MATERIAL CHANGE SIMILARITY TASK GROUP REPORT

9th Triennial International Aircraft Fire and Cabin Safety Research Conference
Resorts Hotel and Casino, Atlantic City, New Jersey,
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Task Group Chairmen: Rich Lyon (FAA) and John Harris (Boeing)
Date: October 31, 2019, 3:30-5PM.
Attendees: Approximately 20

SUMMARY OF PROGRESS TO DATE

The stated goal of the Material Change Similarity Task Group is to explore the possibility that a small-scale test could be used to determine whether a change in the composition of a cabin material would be a minor change with respect to the flammability of the part as measured in 14 CFR 25 fire tests and, if so, to formalize the procedure. The Task Group has down-selected the small-scale test method to ASTM D7309 microscale combustion calorimeter/MCC [1], adopted the MCC Fire Growth Capacity/FGC as the component metric [2], and conducted a coupon-level validation study of the procedure. In the present context a, **construction** is a sidewall panel, stowage bin, bulkhead, partition, passenger service unit, or other cabin material required to pass 14 CFR 25 flammability requirements that may contain one or more combustible **components** such as adhesives, thermosetting resins, thermoplastics, films, fibers, coatings, etc. A **coupon** is a simplified construction that is fabricated for the sole purpose of fire testing the combustible component as part of a construction in accordance with 14 CFR 25 flammability requirements.

A validation study was initiated in 2015 to set the component-level allowable for equivalent fire performance (similarity) of substitute combustible components in 14 CFR 25 compliant coupons. To this end, coupons containing certified and changed components were tested in accordance with 14 CFR 25 and the results compared to FGC of the combustible components from MCC. Task Group members conducted a wide-ranging study of material and process variations, including changes in thermosetting resin, resin formulation, flame-retardants, decorative laminate color, material supplier, and thermoplastic processing conditions. The result of these studies was that, for 14 CFR 25 compliant coupons, the relative change in FGC of the combustible component was comparable to the relative change in 14 CFR 25 fire test results. In particular, if A and B are combustible components that are changed and certified, respectively, and X_A and X_B are average 14 CFR 25 fire test results for coupons/constructions containing A and B, (e.g., OSU peak heat release rate, OSU 2-min heat release, burn length or after-flame time in burner or radiant panel tests), a component-level criterion for equivalent coupon/construction level fire performance (similarity) of coupons/constructions in 14 CFR 25 would be,

$$\frac{|FGC_A - FGC_B|}{FGC_B} \leq \frac{|X_A - X_B|}{X_B} \qquad (\textit{coupons/constructions}) \qquad (1)$$

Applying the component similarity criterion (Equation 1) to 49 tests of 14 CFR 25 compliant coupons resulted in a success rate of 86% and was conservative ($X_A = X_B$) for the remaining 14%, for an overall success rate of 100%. The coupon/construction level similarity criterion can be extended to production cabin materials using the expected variation of 14 CFR 25 test results. If σ_B and X_B are the standard deviation and sample mean, respectively, for 14 CFR 25 fire tests of certified cabin parts/constructions containing combustible component B, then it is expected that when B is changed to A, the 14 CFR 25 fire test results for the changed construction X_A will be in the range, $X_B - 2\sigma_{X_B} < X_A < X_B + 2\sigma_{X_B}$. Substituting, $X_A = X_B \pm 2\sigma_{X_B}$ into Equation 1, the component-level criterion for equivalent fire performance of a construction containing a substitute combustible component A at the 95% confidence ($2\sigma_{X_B}$) level becomes,

$$\frac{|FGC_A - FGC_B|}{FGC_B} \leq \frac{2\sigma_{X_B}}{X_B} \qquad (\textit{constructions}) \qquad (2)$$

Applying this construction-level criterion to the coupon-level tests resulted in a success rate of 96%.

Microscale Flame Spread Parameter for Comparing Material Flammability

A microscale flammability parameter that includes both ignitability and heat release rate, called the Fire Growth Capacity/FGC, was derived from the analysis of full-scale fire growth [2]. The FGC can be measured in the Microscale Combustion Calorimeter (ASTM D 7309) [1], and is the single best predictor of 14 CFR 25 flammability test results of aircraft cabin materials [3]. The FGC has units of J/g-K and is calculated from 3 properties of combustible components measured in the MCC. These properties are: 1) the total heat release of the component in the test Q_∞ (J/g); 2) the ignition temperature, which is approximated by the temperature at which 5% of Q_∞ has been released ($T_{5\%}$, K); and 3) the surface burning temperature, which is approximated by the temperature at which 95% of Q_∞ has been released ($T_{95\%}$, K). Figure 1 shows MCC data for an adhesive plotted as the specific heat release rate Q'(W/g) normalized for the heating rate β(K/s) in the test, Q'/β (J/g-K) versus the sample temperature on the left hand ordinate (y-axis). The integral of this curve is plotted on the right hand ordinate. The heat released by complete combustion of the adhesive at 1073K (800°C) is Q_∞ = 16.7 kJ/g. The temperatures at 5% and 95% of Q_∞ are $T_{5\%}$ = 645K (372°C) and $T_{95\%}$ = 796K (523°C), respectively. These three MCC test parameters and a standard (room) temperature, T_0 = 298K (25°C), are used to calculate the Fire Growth Capacity of the combustible adhesive using Equation 3,

$$FGC = \left(\frac{Q_\infty}{T_{95\%} - T_{5\%}} \right) \left(\frac{T_{95\%} - T_0}{T_{5\%} - T_0} \right) = 158 \frac{J}{g-K} \tag{3}$$

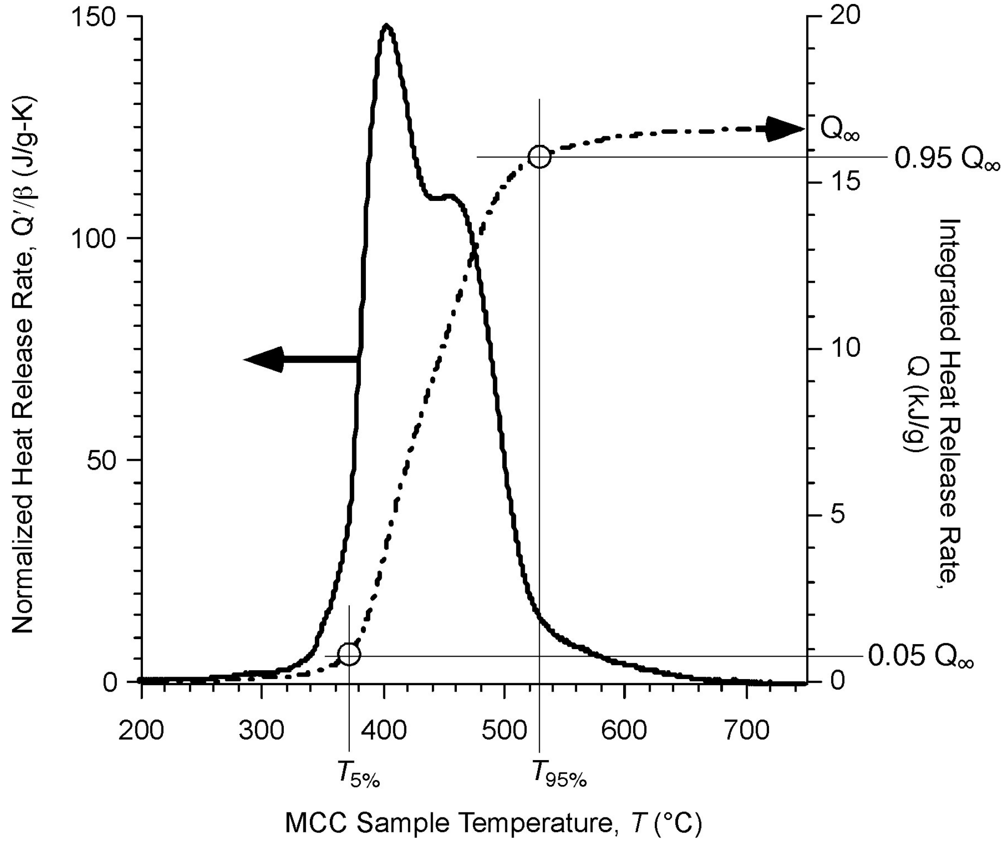

Figure 1. Q_∞, $T_{5\%}$ and $T_{95\%}$ Used to Calculate FGC of Combustible Components.

MCC Criterion for Equivalent Fire Performance in 14 CFR 25 Fire Tests

Natallia Safronava presented an analysis of 10 coupon-level case studies conducted by Task Group members [4]. The case studies included MCC tests of combustible components and 14 CFR 25 fire tests of coupons containing certified components and substitute components in the OSU and vertical Bunsen burner. Changes included in the studies were material substitutions, reformulations, colors, suppliers, and process variations. The allowable difference in fire performance of certified and substitute components at the milligram- (MCC) and coupon- (14 CFR 25) level was Equation 1. This inequality was satisfied for 86% of the 49 comparisons at the coupon level. The remaining 7 comparisons failed because the MCC was overly conservative ($X_A = X_B$).

The component-level criterion for equivalent fire performance at the coupon level (Equation 1), can be extended to any cabin material (i.e., small parts, seating materials, ducting, sidewall/ceiling panels, stowage bins, bulkheads, thermo-acoustic insulation, passenger service units, etc.) fabricated for production airplanes using 14 CFR 25 certification or quality control data for the part in Equation 2. This component-level criterion was satisfied for 94% of the 14 CFR 25 compliant coupon tests in the validation study.

NEXT STEPS

- Update the draft policy letter on the Fire Safety website for the validated similarity criterion for parts and constructions (Equation 2).

- Publish FAA reports and/or peer-reviewed journal articles to document an improved MCC baseline correction method, fire growth capacity concept, and MCC similarity criterion.

- Update the MCC standard (ASTM D7309) to include the improved baseline correction method and procedure for obtaining $T_{5\%}$ and $T_{95\%}$.

- Conduct ASTM inter-laboratory study (ILS) of precision and bias for at least 6 materials tested in at least 6 different laboratories having an MCC as per ASTM D 7309. These 6 materials will include fire resistant and low heat release materials used in aircraft cabins (FGC ≤ 100 J/g-K). Companies attending the Task Group meeting that own/use MCC and volunteered to participate in the ILS were FAA, Boeing, National Institute of Standards and Technology/NIST, 3M, Diehl, Deatak, SGS/Govmark, the University of Dayton Research Institute, the University of Maryland, and the University of Massachusetts.

- Conduct additional case studies that include radiant panel tests of thermo-acoustic insulation and a case study to determine whether the MCC criterion (Equation 2) can discriminate between materials that pass and fail 14 CFR 25 fire tests.

REFERENCES

1. Standard Test Method for Determining Flammability Characteristics of Plastics and Other Solid Materials Using the Microscale Combustion Calorimeter, ASTM D7309, American Society for Testing and Materials (International), West Conshohocken, PA, 2019.
2. R.E. Lyon, R.N. Walters, N. Safronava, *Small Scale Fire Test for Component Substitutions in Aircraft Cabin Materials,* Interflam19, Sussex, UK, July 1-3, 2019.
3. R.E. Lyon and N. Safronava, Isokinetic Parameters for Ignition and Burning of Solids, 9th Triennial International Aircraft Fire and Cabin Safety Conference, Atlantic City, New Jersey, USA, October 28-31, 2019.
4. N. Safronava, R.E. Lyon and R.N. Walters, *Small Scale Fire Test for Component Substitutions in Aircraft Materials*, 9th Triennial International Aircraft Fire and Cabin Safety Conference, Atlantic City, New Jersey, USA, October 28-31, 2019.