Draft, Rev B – October 2018

POSSIBLE ADVISORY CIRCULAR CONTENT

(Author Note: AC25.856-1a was used as a template.)

Subject: MICROSCALE COMBUSTION CALORIMETRY TEST METHOD TO DETERMINE WHETHER A MATERIAL CHANGE REQUIRES ADDITIONAL CERTIFICATION TESTING FOR FLAMMABILITY

Revision A Summary: This revised guidance has been updated based on two years of refinement to the analysis methodology being developed by the FAA Technical Center and the MCC Similarity Task Group. The changes include the definition of a Fire Growth Capacity (FGC) and a recommended statistical analysis to determine similarity.

1. PURPOSE. This advisory circular (AC) provides guidance on using the Microscale Combustion Calorimetry (MCC) test method to determine the relative flammability performance characteristics of a material. This method can be used to compare the flammability properties of a currently certified material with those of the material that has been changed in some way (e.g. chemical/material changes to remove environmental impacts, alternate sources of chemical constituent/material, replacement for out-of-production material, changed material to improve manufacturing & performance properties, etc…) to determine if there is a significant change in the fundamental flammability properties. Once determined to have similar flammability properties at the material level, this data supports a minor determination of the material change, thus eliminating the need to assess the specific flammability properties of all the different part configurations where this material is used.

   This guidance applies to airplanes required to comply with § 25.853, and part TBD of appendix F to Title 14 Code of Federal Regulations (14 CFR) part 25.

2. APPLICABILITY.

   a. The guidance provided in this document is directed to airplane manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) transport airplane type certification engineers and their designees.

   b. This advisory circular is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

c. An applicant may propose to incorporate this methodology into their overall compliance plan, including establishing how changes are identified as either major or minor under § 21.93.

d. This advisory does not change, create, authorize, or permit deviations from regulatory requirements.

3. RELATED REGULATIONS AND DOCUMENTS.

a. Title 14 Code of Regulations 25.853 and Appendix F to 14 CFR part 25
b. ASTM D-7309-13, Standard Test Method for Determining Flammability Characteristics of Plastics and Other Solid Materials Using Microscale Combustion Calorimetry, American Society for Testing and Materials, West Conshohocken, PA (2013)
c. FAATC Reports – (*Key reports from Rich Lyon such as the following)*:
   I. https://www.fire.tc.faa.gov/pdf/TC-12-53.pdf
   II. https://www.fire.tc.faa.gov/pdf/TC-12-13.pdf
   III. https://www.fire.tc.faa.gov/pdf/tc12-39.pdf
   IV. https://www.fire.tc.faa.gov/pdf/TN12-12.pdf
   V. https://www.fire.tc.faa.gov/pdf/materials/Oct17Meeting/Lyon-1017-MaterialChange.pdf
   VI. https://www.fire.tc.faa.gov/pdf/materials/Oct17Meeting/Safronava-1017-AssesingMaterialconsistency.pdf
   VII. https://www.fire.tc.faa.gov/pdf/materials/March17Meeting/Boeing-0317-MCC_SIMILARITY.pdf
   VIII. https://www.fire.tc.faa.gov/pdf/materials/Oct17Meeting/Lyon-1017-MaterialChange.pdf
   IX. https://www.fire.tc.faa.gov/pdf/materials/March18Meeting/Slaton-0318-MCC.pdf
   X. https://www.fire.tc.faa.gov/pdf/materials/June18Meeting/Slaton-0618-MCC-FTWG.pdf
d. Underwriters Laboratory Documentation, Quality Control Procedure, TBD.
   i. (https://www.fire.tc.faa.gov/pdf/materials/Oct15Meeting/Fabian-1015-MCC.pdf)
e. R.E. Lyon, N. Safronava, J.G. Quintiere, S.I. Stoliarov, R.N. Walters and S. Crowley, Material Properties and Fire Test Results, *Fire and Materials*, 38, 264-278 (2014).
f. R.N. Walters, N. Safronava and R.E. Lyon, A Microscale Combustion Calorimeter Study of Gas Phase Combustion of Polymers, *Combustion and Flame*, 162, 855-863 (2015).
g. R.E. Lyon, N. Safronava and S. Crowley, Thermal Analysis of Polymer Ignition, *Fire and Materials*, 42, 668-679 (September 2018).
h. C.M. Lannon, S.I. Stoliarov, J.M. Lord and I.T. Leventon, A Methodology for Predicting and Comparing the Full-Scale Fire Performance of Similar Materials Based on Small-Scale Testing, *Fire and Materials*, 42, 710-724 (2018).

4. BACKGROUND.

a. The flammability properties of materials are one factor that determines how the airplane designs will resist ignition and flame propagation when exposed to an ignition source during flight and in a post-crash fire. The flammability regulations define prescriptive test methods to assess the ignition, propagation, combustion, and burn-through performance of airplane designs. These regulations form the basis for certification of the airplane type design. If changes to the design and materials are made, additional certification effort is required.

b. New and changing global environmental regulations to eliminate hazardous chemicals have a direct impact on the components of many existing material formulations used in the design of commercial aircraft. As industry works to remove these chemical compounds, significant effort is required to evaluate the design change utilizing the modified material and determine if the end use products will continue to meet all the engineering and certification requirements. Another area where this AC may be useful when materials are obsolete or cease to be manufactured for any reason. Flammability performance is a key property that is evaluated when a change in the material is required. This document describes a formalized procedure to assess the impact of a small change on material flammability performance using small samples to simplify testing and implement changes efficiently.

c. Components of aircraft interior materials that can be considered for a flammability determination by microscale combustion calorimetry (MCC) testing are those whose properties can be adequately represented by a 5-10 milligram sample. Examples of these include adhesives, potting compounds, coatings, films, thermoplastics, thermosetting resins, elastomeric compounds/rubber and textile fibers used in different design configurations. At the present time it is common practice to fabricate flammability test samples of all the different design configurations using the new/modified material or new component and perform a full complement of FAA flammability tests (Bunsen burner, OSU heat release, Smoke Optical density, Flame Propagation, etc…) for the different configurations using the material. This approach of fabricating and testing large numbers of test configurations is very expensive. The MCC offers a standard method and procedure to compare the fire properties of a new component with those of an existing component in a certified configuration. If the fire properties of the new component are sufficiently similar to the certified component, and the fabricated part containing this new component is otherwise unchanged, it is expected that the flammability properties of the changed part will be equivalent to the certified part, and that the substitution of the new component for the original component is a small (minor) change - eliminating the need to perform extensive configuration tests.

d. The FAA Technical Center in partnership with industry, academia and a national standards organization have developed and standardized a microscale combustion calorimeter (MCC) and test method, ASTM D 7309, over the last 10 years. The MCC provides a reliable “finger print” or “flammability spectrum” of a component that is sensitive to the chemical composition of the material, and is therefore useful for quality control and product surveillance as well as comparing the flammability properties of a new material to those of an existing certified material. A parametric representation of the flammability fingerprint using a few fire properties is a convenient and accepted way to characterize fire performance.

e. Figure 1 is an MCC test result for a plastic showing the three (3) fire properties that will be used to compare components. The three MCC fire properties are the maximum amount of heat that can be released by combustion of the component in a fire Q_∞, the ignition temperature of the component, T_1 and the temperature at which 95% of the combustion heat has been released, T_2. These 3 properties are used to compute the potential for fire growth, or fire growth capacity (FGC), of the component. The FGC is the basis for comparing materials to determine their similarity with respect to flammability.

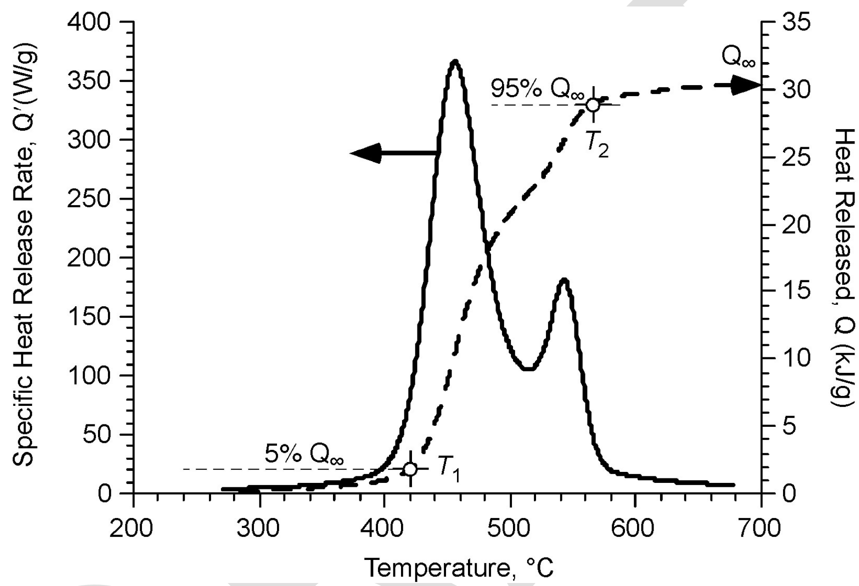

Figure 1. MCC Test of a Plastic Showing the Three Properties Q_∞, T_1 and T_2 Used to Compute FGC of Components.

5. DEFINITIONS.

a. **Component** is any substance used in the construction of an aircraft cabin material whose fire properties are adequately represented by the 5-10 mg sample used in a microscale combustion calorimeter according to ASTM D7309, Method A. Examples of components are adhesives, potting compounds, coatings, films, paints, resins, elastomeric compounds, rubber and fibers.
b. **Similar** is understood to mean that the MCC fire growth capacity (FGC) of a new component as measured in the MCC using method ASTM D7309-A is statistically indistinguishable from the FGC of the original (certified) component.
c. **Maximum Heat Release (Q_∞)** is the total amount of heat released by combustion per unit mass of component as measured in the MCC.
d. **Start Temperature (T_0)** is the temperature at the start of the MCC test prior to any heat release, which is defined to be T_0 = 25°C (298K).

e. **Ignition Temperature (T_1)** is the temperature of the component in the MCC test at which 5% of Q_∞ has been released.
f. **Heat Release Temperature (T_2)** is the temperature of the component in the MCC test at which 95% of Q_∞ has been released.
g. **Fire Growth Capacity (FGC)** is the potential for fire growth by ignition and flame spread,

$$FGC = \left(\frac{Q_\infty}{T_2 - T_1}\right)\left(\frac{T_2 - T_0}{T_1 - T_0}\right) \tag{1}$$

6. PROCESS DECISION FLOW

a. If the MCC result for the fire growth capacity (FGC) of a new or changed component is statistically indistinguishable from FGC of the original (certified) component in accordance with Section 8 of this document, the new material/component is considered to be similar with respect to flammability.

b. The following schematic diagram outlines the decision process for using the MCC to determine if a changed component is similar to a certified component with regard to its impact on the flammability of the part.

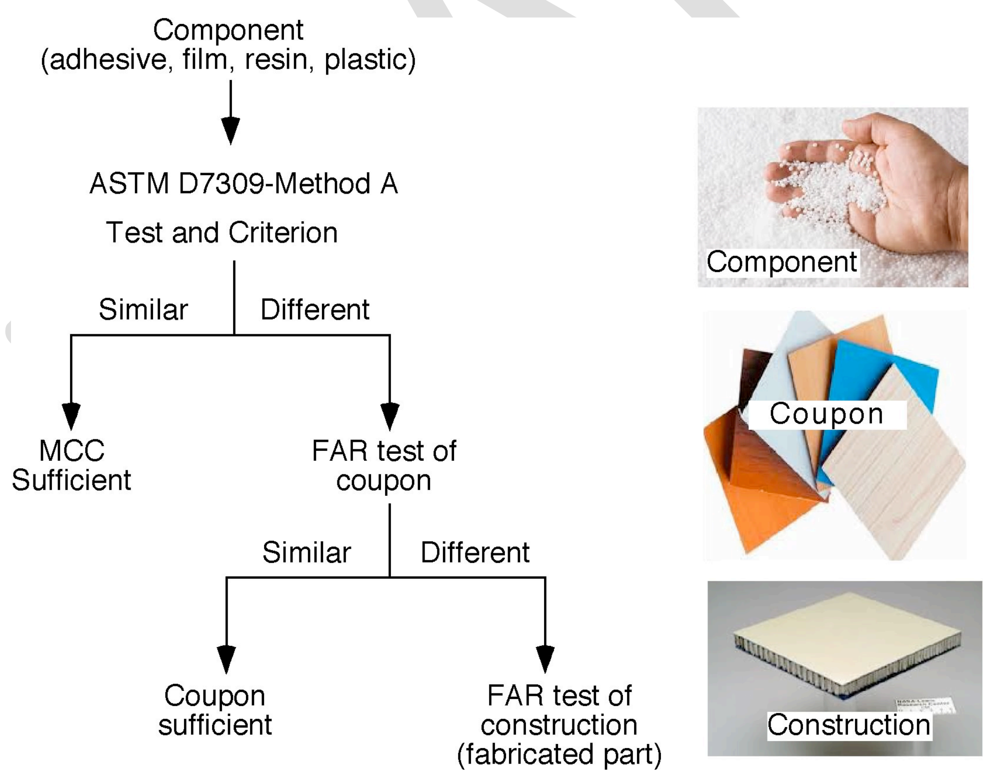

Figure 2. Decision Flow Process for Flammability Testing of a Certified Cabin Material, Part or Construction Containing a Changed Component.

7. TEST METHOD

a. ASTM D7309, Method A, defines the test method, calibration procedures and analysis methods. The temperature and heat measurements in the MCC apparatus must be accurate to within the specifications in ASTM D7309-A as demonstrated by temperature and heat release calibration using polystyrene.

b. At least five (5) samples of the original component and the changed component are to be tested in accordance with ASTM D7309-A by a single operator on a single MCC.

c. Calculate FGC by Equation 1.

d. Calculate the mean and standard deviation of FGC for the original component and the changed component for statistical analysis as per Section 8 of this document.

e. A sample calculation of FGC using Figure 1 as the flammability diagram for a 5 mg sample of a changed component is as follows. The maximum/total/ integrated heat release in Figure 1 is the intersection of the time integral of Q', shown as a dashed line in Figure 1, with the right hand ordinate at T_∞. For Figure 1 this value is, $Q_\infty = 30.2$ kJ/g. The ignition temperature is the abscissa value (temperature) of the dashed line at which 5% of the total heat has been released. In Figure 1, $T_1 = 420°C$ at $0.05Q_\infty = 1.5$ kJ/g. The temperature at which 95% of the heat has been released is the abscissa value of the dashed line at $0.95Q_\infty = 28.7$ kJ/g. In Figure 1, $T_2 = 564°C$. From these 3 properties compute, FGC of the sample of the changed component using Equation 1,

$$FGC = \frac{30.2\,kJ/g}{564°C - 420°C} \times \frac{564°C - 25°C}{420°C - 25°C} = 286\frac{J}{g - °C} = 286\frac{J}{g - K}$$

f. If FGC of the original/certified component is statistically indistinguishable from FGC = 286 J/g-K of the changed component, as determined by statistical analysis in accordance with Section 8 of this document, the changed component is considered to be similar to the certified component with regard to its effect on the flammability of the construction.

8. SIMILARITY CRITERION

a. Let Material 1 be the original/certified component, and let Material 2 be the changed component, and let n_1 and n_2 be the equal number of specimens of each component tested in the MCC, respectively, such that, $n_1 = n_2 \geq 5$.

b. Calculate the mean fire growth capacity of each material $\langle \mathrm{FGC} \rangle_i$ and its standard deviation, s_i, and compute the pooled standard deviation s_p for $\nu = (n_1 + n_2 - 2)$ degrees of freedom,

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \qquad (2)$$

c. Assume the two components are identical with respect to flammability and use the null hypothesis, $\langle FGC\rangle_1 = \langle FGC\rangle_2$ to compare test results using the test statistic t for the original and changed components,

$$t = \frac{\langle FGC\rangle_1 - \langle FGC\rangle_2}{s_p\sqrt{\dfrac{1}{n_1}+\dfrac{1}{n_2}}} \tag{3}$$

d. Define a level of significance, $p = 0.05$ (5%) and find the value of Student's t-distribution for ν degrees of freedom for a two tailed distribution, $t_{0.05}(\nu)$ of the small sample sets from Table 1. If the number of replicate tests n_i is more than 10, consult standard statistical tables for $t_{0.05}(\nu)$.

Table 1. Values of $t_{0.05}$ (95% Confidence Level)

$n_1 = n_2 =$	5	6	7	8	9	10
$t_{0.05}(\nu)$	2.306	2.228	2.179	2.145	2.120	2.101

e. If the absolute value of t for the two components, $|t|$, is greater than $t_{0.05}(\nu)$ of Table 1, there is more than a 5% chance that the difference in $\langle FGC\rangle$ of the components is not due to random error, so the null hypothesis is rejected, and the changed component is *not* interchangeable with the certified component with respect to flammability as measured in the MCC. Conversely, if $|t| < t_{0.05}(\nu)$, the components are considered to be similar with respect to flammability and additional certification testing of the changed material or construction is not required.

f. A sample calculation comparing two grades of the same high temperature plastic using the similarity criterion is as follows. Five samples of plastic component 1 were tested ($n_1 = 5$) in the MCC with mean and standard deviation, $\langle FGC\rangle_1 = 43\pm2$ J/g-K. Five samples of plastic component 2 were also tested ($n_2 = 5$) in the MCC, with $\langle FGC\rangle_2 = 59\pm2$ J/g-K. From Equation 2, $s_p = 2$ J/g-K and, $|t| = 12.65$ by Equation 3. In Table 1, $t_{0.05} = 2.306$ for $n_1 = n_2 = 5$, so $|t| > t_{0.05}$, and the null hypothesis is rejected. That means that random error cannot account for the difference in FGC between plastic component 1 and plastic component 2, so they are considered to be different with respect to flammability in the MCC. The MCC results are therefore insufficient to demonstrate similarity.

g. Reference: Any introductory textbook on statistics. https://www.fire.tc.faa.gov/pdf/materials/March18Meeting/Slaton-0318-MCC.pdf (Statistical analysis methodology starts on slide 21).

9. APPLICABILITY TO CERTAIN MATERIALS

a. Case Study #1: FAATC example of similar MCC results
FAA example from: https://www.fire.tc.faa.gov/pdf/materials/Oct15Meeting/Lyon-1015-Similarity.pdf

b. Case Study #2: FAATC example of similar MCC results. https://www.fire.tc.faa.gov/pdf/materials/June18Meeting/Slaton-0618-MCC-FTWG.pdf Case Study #3: Industry example TBD
c. Case Study #4: Industry example TBD

/s/
TBD,
Manager, Transport Standards Branch
Aircraft Certification Service