tanks (including oxidizer and reducing agents) and zones in which combustible materials are located. Ignition sources are not contained within these zones. The two failures necessary to cause the potential for fire or explosion may consist of combinations that result in ignition source introduction to the zone or flammable fluid or vapor leakage in the zone. Such zones should be provided with adequate means to minimize the presence of the above noted fluids and vapors, to prevent the spread of these fluids and vapors to other compartments, to prevent the introduction of sources of ignition into these zones, and to prevent the spread of any resultant fire or explosion to other compartments."

Examples of Flammable Leakage Zones are those bays next to fuel cells separated by a single barrier, wheel wells, and leading or trailing edges.

Flammable Zones[3]

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[1] MIL-HDBK-221, FIRE PROTECTION DESIGN HANDBOOK FORU.S. NAVY AIRCRAFT POWERED BY TURBINE ENGINES, Paragraph 2.11. This definition combines the fire zone and potential fire zone of JSSG 2009, Appendix G, Paragraph G.3.4.7

[2] JSSG 2009 DEPARTMENT OF DEFENSE JOINT SERVICES SPECIFICATION GUIDE Appendix G Section 3.4.7

[3] JSSG 2009 DEPARTMENT OF DEFENSE JOINT SERVICES SPECIFICATION GUIDE Appendix G Section 3.4.7

“These are zones within which a flammable mixture may exist during normal operation, as within fuel tanks. Ignition sources are not contained within these zones. The two failures necessary to cause the potential for fire or explosion are both related to introduction or an ignition source into this zone. Explosion prevention systems are the desired means of protection. However, other fire and explosion hazard protection means should be included in case the explosion prevention system becomes inoperative. Also, other means may be deemed to be sufficient protection, dependent on the intended mission of the air vehicle.”

Ignition Zone[4]
“These zones are air vehicle compartments which contain equipment, components, or subsystems which experience has shown should be considered ignition sources during normal operating conditions or which may become ignition sources due to malfunction and, also, regions of the air vehicle which, as a result of normal operation, malfunction, or failure, may be the source of high temperature. Flammable fluid or vapor carrying lines or equipment are not contained within these zones. The two failures necessary to cause the potential for fire or explosion are related to flammable fluid and vapor leakage into this zone. Fire and explosion hazard protection that will prevent flammable fluids or vapors from entering these zones should be used. Another consideration is means that will reduce the presence of these fluids and vapors in these zones to a minimum and contain any fire or explosion that may occur. Those zones where high temperature is the problem should be provided with a means of controlling the high temperature and, if overheating is the problem, also with means of detecting this condition. Air cooled electronic bays, electrical bays and potential arcing sources are examples of normal operating ignition potentials. Crew compartments are ignition zones due to food preparation equipment, crew smoking, defogging devices, heaters and high potential electronic equipment.”

Avionics bays and circuit breaker compartments are examples of this type of bays.

For the purposes of this paper, we are concerned about the interfaces between fire zones and flammable or flammable leakage zones.

FAA AC20-135 Guidance

FAA Advisory Circular 20-135 provides guidance on how to prevent a fire that may start in a designated fire zone from spreading to the rest of the aircraft, leading to catastrophic damage. The performance of firewalls can be verified one of two ways. The bulk structure of the proposed firewall is tested against a fire challenge consisting of a 2000°F flame with a heat flux density of no less than 9.3 BTU/ft^2 sec, and must contain the fire for 15 minutes.

[4] ibid

The other approach is to simply make the bulk structure of the firewall from one of the following:

(i) Stainless steel sheet, .015 inch thick.
(ii) Mild steel sheet protected against corrosion, .018 inch thick.
(iii) Titanium sheet, .016 inch thick.
(iv) Monel metal sheet, .018 inch thick.

This assumes that the firewall does not contain a load path.

If this approach assumes that the firewall does not contain a load path, and, if taken, requires no further test of the bulk structure for fire containment.

This requirement is applicable not only to the bulk structure of the firewall, but to all seams and penetrations as well.

The Nature of Containment

The job of the firewall surrounding an engine nacelle or any other fire zone is to isolate the bay, keeping the potential fire on one side from penetrating to the other side for a minimum of 15 minutes. If, during fire exposure, the flames penetrate the firewall before the 15 minutes requirement, then obviously the fire wall failed. Even a successful firewall can be expected to get very hot while containing a fire. If the fire zone is an engine in a nacelle mounted on a wing, any potential issues associated with temperatures on the backside (non-fire side) of the firewall are mitigated by the airflow surrounding the nacelle. If a Fire Zone located within the body of the aircraft, for example, an Auxillary Power Unit (APU) bay or an internal engine bay, boarders on a flammable leakage zone, like an Environmental Control System (ECS) bay containing fuel/air heat exchangers, or landing gear bay, the problem of fire containment becomes more complex. To prevent a fire in the Fire Zone from spreading throughout the aircraft, the designer must do more than assure that flame penetration and backside ignition of the firewall material is prevented. Assuming that this has been accomplished, the backside of the firewall will still heat up asymptotically to the temperature on the fire side. Not only will that exceed the autoignition[5] temperature of Jet A fuel (400°F to 450°F), but it may also approach or exceed its Minimum Hot Surface Ignition Temperature of 820°F[6]. If flammable materials are in the adjacent bay and have achieved a flammable mix, the conditions exist for ignition on the non-fire side of the firewall, thus spreading the fire uncontrollably from the Fire Zone to the neighboring Flammable Leakage Zone. Because Flammable Leakage Zones are not required to be physically isolated from the rest of the aircraft, such a fire can now spread freely.

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[5] Documented autoignition temperatures of Jet-A vary from SDS to SDS.
[6] Clodfelter, R., "Hot Surface Ignition and Aircraft Safety Criteria," SAE Technical Paper 901950, 1990

Additionally, if the structure near the backside of the firewall is Graphite-Epoxy, a 15-minute exposure may cause the structure to lose its properties and fail.

Test Results of Material Exposure to Fire Threats.

With a "Next Generation" burner[7] available to expose materials to the fire threat described in AC20-135, data was collected on the suitability of a common aircraft material to be used as firewalls, with particular attention to the backside temperature of the test sample. The following data showing the effect on backside temperatures to an graphite/epoxy panel exposed to a 2000°F, >9.3 BTU/ft^2 sec flame from a Next Generation Burner. The fire threat was oriented vertically below the test sample to provide data associated with the worst case fire exposure (Figure 4).

Figure 4 Fire Barrier Test Fixture

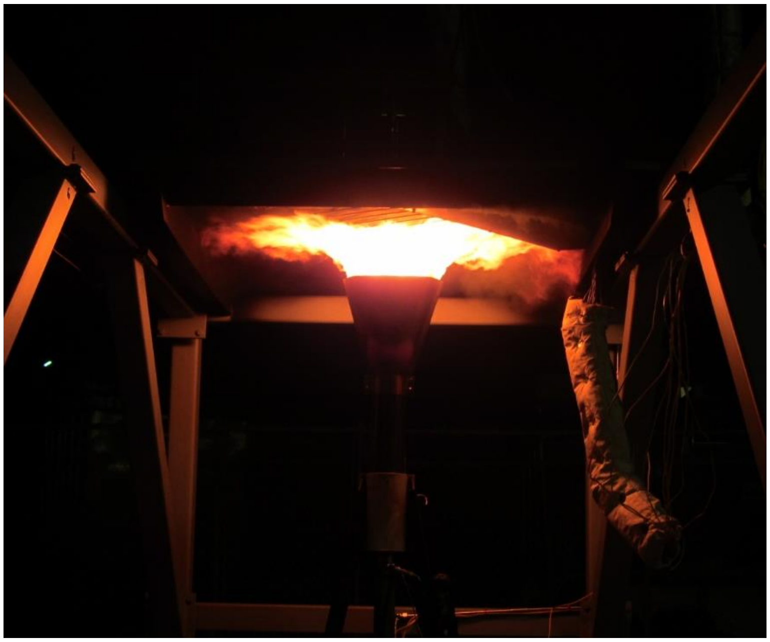


Photo: NGC Fire Barrier Test Stand - Courtesy Area 67

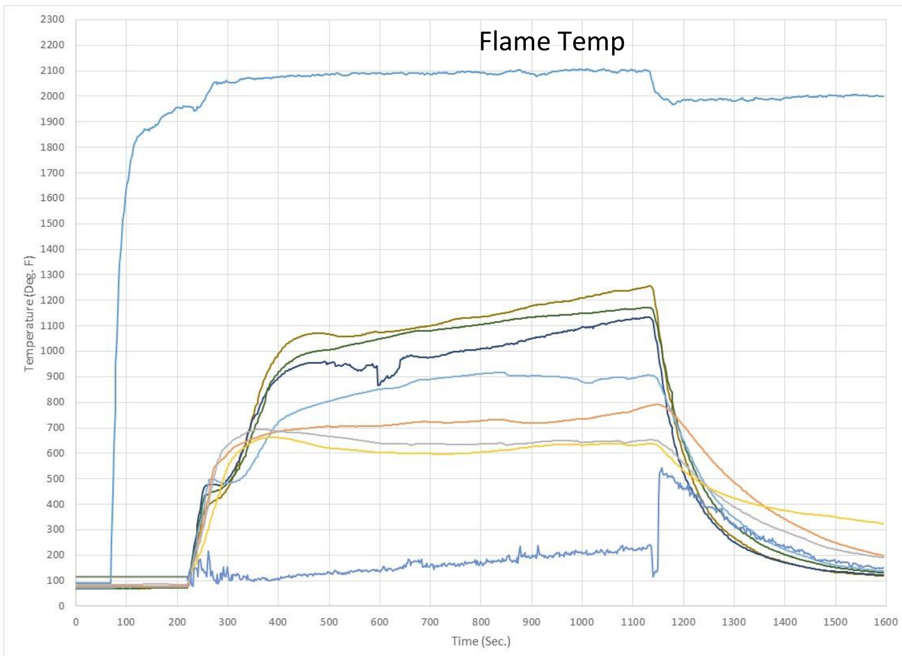
Test data collected using graphite/epoxy composite show the extent to which the backside temperature of a firewall can increase while containing a fire event.

Graphite/epoxy structure is playing an increasingly significant role in the development of new aircraft and may soon be used as the primary structure surrounding fire zones, if it has not already. Samples of ¼" thick samples of graphite/epoxy were exposed to the

[7] Calungcagin & Roberts, *"An Air Framer's Pursuit of AC 20-135 Testing,"* presented at The Ninth Triennial International Fire & Cabin Safety Research Conference, 2019

fire threat. The temperatures on back, non-fire side was measured. Data from a representative sample is shown in Figures 6.

Figure 5. Backside Temperatures - Bare Graphite/Epoxy 0.25" Thick (1/20/15)[8]



In this test the flame did not penetrate the sample panel nor did any of the layers on the backside of the sample ignite through the entire 15-minute test period, making the tests successful by the requirements of AC 20-135. However, the measured backside temperatures of 600°F to greater than 1200°F, well above the autoignition temperature and, is some cases, above the minimum hot surface ignition temperatures (MHSIT) for Jet-A. Had there been a flammable mix on the backside of these test samples, ignition would have been highly probable.

FAA AC 20-135 and similar documents do not address the backside conditions of firewall beyond requiring that it not catch fire itself. Backside temperatures that may pose an ignition threat are not address in any of these documents.

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[8] 2014 - 2015 NGC Fire Barrier Investigation test data

Recommendations

The backside temperatures observed during the tests described above reveal a significant and concerning requirements gap in AC 20-135 as currently written. It is alarming to consider that a fire barrier meeting the test standards of AC 20-135, if used in an internal fire zone, either an internal engine bay or APU bay, will create a condition that provides an ignition source to an adjacent flammable environment on the backside of the firewall. While internal engine bays are rare in commercial airliners, advanced concept designs often feature them, and it is increasingly common to utilize internal engine bays in modern military aircraft. APU bays are also frequently contained in the fuselage. In view of these facts, it is recommended that a focused study on the effects of elevated temperatures on the backsides of firewalls be conducted at the earliest opportunity. Based on the results of the recommended study, design guidance should be provided for the location of a Flammable or Flammable Leakage Zone adjacent to a Fire Zone. Such guidance would help significantly decrease the possibility of a fire in a Fire Zone from spreading uncontrollably to unprotected parts of an aircraft.