Heat Release and Flammability Testing of Surrogate Panels

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16. Abstract

A task group assembled under the auspices of the International Aircraft Materials Fire Test Working Group examined issues involving fire test approval of previously qualified interior material systems following renovation or alteration. A major problem associated with the alteration of interior system components is the difficulty in conducting certification tests that would determine if the altered interior component is still compliant with the heat release, smoke, and flammability certification requirements. In many instances, the appropriate substrates for conducting these follow-up certification tests are unavailable. As discussed in an earlier report, DOT/FAA/AR-TN95/83, International Aircraft Materials Fire Test Working Group, Material Systems Renovation and Repair Subgroup, the use of surrogate materials is the most feasible method for conducting certification tests following renovation, when samples of the actual buildup materials are unavailable. In order to validate the accuracy of using surrogate materials as heat release, smoke, and flammability predictors, tests were conducted in which several similar surrogate panels were compared. The surrogate panels were manufactured by three independent suppliers according to a common specification. Heat release and vertical Bunsen burner tests were conducted on the surrogate panels, which were finished with one of three paints or one of two laminates. The heat release test results indicate that each of the three surrogates reacts slightly different when tested without finish paint or laminate. When tested with a finished surface, the heat release results are even more scattered, providing evidence of the interrelationship between the substrate panels and the finish.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The International Aircraft Materials Fire Test Working Group (IAMFTWG) was formed in an effort to work jointly with the aviation community on issues relating to the fire testing and certification of aircraft interior materials. Among other things, the working group investigates new problems that arise with current Federal Aviation Administration (FAA) test methods, including the Bunsen burner, the 2 gallon-per-hour seat fire blocking and cargo liner tests, the Ohio State University (OSU) Rate-of-Heat Release Apparatus, and the National Bureau of Standards (NBS) smoke chamber. Because of the level of complexity associated with these and other fire tests, unforeseen problems often arise that need to be addressed to insure that certification tests conducted throughout the United States and foreign countries are consistent and according to the intent of the Federal Aviation Regulations (FARs).

In addition to the cultivation of certification testing methods and related equipment, the IAMFTWG was tasked to investigate problems in a variety of areas to support harmonization work involving the FAA and the European Joint Airworthiness Authorities (JAA). These areas were initially broken down into four categories, and individual subgroups were formed to investigate issues in: continued compliance (task group one), minor changes to qualified systems (task group two), quality control (task group three), and material systems renovation and repair (task group four). One area that task group four focused on dealt with certification issues of renovated/refurbished interior material systems, and more specifically, the difficulty of administering certification tests when appropriate buildup materials needed for test coupons are unavailable. Numerous approaches exist for qualifying altered materials. One approach is to use a similar, but nonidentical panel known as a surrogate panel for determining the heat release and smoke emission of in-service panels. Because no data existed which investigated the relationship between surrogate materials and actual materials, a series of tests were run to initially examine the variability of surrogate panels supplied by independent manufacturers. All of the surrogates tested were manufactured according to a common specification, which would enable an initial evaluation of the concept's validity. This report discusses the difficulties associated with the fire test approval of renovated material systems and investigates the results of heat release and flammability tests conducted using surrogate materials produced by three independent manufacturers.

INTRODUCTION

PURPOSE.

The purpose of this report is to summarize the findings of heat release and flammability tests in which surrogate materials were compared, both with and without paint and decorative laminate finishing. The surrogate panels were manufactured by three independent suppliers according to a common specification. The tests were run to determine the degree of variability that may result when panels are constructed by independent manufacturers or when nonidentical resins are used.

BACKGROUND.

The Federal Aviation Administration (FAA) Transport Airplane Directorate (TAD) tasked the International Aircraft Materials Fire Test Working Group (IAMFTWG) to investigate several areas relating to aircraft material system compliance. This task stemmed from a harmonization program between the FAA and the European Joint Aviation Authorities (JAA). One of the tasks was to investigate the prevalence of repair and renovation of previously qualified material systems because a number of incidents had alerted the authorities of a potential problem. The task group was comprised of representatives from major airframe manufacturers, several interior panel paint and decorative vendors, and initially one airline. After several task group meetings were held, it was determined that a large percentage of the repairs that take place in an aircraft involved the patching of damaged cargo liners. Other materials, including the seats and carpet, were found to be replaced more often than repaired. To a lesser degree, spot repairs were often made to interior panels using polyester fillers, but these repairs tend to be confined to a small specific area [1]. The cargo liner repair issue was within the scope of the task group, therefore, further investigation resulted. Two companies that manufactured products specifically used for this application became involved in the task group, which led to the codevelopment of testing criteria for cargo liner patching systems. As a result, a chapter was implemented into the Aircraft Materials Fire Test Handbook that specifies a battery of tests; by meeting these tests, a high degree of confidence is gained that the patching system will enable repaired cargo liners to maintain compliance.

In addition to the repair of cargo liners, the subgroup also focused on a potentially larger issue, the renovation/refurbishment of cabin interior surfaces because it was revealed that this type of alteration is fairly commonplace and becoming more prevalent. The subgroup discussions uncovered inconsistencies in the methods used to qualify the completed materials systems. Subgroup participants also discussed a variety of situations whereby used aircraft had undergone a cabin "refresh" in which all or nearly all of the interior surfaces were repainted or relaminated. Since these processes would not be considered a "substantially complete replacement," the materials used would be required to meet the flammability standards based on the aircraft's type certification only[1]. An airline could thereby achieve a very contemporary looking interior by

[1] The low-heat release standard that was implemented in 1988, Amendment 25-61, focused on large surface area panels used in areas such as sidewalls, ceilings, and stowage bin doors that have a tendency to dominate the growth of a cabin fire. Based on full-scale tests conducted at the FAA William J. Hughes Technical Center, low-heat release panels that meet the new flammability standard have been found to significantly increase the amount of available escape time in a postcrash fire. The FAA requires that the improved materials be installed in newly manufactured airplanes, airplane models with Amendment 25-61 in their type certification basis, and in existing

simply installing a decorative laminate or paint over the existing interior panels, alleviating replacement of the entire shipset of new technology structural panels, at a substantial cost savings. According to current FARs, however, any change to the interior surface must be accompanied with proof that the finished system is still in compliance with the original type certification of the particular aircraft.

DISCUSSION

An altered (i.e., renovated or refurbished) surface could be defined as one which has previously met the required FAA fire test(s) but, for aesthetic purposes, has been repainted or resurfaced. There are varying degrees of resurfacing processes that are currently taking place in the field. For example, a very thin decorative film laminate may be placed over the original painted surface and bonded using an adhesive. In other instances, the thin decorative laminate is stripped from the original interior panel and a new decorative is installed in its place. A third process involves the installation of a decorative over the original panel decorative that is not removable. This process is often referred to as "piggybacking." From a regulatory standpoint, the process of renovating/refurbishing an aircraft interior raises several concerns. The most important is that the airplane must continue to comply with the flammability requirements contained in its type certification basis and, if applicable, (i.e., if the airplane is operated under Title 14 Code of Federal Regulations (CFR) Part 121 and was manufactured on or after August 20, 1988) the requirements of 14 CFR Part 121.312(a). Therefore, for airplanes with a type certification basis that includes Amendment 25-61 and later or which must comply with 14 CFR Part 121.312(a), any renovation, refurbishment, or repair of the major interior components must continue to meet either 100/100 or 65/65/200[2]. These requirements necessitate testing with the Ohio State University (OSU) Rate-of-Heat Release Apparatus and, if applicable, smoke emissions tests to ensure that the refurbished material system is still in compliance. If there is an adequate supply of flat panel "spares," which are identical to the in-service panels being altered, all repair and renovation materials (fillers, paints, or new laminates) can be applied over this substrate, exactly as it will exist in service, and tests can easily be administered to show compliance. In some cases, the airframe manufacturers will supply the customer with several spare panels for the purpose of conducting laboratory tests when performing an interior renovation. However, this has been the case only more recently. In most instances, as mentioned previously, there are no spares available, and the exact buildup materials needed to construct these test coupons are no longer produced.

If the materials used to produce representative test coupons are not available, it is impossible to conduct valid heat release and smoke chamber certification tests or, in older airplanes, a vertical Bunsen burner test, on a fabricated test sample as specified in the regulations. This has been a major issue raised by members of the renovation and repair subgroup during working group discussions.

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airplanes that undergo a "substantially complete replacement". Should an operator choose to replace interior parts on a piece meal basis, (e.g., the ceiling panels, then the bins, then the sidewall panels) it would be exempt from meeting the upgraded standard. If, however, the operator removes a majority of the interior panels for replacement purposes, the new panels would have to meet the more stringent heat release test criteria.

[2] Refers to the peak- and total-heat release rate in kW/m^2, and $kW\text{-}min/m^2$, respectively, of a sample tested in the OSU Rate-of-Heat Release Apparatus.

Faced with this problem, some carriers have reportedly cut specimens from existing sidewall, ceiling, and stowage bin panels to perform the required certification tests with the new decoratives or paints. The "cutout" specimen obtained from the in-service panel could be used as the test specimen substrate and be altered identically, allowing for a very accurate measurement of the final heat release/smoke characteristics of the material system. As mentioned, this would be a costly procedure, necessitating replacement of the cutout panel. To compound this situation, it is often very difficult to obtain the desired amount of flat surface necessary to conduct the required heat release (or smoke chamber) test from contoured factory sidewalls or stowage bin panels. Other potential solutions have been considered with regard to this problem, including the use of common substrates or standardized test panels that could be manufactured according to a tight specification for the purpose of conducting certification tests only. The common substrate method would simplify testing, but experience has shown that interactions or synergism may exist between certain combinations of materials not covered by the standardized material so this method could potentially produce inaccurate results. Another option would be to use a critical panel that could be manufactured according to a stringent specification, which has a heat release rate very near the 65/65 limit. By applying the appropriate renovation materials to this type of panel, a simple determination could be made regarding any increase in heat release. This would work in theory, but in practice would be hard to produce, since the heat release rate would have to be so tightly controlled. This would also be difficult from the testing standpoint; as ongoing "round-robin" tests have indicated, a fair amount of data fluctuation still exist between testing labs. As with the common substrates, a critical panel would also be faced with the same synergistic problems. The only indisputable method for ensuring compliance is to test the altered materials. The next best solution is to run the test using panel spares that are identical to the in-service panels. As discussed, this too is often difficult (if not impossible) as many of the materials are no longer available or have changed significantly since the original manufacture. For example, a request to the manufacturer for panel spares based on the original design specifications may result in panels supplied that have the same basic construction, but utilize a newer, more fire-resistant resin. In many instances, the material processes have changed, old resins have been superseded by better, more fire-resistant ones or composite panel prepregs (a major component of the interior panels) have evolved into slightly different forms. In those cases, the lab test is conducted on a test coupon that has a lower heat release rate, which could result in a false sense of compliance. In reality, the in-service panels may have heat release rates significantly higher which, with the addition of a new decorative, could render the interior noncompliant. Although the materials have improved, the certification issue actually has become more complicated.

Although the issues surrounding the problem were complex, the task group's objective became clearer: to simplify and standardize the current method of approving alterations to cabin material systems when the necessary materials for conducting heat release/smoke certification tests are unavailable. In general, the task group had been searching for an appropriate means of standardizing the certification process following renovation, which has created a hardship for the operators who must show compliance when resurfacing their interiors. Although it may be impossible to remove altered materials for direct testing, the task group felt it was possible to insure compliance by conducting laboratory tests based on the in-service materials. The test specimens and procedure must be simple, straightforward, and accurate, as the airlines are often under very strict time constraints[3]. At subsequent meetings, the subgroup further developed a standardized procedure that could ensure compliance. The standardized procedure would incorporate a safety factor to allow for the use of nonidentical materials, commonly referred to as surrogates. By using surrogate materials, the applicant would, in effect, be gaining approval through an alternative means of compliance (AMOC). Due to additional suggestions from operators, airframe manufacturers, refurbishment facilities, and other interested IAMFTWG participants, the recommended test procedure was further refined. The original suggested method required using three "nonidentical but similar" surrogates to certify a refurbishment. This would have required six tests to be done, since a two-panel average was needed for each surrogate. A more feasible approach would be to mandate tighter controls on the specific surrogate construction and layup process, thereby eliminating excessive testing and likely producing more accurate results (i.e., the more closely the surrogate resembles the original equipment manufactured (OEM) panel, the likelier the surrogate will perform like the OEM panel).

The definition of a surrogate material, as agreed to by the task group, became "a material, usually in the form of a heat release or smoke chamber test panel, which has the same basic construction and buildup as the OEM panel, with a comparable layup process during manufacture wherever possible. It is important that the honeycomb core thickness, the number of prepreg plies per side, and the reinforcement (carbon or glass) of the surrogate be identical to the in-service panel because differences in these basic constructions would yield erroneous results." For example, a surrogate panel could be considered an adequate replicate of the OEM panel, even when using buildup materials supplied by different manufacturers or prepregs with different cure cycles. If a surrogate could be constructed similar enough to the original panel, it was believed that near identical heat release rates could be obtained. The surrogates could be used in cases where the appropriate buildup materials were not available to construct exact test coupons.

A formalized document of the recommended procedures for using surrogate panels was finalized, with the intent of implementing the procedure into the Aircraft Materials Fire Test Handbook. However, upon further review of the proposed standardized procedure, the FAA concluded that it could not be implemented into the Handbook because the basis of the procedure relied on the use of surrogate, not exact, materials. Although a surrogate panel could be manufactured to resemble the original panel substrate, it would usually not be identical. Additionally, no data existed which supported or refuted the accuracy of surrogate panels. Until data was made available on the accuracy of surrogate materials at predicting the heat release/smoke output of actual cabin materials, individual test plans would still be required. The test plan would be submitted and reviewed prior to initiation of any cabin refurbishment (i.e., reviewed on a case-by-case basis) for determining the validity of the test approach.

[3] The real push for implementing a standardized procedure was for the benefit of the operators, who must maintain and continually update their fleet. By following a standardized set of procedures, the operators could save time and money when making repairs, resurfacing panels, redecorating, etc. In order to develop a comprehensive and accurate set of standardized procedures, a multitude of comparative testing was required. However, there was very little participation on the part of the domestic operators in this endeavor.

The validity of the surrogate materials for measuring the heat release/smoke characteristics of the altered materials was obviously the key issue. Because data did not exist which compared the heat release rates of surrogates and actual in-service panels, it was necessary to conduct laboratory tests to examine this relationship. In general, the applicability of the surrogate materials must be clearly demonstrated in order for the recommended procedure to be accepted as a certification testing vehicle.

TESTING.

A test program was initiated to determine the variability (scatter) in heat release measured for surrogate panels supplied by various manufacturers. All surrogates were constructed according to a particular specification established by the subgroup. The tests would establish whether or not a surrogate panel could be considered a reliable and accurate approach for conducting heat release/smoke certification testing. If the tests indicated a high degree of scatter amongst the various surrogates, the research would be discontinued. If, however, the tests showed very little difference between the various manufactured panels, the subgroup would investigate a second case utilizing a different panel specification. The panel specification is shown in figure 1, which represents a very typical construction used in a variety of cabin applications. The substrate consists of a 0.5-inch Nomex paper/phenolic resin core, with 2-ply fiberglass facings on the front and back.

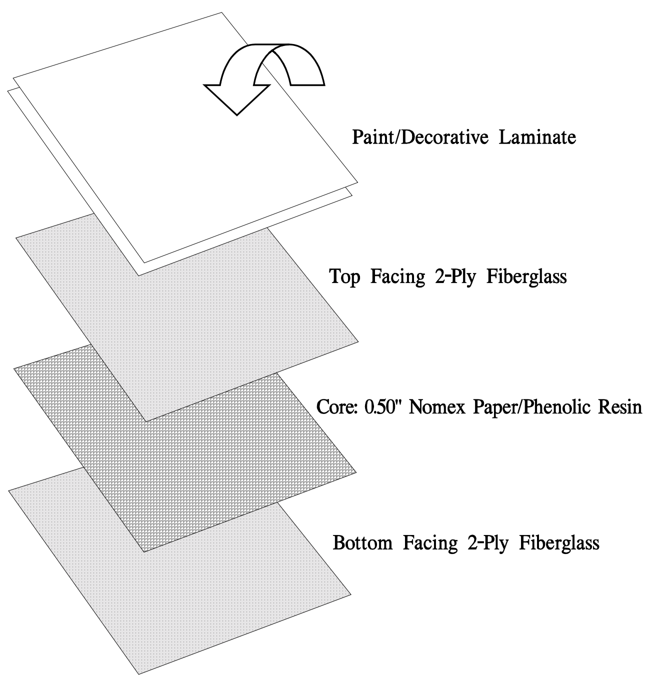

FIGURE 1. SURROGATE TEST PANEL SPECIFICATION

The panels were inspected and coded by the FAA William J. Hughes Technical Center and sent to various participants for finishing (painting or decorative laminating). Table 1 shows the fabricators and descriptive codes. After finishing, the panels were sent back to the FAA Technical Center to undergo heat release, smoke, and flammability testing.

TABLE 1. TEST MATRICES AND DESCRIPTION CODE

Heat Release Test Matrix

	Finish Q	Finish R	Finish S	Finish T	Finish U
Panel B	HBPQX (15)	HBPRX (15)	HBPSX (13)	HBLTX (15)	HBLUX (15)
Panel C	HCPQX (15)	HCPRX (15)	HCPSX (12)	HCLTX (15)	HCLUX (15)
Panel D	HDPQX (16)	HDPRX (16)	HDPSX (16)	HDLTX (16)	HDLUX (16)

Flammability Test Matrix

	Finish Q	Finish R	Finish S	Finish T	Finish U
Panel B	FBPQX (15)	FBPRX (15)	FBPSX (15)	FBLTX (15)	FBLUX (15)
Panel C	FCPQX (15)	FCPRX (15)	FCPSX (15)	FCLTX (15)	FCLUX (15)
Panel D	FDPQX (15)	FDPRX (15)	FDPSX (15)	FDLTX (16)	FDLUX (16)

Panel Description Code:

Test type	Panel Fabricator	Finish Type	Finish Fabricator	Renovation	Number of Tests
H = Heat Release F = Flammability	B (Boeing) C (C&D Interiors) D (Skyline Prod)	P = Paint L = Dec Laminate	Q HSH Aerospace R Boeing S Mankiewicz T Schneller U Boeing	X = No Renovation Y = Paint Z = Dec Laminate	(in parenthesis)

HEAT RELEASE TEST RESULTS ON BASELINE PANELS.

Prior to any tests on finished panels, baseline tests were conducted on the bare surrogate panels to investigate their similarity. Table 2 shows the numerical heat release results for the three surrogates used in the comparison. As shown, the total and peak heat release rates (HRR) are reasonably close, within a few units of each other.

TABLE 2. BARE PANEL NUMERICAL HEAT RELEASE RESULTS

Panel B Type	Total HR (kW/m^2)min	Peak HRR (kW/m^2)
Panel B Baseline 1	30.48	33.63
Panel B Baseline 2	29.89	32.52
Panel B Baseline 3	27.45	32.07
Average	**29.27**	**32.74**

Panel C Type	Total HR (kW/m^2)min	Peak HRR (kW/m^2)
Panel C Baseline 1	35.23	31.27
Panel C Baseline 2	26.70	25.43
Panel C Baseline 3	32.13	28.39
Average	**31.35**	**28.36**

Panel D Type	Total HR (kW/m^2)min	Peak HRR (kW/m^2)
Panel D Baseline 1	32.78	35.85
Panel D Baseline 2	26.07	28.98
Panel D Baseline3	20.25	30.06
Average	**26.37**	**31.63**

Figures 2, 3, and 4 show the three HRR histories for each panel. The results for a particular panel are fairly repeatable, although panel D exhibited greater scatter.

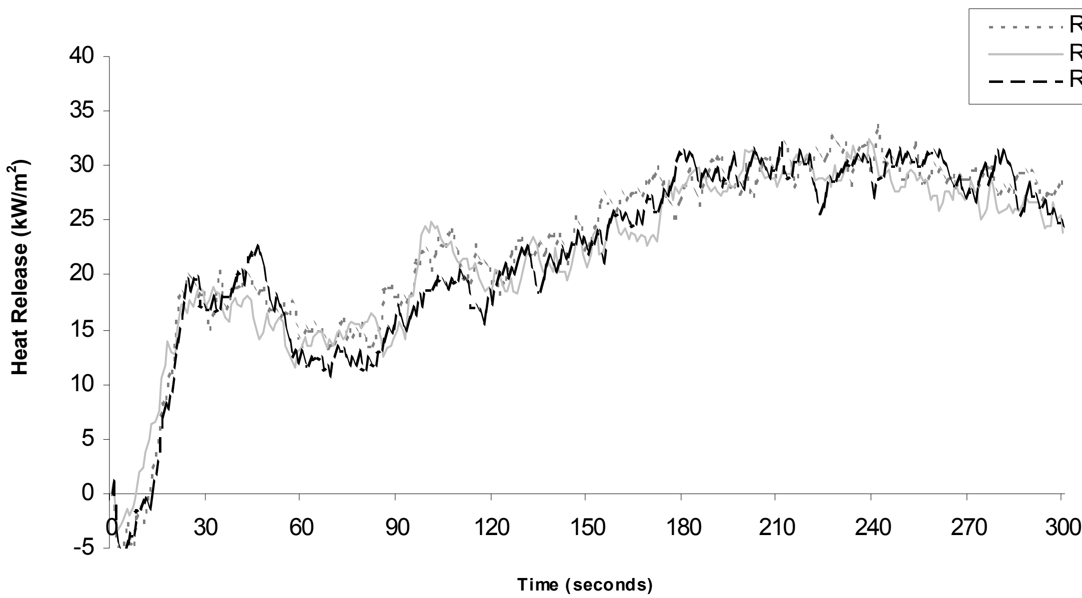

FIGURE 2. PANEL B HEAT RELEASE RESULTS (Bare panel)

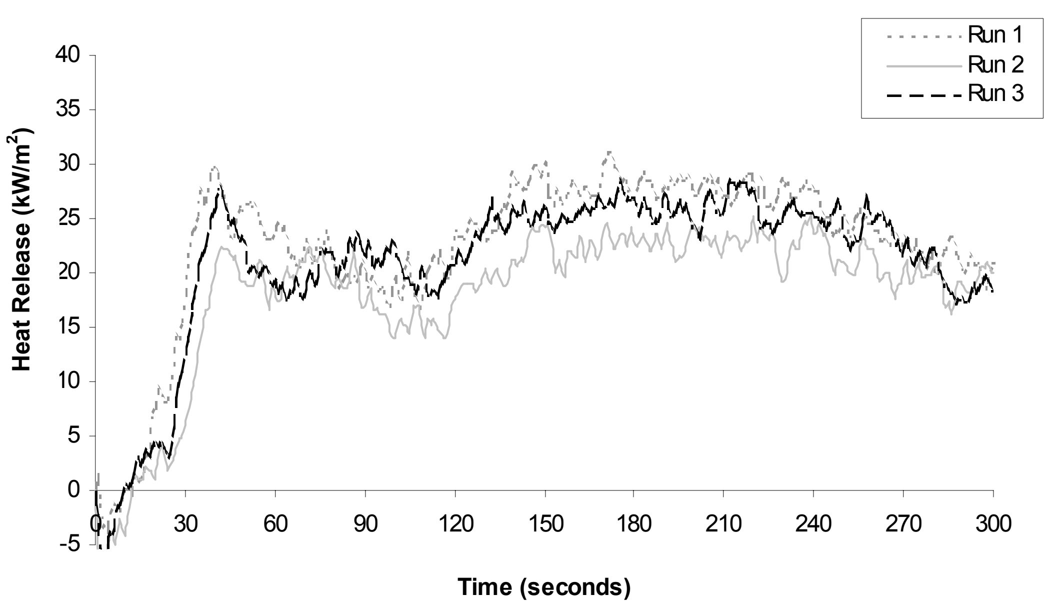

FIGURE 3. PANEL C HEAT RELEASE RESULTS (Bare panel)

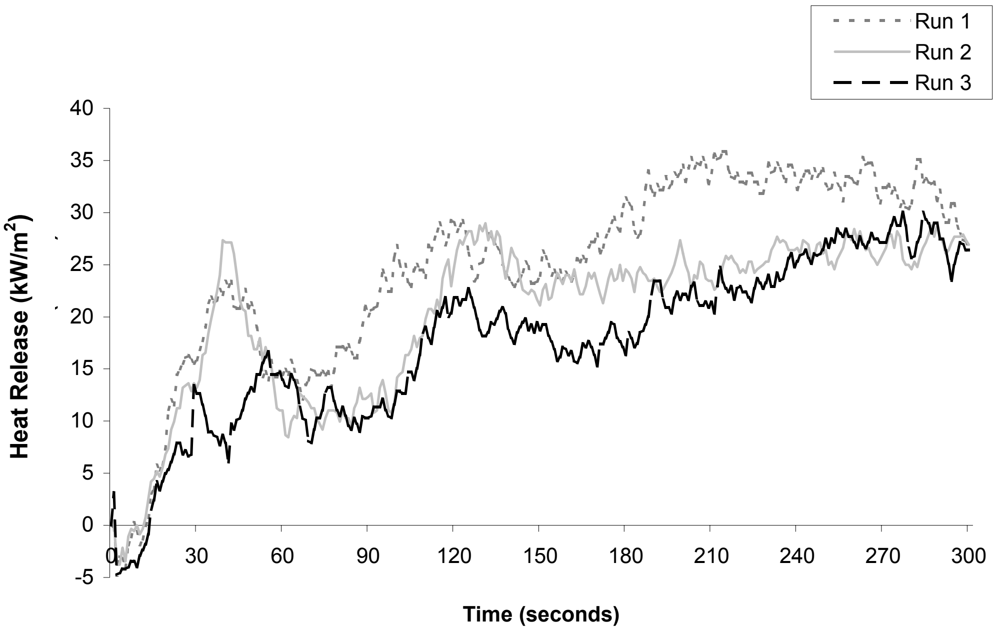

FIGURE 4. PANEL D HEAT RELEASE RESULTS (Bare panel)

Next, a more in-depth comparison of the three panels was made by point-by-point averaging of the three runs. As shown in figure 5, each of the three panels produces a distinctly different profile. These preliminary results indicate that although the panels are constructed according to one specification, they all react somewhat differently when tested, perhaps the result of using slightly different resins during the manufacturing process.

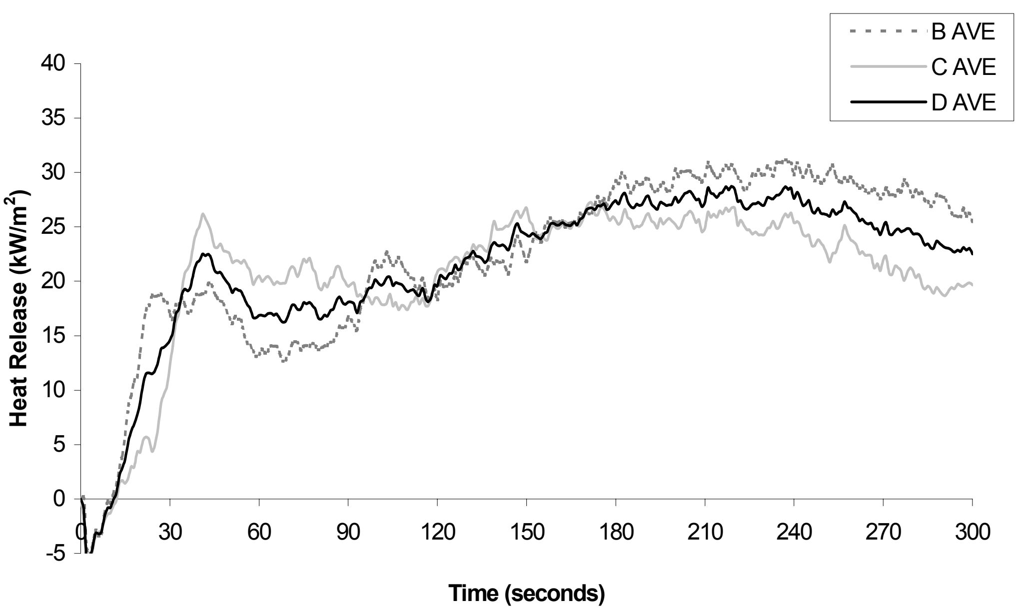

FIGURE 5. HEAT RELEASE AVERAGE (POINT-BY-POINT) OF PANELS B, C, AND D

<u>HEAT RELEASE TEST RESULTS ON FINISHED PANELS</u>.

In addition to the baseline comparisons, heat release trials were performed on all of the finished panels. Tables 3 and 4 display the numerical total heat release and peak heat release rates for all test-sample combinations, along with a numerical average for each series (most of the test series were based on 16 samples; however, some specimens were unusable, reducing the number of samples).

TABLE 3. SURROGATE PANEL HEAT RELEASE DATA (Paint finishes)

Panel B	**Baseline**		**Finish Q**		**Finish R**		**Finish S**	
	Total	Peak	Total	Peak	Total	Peak	Total	Peak
	30.48	33.63	39.07	36.06	41.27	37.44	37.95	36.33
	29.89	32.52	35.44	34.99	38.99	35.18	x	x
	27.45	32.07	39.38	36.83	48.66	36.49	x	x
			40.27	34.83	42.67	35.91	39.63	35.32
			34.44	34.96	45.63	37.31	36.34	29.51
			36.19	36.23	38.99	34.15	45.47	40.01
			40.96	35.38	45.24	33.55	38.83	32.99
			28.02	32.88	46.10	36.54	34.21	30.31
			38.35	36.08	38.83	32.19	42.41	36.04
			37.86	36.87	41.54	34.05	35.10	33.89
			35.92	32.54	47.63	37.67	44.10	38.92
			39.41	37.94	50.05	39.78	46.01	40.36
			36.54	36.15	45.00	37.10	38.15	36.26
			36.09	33.23	40.79	34.12	33.67	31.34
			40.46	38.24	47.11	37.53	49.13	40.01
Average	**29.27**	**32.74**	**37.23**	**35.55**	**43.90**	**35.93**	**40.08**	**35.48**

Panel C	**Baseline**		**Finish Q**		**Finish R**		**Finish S**	
	Total	Peak	Total	Peak	Total	Peak	Total	Peak
	35.23	31.27	43.95	54.10	42.66	36.68	33.64	32.12
	26.70	25.43	39.34	46.65	43.50	45.63	28.16	28.27
	32.13	28.39	36.62	49.63	40.65	35.03	30.46	29.77
			44.43	43.03	31.32	27.41	37.70	44.06
			44.05	39.50	39.43	28.69	27.84	27.97
			35.13	42.32	46.99	46.76	35.49	43.05
			48.61	47.62	30.81	27.03	41.47	51.58
			37.18	46.83	37.12	30.32	29.55	30.71
			40.16	49.65	33.71	29.28	34.01	32.78
			40.24	48.54	34.37	29.14	30.62	30.89
			48.19	43.94	53.33	47.74	34.88	40.92
			40.78	47.46	37.09	30.31	30.85	31.56
			36.72	50.05	44.32	33.54	x	x
			27.21	39.80	39.71	28.23	x	x
			41.93	52.76	45.68	55.16	x	x
Average	**31.35**	**28.36**	**40.30**	**46.79**	**40.05**	**35.40**	**32.89**	**35.31**

Panel D	**Baseline**		**Finish Q**		**Finish R**		**Finish S**	
	Total	Peak	Total	Peak	Total	Peak	Total	Peak
	32.78	35.85	38.02	45.02	46.36	45.25	39.51	34.97
	26.07	28.98	42.58	44.97	48.71	43.83	36.56	34.83
	20.25	30.06	33.66	39.26	37.75	47.84	37.72	43.47
			40.89	47.07	49.08	43.60	43.59	43.86
			33.83	48.05	42.53	42.35	39.42	36.79
			34.82	44.32	45.66	42.01	32.87	32.78
			38.97	47.84	46.44	42.96	31.52	31.76
			44.18	49.77	49.43	43.48	29.97	38.36
			40.17	46.59	42.10	41.26	35.42	33.53
			42.83	47.84	45.33	39.44	33.77	33.35
			40.73	47.70	43.93	41.94	37.10	37.00
			48.14	50.87	41.59	44.72	x	x
Average	**26.37**	**31.63**	**39.90**	**46.61**	**44.91**	**43.22**	**36.13**	**36.43**

TABLE 4. SURROGATE PANEL HEAT RELEASE DATA (Laminate finishes)

Panel B	Baseline		Finish T		Finish U	
	Total	Peak	Total	Peak	Total	Peak
	30.48	33.63	37.82	38.25	48.96	47.79
	29.89	32.52	38.90	35.68	44.94	43.33
	27.45	32.07	38.35	34.46	31.33	40.28
			40.79	33.18	46.20	43.60
			36.49	35.13	43.02	41.41
			36.27	34.32	41.64	39.96
			37.47	37.70	43.10	45.97
			44.76	37.96	37.38	40.49
			39.58	34.41	40.94	40.28
			41.80	41.71	41.63	41.87
			40.46	36.75	46.31	50.66
			43.90	37.07	26.73	42.02
			41.45	36.08	33.87	36.02
			41.62	35.71	36.21	40.57
			40.47	36.29	34.56	41.95
Average	**29.27**	**32.74**	**40.01**	**36.31**	**39.79**	**42.41**

Panel C	Baseline		Finish T		Finish U	
	Total	Peak	Total	Peak	Total	Peak
	35.23	31.27	48.25	39.92	46.50	35.41
	26.70	25.43	43.25	36.94	52.36	39.60
	32.13	28.39	49.32	36.50	47.74	36.72
			49.48	42.22	53.61	37.14
			52.48	36.97	52.38	38.88
			47.71	41.19	49.35	39.68
			49.30	37.41	50.68	36.15
			55.18	39.43	46.82	37.41
			48.02	43.24	48.23	36.51
			53.61	44.52	52.53	39.35
			51.69	38.86	44.50	32.82
			51.80	35.72	40.67	31.49
			52.60	38.89	45.76	35.23
			53.73	41.60	37.37	30.82
			52.36	37.81	48.76	36.41
Average	**31.35**	**28.36**	**50.59**	**39.41**	**47.82**	**36.24**

Panel D	Baseline		Finish T		Finish U	
	Total	Peak	Total	Peak	Total	Peak
	32.78	35.85	37.00	35.90	38.98	37.37
	26.07	28.98	38.48	37.81	33.17	37.10
	20.25	30.06	42.29	34.90	44.42	41.31
			44.28	37.63	38.44	40.31
			39.40	35.21	51.10	42.48
			42.46	40.70	42.94	38.92
			42.45	40.16	43.31	39.33
			44.88	39.60	47.35	40.09
			40.14	36.78	38.88	39.49
			35.15	42.09	39.19	39.95
			42.81	37.38	40.94	38.67
			42.07	45.29	40.18	38.91
			42.43	41.86	x	x
			42.09	40.44	x	x
			43.51	43.62	x	x
Average	**26.37**	**31.63**	**41.30**	**39.29**	**41.58**	**39.49**

In figures 6 through 10, the three surrogate panels are compared for each type of finish. The heat release versus time plot for each combination is a point-by-point average of all the samples in the series.

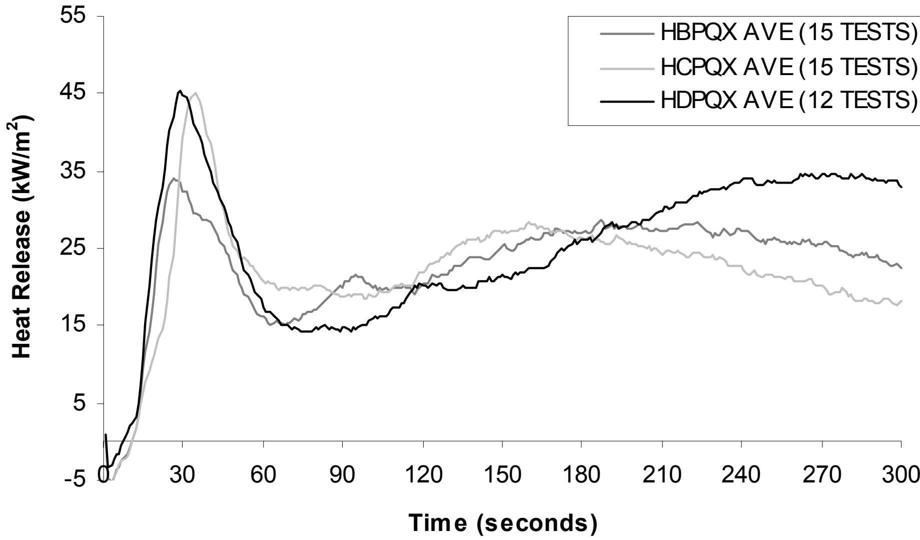

FIGURE 6. HEAT RELEASE AVERAGE (POINT-BY-POINT)—COMPARISON OF PANELS B, C, AND D FINISHED WITH PAINT Q

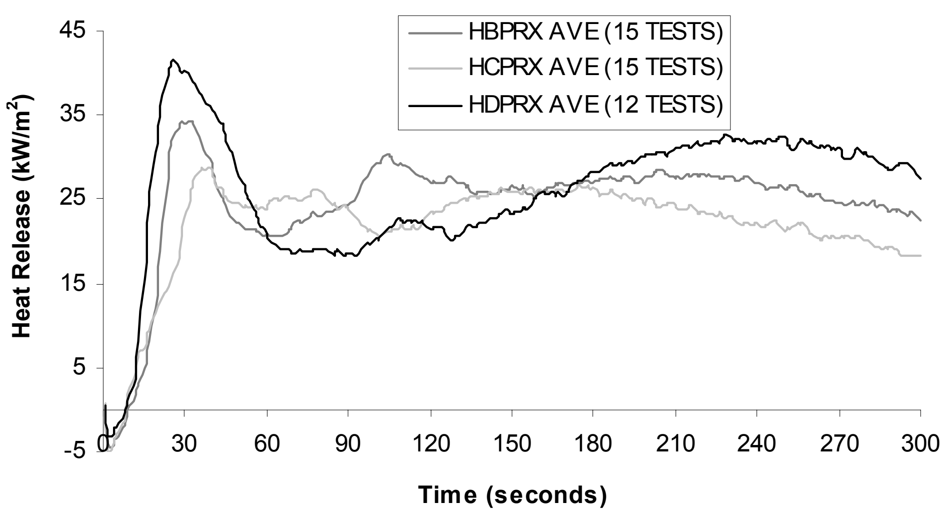

FIGURE 7. HEAT RELEASE AVERAGE (POINT-BY-POINT)—COMPARISON OF PANELS B, C, AND D FINISHED WITH PAINT R

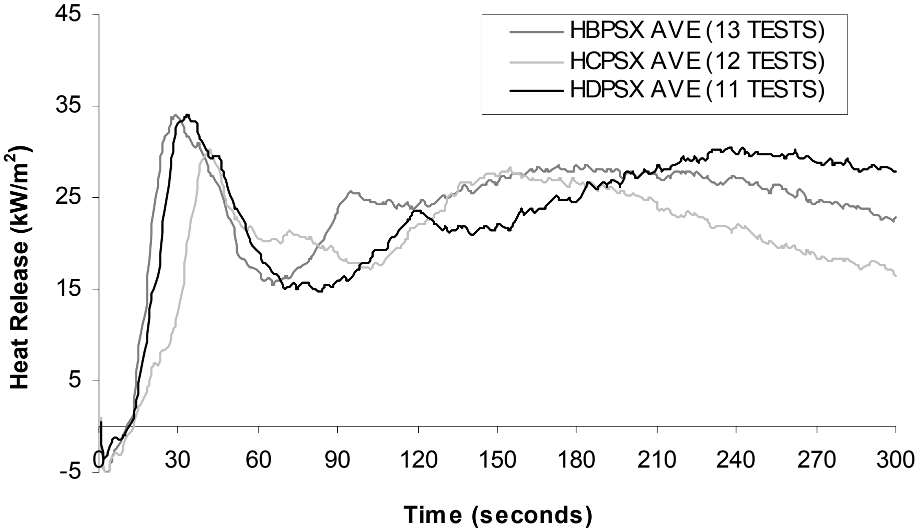

FIGURE 8. HEAT RELEASE AVERAGE (POINT-BY-POINT)—COMPARISON OF PANELS B, C, AND D FINISHED WITH PAINT S

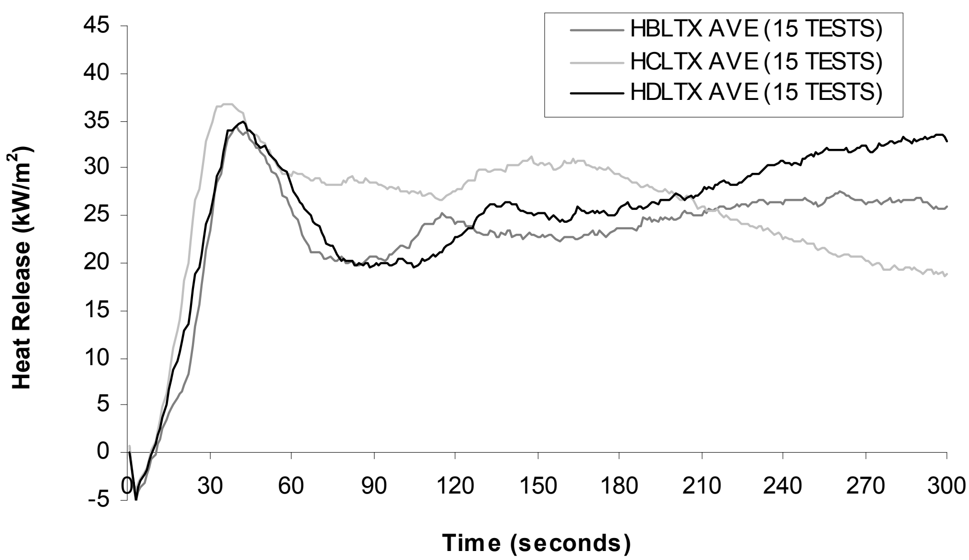

FIGURE 9. HEAT RELEASE AVERAGE (POINT-BY-POINT)—COMPARISON OF PANELS B, C, AND D FINISHED WITH LAMINATE T

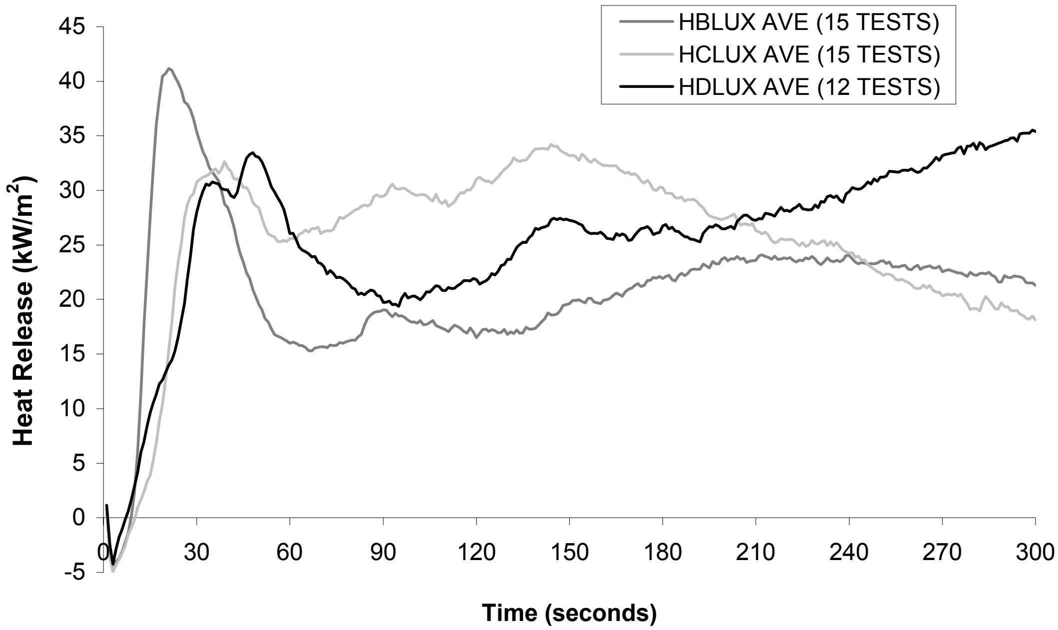

FIGURE 10. HEAT RELEASE AVERAGE (POINT-BY-POINT)—COMPARISON OF PANELS B, C, AND D FINISHED WITH LAMINATE U

A cursory review of the data indicates inconsistent results. For example, a comparison of panel B/paint Q with panel B/paint S indicates a higher heat release total from paint S. However, this trend is not repeated when panel C/paint Q is compared with panel C/paint S. This would indicate the contrary, that paint Q yields a higher heat release total than paint S. Table 5 summarizes the peak and total heat release data for all combinations of panels and finishes, as well as the increase in heat release for each finish.

Although many operational factors can affect the outcome of heat release results, these were minimized. Of greatest significance was the fact that all tests were performed at one facility, with one highly experienced tester, and each series of tests was based on large sample quantities, to maximize accuracy. Thus, although the operational errors were minimized, it appears that a finish may interact differently with different substrate materials that are constructed to the same specification. One would expect to have similar increases in HRR from a given finish, regardless of the manufacturer of the substrate panel.

TABLE 5. COMPARISON OF HEAT RELEASE INCREASE FROM ALL PANEL COMBINATIONS

		Unfinished		Finish Q		Increase	
		Total HR	Peak HRR	Total HR	Peak HRR	Total HR	Peak HRR
Panel B	**Average**	29.27	32.74	37.23	35.55	**7.95**	**2.81**
Panel C	**Average**	31.35	28.36	40.30	46.79	**8.95**	**18.43**
Panel D	**Average**	26.37	31.63	39.90	46.61	**13.54**	**14.98**

		Unfinished		Finish R		Increase	
		Total HR	Peak HRR	Total HR	Peak HRR	Total HR	Peak HRR
Panel B	**Average**	29.27	32.74	43.90	35.93	**14.63**	**3.19**
Panel C	**Average**	31.35	28.36	40.05	35.40	**8.69**	**7.03**
Panel D	**Average**	26.37	31.63	44.91	43.22	**18.54**	**11.59**

		Unfinished		Finish S		Increase	
		Total HR	Peak HRR	Total HR	Peak HRR	Total HR	Peak HRR
Panel B	**Average**	29.27	32.74	40.08	35.48	**10.80**	**2.74**
Panel C	**Average**	31.35	28.36	32.89	35.31	**1.54**	**6.94**
Panel D	**Average**	26.37	31.63	36.13	36.43	**9.77**	**4.80**

		Unfinished		Finish T		Increase	
		Total HR	Peak HRR	Total HR	Peak HRR	Total HR	Peak HRR
Panel B	**Average**	29.27	32.74	40.01	36.31	**10.74**	**3.57**
Panel C	**Average**	31.35	28.36	50.59	39.41	**19.23**	**11.05**
Panel D	**Average**	26.37	31.63	41.30	39.29	**14.93**	**7.66**

		Unfinished		Finish U		Increase	
		Total HR	Peak HRR	Total HR	Peak HRR	Total HR	Peak HRR
Panel B	**Average**	29.27	32.74	39.79	42.41	**10.51**	**9.67**
Panel C	**Average**	31.35	28.36	47.82	36.24	**16.46**	**7.88**
Panel D	**Average**	26.37	31.63	41.58	39.49	**15.21**	**7.86**

BUNSEN BURNER FLAMMABILITY TESTING ON FINISHED PANELS.

Tables 6 and 7 show the vertical Bunson burner flammability test results for all the panel/finish combinations. As previously observed for heat release, the flammability results are sometimes inconsistent. For example, panel B/paint Q yielded a 1.58-inch burn length, while panel B/paint S's, burn length was 1.27 inches, indicating that paint S is more fire resistant than paint Q. Conversely, an examination of the data from panel C would lead to the conclusion that paint Q is more fire resistant than paint S. Despite the somewhat contradictory trends taking place, in terms of the required maximum burn length (6 inches), one is confident that the paints are compliant. Table 8 summarizes the results of the flammability testing.

TABLE 6. SURROGATE PANEL FLAMMABILITY TEST RESULTS (Painted finishes)

	Finish Q		Finish R		Finish S	
Panel B	Burn Length	After Flame	Burn Length	After Flame	Burn Length	After Flame
	1.25	0.00	2.37	0.00	1.37	0.00
	1.43	0.00	2.62	0.00	1.37	0.00
	1.56	0.00	2.68	0.00	1.43	0.00
	1.62	0.00	2.31	0.00	1.00	0.00
	1.25	0.00	2.56	0.00	1.25	0.00
	1.62	0.00	2.43	0.00	1.43	0.00
	1.62	0.00	2.56	0.00	1.37	0.00
	1.37	0.00	2.50	0.00	1.00	0.00
	1.68	0.00	2.43	0.00	1.25	0.00
	1.81	0.00	2.43	0.00	1.18	0.00
	1.75	0.00	2.43	0.00	1.37	0.00
	1.56	0.00	2.50	0.00	1.31	0.00
	1.68	0.00	2.50	0.00	1.25	0.00
	1.75	0.00	2.50	0.00	1.18	0.00
	1.75	0.00	2.37	0.00	1.25	0.00
Average	**1.58**	**0.00**	**2.48**	**0.00**	**1.27**	**0.00**

Panel C	Finish Q		Finish R		Finish S	
	Burn Length	After Flame	Burn Length	After Flame	Burn Length	After Flame
	1.18	0.00	2.12	0.00	1.50	0.00
	1.12	0.00	2.56	0.00	1.56	0.00
	1.12	0.00	2.43	0.00	2.25	0.00
	1.00	0.00	2.50	0.00	1.06	0.00
	1.00	0.00	2.25	0.00	1.25	0.00
	1.00	0.00	2.01	0.00	1.31	0.00
	0.93	0.00	2.25	0.00	1.43	0.00
	1.12	0.00	2.31	0.00	1.37	0.00
	0.93	0.00	2.31	0.00	1.31	0.00
	1.06	0.00	2.18	0.00	1.18	0.00
	1.00	0.00	2.50	0.00	1.00	0.00
	0.93	0.00	2.31	0.00	1.25	0.00
	1.00	0.00	2.56	0.00	1.37	0.00
	1.00	0.00	2.37	0.00	1.25	0.00
	0.93	0.00	2.50	0.00	1.50	0.00
Average	**1.02**	**0.00**	**2.34**	**0.00**	**1.37**	**0.00**

Panel D	Finish Q		Finish R		Finish S	
	Burn Length	After Flame	Burn Length	After Flame	Burn Length	After Flame
	1.56	0.00	2.00	0.00	0.56	0.00
	1.50	0.00	2.31	0.00	0.43	0.00
	1.75	0.00	1.75	0.00	0.43	0.00
	1.12	0.00	2.12	0.00	0.50	0.00
	1.43	0.00	2.12	0.00	0.50	0.00
	1.25	0.00	2.18	0.00	0.43	0.00
	1.31	0.00	2.00	0.00	0.43	0.00
	1.25	0.00	2.12	0.00	0.37	0.00
	1.50	0.00	2.00	0.00	0.37	0.00
	1.56	0.00	1.87	0.00	0.50	0.00
	1.43	0.00	2.12	0.00	0.43	0.00
	1.56	0.00	2.25	0.00	0.43	0.00
	1.43	0.00	2.25	0.00	0.50	0.00
	1.25	0.00	2.00	0.00	0.43	0.00
	1.37	0.00	2.12	0.00	0.37	0.00
	1.43	0.00	2.18	0.00	0.50	0.00
Average	**1.42**	**0.00**	**2.09**	**0.00**	**0.45**	**0.00**

TABLE 7. SURROGATE PANEL FLAMMABILITY TEST RESULTS
(Laminated finishes)

Panel B	Finish T		Finish U	
	Burn Length	After Flame	Burn Length	After Flame
	5.12	0.00	3.37	0.00
	4.31	0.00	3.43	0.00
	5.00	0.00	3.25	0.00
	5.00	0.00	3.87	0.00
	4.31	0.00	3.12	0.00
	5.90	0.00	3.81	0.00
	5.31	0.00	4.00	0.00
	5.43	0.00	3.75	0.00
	5.25	0.00	3.68	0.00
	5.12	0.00	3.56	0.00
	5.18	0.00	3.68	0.00
	5.00	0.00	3.50	0.00
	5.50	0.00	3.43	0.00
	5.31	0.00	3.50	0.00
	5.25	0.00	3.56	0.00
Average	**5.13**	**0.00**	**3.57**	**0.00**

Panel C	Finish T		Finish U	
	Burn Length	After Flame	Burn Length	After Flame
	5.00	0.00	3.18	0.00
	5.50	0.00	3.31	0.00
	5.75	0.00	3.50	0.00
	4.50	0.00	2.37	0.00
	5.43	0.00	2.56	0.00
	5.62	0.00	2.43	0.00
	5.50	0.00	3.56	0.00
	6.00	0.00	2.62	0.00
	5.56	0.00	2.43	0.00
	5.00	0.00	2.25	0.00
	5.62	0.00	2.93	0.00
	5.56	0.00	2.50	0.00
	5.00	0.00	2.25	0.00
	5.93	0.00	2.37	0.00
	5.75	0.00	2.81	0.00
Average	**5.45**	**0.00**	**2.74**	**0.00**

Panel D	Finish T		Finish U	
	Burn Length	After Flame	Burn Length	After Flame
	4.31	0.00	4.00	0.00
	4.43	0.00	3.25	0.00
	4.12	0.00	3.12	0.00
	4.56	0.00	4.00	0.00
	4.68	0.00	3.06	0.00
	4.56	0.00	2.18	0.00
	5.00	0.00	2.25	0.00
	4.43	0.00	2.25	0.00
	4.68	0.00	2.12	0.00
	4.62	0.00	3.43	0.00
	4.68	0.00	2.18	0.00
	4.25	0.00	2.43	0.00
	4.81	0.00	2.31	0.00
	4.56	0.00	2.06	0.00
	4.50	0.00	2.18	0.00
	5.00		2.25	
Average	**4.57**	**0.00**	**2.69**	**0.00**

TABLE 8. SUMMARY OF FLAMMABILITY TEST RESULTS

Finish Q

	Burn Length (in)	After Flame (sec)
Panel B	**1.58**	**0.00**
Panel C	**1.02**	**0.00**
Panel D	**1.42**	**0.00**

Finish R

	Burn Length (in)	After Flame (sec)
Panel B	**2.48**	**0.00**
Panel C	**2.34**	**0.00**
Panel D	**2.09**	**0.00**

Finish S

	Burn Length (in)	After Flame (sec)
Panel B	**1.27**	**0.00**
Panel C	**1.37**	**0.00**
Panel D	**0.45**	**0.00**

Finish T

	Burn Length (in)	After Flame (sec)
Panel B	**5.13**	**0.00**
Panel C	**5.45**	**0.00**
Panel D	**4.57**	**0.00**

Finish U

	Burn Length (in)	After Flame (sec)
Panel B	**3.57**	**0.00**
Panel C	**2.74**	**0.00**
Panel D	**2.69**	**0.00**

PAINT THICKNESS INFLUENCE ON HEAT RELEASE RESULTS.

In order to reduce the effect of paint thickness on test results, all samples were required to be coated with a thickness of 50 microns, plus or minus 5 microns. Table 9 shows the panel weight measurements and the calculations necessary to determine the thickness of paint on the test specimens. This was done by calculating the weight per area on both the test specimen and an accompanying steel referee panel. The paint thickness of the referee panel was measured directly using a Gardco electronic thickness gauge. By ratio, the thickness of the paint on the nonmetallic test specimen is calculated. Although it is next to impossible to apply the exact thickness of paint desired, there is a noticeable trend among the three paint participants. As shown, paint R is applied in the thickest amount, while paint Q, the thinnest. Although there are differences, it is assumed that all specimens are painted in the same manner each time (i.e., each of the paint vendors will supply finished samples with consistent thicknesses of paint).

TABLE 9. PAINT THICKNESS CALCULATION

Panel Type	Panel Area (cm^2)	Bare Weight (g)	Finished Weight (g)	Paint Weight (g)	Weight/Area (g/cm^2)	Paint Thickness (microns)
Referee*	150	99.0	100.1	1.1	0.0073	42.00
$DPQX_1$	2330	690.0	706.0	16.0	0.0069	39.33
$DPQX_2$	2330	687.5	706.0	18.5	0.0079	45.47
$DPQX_3$	2330	690.0	707.2	17.2	0.0074	42.28
$DPQX_4$	2330	804.0	820.9	16.9	0.0073	41.54
Referee*	150	100.3	101.3	1.0	0.0067	96.00
$DPRX_1$	2330	700.0	715.0	15.0	0.0064	92.70
$DPRX_2$	2330	696.0	711.1	15.1	0.0065	93.32
$DPRX_3$	2330	676.0	691.1	15.1	0.0065	93.32
$DPRX_4$	2330	672.5	685.5	13.0	0.0056	80.34
Referee*	150	98.8	99.6	0.8	0.0053	64.00
$DPSX_1$	2330	700.0	712.5	12.5	0.0054	64.38
$DPSX_2$	2330	690.0	701.8	11.8	0.0051	60.77
$DPSX_3$	2330	646.0	658.8	12.8	0.0055	65.92

* Paint thickness measured directly (actual) using a Gardco electronic thickness gauge.

PAINT THICKNESS/QUALITY CONTROL.

Several task group participants had expressed concern over interior panel painting when making renovations. More specifically, they stated that during certain painting procedures, the thickness of the paint could often vary several 10's of microns, resulting in fluctuations of the OSU test results. Of concern, is that a certification test could be passed using a particular thickness of paint, but a follow-up test performed at the request of the aviation authority could reveal that the actual in-service painted panels are not in compliance, the result of a thicker paint layer. The participants, including an airline representative, felt that an incident such as this would necessitate costly procedures to remove the noncompliant panels and other similarly finished units. Although these concerns were more of a quality control/procedural issue than a renovation issue, they were discussed nonetheless. The best recommendation the task group could offer is to run tests on a variety of paint thicknesses, determine what the worst case would be (usually the thickest amount of paint), and implement control measures to ensure that this thickness is not exceeded at any time during interior overhaul/renovation. Since it is often not feasible for an Aircraft Certification Officer/Designated Engineer Representative (ACO/DER) to witness OSU tests after each and every painting procedure, these types of safeguards should be implemented and adhered to by the operators themselves, since it is ultimately their responsibility to maintain compliance. An operator could, for example, run tests on specimens layered with various thicknesses of paint, where each layer could represent a subsequent renovation. If the operator determines that after a particular thickness is applied, the highest total HR/peak HRR of any of the interior panels is 63/63, and after additional layers it is 66/66, then the operator should make note of this and refrain from making any painting renovations beyond this. This same approach could be used when making renovations consisting of "piggybacked" laminates.

SUMMARY OF RESULTS.

Initial testing of the unfinished surrogate panels constructed by three fabricators reveals differences in the HRR histories. As shown in figure 5, the point-by-point averages result in the highest initial peak from panel C, but the highest final peak from panel B. Although the shape of the curves are similar (2 discernible peaks), the peak HRR for panel C occurs at approximately 180 seconds, while the peak for panel B occurs much later, at 240 seconds. Panel D generates results that more closely resemble those of panel C; however, panel C yields a higher initial peak and panel D a higher final peak. Although the specification calls out the basic materials and construction of the surrogates, it does not specify other details, such as exact resin formulation, curing temperatures, and specific layup processes, all of which have the ability to influence the burning rate of the materials, and hence, the HRR. This is the most likely reason for the differences in heat release between the three panels.

The inconsistent HRR histories observed in the unfinished panels become more pronounced when finished with various paints and decorative laminates (refer to figures 6 through 10). For example, with paint Q, panels C and D produce relatively similar initial peaks, yet the final peaks become very segregated (figure 6). During these same trials, panel B produces a much lower initial peak than either panel C or D, and yields a "subpeak" at approximately 90 seconds. Ideally, all panels in this group should produce nearly identical curves, but this does not occur. When the surrogates are coated with paint R, the initial and final peaks are very segregated (figure 7). In addition, the small subpeak that existed with panel B becomes a substantial peak. When panel B was coated with paint Q, it was much less pronounced. With paint S (figure 8), the initial peaks tighten up considerably, but the final peaks are again segregated. Panel D yields a higher final peak, which again occurs much later than the final peak produced by panels B and C. Similar inconsistencies occur when the panels are finished with decorative laminates. In figure 9, the initial peaks are close for decorative T, but the final peak for panel C is completely secluded and not resembling either panel B or D. In figure 10, the results are even more disseminated. Panels C and D produce a similar initial peak, but then separate and form completely opposite trends. Panel B forms a much higher initial peak, then drops off substantially and forms the lowest final peak.

CONCLUSIONS

Ideally, each of the three bare surrogate panels should produce nearly identical heat release rate (HRR) traces, but the results indicate different peaks that occur at different times. These differences are compounded when various finishes are applied, representing typical in-service situations likely to occur during the certification testing of renovated or altered interiors. Although many factors can contribute to irregular test results, all tests were performed at one facility, with one tester, and each series of tests was based on a large number of replicate tests, which greatly improved the overall accuracy of the results. Normal fluctuations between different labs will only compound the inaccuracy of test results. These considerations indicate that slight differences in the surrogate panels were amplified in the finished panels. It was expected that each series of tests would be nearly identical, that the increase in heat release caused by a particular paint or other finish should be independent of the identity of the surrogate panel. The results clearly show that this is not always the case. Thus, it would be very difficult to adopt a standardized procedure in which renovated interiors could be certified using surrogate materials.

REFERENCE

1. Marker, T., "International Aircraft Materials Fire Test Working Group, Material Systems Renovation and Repair Subgroup," DOT/FAA/AR-TN95/83, February 1996.