2018 Fire Safety Highlights

2018 Fire Safety Highlights

Contents

Development of a New Flammability Test for Magnesium Alloy Cabin Components Located in Inaccessible Areas

In recent years, magnesium alloys have been suggested as substitute for aluminum alloys in aircraft seat structure, as well as other passenger cabin applications, due to the potential for weight savings. The FAA's central concern regarding the use of magnesium alloys in the cabin is flammability. The current regulations do not address the potential for a flammable metal to be used in large quantities in the cabin. Therefore, if such a material was introduced into the cabin, the FAA must be convinced that the level of safety would not be reduced. Recent developments in materials technology have shown that different magnesium alloys have different susceptibility to ignition. However, magnesium remains a material that, once ignited, is very challenging to cope with using fire extinguishers currently available on aircraft.

In 2003 the FAA implemented new flammability standards for thermal acoustic insulation, which is located throughout aircraft fuselages, primarily in inaccessible areas. Additionally, the FAA is planning to introduce new flammability standards for other high-volume materials located in inaccessible areas, such as wiring insulation, air ducting, and non-metallic fuselage structure. The use of magnesium alloy in these inaccessible areas would also be required to exhibit self-extinguishing properties. In order to better evaluate their propensity to ignite and ability to self-extinguish, a preliminary assessment of several magnesium alloys was conducted using the radiant panel flame propagation apparatus used for testing thermal acoustic insulation. The test rig consisted of an electrically-powered radiant heat panel, and a propane-fired pilot flame. Test samples were situated horizontally on a sliding platform. Three magnesium alloys having previously demonstrated good resistance to ignition were evaluated (WE43, Elektron 21™, and ZE41) along with 2 poor performing alloys (AZ31 and AZ80). Experimentation with various sizes and thicknesses of test samples followed, to determine their flammability characteristics. After careful trialing, a test condition was created using a 0.025-inch thick sample measuring 3 by 6 inches. The test sample was inserted into the radiant panel apparatus, and the pilot flame was applied for 120 seconds (figure 1). Following pilot flame exposure, the sample remained under the radiant panel for an additional 120 seconds (240-second total test time).

Figure 1. 3- by 6-inch Test Sample Inside Radiant Panel Apparatus

Following initial testing, refinement of the sample holder proved to produce more repeatable results. Other parameters such as time of ignition, time of self-extinguishment, and sample weight loss were also studied. Due to the subjectivity of measuring extinguishment time, it was eliminated from the test as a requirement. Calculating the sample weight loss proved to be a more accurate assessment of how much burning occurred during the test. Based on the hundreds of tests conducted by the Fire Safety Branch, a value of 30% weight loss was proposed as the maximum allowable weight loss (figure 2). The test method was introduced into the Aircraft Materials Fire Test Handbook in October of 2018, allowing manufacturers to begin experimentation at their facilities. An interlab study is planned for 2019, in which identical samples are provided to participating labs, to better determine the reproducibility of the new test method.

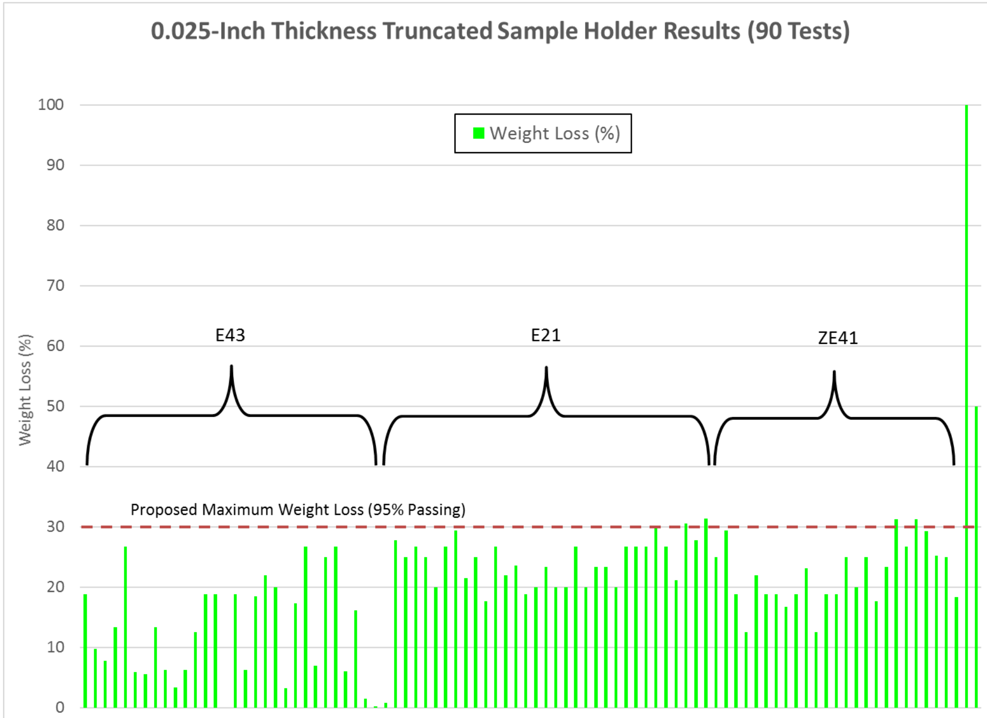

Figure 2. Weight Loss Results of 3 Magnesium Alloys

Progression of the Vertical Flame Propagation Test Method for Composite Fuselage Structures and Inaccessible Area Materials

In 2003 the Federal Aviation Administration (FAA) implemented new flammability standards for thermal acoustic insulation, which is located throughout aircraft fuselages, primarily in inaccessible areas. An additional effort is currently underway to elevate the flammability requirements for all other high-volume materials located in inaccessible area of the cabin, including wiring insulation, air ducting, and non-metallic fuselage structure. Prior to the development of the Boeing 787 Dreamliner, all passenger carrying aircraft utilized aluminum as the fuselage primary construction material. However, the 787 utilized carbon fiber reinforced polymer (CFRP) in the construction of the fuselage skin and structural components. The use of this non-metallic material has lead the FAA to develop a flammability standard for the basic fuselage structure, which had previously not been necessary. The Fire Safety Branch conducted intermediate-scale flammability tests on CFRP panels using a variety of ignition sources and configurations. Following these experiments, a laboratory-scale flammability test method was developed to simulate the conditions found during the intermediate scale tests. The new test utilized a vertically-oriented test sample, which was exposed to a radiant heat source and piloted ignition on the bottom edge. The Vertical Flame Propagation (VFP) test apparatus was refined over the course of several years, and replicate apparatuses were fabricated by the Fire Safety Branch and supplied to Boeing and Airbus for comparative testing at their facilities. The scope of the test apparatus was recently broadened to measure the flammability of wiring insulation and air ducting, both of which are used extensively in the inaccessible areas of the cabin. A commercial VFP apparatus has also been developed, and contains an 875-watt radiant coil furnace that is mounted in front of a six-inch by twelve-inch test sample. Improvements have been made in the construction of the VFP apparatus shown in Figure 1. A much more robust methane-air ribbon burner now replaces the six-flamelet pilot burner situated in front of the radiant furnace. The stronger and more severe flame from the ribbon burner produces a more realistic fire as compared to the original pilot burner. The previous pilot burner was shown to be biased towards the burning test samples, resulting in a decreased flame, whereas the new ribbon burner produces a continuous fire throughout the test. This ribbon burner impinges on the lower portion of the test sample for only 30 seconds, instead of the original 50 seconds, and is then translated away from the test sample. The impingement time was shortened to balance the increased severity of this flame. With this new flame the test has become more robust, resulting in increased confidence in the performance of the test apparatus, ensuring only high performance materials are permitted for use in the inaccessible areas. Acceptable materials include those that show the fire remains localized and does not propagate extensively along the sample.

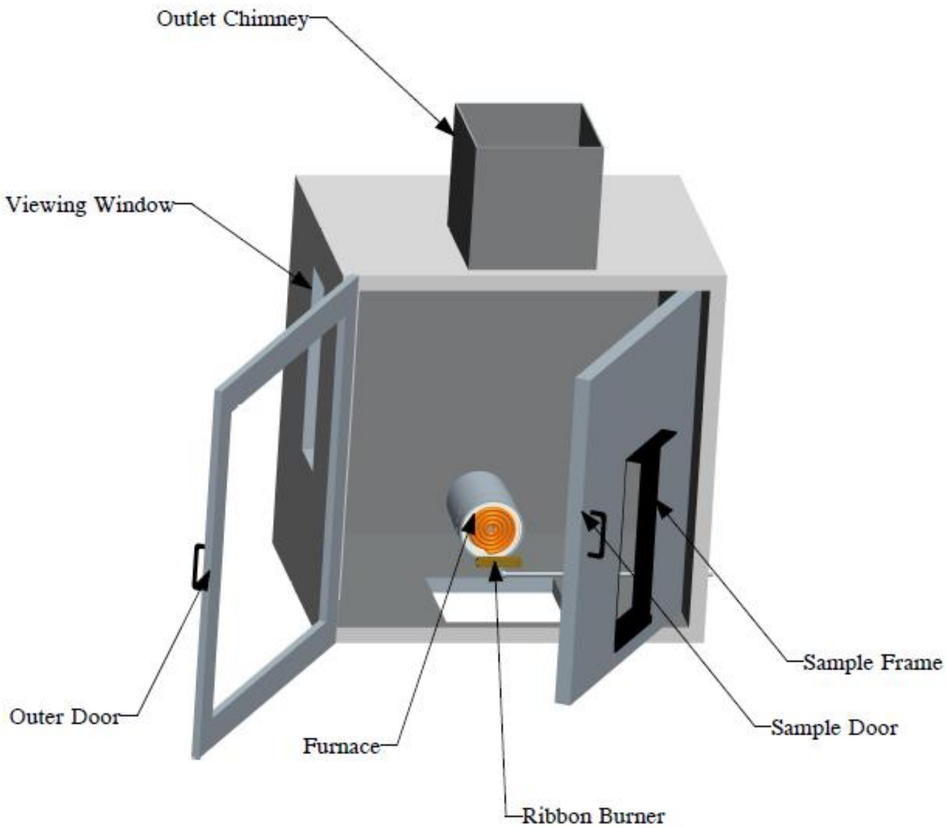

Figure 1. Schematic of the Vertical Flame Propagation (VFP) Test Apparatus

The VFP is now capable of testing 11-inch long wire samples due to a newly developed wire sample holder. The procedure for testing these wires as well as air ducts of various diameters remains the same as for testing the non-metallic structural composites: the ribbon burner flame impinges on the sample for 30 seconds and is then translated away. The burn time after the flame removal is recorded, as well as the burn length of the material. Various 20 AWG wires that meet the requirements of the current 60-degree Bunsen Burner Test for electric wire were also tested in the VFP (figure 2). One wire in particular produced a burn length of 1.93 inches in the 60-degree Bunsen burner test, which is considered passing. By comparison, this same wire had a burn length of 9.75-inches in the VFP apparatus, burning almost entirely. Although this result indicates the VFP is a more severe test than the current Bunsen burner requirement, other results indicate it to be realistic. As shown in figure 2, many wires still have a very small burn length or no burn length at all. Future work will involve the standardization of the major components, including the radiant heater and the ribbon burner.

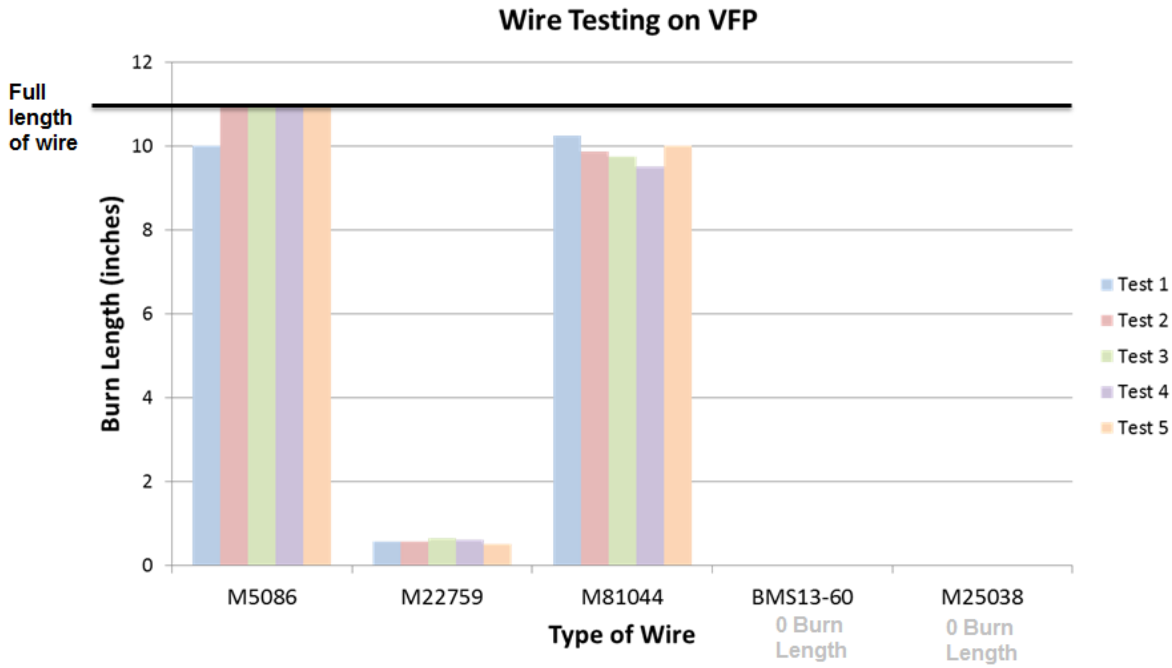

Figure 2. Chart of Measured Burn Lengths for Testing of Various Wires

Full-Scale Burnthrough Testing to Investigate Equivalent Level of Safety Approaches

In 2009, a new Rule governing the flame penetration resistance of thermal acoustic insulation became effective. The new Rule requires that transport category airplanes manufactured after September 2, 2009, comply with the provisions of 14 CFR 25.856(b) when entering part 121 service. Section 25.856(b), in turn, requires that thermal/acoustic insulation installed in the lower half of the fuselage of those airplanes resist penetration of an external fire. The performance criteria are contained in Appendix F, part VII of part 25. The use of fire-resistant insulation is the most practical means of extending the burnthrough resistance of an aircraft fuselage. Airframe manufacturers have successfully met this new requirement using lightweight, flame resistant barriers in combination with industry-standard fiberglass insulation batting. In most cases, paper-thin ceramic barriers are installed inside existing insulation blankets, or the ceramic barrier is laminated directly to the moisture barrier used to encapsulate the fiberglass batting. An Advisory Circular (25.856-2A) was also issued by the FAA in July of 2008 to address installation techniques. Research and full-scale testing determined the importance of robust attachment methods at keeping the flame-resistant insulation barriers in place. Another aspect of the Advisory Circular (AC) addressed the location of the insulation flame barriers, which are required in the lower half of the fuselage only. As stated in the AC, section 7. INSTALLATION OF THERMAL/ACOUSTIC INSULATION, subsection e: "Section 25.856 requires that thermal/acoustic insulation installed in the lower half of the fuselage comply with the test requirements of part VII of Appendix F for flame penetration resistance. As discussed in the preamble to Amendment 25-111, the requirement applies to thermal/acoustic insulation installed against the fuselage skin, or in another manner that provides burnthrough protection"… "The requirement does apply to insulation installed on the floor panels, if there was no insulation installed on the outer fuselage in the lower half. The requirement does not apply to both places when insulation is installed in both places. It is the intent of the regulation that the occupied areas of the airplane have greater fire protection through enhanced burnthrough resistance of the lower half of the fuselage, using installed insulation (see figure 11)."

Figure 11 of the AC (figure 1) illustrates two approaches to insulating the lower half of the airplane. On the left, the insulation is installed on the fuselage skin; on the right, the insulation is installed along the floor. Either approach would have to comply with the requirement. But if insulation was installed in both places, it would only have to comply in one place.

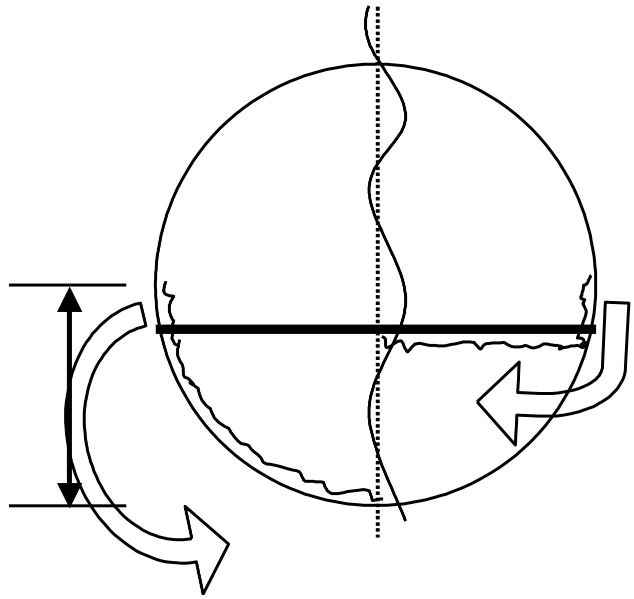

Figure 1. Different Approaches to Installing Flame-Penetration-Resistant Thermal Acoustic Insulation in the Lower Half of the Fuselage

Although the new regulation has been in effect since 2009, industry has recently requested the FAA to consider addressing burnthrough protection on a system basis, rather than through a specific component, in this case the thermal acoustic insulation.   One example of a systems approach would be to utilize the flame penetration resistance of composite floor panels. While the FAA agreed the floor panels (typically honeycomb or composite construction) could meet the new test requirements, they were concerned about the vulnerability of the crease beam area at the cabin floor level. Current installation methods protect this area with blankets installed against the inner side of the aircraft skin. However, removal of the blankets in this area may allow a direct path into the cabin via the baseboard return air vents. In order to investigate this possibility, the Fire Safety Branch conducted full-scale fuel fire tests to observe the fire ingress into a fuselage in the crease beam area (figure 2).

Figure 2. Full-Scale Fuel Fire Burnthrough Test to Investigate Fire Ingress in the Crease Beam Area

Although the tests did not use thermal acoustic insulation behind the skin for simplicity, they illustrated the rapid ingress of fire into the passenger once the skin melts at 50 seconds (prior research has shown that non-burnthrough-resistant insulation blankets will only delay this ingress for an additional 90 seconds to 2 minutes). In addition, the recent testing has also shown that a fully developed fire can progress through the tunnel area (below cabin floor, above cargo compartment ceiling) to the opposite side of the fuselage, once the skin/insulation barrier is breached. Thermocouples were placed at the opposite side of the test fuselage to measure the heat/fire progression across the tunnel area and through the decompression holes at floor level (figure 3). Results indicated a rapid temperature rise at 50 seconds, followed by another sharp increase at 90 seconds.

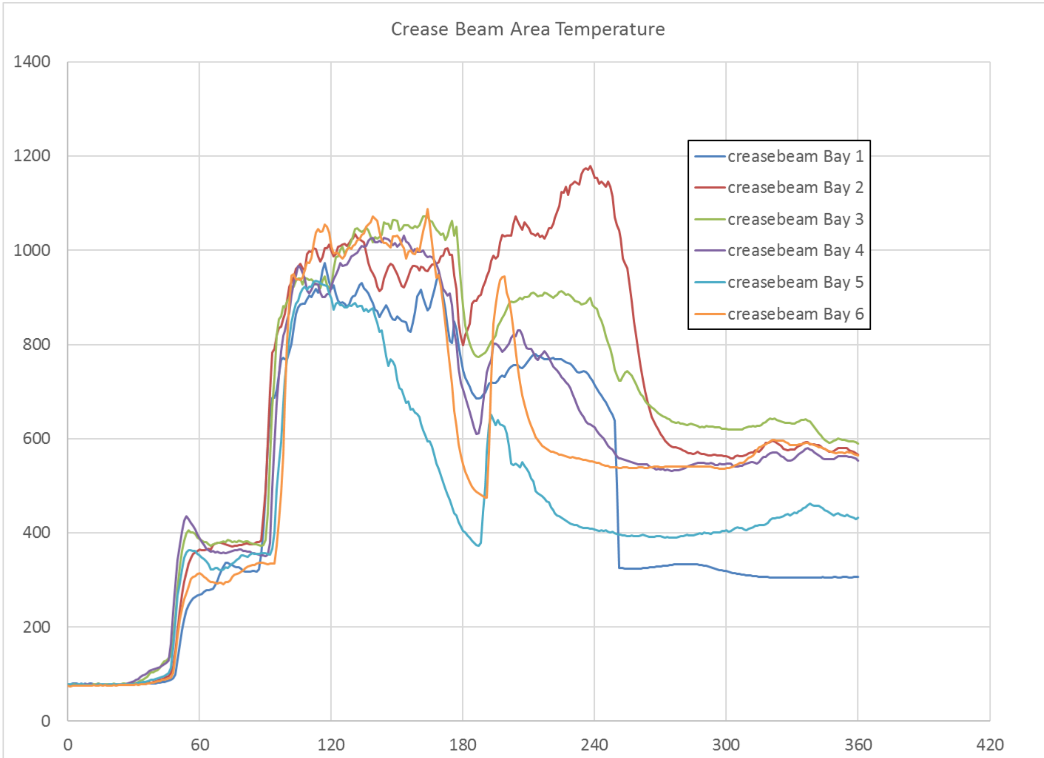

Figure 3. Air Temperatures in the Crease Beam Area at the Opposite Side of Test Fuselage from the External Fire

Follow-on tests with a full array of cabin materials are planned, in order to more accurately assess the ingress and propagation of fire. These tests will involve actual airframe components, including fitted insulation blankets, cargo compartment liner, passenger sidewall panels, baseboard return grills and associated hardware, carpeting, and seats. Fractional effective dose calculations will be performed, to determine the calculated theoretical survivability at various cabin locations during each test.

The Use of Shrouds to Minimize Air Current Influence on Test Results in the Cargo Liner Flame Penetration Test

Beginning in 1984, The FAA implemented a number of flammability test methods aimed at reducing the consequences of an impact-survivable postcrash fire accident, as well as minimizing the inflight threat from a cargo compartment fire. In 2005, another test requiring burnthrough-resistant thermal acoustic insulation was also introduced. Several of these flammability tests use an oil-fired burner as the basic apparatus for producing the fire threat. From the beginning of the test development in the early 1980's until shortly after the insulation burnthrough test became a regulation, the Park DPL-3400 burner was the burner of choice. Several hundred Park burners were manufactured for these applications. However, production of the Park burner eventually ceased, necessitating the need for a replacement burner. Studies also indicated the Park burner could be configured using a variety of internal components and adjustment settings, which greatly reduced reproducibility of test results.

This need for a standard oil burner apparatus prompted the Fire Safety Branch to develop the next-generation, or "Nexgen", burner that could be built from readily-available components. Rather than using an electric motor to drive the blower fan and fuel pump, the Nexgen burner relies on a pressurized air source and a sonic orifice to meter in the precise amount of combustion air, which provides more consistent flame characteristics over a range of ambient laboratory conditions. Internal burner components and settings were standardized during the development, resulting in more precise and repeatable test conditions for each application. After careful evaluations, the existing flammability test methods detailed in the Aircraft Materials Fire Test Handbook were revised to include the Nexgen burner, allowing laboratories the opportunity to fabricate or purchase the appropriate burner equipment necessary to conduct these flammability tests with greater accuracy.

Despite a thorough standardization of the burner apparatus, FAA-led intra-laboratory studies on the cargo liner test and the seat cushion flammability test revealed unacceptable levels of variation in the results. The studies indicated good repeatability within a particular laboratory, however the various laboratories in the studies were not in agreement (poor reproducibility). This result indicated there were other factors influencing the test results, since the basic burner apparatus had now been standardized. Surveys of laboratory configuration, size, and other environmental conditions highlighted a large variation amongst participants. The potential factors were narrowed down, uncovering the movement of air in the vicinity of the test apparatus as the most likely cause of inter-laboratory test variation. There were a range of causes, stemming from the location of test area ventilation exhaust (ceiling, wall, or floor), to the volumetric flowrate of air being exhausted in a particular lab. Some laboratories had large, powerful ventilators in small testing areas, while others had less powerful units in very large testing areas. Since it would be nearly impossible to regulate test area geometry and other facility features without cost-prohibitive measures, the Fire Safety Branch investigated simple ways of correcting the localized air currents around the burner apparatus. One concept involved the partial encapsulation of the cargo liner test apparatus near the flame impingement area with a steel shroud designed to minimize airflow disruptions (figure 1). The shroud mounted directly onto the test frame and was exposed (open) at the top of the shroud. Sample test peak temperatures increased significantly, even nearing the failure temperature mark of 400˚F, which was not unexpected. An improved shroud design was constructed to reduce the increase in peak temperatures (figure 2).

Figure 1. Early Shroud Design Used to Minimize Airflow Disruptions

Figure 2. Improved Shroud Design

The shroud sides were spaced away from the sample test frame and attached using threaded rod. This design allowed for vertical air flow around the sample while minimizing horizontal airflow disturbances from cooling the backside thermocouple located above the horizontal test sample. Although the improved shroud design was found to be effective at reducing the above-liner air currents, which reduced temperature fluctuations and increased repeatability, the metallic sides heated up during the 5-minute test, resulting in increased backface temperatures. The shroud sides also made it impossible to visually determine when a flame penetration had occurred. Based on this feedback, an updated version of this concept was developed, using a more effective baffle fabricated from perforated sheet steel, which also permitted visibility (figure 3).

Figure 3. Cargo Liner Test Apparatus with Vertically-Oriented Shroud Fabricated from Perforated Sheet Metal

Testing was conducted using the updated perforated design, which allowed for some airflow through sidewalls, slightly reducing entrapped or reradiated heat. Peak temperatures dropped significantly, proving the effectiveness of the new design. A comparison of tests with the shroud versus no shroud clearly illustrates the reduction in backface temperature fluctuations (figure 4).

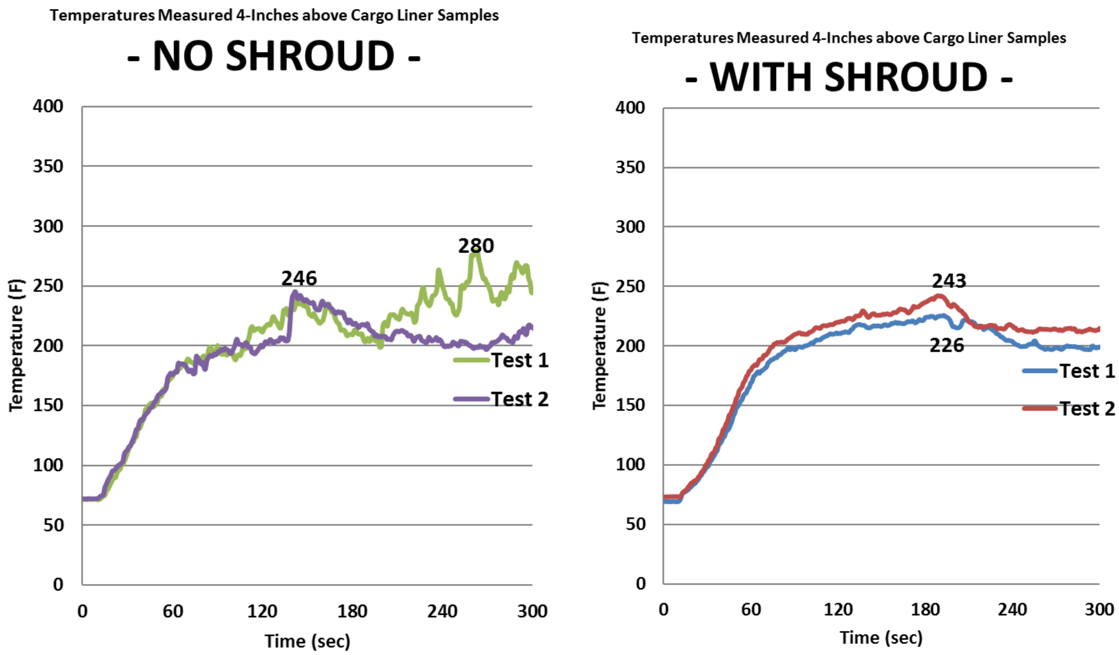

Figure 4. Test Comparison, Shroud Versus No Shroud

The next phase of the work will involve fabrication of additional shrouds for an interlab study. The study will determine if the results obtained by the Fire Safety Branch can be replicated by other laboratories using identical equipment. A follow-up project is aimed at the development of a similar shroud for the seat cushion flammability test.

RTCA Development of a New Flammability Test for Electronic Boxes

RTCA, Inc., formerly known as Radio Technical Commission for Aeronautics, is a United States volunteer organization that develops technical guidance for use by government regulatory authorities and by industry. It was founded in 1935, and was re-incorporated in 1991 as a private not-for-profit corporation. It has over 200 committees and overall acts as an advisory body to the FAA to develop comprehensive, industry-vetted and endorsed standards that can be used as a means of compliance with FAA regulations. Their deliberations are open to the public and their products are developed by aviation community volunteers functioning in a consensus-based, collaborative, peer-reviewed environment.

One such standard, RTCA/DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment*, provides a laboratory means to determine the performance characteristics of airborne electronic equipment. Chapter 26 of this standard defines test conditions and procedures for flammability and fire resistance. A task group formed within the International Aircraft Materials Fire Test Forum (chaired and administered by the Fire Safety Branch) has been the primary conduit for discussion and information exchange on revising Chapter 26 of the standard. The main focus of this task group is on flammability testing of electronic boxes in commercial aircraft, with specific emphasis on test simplification and reducing testing redundancy.

As per the current test requirements, an electronic box must be broken down and each part tested individually using the different Bunsen burner test methods. This has led to several tests having to be done to certify one box and confusion over how the rules apply to each part. The goal of this group is to create an alternative test method where the complete electronic box can be tested as an assembly to simplify testing while maintaining or improving the level of safety.

The starting point for this new test method was the telecommunications industry fire propagation test standard, American National Standards Institute (ANSI) T1.319. It consists of a methane line burner constructed from a 0.375 inch stainless steel tube with 11 burner holes placed 0.5 inch away from each other (figure 1). The burner is inserted into an electronic box with different fuel flow rates depending on the size of the circuit boards inside. Comparison testing between the vertical Bunsen burner and the methane line burner inserted into a vented box using several circuit board materials was completed. The testing indicated the line burner method was much more severe.

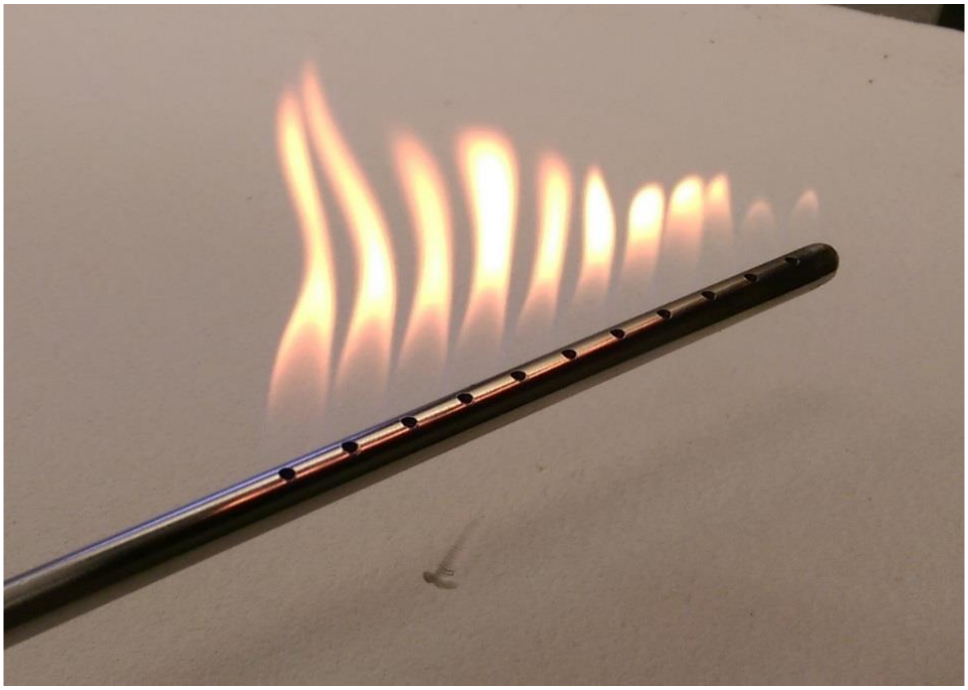

Figure 1. Methane-Fueled Line Burner

Further testing was done to find the limitations of electronic boxes that do not need to be tested, for example when there is insufficient ventilation to sustain a flame. To find the limit of airflow needed to sustain a flame, a flame with a known fuel flow rate was placed in a sealed box with a few small holes located on the top and bottom for ventilation. If the flame went out, two additional holes were drilled and the test was repeated. This process was repeated until the flame was able to sustain itself. Two box sizes, two burner placements inside the box, two different hole patterns, and several different fuel flow rates were tested in order to determine the minimum airflow needed to sustain a flame. Figure 2 shows the minimum airflow required to sustain a flame inside 2 different box sizes.

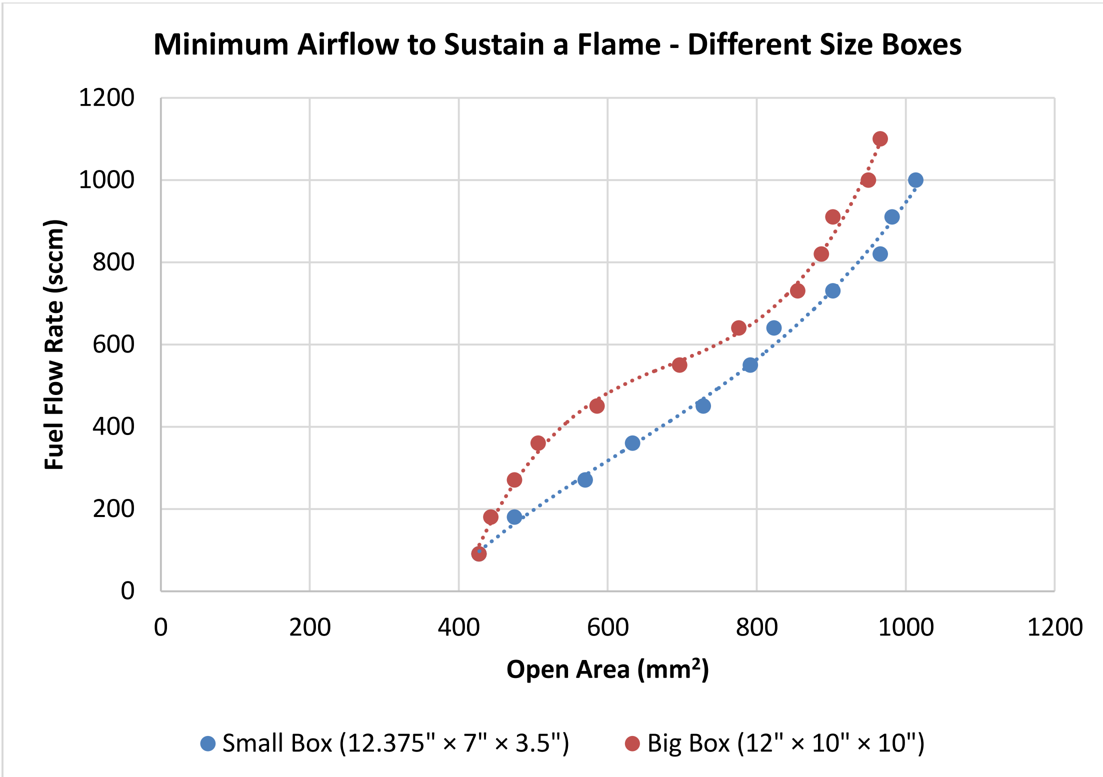

Figure 2. Minimum Airflow to Sustain a Flame Inside Two Different Box Sizes

In an effort to further refine the test method, additional tests were completed using production-spec aircraft electronic boxes and other non-production vented boxes with flame resistant and non-flame resistant materials placed inside. It was found that certain capacitors can explode when placed in a fire, so the line burner must be placed near capacitors if they are included as part of an electronic box, in order to test the worst possible case. Another important point of emphasis of the testing was the development of a simple pass-fail criteria for a box. The current acceptance criteria proposes that no flame of any size be permitted to escape the box for more than 12 seconds. The 12-second time limit is based on the 12-second vertical Bunsen burner flame exposure time, since the goal is to prevent flames from spreading to any other material placed around the box in an aircraft. Further intra-laboratory testing is planned with production-spec boxes at 4 different laboratories using the line burner test method.

Additive Manufacturing and Vertical Bunsen Burner Testing of 3D Printed Material

Additive Manufacturing (AM) is the term used to describe the technologies that build three dimensional (3D) objects by adding layer-upon-layer of material, whether the material is plastic, metal, or concrete. AM uses computer-aided-design (CAD) data software or 3D object scanners to direct hardware to deposit material in successive layers in precise geometric shapes. As its name implies, AM adds material to create an object. This is a transformative approach to industrial production that enables the creation of lighter, stronger parts and systems. By contrast, when creating an object using traditional methods, it is often necessary to remove excess material through milling, machining, carving, shaping or other means. The concept of creating lighter, stronger parts and reducing machining processes has attracted the attention of airframe manufacturers, who continuously strive to build lighter, more fuel efficient aircraft. Through discussions in the Aircraft Materials Fire Test Forum, airframe manufacturers and their supply chain companies have expressed interest in installing 3D printed parts in aircraft interiors. All AM-manufactured parts and components used in the cabin interior would still need to meet the appropriate flammability requirements, including the vertical Bunsen burner and Heat Release test where applicable. Although the raw materials used in the AM process may have known, robust flammability properties, it is possible the innovative process could impact the flammability of the finished component. AM introduces new variables during the construction, including the printing direction, raster angle, layer thickness, printing width, and infill percentage. It's possible to adjust any of these parameters even when producing parts with identical external dimensions.

In order to gain a better understanding of the impact of various manufacturing parameters on flammability, the Fire Safety Branch recently purchased the Fortus 450mc additive manufacturing machine made by Stratasys (figure 1). The apparatus has the ability to build production-quality parts up to a size of 16 by 14 by 16 inches using 13 different thermoplastics, including a few high-performance materials for specialized aerospace applications. This capability allows engineers to quickly produce samples for fire testing while easily varying the build parameters mentioned above. It also provides the capability of building complex parts for other purposes that may be difficult to produce using more traditional methods. In summary, the primary goal of procuring the AM apparatus and conducting research is to quantify the impact that these variables have on flammability, and possibly find a worst-case scenario that can be used to simplify future testing.

Figure 1. Stratasys Fortus 450mc at the FAA Technical Center

The first variable tested was printing direction using four different materials – Ultem 9085, PC-ABS, Polycarbonate, and Nylon-12. Ultem 9085 showed very minor differences in after flame time when printed in the YZ-direction compared to the XY and ZX directions, but overall showed very little burning. This material may be too flame resistant to show any differences in printing parameters. PC-ABS and Polycarbonate were both too flammable to show any differences as most samples burned up completely. Nylon-12 showed a relatively large difference in drip flame time between the YZ-direction and the ZX-direction, but more testing is necessary as only five samples were tested in each direction (figure 2). Future plans include testing Nylon-12 in the XY-direction and testing more samples for all directions to generate a more robust data set. The next printing variable to be tested will be infill percentage using Ultem 9085, since it may show more burning with the increased surface area that a lower infill percentage will bring.

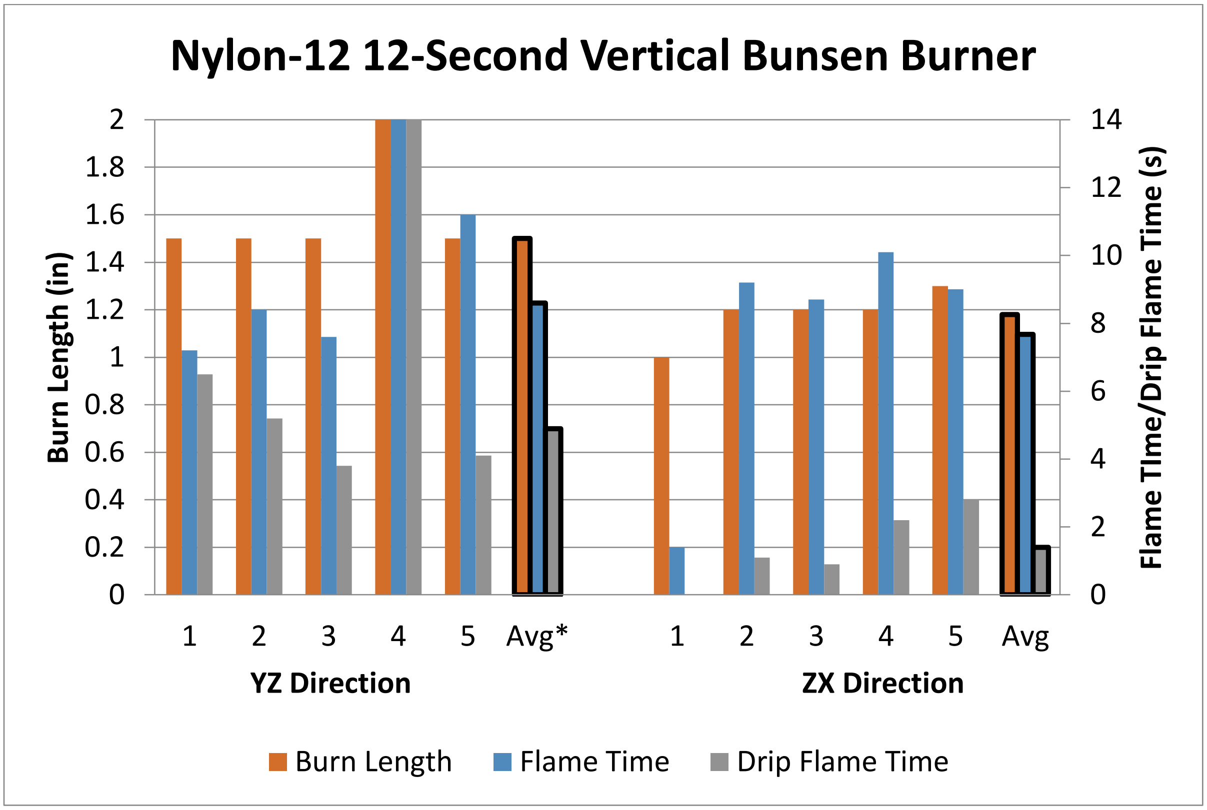

Figure 2. Nylon-12 Vertical Bunsen Burner Test Results in the YZ and ZX Direction