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Evaluation of the Reproducibility of the FAA Oil Burner Fire Test for Aircraft Seat Cushions

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16. Abstract

The Federal Aviation Administration oil burner round-robin fire tests were conducted on aircraft seat cushions to determine the status of the test facilities that perform the tests. Two sets of fire-hardened foam and one set of fire-blocked foam test seat cushions were evaluated. The data showed that the weight loss and burn lengths were generally consistent in each individual laboratory. The most significant difference among all the laboratories was seen in the weight loss and burn lengths of the fire-blocked foam seat cushion. For two of the cushions there were a significant number of the laboratories that passed and failed the 10% average weight loss criteria.

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EXECUTIVE SUMMARY

This report discusses the results of oil burner round-robin fire tests performed on aircraft seat cushions. All test facilities that are Federal Aviation Administration (FAA)-accepted in the United States participated in this round robin. The FAA is currently working with governing bodies, such as European Aviation Safety Authority, in preparation for the round robin to begin in other countries. Three sets of seat cushions were evaluated. Four test facilities ran the seat cushion fire test according to Title 14 Code of Federal Aviation Regulation (CFR) Part 25.853, and five facilities ran the seat cushion fire test according to FAA report DOT/FAA/CT-99/15, "Aircraft Materials Fire Test Handbook," which is equivalent to the method specified in CFR 25.853. The FAA William J. Hughes Technical Center, while not a commercial laboratory, also participated in this round-robin fire test. The test results showed that there is no correlation in the pass/fail data among the laboratories that ran the seat cushion fire test according to 14 CFR 25.853 versus the Handbook. The data also showed that the failures reported by all the laboratories were due to weight loss and not burn length. For two of the cushions there were a significant number of the laboratories that passed and failed the 10% average weight loss criteria.

INTRODUCTION

PURPOSE.

The objective of this activity was to compare data from test laboratories that perform oil burner aircraft seat cushion fire tests. This is the first part of round-robin tests that should eventually include test facilities worldwide that will enable the Federal Aviation Administration (FAA) to know the status of the laboratories that perform this testing.

BACKGROUND.

The oil burner fire test for aircraft seat cushions has been mandated per Title 14 Code of Federal Aviation Regulation (CFR) Part 25.853 since November 26, 1987. The test method and requirements of the test are specified in part II of Appendix F in 14 CFR 25.853 (referred throughout this report as the Rule).

In September 1990, the FAA published report DOT/FAA/CT-99/15, "Aircraft Materials Fire Test Handbook" (referred throughout this report as the Handbook). The Boeing Company, with the assistance of the former McDonnell Douglas Aircraft Company, developed the Handbook under contract to the FAA. On February 14, 2001, the FAA issued a Policy Statement (Policy Statement Number ANM-01-01). This notice announced an FAA policy applicable to the use of the Handbook. It advised the public that the FAA considered the material flammability tests described in the latest version of the Handbook to be the preferred acceptable test methods for showing compliance with the relevant regulations.

The oil burner fire test for aircraft seat cushions specified in the Handbook differs in some aspects from the method specified in the Rule. Those differences are thermocouple temperatures and airflow adjustment.

In the early summer of 2004, a request from industry and the Aircraft Certification Offices (ACO) to review the aircraft seat fire test was received. It was decided that a round-robin series of tests be performed by those laboratories/companies that perform oil burner fire tests for aircraft seats. In August of 2004, a letter from the Transport Aircraft Directorate in Seattle, Washington, was sent to the ACOs throughout the United States informing them of the forthcoming round-robin fire tests. The letter also requested that a representative from the ACO be present along with an FAA William J. Hughes Technical Center representative at the test facility under their jurisdiction to witness the testing. Initially, this testing was limited to test facilities in the United States; however, it was decided that it should eventually include test facilities throughout the world, if possible. Rationale for worldwide inclusion was based on the number of aircraft seat manufacturers outside the United States and the international nature of aviation.

Currently, the FAA is working with governing bodies, such as the European Aviation Safety Authority (EASA), in preparation for the round-robin fire tests to begin in other countries. This report documents the round-robin fire test results on the oil burner seat cushion fire test performed by laboratories in the United States.

DISCUSSION

AIRCRAFT SEAT TEST CUSHIONS.

Two manufacturers supplied the seat cushions for the round-robin fire tests. Three types of seat cushion sets (bottom and back) were fabricated. One set of seat cushions consisted of a polyurethane foam fire-blocking layer and a 90% wool/10% nylon dress cover. The other two sets of seat cushions were constructed with two different fire-hardened foams and 90% wool/10% nylon dress covers. The fire-blocked seat cushions and one set of the fire-hardened seat cushions were fabricated with hook and loop closures. The other set of fire-hardened seat cushions were closed with thread (sewn). The test seat cushions are shown in figures 1, 2, and 3. These test seat cushions were selected because they are currently in service throughout the world.

Figure 1. Fire-Hardened Foam 1

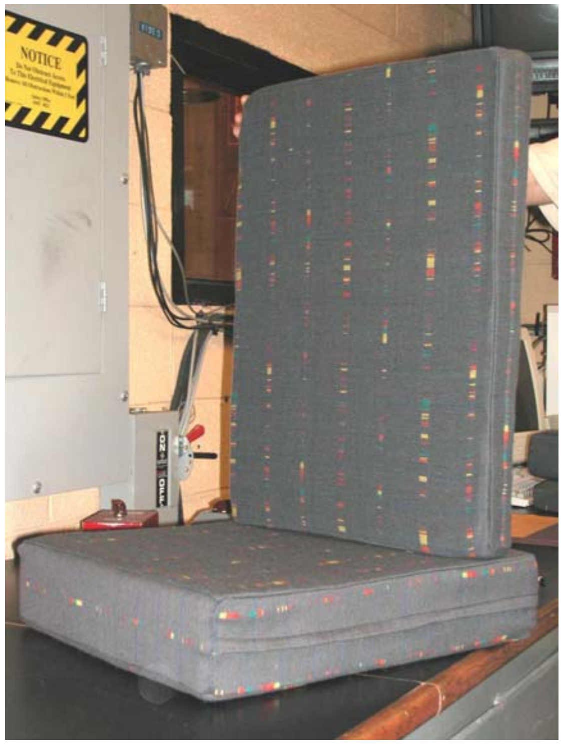

Figure 2. Fire-Blocking Layer

Figure 3. Fire-Hardened Foam 2

ROUND-ROBIN PARTICIPANTS.

Seven independent test laboratories participated in the round-robin fire tests, all of which are FAA-accepted to perform aircraft seat cushion fire tests. The eighth participant (FAA-accepted) is an airframe manufacturer who will do independent testing based upon their availability. In this report, the individual laboratories will not be named. While not a commercial laboratory, the FAA William J. Hughes Technical Center also performed the tests and are included. Hence, a total of nine laboratories participated.

LABORATORY DIFFERENCES.

The breakdown of laboratories that ran the tests according to the Rule or Handbook is given in table 1.

Table 1. Test Method

Laboratory	Rule	Handbook
A		Yes
B	Yes	
C		Yes
D	Yes	
E		Yes
F		Yes
G		Yes
H	Yes	
I	Yes	

Table 1 shows that four laboratories ran the oil burner fire test according to the Rule and five ran the test according to the Handbook. Table 2 presents other differences among the laboratories that are acceptable according to both the Rule and Handbook.

Table 2. Laboratory Equipment and Fuel Differences

Laboratory	Oil Burner Fuel	Nozzle Type	Air Stabilizer
A	JP8	80° CC 2.0 gph*	Tabs
B	Jet A	80° AR 2.25 gph	No
C	No. 2 fuel oil	80° PLP 2.25 gph	Static Disk
D	No. 2 diesel	Unknown	Unknown
E	No. 2 home heating oil	80° CC 2.0 gph	Tabs and Static Disk
F	Jet A	80° CC 2.0 gph	No
G	Jet A	80° AR 2.25 gph	No
H	No. 2 home heating oil	80° CC 2.25 gph	Tabs
I	No. 2 kerosene	80°AR 2.25 gph	Static Disk

*gph = gallons per hour

Referring to table 2, the fuels used are similar, although No. 2 fuel oil has a slightly higher heat of combustion than the other fuels. No. 2 fuel oil and No. 2 home heating oil are the same fuel (different names). No. 2 kerosene and Jet A are basically equivalent, and JP8 is the military version of Jet A with an antistatic agent added.

The laboratories use three different nozzle types, as shown in table 2, with laboratory D not known. CC, AR, and PLP refer to the different nozzle series, each of which produces a different spray pattern, fineness of atomization, and velocity of spray.

The use of air stabilizers is not discussed nor mandated in the Rule. Static disks were developed to stabilize the air before entering the combustion area to help produce a fuller and even flame pattern. Tabs (short pieces of thin metal) are also used for this purpose. Both of these tools were developed because of problems with calibration. The static disk is discussed in the Handbook only, since it was not developed at the time the Rule was published. Table 2 shows that five laboratories used a static disk or tabs (or both), three laboratories did not use either tabs or static disks, and laboratory D was not known.

Table 3 combines tables 1and 2 for ease of reference.

Table 3. Test Method, Laboratory Equipment, and Fuel Differences

Laboratory	Test Method	Oil Burner Fuel	Nozzle Type	Air Stabilizer
A	Handbook	JP8	80° CC 2.0 gph*	Tabs
B	Rule	Jet A	80° AR 2.25 gph	No
C	Handbook	No. 2 fuel oil	80° PLP 2.25 gph	Static Disk
D	Rule	No. 2 diesel	Unknown	Unknown
E	Handbook	No. 2 home heating oil	80° CC 2.0 gph	Tabs and Static Disk
F	Handbook	Jet A	80° CC 2.0 gph	No
G	Handbook	Jet A	80° AR 2.25 gph	No
H	Rule	No. 2 home heating oil	80° CC 2.25 gph	Tabs
I	Rule	No. 2 kerosene	80°AR 2.25 gph	Static Disk

* gph = gallons per hour

EQUIPMENT READINESS.

Prior to visiting the participating test laboratories, each laboratory was asked to ensure that their oil burner and calibration tools were operating correctly. The calibration tools used were a calorimeter, which measured the heat flux, and thermocouples, which measured the burner flame temperature. The FAA recommends that the calorimeter be recalibrated at least once yearly by the manufacturer. While this is not stated in the Rule or Handbook, it is mandated in other FAA flammability tests. Because of its inclusion in other tests, the participating laboratories have added a yearly recalibration requirement in their facility's test plan. The Handbook (Supplement) addresses the thermocouples and recommends that a record be kept as to the time of burner flame exposure due to degradation of the thermocouples after prolonged exposure to extreme heat. This is not addressed in the Rule.

PASS/FAIL CRITERIA.

Weight Loss. The pass/fail criteria for weight loss specified in the Rule and Handbook are:

- the weight loss of at least two-thirds of the total number of specimen sets tested will not exceed 10 percent.
- the average weight loss of the total number of specimen sets tested will not exceed 10 percent.
- both above criteria must be met in order to pass weight loss.

Burn Length. The pass/fail criteria specified in the Rule and the Handbook states that:

- For each of the burn lengths measured, the burn length may not exceed 17 inches on at least two-thirds of the total number of specimen sets tested.
- The average burn length for each of the measured lengths will not exceed 17 inches.

For a cushion set to pass, both the weight loss and burn length requirements must be met.

TEST RESULTS

WEIGHT LOSS.

The percent weight loss of each test cushion set for each laboratory is given in table 4. The pass/fail data for weight loss specified in the Rule and Handbook is given in tables 5 and 6.

Table 4. Percent Weight Loss of Each Cushion Set

	Fire-Hardened Foam 1			Fire-Blocking Layer			Fire-Hardened Foam 2		
Laboratory	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3
A	5.56	6.20	5.03	6.79	7.20	6.54	9.64	9.59	11.33
B	5.97	5.52	5.58	14.11	13.43	13.54	12.10	10.11	13.74
C	5.4	7.0	5.7	12.9	14.7	13.6	8.7	9.3	9.4
D	9.6	NA	12.7	27.6	25.3	23.6	17.2	12.1	16.9
E	4.5	5.9	4.5	5.55	5.1	7.3	6.7	7.7	8.8
F	10.2	7.89	5.92	7.6	17.9	14.8	12.0	10.6	10.2
G	5.7	7.3	7.2	11.4	14.48	12.0	12.5	11.6	11.8
H	4.88	4.52	4.83	6.06	7.49	6.84	9.27	9.21	8.85
I	6.75	6.81	6.12	8.50	7.74	8.98	11.85	12.26	12.89

NA = not applicable

Table 5. Pass/Fail Data—Average Percent Weight Loss of Three Sets

Laboratory	Fire-Hardened Foam 1	Fire-Blocking Layer	Fire-Hardened Foam 2
A	5.6	6.84	10.19
B	5.7	13.69	11.98
C	6.0	13.73	9.13
D	11.2*	25.5	15.4
E	5.0	5.98	7.73
F	8.0	13.43	10.93
G	6.7	12.63	11.97
H	4.7	6.8	9.11
I	6.6	8.41	12.33

* average of two tests

Table 6. Pass/Fail Data—Lowest Weight Loss of Two-Thirds of the Total Number of Specimen Sets Tested

Laboratory	Fire-Hardened Foam 1			Fire-Blocking Layer			Fire-Hardened Foam 2		
A	5.56	5.03	Pass	6.79	6.54	Pass	9.64	9.59	Pass
B	5.52	5.58	Pass	13.43	13.54	Fail	12.10	10.11	Fail
C	5.4	5.7	Pass	12.9	13.6	Fail	8.7	9.3	Pass
D	NA	NA	NA	25.3	23.6	Fail	12.1	16.9	Fail
E	4.5	4.5	Pass	5.55	5.1	Pass	6.7	7.7	Pass
F	7.89	5.92	Pass	7.6	14.8	Fail	10.6	10.2	Fail
G	5.7	7.2	Pass	11.4	12.0	Fail	11.6	11.8	Fail
H	4.52	4.83	Pass	6.06	6.84	Pass	9.21	8.85	Pass
I	6.75	6.12	Pass	8.50	7.74	Pass	11.85	12.26	Fail

NA = not applicable

FIRE-HARDENED FOAM 1. As shown in tables 5 and 6, all laboratories passed fire-hardened foam 1, meeting both criteria. From table 4, it can be seen that only two tests were run at laboratory D due to an equipment failure during the second test, and therefore, not applicable is recorded. Table 4 shows that laboratory D just passed the first set with a percent weight loss of (9.6) and failed the third set (12.7 percent). Referring to table 4, laboratory F had one failure on one set of fire-hardened foam 1. However, in table 5, it can be seen that the average of all three sets was 8.0 percent and therefore passes. After investigation, it was noticed that laboratory F was moving their oil burner into test position too slowly and this was causing premature burning on the backside of the vertical cushion. The slow movement of the actuator, however, did not cause weight percent failures on the remaining two sets of fire-hardened foam 1. Laboratory H recorded the lowest average weight percent loss of fire-hardened foam 1 and laboratory F recorded the highest weight percent loss (refer to table 5). The average weight loss and standard deviation of these samples is shown as a bar graph in figure 4. The average standard deviation of all laboratories is approximately 1 percent.

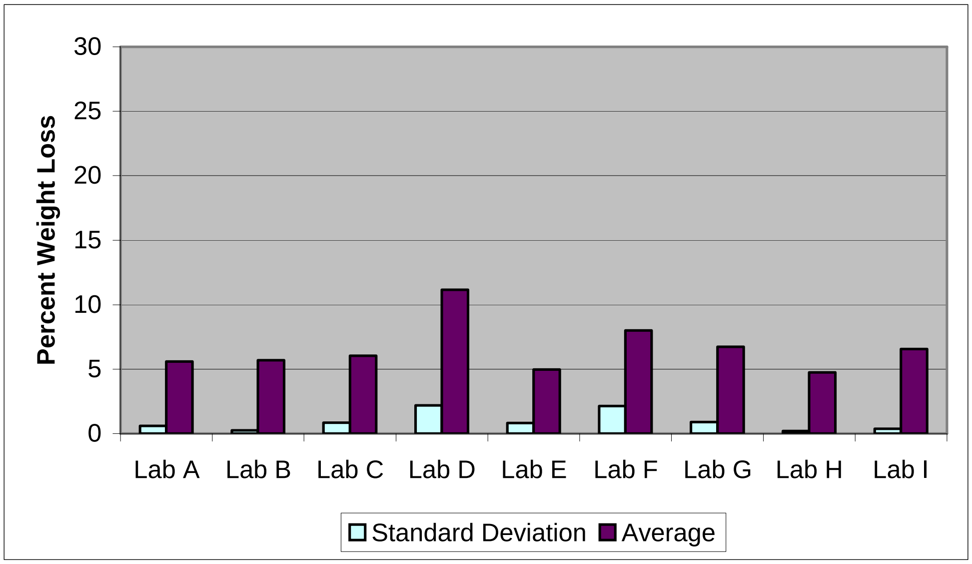

Figure 4. Fire-Hardened Foam 1; Percent Weight Loss Average and Standard Deviation

FIRE-BLOCKING LAYER. Referring to table 5, four laboratories passed and five laboratories failed weight percent loss on these samples. Laboratory D recorded the highest average weight percent loss and Laboratory E recorded the lowest. The bottom seat cushions from Laboratory A are shown in figure 5. This figure shows that the hook and loop closure strips and blocking layer were breached, leaving the polyurethane foam exposed to the flame. This phenomenon was seen at laboratories that passed and failed these samples. However, Laboratory A passed all samples. At laboratories that failed these samples, the burner flame breached the hook and loop closure and blocking layer in less time than the laboratories that passed these samples. This resulted in deeper flame penetration into the polyurethane foam, which would account for greater weight loss. The average weight loss and standard deviation of these samples is shown as a bar graph in figure 6. The average standard deviation of all laboratories is approximately 1.5 percent.

Figure 5. Fire-Blocking Layer; Horizontal Cushions

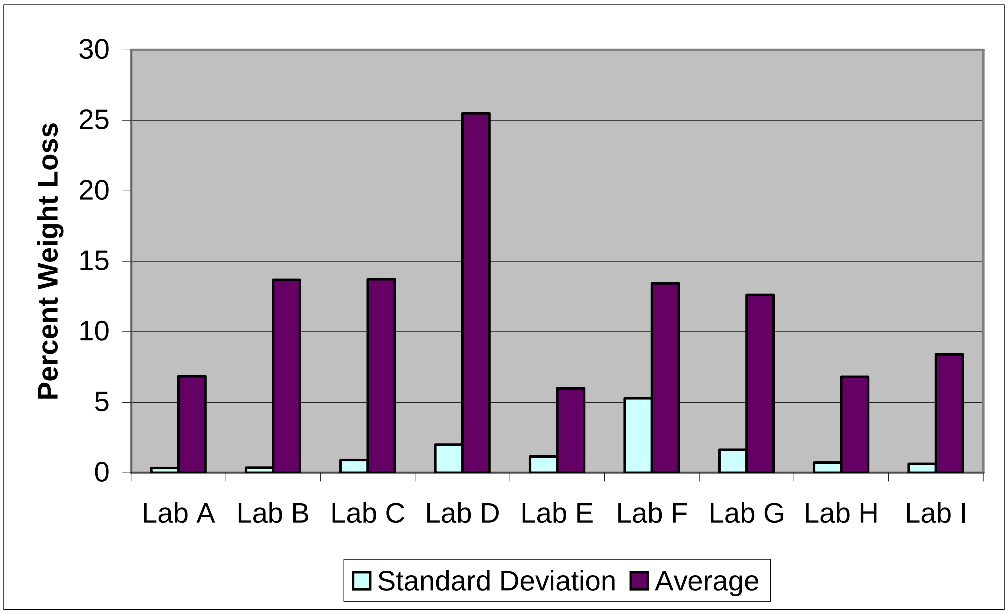

Figure 6. Fire-Blocking Layer; Percent Weight Loss Average and Standard Deviation

FIRE-HARDENED FOAM 2. Table 5 shows three laboratories passed and six laboratories failed these samples. Laboratory D recorded the highest average weight loss of 15.4 percent, and laboratory E recorded the lowest at 7.73 percent. For those laboratories that passed these samples, (laboratories C, E, and H), laboratories C and H had weight loss averages above 9 percent (see table 5). The average weight loss and standard deviation of these samples is shown as a bar graph in figure 7. The average standard deviation of all laboratories is approximately 1 percent.

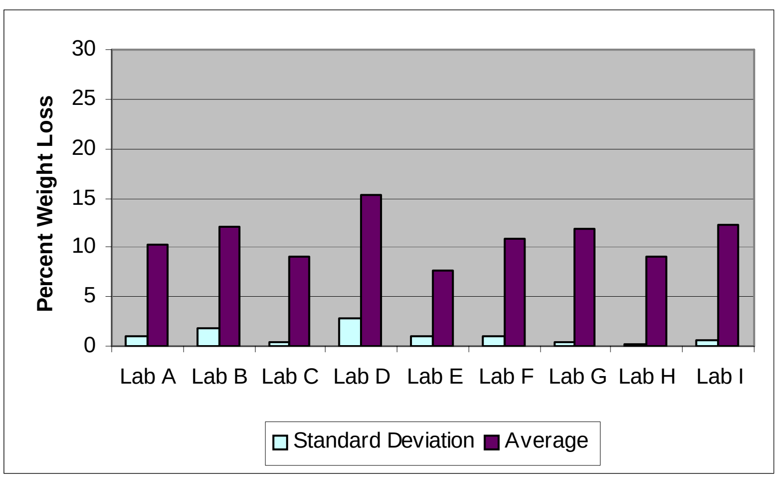

Figure 7. Fire-Hardened Foam 2; Percent Weight Loss Average and Standard Deviation

BURN LENGTH.

There were no burn length failures encountered by any laboratory and, therefore, average values were calculated and are presented in tables 7, 8, and 9. This data consists of horizontal top, horizontal bottom, vertical front, and vertical back burn lengths. Figure 8 shows a sample test cushion and the naming convention.

Table 7. Average Burn Lengths of Fire-Hardened Foam 1

Laboratory	Horizontal Top	Horizontal Bottom	Vertical Front	Vertical Back
A	3.17	13.92	6.33	0.00
B	3.77	12.00	4.50	0.00
C	4.67	11.50	6.67	0.00
D	7.0	11.50	6.50	0.00
E	5.13	7.60	6.97	0.00
F	5.33	11.54	7.29	2.83
G	5.42	10.75	8.58	0.00
H	3.83	1.17	6.67	0.00
I	5.50	16.17	8.33	0.00

Table 8. Average Burn Lengths of Fire-Blocking Layer

Laboratory	Horizontal Top	Horizontal Bottom	Vertical Front	Vertical Back
A	3.67	14.67	6.75	0
B	9.43	17.0	10.90	0
C	7.33	17.0	10.33	0
D	13	Incomplete	Incomplete	Incomplete
E	6.10	5.97	7.40	0
F	7.92	14.75	9.33	1.67
G	8.17	16.08	11.50	0
H	5.0	5.0	8.50	0
I	8.67	8.50	9.33	0

Table 9. Average Burn Lengths of Fire-Hardened Foam 2

Laboratory	Horizontal Top	Horizontal Bottom	Vertical Front	Vertical Back
A	5.25	16.33	8.25	0
B	6.13	17.0	6.10	0
C	8.67	10.83	10.170	0
D	15.0	Incomplete	Incomplete	Incomplete
E	6.83	10.67	8.67	0
F	8.96	10.38	9.88	2.88
G	14.75	15.50	12.17	0
H	12.50	1.67	15.0	0
I	8.33	17.0	10.33	0

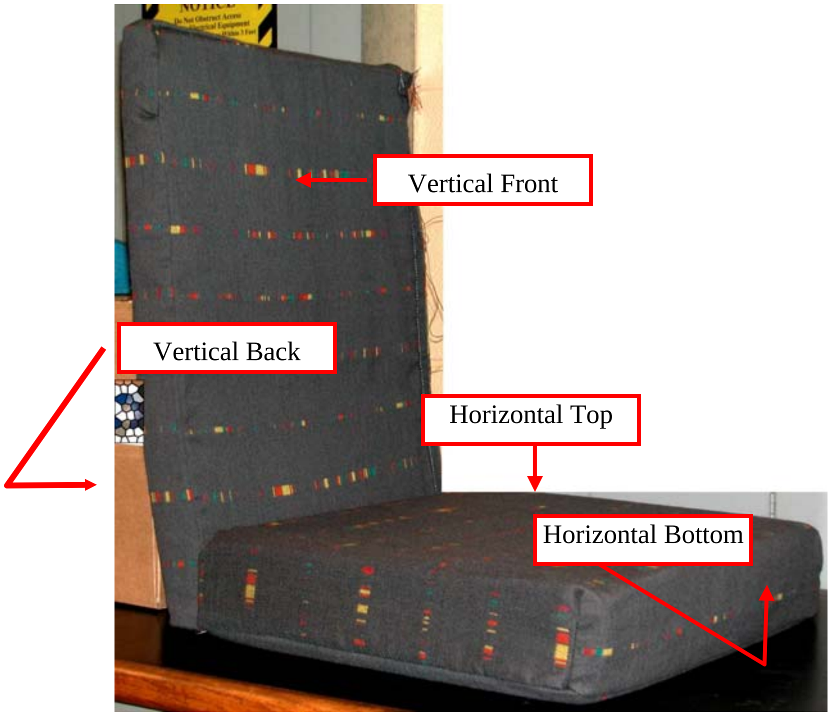

Figure 8. Sample Test Cushion and Naming Convention

Referring to tables 7, 8, and 9, it can be seen that the majority of laboratories recorded greater burn length on the horizontal bottom cushions than the horizontal top cushions. Laboratory H was an exception, with slightly more horizontal top burn on fire-hardened foam 1, significantly more horizontal burn on fire-hardened foam 2, and equal top and bottom burn on the fire-blocking layer. Laboratory D did not provide all data; therefore, an incomplete was recorded. All laboratories, except Laboratory F, found no burning on the vertical cushion backs. As stated in the weight percent discussion of this report, Laboratory F had a very slow burner positioning actuator and that would explain why they had vertical back burn.

LABORATORY PROBLEMS.

As stated above, each laboratory that participated in this round robin believed they were operating properly and had no problems that would have delayed the testing. This was not the case. Problems encountered on test day were:

- Laboratory A—one thermocouple had to be replaced during postcalibration due to low reading.
- Laboratory B—could not achieve calibration during the time FAA personnel were present. Ran tests the following day.
- Laboratory D—collection tray for sample remains too small. Laboratory personnel did not know nozzle type or if air stabilizer was used. Air flow measurements near seat not taken. Did not complete testing until following week.
- Laboratory E—one thermocouple had to be replaced during postcalibration due to low reading. Inadvertent closing of the air intake cover caused inaccurate calibration readings (poor location).
- Laboratory F—oil burner positioning actuator too slow, causing burning on the back of the vertical test cushion.
- Laboratory I—calibration not performed due to actuator failure.

CONCLUSIONS

1. There is no correlation in the pass/fail data among those laboratories that run according to Title 14 Code of Federal Regulations Part 25.853 versus the Federal Aviation Administration published report DOT/FAA/CT-99/15, "Aircraft Materials Fire Test Handbook."
2. All of the failures reported by all of the laboratories were due to weight loss. There were no failures due to burn length. Hence, it appears that the foam cushions and not the dress covers (all 90/10% wool/nylon) are causing the failures.
3. The variations in air velocity through the burner may be one of the reasons that cause the rapid breaching of the hook and loop closures and blocking layer into the polyurethane foam, resulting in failures of those test samples.
4. The use of tabs and/or a static disk may influence test results.