A Physical Comparison of Films Used to Encapsulate Aircraft Thermal/Acoustic Insulation

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Abstract

Recent regulatory changes have resulted in the need to improve the flame propagation characteristics of covering films that are used in the construction of aircraft thermal/acoustic insulation blankets. The challenge for the aircraft industry is to find films that meet the physical characteristics required by the industry, plus satisfy the new flammability requirements, and do so without paying a weight penalty. The purpose of this paper is to determine if these criteria can be met.

COVERING FILM FLAMMABILITY STANDARDS

There are no regulatory requirements mandating the use of thermal/acoustic insulation blankets in aircraft. But, flammability requirements must be met when insulation is employed. These standards have evolved over the decades, becoming increasingly stringent. For example, prior to 1967, the FAA required that the flame travel rate in a horizontal test could not exceed 20 inches per minute. In 1967, the FAA upgraded the requirement to char lengths not to exceed 4 inches in a horizontal flame test and 8 inches in a vertical flame test. In 1972, the FAA again upgraded the requirement to a maximum burn length of 8 inches, a self-extinguishing time not to exceed 15 seconds, and a drip extinguishing time not to exceed 5 seconds in a vertical flame test. These requirements were intended to increasingly improve the flame propagation characteristics of the covering films.

The most recent upgrades to the FAA standards were released in 2003, and require that thermal/acoustic insulation have flame propagation lengths not to exceed 2 inches and a self-extinguishing time not to exceed 3 seconds in a radiant panel test. Additionally, all insulation in the lower half of the fuselage is required to provide a burn through barrier for a minimum of 4 minutes when subjected to an oil burner test. An additional requirement is imposed on insulation forming the bottom of some cargo compartments that do not have an integral floor. The requirement is that there be no burn through, a self-extinguishing time not to exceed 15 seconds, and a maximum after-glow time of 10 seconds in a 45-degree flame test.

Aircraft thermal/acoustic insulation installed in the fuselage is made of two primary components: fiberglass insulation batting and covering film. The batting provides thermal and acoustic insulation. The purpose of the covering film is to hold the insulation batting in place, to protect the batting from contamination, and to provide a marginally effective moisture vapor barrier. The vast majority of covering films found in the aircraft that are currently being built are made of three components: polyester (PET) film, scrim, and adhesive.

PET film has been the material of choice for years because it is light in weight, offers a tough, easy to clean surface, is resistant to aviation fluids, and is somewhat effective in reducing moisture permeance. Scrim is used to increase burst and tear values. Nylon scrim is normally used because it is relatively light in weight, although polyester scrim is also used. The adhesive serves three primary purposes: to adhere the scrim to the film, to allow the film to be heat sealed around the insulation batting, and as a medium to hold fire retardants. There may also be a deluster coating on the surface of the film to reduce glare, and this coating may or may not contain fire retardants.

The problem with PET covering films has been that even though they have met the minimum requirements of FAR 25.853 and 25.855, they still are capable of propagating a fire after ignition from a small flame source if they lack a sufficient amount of fire retardant and/or they are contaminated with debris such as oil or grease. Reviewing the myriad reports concerning aircraft fires involving thermal/acoustic insulation covering films is not part of this report. But, it is worth quoting one passage from a September, 2001 professional engineering opinion from the FAA Technical Center: "…there are between three and five in-flight fires causing serious damage on part 121 aircraft in the

U.S per year. Most of those occurrences included the spread of fire on the thermal/acoustic film." Overall, the reports continued to indicate the need to improve the methods used to test covering films for resistance to flame propagation and to design covering films to meet these more demanding flame tests.

INADEQUACIES OF CURRENT STANDARDS

The crash of the Swissair 111 (an MD-11) on September 2, 1998, brought this issue to a head. A metalized polyester (MPET) thermal/acoustic insulation covering film appears to have been involved with the propagation of a flame from a small ignition source. The Canadian Transport Safety Board's final report included the following statement:

> The TSB believes that the use of material, regardless of its location, type or quantity that sustains or propagates fire when subjected to realistic ignition scenarios, constitutes an unacceptable risk, and that, as a minimum, material used in the manufacture of any aeronautical product should not propagate or sustain a fire in any realistic operating environment.
> (TSB, SR 111 final report, p. 280, as reported in Air Safety Week, April 7, 2003)

COVERING FILM FLAMMABILITY STANDARDS

As a result of this tragedy, the FAA released an Airworthiness Directive that required that all thermal/acoustic insulation covered with MPET be removed from commercial aircraft. To ensure that the replacement covering films offered better resistance to flame propagation, the FAA Technical Center was charged with developing a test method that was more challenging than FAR 25.853 and 25.855. The result was the radiant panel test, a modification of ASTM E648.

While this new flame propagation test reverts to the previous horizontal orientation of the flame, it has added a new component: a high energy radiant heat source. This radiant panel exposes the test specimen to 1.5 BTUs/ft^2 second. This is hot enough to challenge even the most heat resistant films.

This was followed by the release of a rule in September, 2003, that required all new transport category aircraft with seating for 20 or more passengers to use covering films that meet the requirements of FAR 25.856(a). This rule better defines the requirements of the radiant panel equipment and test methods. It takes effect in September of 2005, and has a compliance period of 2 years. The rule summary explains that the upgrade is needed "because the current standards do not realistically address situations in which thermal or acoustic insulation materials may contribute to the propagation of a fire. This action is intended to enhance safety by reducing the incidence and severity of cabin fires, particularly those in inaccessible areas where thermal and acoustic insulation materials are installed…"

This rule also includes a section, 25.856 (b), which requires that thermal/acoustic insulation blankets installed in the lower lobe of transport category aircraft prevent the penetration of "a high intensity open flame" for a minimum of 4 minutes. Experiments at the FAA Technical Center indicate that covering films have no effect on burn through time. Therefore, this part of the rule, which has an implementation period of 4 years from September, 2005, will be addressed by modifying the insulation batting systems, and therefore will not be covered in this paper.

The writers of this rule were careful to point out that the new test procedures were not a panacea for aircraft fires. They do claim that "The improved test will…ensure that insulation used in airplanes will resist the propagation of fire and therefore reduce the severity of fires or the speed with which fires spread."

Most insulation blankets covered with PET films fail this new test. The only exception that we have found involves a very light weight PET covering film that has limited application. Commercially available covering films that have been considered to be the best candidates to meet the requirements of 25.856(a) include those made with polyvinylfloride (PVF) and polyimide (PI) films. (It should be noted that even these two covering films propagate a flame if not properly loaded with flame retardant or are constructed incorrectly.) The majority of the industry appears to be favoring PVF type covering films for weight and economic reasons.

It was reported in the NPRM for this new rule that it had been "determined that some materials that would meet the proposed test requirements … weigh no more than materials currently being installed in newly-produced airplanes." This turned out to be less than correct. (The final rule did acknowledge that there would be "cost implications for aircraft manufacturers.")

WEIGHT PENALTY

The reality is that weight has the potential to be a considerable issue under this new rule. PET covering films, which are the films of choice under the current regulations, generally weigh less than PVF covering films, which is the film type generally being considered to comply with the new rule. Following are the typical ranges of weights for each covering film type:

PET Covering Films	PVF Covering Films
17 g/m^2 (0.5 oz/yd^2)	30 g/m^2 (0.9 oz/yd^2)
to	to
47.6 g/m^2 (1.4 oz/yd^2)	47.6 g/m^2 (1.4 oz/yd^2)

The vast majority of the PET films are in the range of 17 g/m^2 (0.5 oz/yd^2) to 30 g/m^2 (0.9 oz/yd^2).

Here are examples of the weight penalties that will result when changing from PET to PVF covering films. NOTE: Aircraft 1 & 2 are single aisle commercial aircraft and 3 & 4 are wide body aircraft.

Weight Penalty

	Metric	British
Aircraft #1	32 kg	70#
Aircraft #2	64 kg	140#

Aircraft #3	68 kg	150#
Aircraft #4	91 kg	200#

It is important to note that PVF covering films have excellent resistance to flame propagation, meet the typical physical requirements for the various aircraft specifications, and exhibit acceptable smoke and toxicity values. PVF covering films meet or exceed the industry's functional and regulatory requirements for thermal/acoustic insulation covering films.

The challenge to suppliers is to offer covering films that pass the radiant panel test, meet the physical requirements of the aircraft manufacturers, and do so with a minimum weight penalty. To determine if this challenge can be met, examples of PVF covering films will be compared with examples of a lighter weight covering film with the generic name of APK film.

	PVF Cover Film		APK Cover Film	
	Ex. 1	Ex. 2	Ex. 1	Ex. 2
Flammability				
Radiant panel	Pass	Pass	Pass	Pass
12-sec. vertical	Pass	Pass	Pass	Pass
Smoke Density[1]	Pass	Pass	Pass	Pass
Toxicity[2]	Pass	Pass	Pass	Pass
Physical Char.				
Film Thickness (mm)	12.5	12.5	6.3	6.3
Weight (g/m^2)	42.4	33.5	22.9	16.6
Puncture[3] (N)	80.4	56.2	40.9	29.0
Burst[3] (KN/m^2)	506.0	390.0	320.0	208.0

All of the PVF and APK covering films easily pass the radiant panel and 12 second vertical burn tests. The PVF film passes because the radiant heat source causes the film to melt, along with the underlying scrim and adhesive, and therefore removing the fuel source. The APK film passes because it is inherently flame resistant. All of the test specimens also passed the FAA's Smoke Density test, and toxicity requirements of the Draeger Tube test.

[1] FAA Smoke Density: FAR 25.853(d) Appendix F, Part V

[2] Toxicity: Draeger Tube

[3] Both film thickness and scrim configuration affect puncture and burst

It should be noted that both PVF examples are metalized, and therefore have better permeance values than the APK covering films. Tests have shown that metalized APK films have permeance values similar to metalized PVF films.

Physical characteristics differ, based on the thickness of each film type and the type of scrim used. It would be expected that the PVF covering films would have higher puncture and burst values than the APK covering films because the PVF films are twice the thickness of the APK films. The scrims used in the examples become lighter as you move from left to right in the above table, with the puncture and burst values decreasing, as would be anticipated.

The APK covering film examples have the lowest weights because the APK film is thinner and is about 92% the density of the PVF film. This brings up an obvious tradeoff between the two film types: weight verses strength. The APK film can be made stronger by choosing a heavier scrim, but that increases the covering film's weight. The PVF covering films can be made lighter by choosing a lighter scrim, but that decreases the covering film's strength. But, this tradeoff could lead to a solution to the weight penalty issue.

CONCLUSION

Examining the benefits and deficits of APK and PVF films indicates that there is room for both of these films under the new rule. The APK type covering films may be the best choice in areas that currently use PET covering films weighing from 17 g/m^2 (0.5 oz/yd^2) to 30 g/m^2 (0.9 oz/yd^2). PVF type covering films would be the best choice for the heavier wear areas in an aircraft.

It appears that there will be some weight added to an aircraft as a result of FAR 25.856(a). But, using a thoughtful combination of APK and PVF covering films will go a long way toward satisfying the rule without paying a large weight penalty.