FIRE RESISTANT SEAT CUSHIONS

A I A

Aerospace Industries Association (AIA) of America, Inc.

Transport Airworthiness Requirements Committee
Project 210-9 Final Report
June 14, 1983

SUMMARY

Several events and programs in 1977 through 1980 emphasized the likelihood of significant contribution by the urethane seat cushions to airplane cabin fires. In 1979 the SAFER (Special Aviation Fire and Explosion Reduction) Advisory Committee to the FAA formulated the short term recommendation to develop fire blocking layers for urethane cushions and the long term recommendation to develop low smoking, fire resistant aircraft seat cushion foam. The recommendations were formalized in 1980 with the final SAFER report. The AIA-TARC Project 210-9, Fire Resistant Seat Cushions, was established to provide cohesive support by airplane manufacturers to the FAA to define guidelines for seat cushion constructions with improved fire performance.

The AIA effort has been part of a closely coordinated program with the FAA and NASA including testing, data analysis and cost benefit evaluation. The analysis of laboratory fire test data and full scale fire test results on candidate seat cushion configurations has led the 210-9 project to technical conclusions and recommendations for improving and evaluating the fire resistance of airplane seat cushions.

Although specific, quantitative test values could not be established for seat cushion fire resistance, an available seat cushion fire blocking layer has been defined as exhibiting a desirable level of fire performance, and test methods have been identified for screening and validating candidates for comparative performance.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Presented herein are the results, conclusions and recommendations from an AIA TARC Project Study on fire resistant airplane seat cushions.

2.0 BACKGROUND

In 1980 the AIA-TARC Project 210-9 Fire Resistant Seat Cushions" was established to define guidelines for airplane seat cushion construction that would provide improved fire performance. Primary events leading to the project initiation were:

- 1977 - A NASA contract was initiated with the McDonnell Douglas Corporation to evaluate new materials and configurations to improve fire properties of aircraft seat cushions as part of the FIREMEN (Fire Resistant Materials Engineering) program.

- 1979 - A destructive fire occurred in a Bay Area Rapid Transit (BART) car involving seat cushions with urethane foam. Dr. Brady Williamson (University of California - Berkley) was contracted to study the fire. McDonnell Douglas was contracted by BART to test in full scale fires three seat cushion configurations utilizing different foams and coverings.

- 1979 - NASA-JSC conducted full scale tests on airplane interior fire performance using jet fuel fires. The Boeing Company conducted similar tests simulating flame exposure with heating lamps and propane flames. The NASA contract with McDonnell Douglas continued, encompassing laboratory tests and both fuel-fed and simulated fire full scale tests of seat cushion configurations.

- 1979 - SAFER (Special Aviation Fire and Explosion Reduction) Advisory Committee (to the FAA) formulated recommendations that in the short term fire blocking layers should be developed for urethane cushions and in the long term low smoking, fire resistant aircraft seat cushion foams should be developed. The AIA participated in development of the recommendations based on data from the preceding events.

3.0 OBJECTIVE

When Project 210-9 was first established, it was proposed that properties for acceptable seat functional performance would be identified to support guidelines for improved fire performance based on available materials meeting the functional properties objectives. In March 1982, it was agreed within the project that meeting these objectives was not practicable using seat design experience readily available within the AIA and could not be accomplished within a reasonable time. Experience and discussions with the airline and seating industries had shown that many of the passenger seating functional properties are based subjectively upon "comfort". In addition, seat functional properties are not determined solely upon seat cushion materials, but are highly dependent upon seat and seat cushion design.

The project objective was then revised to define a desirable level of fire resistance consistent with materials available giving reasonable consideration to durability, cost, weight, apparent comfort, etc. Airlines and seat manufacturers must collaborate on passenger seat and seat cushion design to meet specific functional needs while providing the recommended level of fire resistance. The AIA members are involved in flight crew and attendant seat design considerations for improved fire resistance and functional requirements; but, the small number of such seats makes cost and weight less significant than for the passenger seats.

4.0 APPROACH

For the purpose of this project, the seat cushion is defined as the fabric, cushion reinforcement (slip cover), fire blocking layer (where used) and the foam. The approach established to gain the objective stated in section 3.0 was:

- o Gather data/conclusions/recommendations from existing seat cushion tests, development programs, and involved industry representatives.

- o Evaluate the results of programs to establish fire resistance guidelines for functional seat cushions.

- o Draft guidelines for fire resistant seat cushions identifying those areas in which lack of data, available materials or fabrication technology prevents or limits industry capability to develop guidelines.

- o Apprise government and industry of needed R&D.

- o Participate with R&D where appropriate.

4.1 Seat Cushion Test and Development Program Review

In 1980 there were many programs in progress or proposed which related to this project. Those reviewed and evaluated were:

a. NASA-ARC/McDonnell Douglas Corporation Fire Resistant Seat Program
b. NASA-JSC/McDonnell Douglas Corporation Cabin Fire Simulator (CFS) Seat Cushion Burn Tests
c. FAA/NASA-ARC/McDonnell Douglas Corporation C-133 Post Crash Cushion Burn Tests
d. FAA/DuPont C-133 Cushion Burn Tests with Vonar and FS-200 Fire Blocking
e. NASA-JSC 737 Tests of Improved Fire Resistant Interior Components, e.g., linings and seats

f. NASA/Southwest Research Institute Room Size Calorimeter Tests

g. AMI Lightweight Passenger Seat Employing an Advanced Composites Seat Structure

h. BART/McDonnell Douglas Corporation Evaluation of Seat Cushions

i. NASA-JSC/Solar (International Harvester)/Weber Aircraft Evaluation of Polyimide Seat Cushions

j. Pan American Airlines/DuPont In-Service Evaluation of Vonar Fire Blocking

k. American Airlines/Solar In-Service Evaluation of Polyimide Seat Cushions

l. FAA/NASA-ARC/McDonnell-Douglas Corporation Short Term Fire Blocking Optimization Program (Proposed in 1980)

m. FAA/NASA Interagency C-133 Fire Tests of Baseline and Improved Cabin Interiors

4.2 Government and Industry Cooperation

After reviewing the programs, the TARC project reached several conclusions. An AIA letter relating these results was sent to the FAA in early August 1981. This letter and the formal FAA replies are in Appendix A. In January 1981, the TARC project had met with the FAA and NASA at the Technical Center and had attended a NASA-sponsored review of fire resistant seat cushion programs at Houston in February 1981. By August 1981, the results of the AIA program review had been discussed with the FAA Technical Center personnel. The FAA arranged a meeting of NASA, FAA and AIA representatives to formulate plans in research and development on the fire resistant seat cushion concept. The letters in Appendix 10.1 attest to the beneficial results of the cooperative planning conducted by those involved.

4.3 Government and Industry R&D Response

Briefly, the reviews and discussions ended with the following major conclusions for action.

- The high density of neoprene (i.e. LS-200) is unacceptable for complete airplane cushions and the functional properties of polyimide foam are unproven; therefore, fire blocking is still the only currently viable solution for improved seat cushion fire resistance. NASA-ARC under an interagency agreement with the FAA would optimize for cost and weight possible state-of-the-art fire blocking configurations utilizing laboratory scale fire test methods. This would demonstrate concept feasibility and practicality.

- The FAA Technical Center C-133 fire test facility is the best available instrument to evaluate the actual fire performance characteristics; however, baseline and proposed configurations need evaluation at conditions other than just the large post-crash scenerio currently being tested. The FAA would continue to use the near-maximum post-crash scenerio but would also test under ramp (pre-flight, post-flight) and in-flight conditions as well. The FAA/NASA Interagency Agreement would also provide for McDonnell Douglas to test full scale configurations with fire exposure simulated by radiant heat from quartz lamps and ignition with a propane torch.

- Laboratory and/or small scale tests are needed for configuration screening, certification, and quality control purposes. Eleven seat cushion configurations were established for evaluation by fire tests. NASA-ARC would provide uniform material samples for specimen construction, and NASA, FAA, Lockheed, McDonnell Douglas and Boeing would participate in laboratory/small scale tests. Results would be compared to large scale test data obtained at the FAA Technical Center and McDonnell Douglas.

5.0 FULL SCALE FIRE TEST RESULTS

Not all full scale tests planned by the FAA have been completed. Also, not all those conducted have been documented formally. However, the FAA has informally reported Technical Center test results to this TARC project and the tests conducted by McDonnell Douglas have been documented. Sufficient data is available to establish desirable fire resistance for state-of-the-art fire blocking materials.

5.1 FAA C-133 Fire Tests

A surplus C-133 airplane has been modified by the FAA Technical Center to accomodate full scale fire testing of airplane interior components. The testing can be conducted under simulated conditions for wide-body commercial jet transport operations. The test facility and results of seat cushion fire blocking tests are described in more detail in Reference 1.

In each test the blocking layer material is installed as an interliner between the upholstery cover and foam cushion. Table 1 is a list of candidate blocking layer materials evaluated. Table 2 describes the ignition sources for each type fire tested. The significant findings were summarized in Reference 1:

> "Based on the realistic cabin fire tests and analysis described in this paper, and on the seat cushion blocking layer materials evaluated and the types of fire test conditions employed, the following are the significant findings:
>
> (1) Seat cushion fire blocking layer materials such as neoprene foam or aluminized high-temperature fabrics can prevent ramp and in-flight fires which become out of control when initiated at an unprotected seat and left unattended.
>
> (2) Seat cushion fire blocking layer materials can significantly increase the safe time available for evacuation during specific types of postcrash cabin fire scenarios.

TABLE 1

MATERIALS EVALUATED IN C-133 FULL SCALE TESTS

MATERIAL	CHEMICAL COMPOSITION
Baseline	
(1) Wool (90%)/Nylon (10%) Fabric	-
(2) FR Urethane Foam	-
Foam Blocking Layer	
(3) Vonar®, 3/16 in. thick, 24 oz/yd^2	FR polychloroprene
(4) LS-200, 3/8 in. thick, 34 oz/yd^2	FR polychloroprene
Fabric Blocking Layer	
(5) Norfab®, 13 oz/yd^2	Blend of predominantly aromatic polyamide fibers wrapped around a fiberglass fire core, aluminized outer surface
(6) Preox®, 11 oz/yd^2	Heat stabilized polyacrylonitrile, aluminized outer surface

(1) Type of seat upholstery cover used in all tests
(2) Fire-retardant
(3) Registered Trademark, DuPont Co., Wilmington, Delaware
(4) Product of Toyad Corporation, Latrobe, Pa
(5) Registered Trademark, Norfab Corporation, Morristown, Pa
(6) Registered Trademark, Gentex Corporation, Carbondale, Pa

TABLE 2

IGNITION SOURCES FOR FAA C-133 FIRE TESTS

TYPE OF FIRE	IGNITION SOURCE
Ramp	o Plastic trash bag filled with approximately 18 ounces of paper towels and newspaper
In-Flight	o Cigarette o Newsprint (4 double sheets) o Gasoline (1 pint) o Simulated nylon flight bag (contents 2 shirts and 2 double sheets of newsprint approximately 22 ounces)
Postcrash	o Jet fuel (80-square-foot pan containing 50 gallons of fuel)

(3) Under severe fire conditions, such as a postcrash fuel fire, neoprene foam materials are more effective seat cushion blocking layers than aluminized high-temperature fabrics.

(4) Fire-retardant urethane foam can be replaced by nonfire-retardant urethane foam in aircraft seat cushions covered with a blocking layer material without essentially any loss in in-flight fire protection."

A review of reference 1 reveals that except for the severe post-crash fire conditions, the aluminized fabric fire blocking performed as well, or nearly as well, as the much heavier foam blocking layers. The results implied that in many post-crash fire conditions the aluminized fabric would be nearly as effective as the foam blocking. Only in the very severe post-crash fire condition was the foam fire resistance appreciably better than that of the aluminized fabric. However, the protection afforded the cushion by the aluminized fabrics delayed development of hypothetically unsurvivable cabin thermal conditions by 70% as long as did use of a foam blocking layer.

5.2 FAA/NASA/McDonnell Douglas Corporation Fire Tests

Under a FAA/NASA Interagency Agreement, NASA-ARC contracted the Douglas Aircraft Company of McDonnell Douglas Corporation to conduct simulated fire tests of thirteen seat cushion configurations. The tests were conducted in the Douglas Cabin Fire Simulator (CFS) using a quartz lamp radiant energy panel and a propane pilot flame. Reference 2 describes the test facility and the results. The test article consisted of two full-size simulated seat cushions (two bottoms and two backs) situated side by side on a frame suspended from a weighing apparatus. The radiant heat source was arranged as a flat vertical panel parallel to, and six inches from, the outside edges of one seat bottom and back (Figure 1). The radiant incident flux measured in a plane parallel to, and six inches from, the panel was approximately 10 watts per square centimeter. This is representative of the heating rates which might be experienced by seats near an open door or a large fuselage rupture in a large post-crash fire situation.

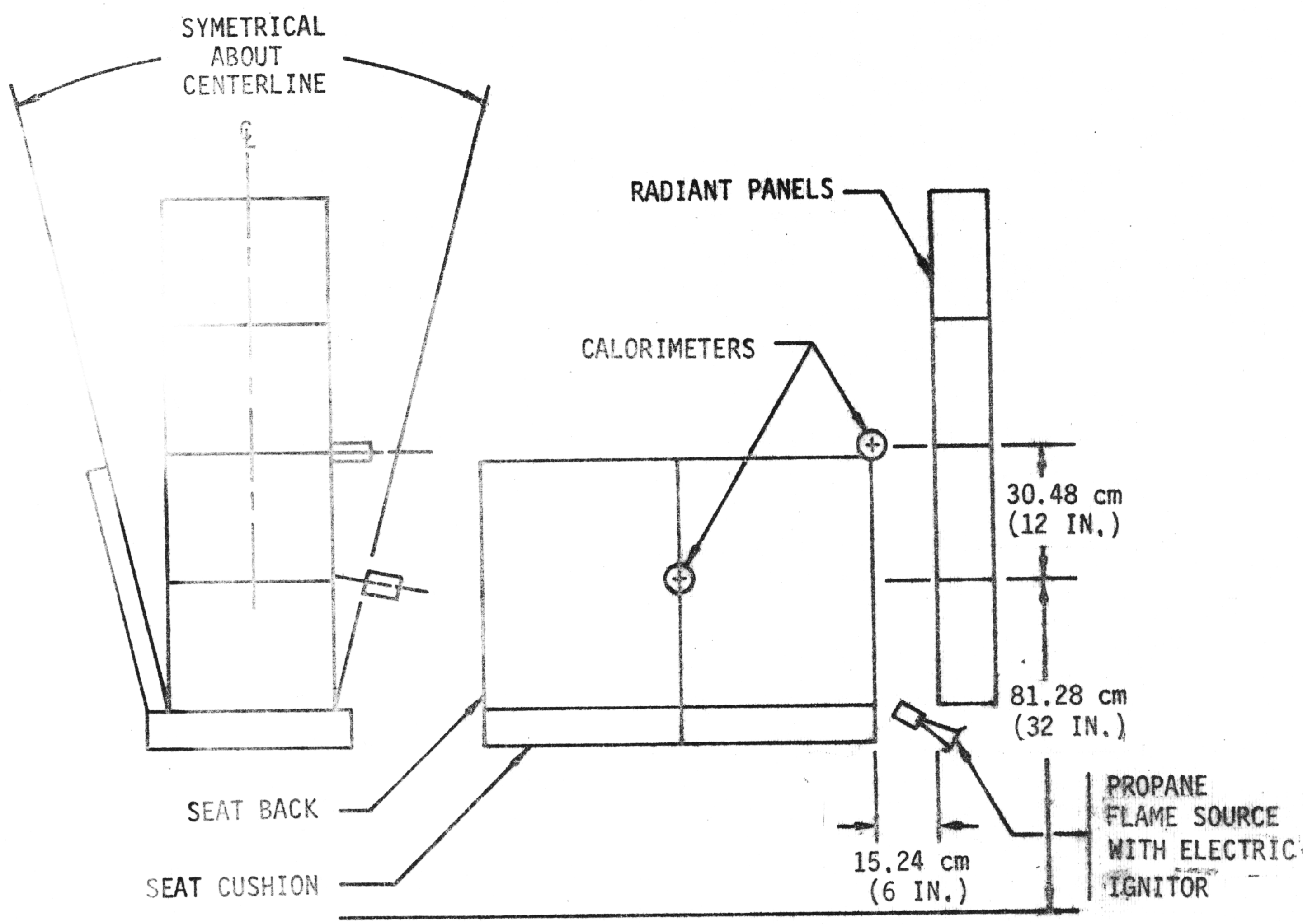


FIGURE 1 SET UP FOR McDONNELL DOUGLAS FULL SCALE FIRE TESTS

Thirteen seat cushion configurations were tested with five minutes of radiant heat exposure. After fifteen minutes each test was considered complete. Post-test photos were taken and seat residue was weighed.

The thirteen seat cushion configurations are listed in Table 3 and their materials are described in Table 4. Both tables are reproduced from Reference 2. Results of weight loss analysis are shown in Figure 2 from Reference 2. Reference 2 concluded and recommended the following:

CONCLUSIONS

"Urethane foam decomposes into a volatile gas when exposed to a severe heat source. If this generated gas can be contained in such a manner as to prevent its igniting or to control the rate at which it burns, the severity of the fire will be reduced. This was clearly shown in the testing of standard cushion constructions with a protective covering, "fire-blocking", enveloping the urethane foam.

When the fire blocking was able to contain the decomposing urethane by-products, i.e., fluid and gas, the cushions closest to the heat source burned with less intensity, generated a minimum of heat and were unable to ignite the adjacent cushions. However, when the decomposing urethane fluid was able to escape from the fire-blocking envelope and pool on the floor, an uncontrolled fire erupted which resulted in total burning of all cushion materials.

Some of the Norfab and Celiox materials utilized aluminum coatings. It was not the aluminum's reflecting properties which made the cushions perform well as it was its non-permeable properties. This coating helped contain the decomposed by-products and prevented propagation to the adjacent cushion.

TABLE 3

SEAT CONSTRUCTIONS EVALUATED IN McDONNELL DOUGLAS FULL SCALE FIRE TESTS

CONSTRUCTION NUMBER	DECORATIVE UPHOLSTERY	SLIP COVER	FIRE BLOCKING	FOAM
1	Wool-Nylon	None	None	F. R. Urethane *
2	Wool-Nylon	Cotton-Muslin	Vonar-3	F. R. Urethane
3	Wool-Nylon	Cotton-Muslin	Vonar-2	F. R. Urethane
4	Wool-Nylon	None	3/8 LS 200	F. R. Urethane
5	Wool-Nylon	None	Celiox 101	F. R. Urethane
6	Wool-Nylon	None	Norfab 11 HT-26-AL	F. R. Urethane
7	Wool-Nylon	Cotton-Muslin	Vonar-3	N. F. Urethane *
8	Wool-Nylon	None	Norfab 11 HT-26-AL	N. F. Urethane
9	Wool-Nylon	None	None	LS 200 Neoprene
10	Wool-Nylon	None	None	Polyimide
11	Polyester	None	None	Polyimide
12	Wool-Nylon	None	Norfab 11 HT-26	F. R. Urethane
13	Wool-Nylon	None	PBI	F. R. Urethane

* F. R. Urethane (Fire Retarded Urethane)

* N. F. Urethane (Non-Fire Retarded Urethane)

TABLE 4

MATERIALS IN THE McDONNEL DOUGLAS FULL SCALE FIRE TESTS

MATERIAL	SOURCE
#2043 urethane foam, fire-retardant (FR), 0.032 g/cm^3 (2.0 lb/ft^3) 43 ILD	North Carolina Foam Ind. Mount Airy, NC
Urethane foam, non-fire retardant (NF), 0.022 g/cm^3 (1.4 lb/ft^3) 24-35 ILD	CPR Division of Upjohn Torrance, Ca.
Vonar-3, 3/16-inch thick with Osnaburg cotton scrim (23.5 oz/yd^2) .079 g/cm^2	Chris Craft Industries Trenton, NJ
Norfab 11HT26-aluminized (12.9 oz/yd^2) .044 g/cm^2, aluminized one side only	Amatex Corporation Norristown, Pa.
Gentex preox (celiox) (10.9 oz/yd^2) .037 g/cm^2, aluminized one side only	Gentex Corporation Carbondale, Pa.
Wool nylon (0.0972 lb/ft^2) .0474 g/cm^2 90% wool/100% nylon, R76423 sun eclipse, azure blue 78-3080 (ST7427-115, color 73/3252)	Collins and Aikman Albermarle, NC
Vonar 2, 2/16 inch thick, .068 g/cm^2 (19.9 oz/yd^2) Osnaburg cotton scrim	Chris Craft Industries Trenton, NJ
LS-200 foam, 3/8" thick (33.7 oz/yd^2) .115 g/cm^2 LS-200 foam, 3-4 inches thick (7.5 lb/ft^3) 0.12 g/cm^3	Toyad Corporation Latrobe, Pa.
Polyimide Foam (1.05 lb/ft^3) .017 g/cm^3	Solar Division, International Harvester San Diego, Ca.
100% polyester (10.8 oz/yd^2) .037 g/cm^2 4073/26	Langenthal Corporation Bellevue, Wa.
Norfab 11HT26 Approximately (11.3 oz/yd^2) .038 g/cm^2	Gentex Corporation Carbondale, Pa.
PBI Woven Cloth Approximately (10.8 oz/yd^2) .037 g/cm^2	Celanese Plastic Company Charlotte, NC

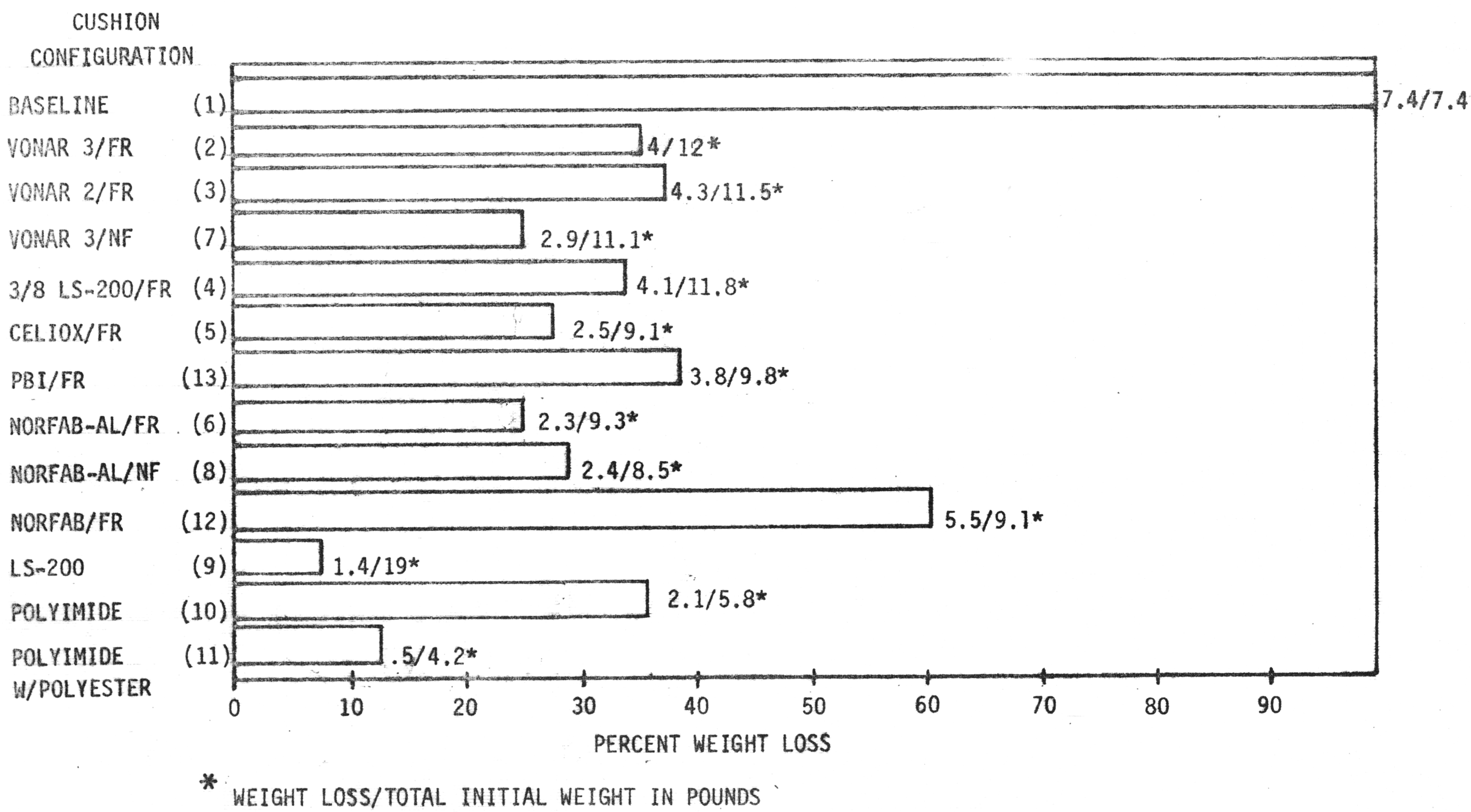


FIGURE 2 WEIGHT LOSS IN McDONNELL DOUGLAS FULL SCALE FIRE TESTS

Had the seams held and all the gases vented out the back of the cushions and away from the heat, the decomposing of the cushions may have been even less severe. Undoubtedly, the reflective properties had an effect in slowing down the decomposing of the urethane, but only by a few seconds. The reason being the emissivity and thermal conductivity of the aluminum coating was inadequate to resist the severe radiant energy being applied to the surfaces.

The charred foam fire-blocking layers did not act primarily as a heat barrier as they did a liquid and gas barrier. In the cushions farthest from the radiant source, the urethane foam still thermally decomposed. It formed a pocket of gas behind the intact charred envelope. This was verified in post test inspection. However, the gas escaped slowly and only created a small pilot flame. The flame extinguished itself when the radiant energy source was switched off.

The polyimide cushions are examples of a foam which thermally decomposes at high temperatures and generates gas and char but no noticeable liquids. The wool-nylon upholstery trapped gases between itself and the foam. When these gases ignited, the foam decomposed rapidly. The polyester upholstery decomposed from the cushions fast enough to prevent the trapping of these gases. Subsequently, the foam in the cushions decomposed at a slower rate. From these tests, it is concluded that no matter the foam used as a core for the cushion, if the gases generated by the foam can be expelled or contained in such a manner as to prevent their burning or reduce the rate at which they burn, a severe fire can be avoided or delayed. It is further concluded that if the thermal decomposition characteristics can be altered so as to slow down the generation of gas, the time before a fire becomes severe can be extended to the point where appropriate extinguishment of the fire may be possible."

RECOMMENDATIONS

"It is recommended that a study be made to incorporate cushion designs and fire-blocking materials which are thermally stable and nonpermeable to urethane fluids and gases to prevent or reduce the rate at which a seat cushion burns.

This study should include considerations for wearability of fire blocking layers, fatigue life of cushion foams and methods of venting decomposition gases from the cushion assembly. Test results from this program have shown that seam constructions significantly affect cushion burn performance. Therefore, seam constructions previously studied by the NASA seat program should be reconsidered in future cushion designs.

It is also recommended to use these studies as a basis to develop a design standard for a fire resistant passenger seat. This standard must be supported by inexpensive laboratory burn test methods that can verify these standards are being met."

As was stated in the conclusions, Figure 2 shows that all the fire blocking layers reduced the percent of total material burned. It is also apparent that the aluminized fabrics (configurations 5, 6 and 8) were more effective than the non-aluminized fabrics (configuration 12). The performance of the aluminized fabrics in these tests is consistent with that found in the tests with real fires (Reference 1) discussed in Section 5.1.

6.0 LABORATORY FIRE TEST RESULTS

August 25-26, 1981, FAA, NASA, and AIA technical representatives met at the FAA Technical Center to coordinate development of small scale fire test criteria for seat cushions with improved fire resistance. Data from small scale tests conducted by the participants on various seat cushion configurations were reviewed. A concensus developed that no test method was adequately defined and sufficiently available to establish a "GO-NO GO" standard for seat cushions with improved fire resistance. Therefore it would be necessary to establish a configuration standard considered to have an acceptable performance within state-of-the-art materials availability. Any proposed seat cushion systems could be compared to the standard for equivalency.

The representatives agreed that the primary fire blocking characteristics pertinent to fire performance are probably fire spread, time to foam fire involvement and heat release rate (for cushion, including blocking and foam). Smoke and toxicant release should not be a primary concern with materials presently being considered as control of these properties is beyond the state-of-the-art test methods. However, it is assumed that unusually high smoke or known high toxicant producers would not be used.

It was suggested that urethane foam wrapped in 181 E-glass fabric be considered a possible standard. Such a standard, although unusable as a practical seat cover, would be readily available for comparison tests. The samples would be consistent in quality and properties and would probably provide an acceptable degree of fire blocking for comparison purposes. It was agreed that the concept was desirable but that the selection of glass fabric would have to be validated by large and small scale tests.

Since all previous small scale testing had been accomplished at different places with different test apparatus on different seat cushion fire blocking configurations, it has been difficult to evaluate the degree of data correlation from one test to another and with large scale test results. It was decided that a fire retardant foam baseline and six fire blocking concepts on fire retardant foam should be tested in the available test facilities at participating organizations for mutual comparison, and for comparison to C-133 and CFS results. In addition, two of the fire blocking materials would be tested on a non-fire retardant foam having the same comfort and functional properties as the 2.2 pcf F.R. foam. Unprotected polyimide and LS-200 foam specimens were added to the test configuration list to make a total of eleven. It was hoped that a test for fire blocking performance could indicate the acceptability of new fire resistant cushioning materials and concepts as well. In all cases the same decorative wool upholstery would cover the specimens; however, slip covers would not be used as part of the tested configuration unless the slip cover is considered a portion of the fire blocking. The configurations selected for test are shown in Table 5, reproduced from Reference 3. The configurations will be designated by the numbers shown throughout this report section.

Some of the test methods available to participants may be operated readily at several selected heating rates (i.e., the NBS Smoke Density Chamber and the OSU). It was agreed that wherever possible, on these facilities, testing should be done at 2.5, 5.0 and 7.5 W/cm^2 to determine performance over a range of heating rates the cushions may most likely encounter in airplane fires. To insure specimen uniformity at the testing agencies, FAA and NASA-ARC ordered and distributed all materials as part of the FAA/NASA interagency agreement. The testing conducted and the results are summarized in the following sub-sections.

TABLE 5

SEAT CUSHION CONFIGURATIONS FOR FIRE TEST METHODS EVALUATION

CONFIG-URATION	FOAM	FIRE BLOCKING LAYER (FBL)	FBL kg/m^2	WEIGHT oz/yd^2	SUPPLIERS OF FIRE BLOCKING LAYERS
1	FR urethane	none			
2	FR urethane	Vonar ® -3, 0.48 cm (3/16 in)*	0.91	27.07	Chris Craft Industries 1980 East State St. Trenton, NJ 08619
3	FR urethane	Vonar ® -2, 0.32 cm (2/16 in)*	0.67	19.97	Chris Craft Industries 1980 East State St. Trenton, NJ 08619
4	FR urethane	LS-200 neoprene ® 0.95 cm (3/8 in)	1.15	33.7	Toyad Corporation 16 Creole Drive Pittsburg, PA 15239
5	FR urethane	Preox ® 1100-4 aluminized Preox ® fabric, plain weave, neoprene CTD, P/N 1299013	0.39	11.53	Gentex Corporation P. O. Box 315 Carbondale, PA 18307
6	FR urethane	Norfab ® 11HT-26-A1 aluminized on one side, 25% Nomex ® 70% Kevlar ®, 5% Kynol ®, weave structure 1x1 plain	0.40	11.8	Amatex Corporation 1032 Stonabirdge St. Norristown, PA 19404
7	FR urethane	181 E-Glass			Uniglass Industries Statesville, NC
8	NF urethane	Vonar ® -3, 0.48 cm (3/16 in)	0.92	27.07	Chris Craft Industries 1980 East State St. Trenton, NJ 08619
9	NF urethane	Norfab ® 11HT-26-A1	0.40	11.8	Amatex Corporation 1032 Stonabirdge St. Norristown, PA 19404
10	LS-200 Neoprene ®	none			
11	Polyimide	none			

® Registered Trademark

NOTES ON TABLE 5:

All decorative upholstery is a wool/nylon blend fabric (R76423 Sun Eclipse, Azure Blue, 78-3880) by Collins & Aikman, Albemarle, NC

Suppliers of Foams:

FR urethane (No. 2043 FA foam, density of 29.9 kg/m^3 or 1.87 lb/ft^3): North Carolina Foam, P. O. Box 1112, Mt. Airy, NC 27030

NF urethane (medium firm, ILD32, density of 23.2 kg/m^3 or 1.45 lb/ft^3): Foam Craft, Inc., 11110 Business Circle Dr., Cerritos, CA 90701

Polyimide foam: International Harvester, 701 Fargo Ave., Elk Grove Village, IL 60007

LS-200 neoprene foam: Toyad Corporation

* The Vonar was on a cotton fabric carrier.

6.1 NASA-ARC Small Scale Tests

The most extensive program of laboratory scale testing and analysis of the eleven cushion configurations was conducted by NASA-ARC through the FAA/NASA interagency agreement. This program also included the large scale simulated fire tests conducted by McDonnell Douglas (see 5.2) and weight/cost/durability studies. The entire program is reported in reference 3. The laboratory scale tests and results will be summarized here. Conclusions and recommendations of the program will be included in sections 7.0 Comparison of Laboratory and Full Scale Test Results and 8.0 Conclusions and Recommendations.

6.1.1 NASA-ARC T-3 Burner Tests

A series of initial screening tests for potential candidate blocking layers was conducted by Scientific Service, Inc. The objective was to compare the effects of thermal exposure on several of the seat cushion configurations by measuring the time that it took to raise the surface temperature of the foam material to $300^{\circ}C$ ($598^{\circ}F$) using the T-3 burner described in reference 3 Appendix A. Heat fluxes tested were $11.3 W/cm^2$ ($9.95 Btu/ft^2 sec$) and $8.5 W/cm^2$ ($7.49 Btu/ft^2 sec$). Results in order of descending time for the foam to reach $300^{\circ}C$ were:

CONFIGURATION NO.	FIRE BLOCKING LAYER
4	0.95 cm(3/8 in.) LS-200
2	0.48 cm(3/16 in.) Vonar 3
3	0.32 cm(2/16 in.) Vonar 2
6	Norfab 11HT-26-Al
5	Preox 1100-4
7	181 E-Glass
1	No Fire Block Layer

The thermal threat of these tests was extreme and short foam protection times were observed. Reference 3 stated:

> "The NASA T-3 burner test results were inconclusive in determining the fire protection afforded by various fire blocking layers and foams and does not appear to offer a viable small scale testing procedure for these purposes."

6.1.2 NASA-ARC Studies of Mass Injection by Thermal Degradation

This investigation was done by San Jose State University. An NBS smoke density chamber was modified to measure weight loss as well as smoke density.

The tests were conducted on 3 in. x 3 in. specimens with 1/2 inch thick cushioning foam wrapped with the appropriate fire blocking layer and the upholstery material. The sample was exposed to only radiant heating with no pilot flame. Specimen weight was measured continuously throughout the test. Complete testing procedures and setup may be found in Reference 3.

Tests were conducted at incident heat fluxes of 2.5, 5.0 and 7.5 W/cm^2. From the weight loss data at 2 minutes into the radiant heat exposure, the specific mass injection rate (m) was calculated for ten of the eleven configurations.

$$\dot{m} = \frac{\text{(weight loss)}}{\text{(area of sample exposed) (time elapsed)}} \qquad \frac{g}{cm^2 \ sec}$$

The results for this calculation are shown in Figures 3 and 4 developed from data in Reference 3. It can be seen that all experimental configurations demonstrated significantly lower mass injection rates than the baseline, configuration 1, when exposed to either 2.5 or 5.0 W/cm^2. The reduction in mass injection rate was not as significant for some fire blocking layers with 7.5 W/cm^2 exposure.

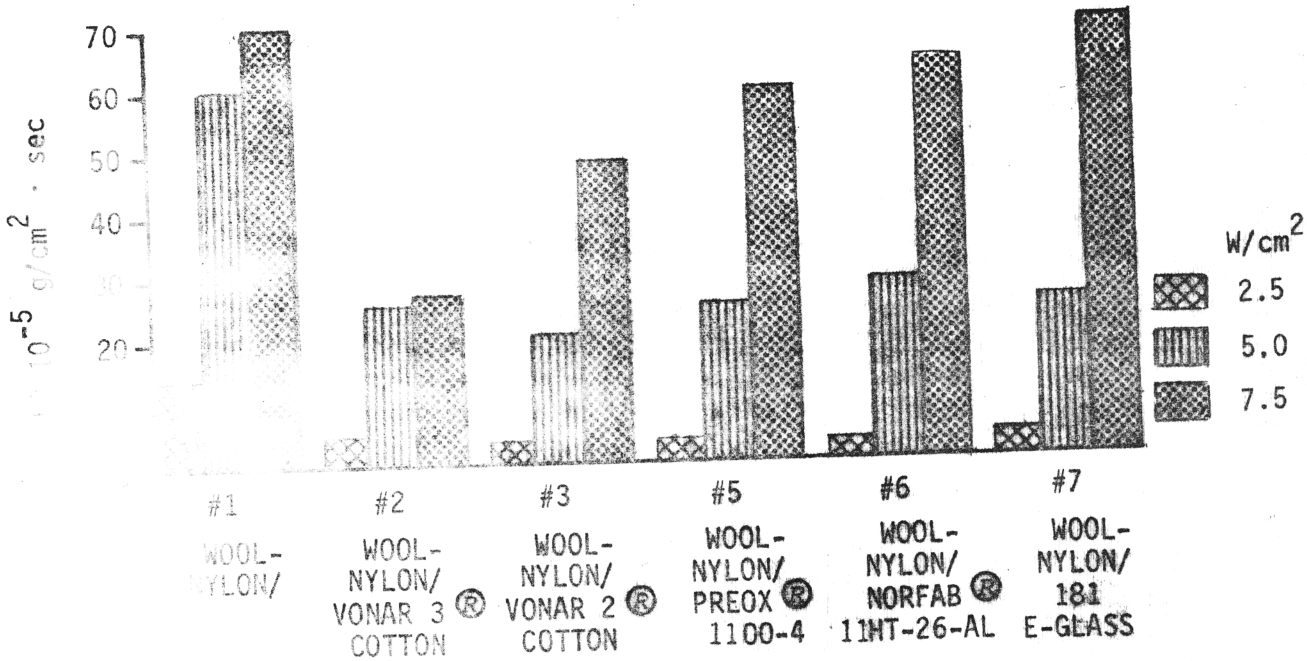
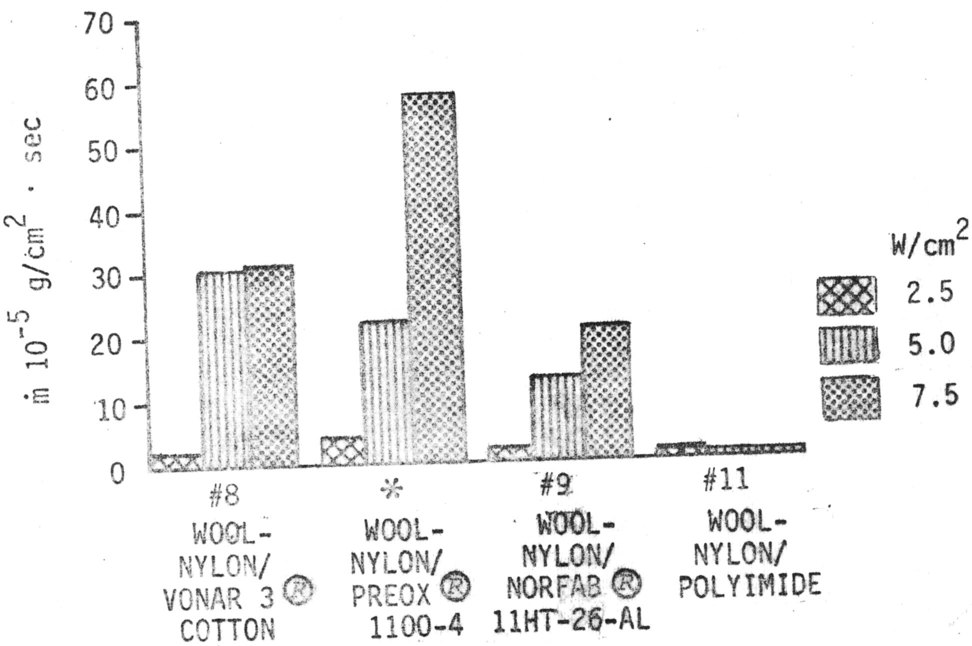


FIGURE 3: SPECIFIC MASS INJECTION RATE OF F.R. URETHANE FOAM AT 2 MIN.



* CONFIGURATION IN ADDITION TO ORIGINAL 11

FIGURE 4: SPECIFIC MASS INJECTION RATE OF N.F. URETHANE AND POLYIMIDE FOAMS AT 2 MIN.

6.2 Lockheed Meeker Burner Tests

The Lockheed Aircraft Company (Lockheed-California Company) conducted tests on the eleven configurations using the specimen holder developed for compliance with tests required in FAR 25.853 and a Meeker burner. The set-up is described in Figure 5. Adjustment of the flame to specified temperatures is defined in Figure 6. Samples fabricated as shown in Figure 7 were tested with 60 seconds exposure to the Meeker burner flame. The results of the flame test are summarized in Table 6. It is noted that all but the baseline demonstrated short after-flame times. All demonstrated much shorter foam burn lengths than observed for the baseline, with the neoprene blocking layers, the neoprene foam and the polyimide foam burning less than those foams protected by fabric fire-blocking. The burning intensity of the polyimide sample was significantly greater than all but the baseline. However, the length of polyimide foam burned was short. This phenomena will be discussed more in Sections 7 and 8.

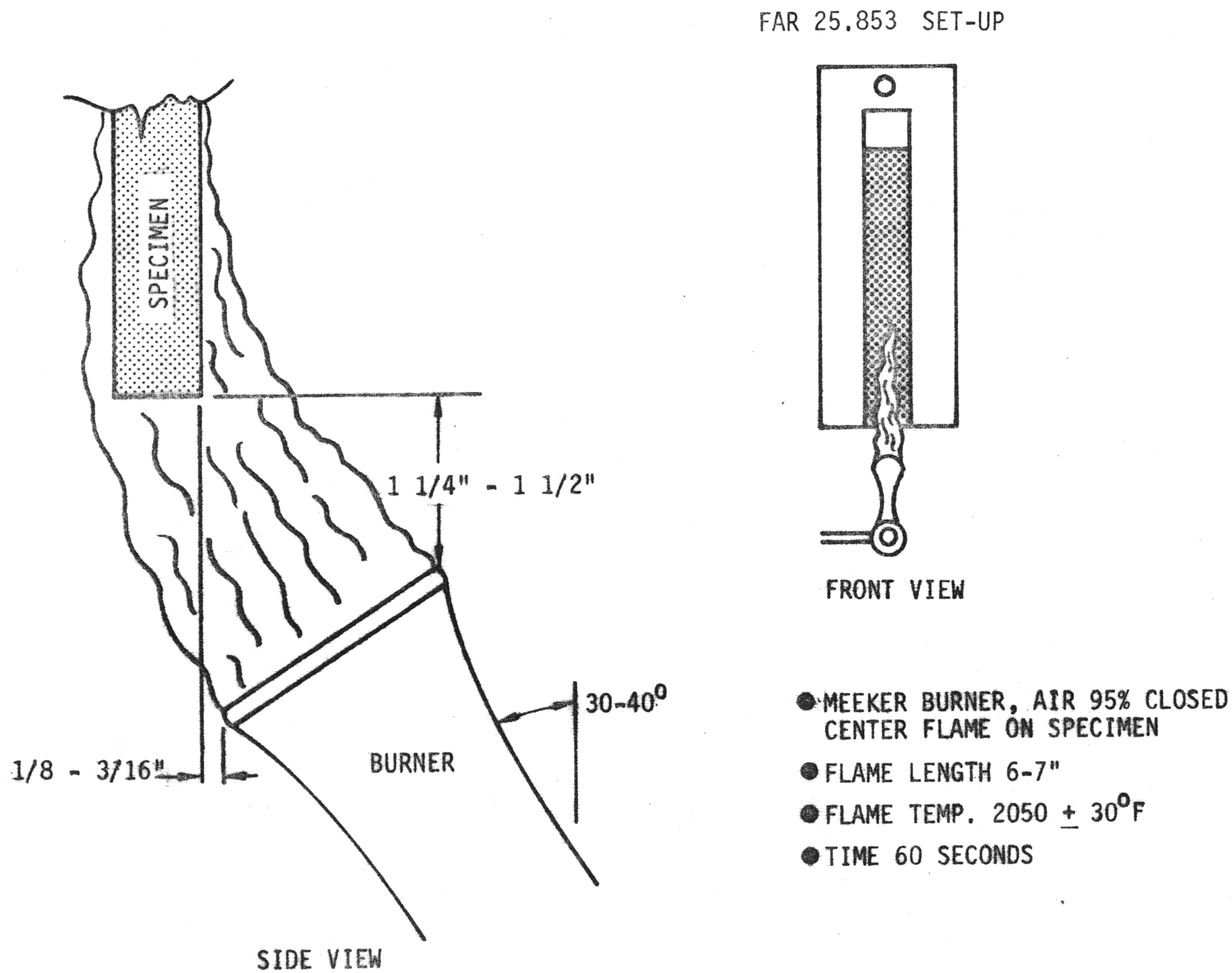
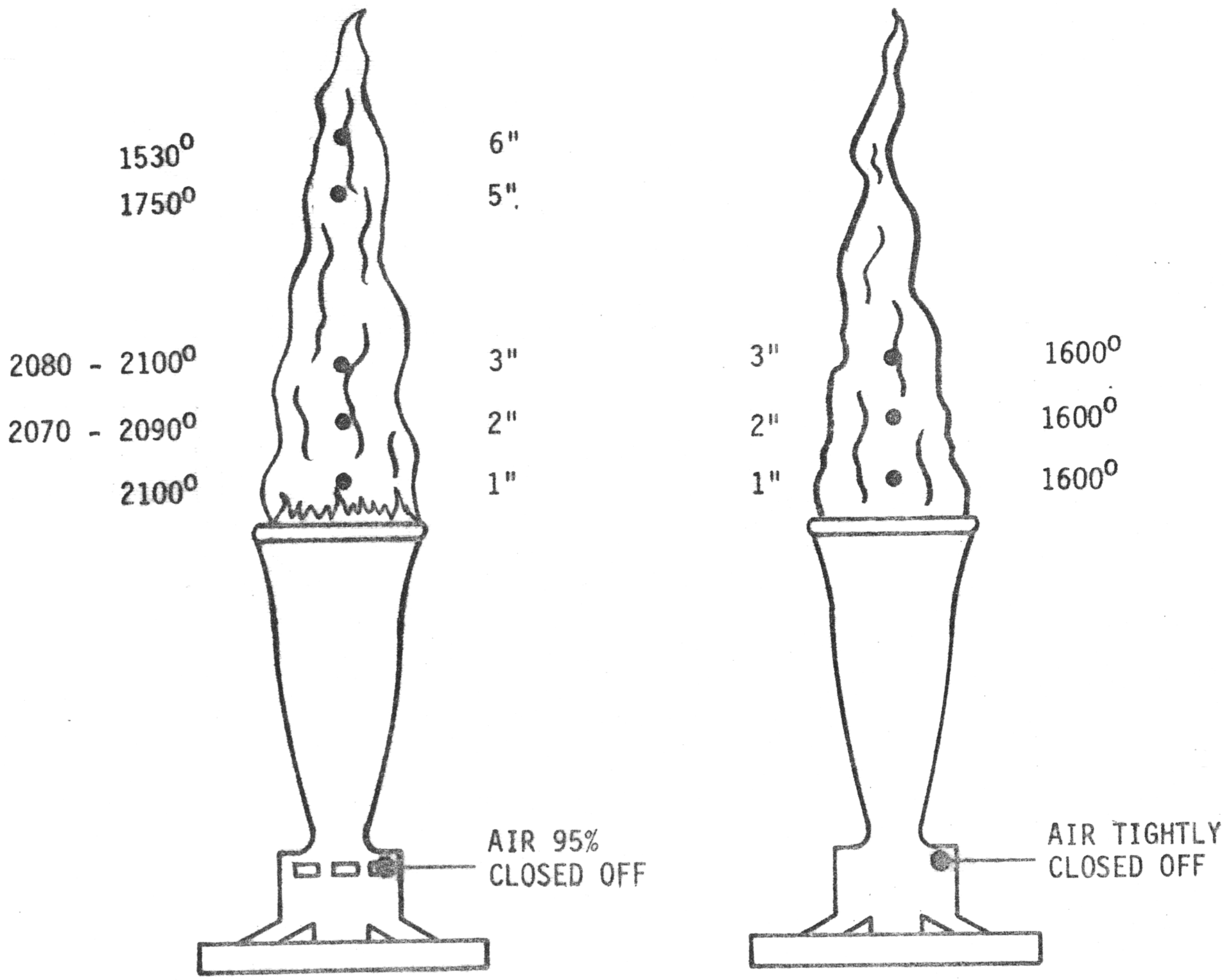
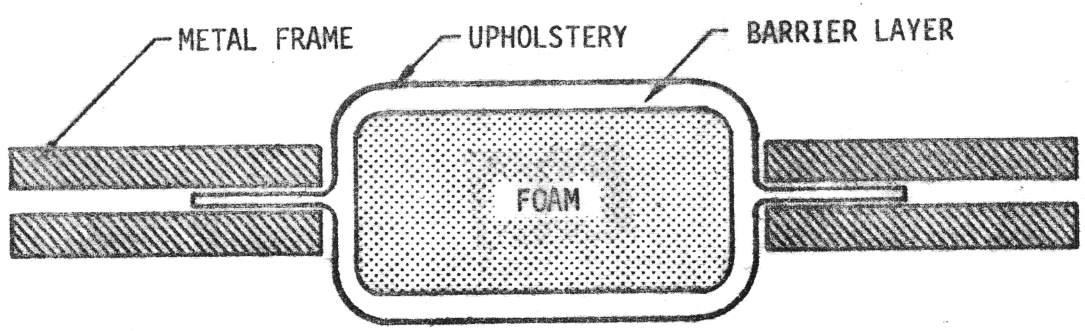


FIGURE 5: MEEKER BURNER FLAME TEST SETUP



TEMPERATURES MEASURED WITH 24 GAUGE Cr - Al THERMOCOUPLE

FIGURE 6: MEEKER BURNER FLAME TEMPERATURE ADJUSTMENT



CROSS SECTION VIEW

FOAM	2" W x 1" T x 12" L
BARRIER LAYER	4 1/2" W x 25" L
UPHOLSTERY	4 1/2" W x 25 1/2" L

FIGURE 7: SPECIMEN CONFIGURATION FOR MEEKER BURNER FLAME TEST

TABLE 6

MEEKER BURNER FLAME TEST RESULTS

NO.	CONFIGURATION	BURN INTENSITY	BURN LENGTH, INCHES UPHOLSTERY	FOAM	AFTER FLAME (SECONDS)
1	BASE	5	9 3/4	5 3/4	60+
2	VONAR 3	2	5 1/4	1/8	0-2
3	VONAR 2	2	5 1/4	5/16	0
4	LS-200	2	4 1/2	1/8	0
5	CELIOX	3	4 3/4	1	2
6	NORFAB	2	4 3/4	1 1/4	3
7	181 E GLASS	2	4 3/4	1 1/8	3
8	VONAR 3, NF	2	4 1/4	1/4	0
9	NORFAB, NF	3	5	1 1/4	0-6
10	LS-200 FOAM	2	4 1/2	1/8	0
11	POLYIMIDE	4	7	1/2	0-2

BURN INTENSITY 1 = GOOD, 5 = POOR

6.3 OSU Tests

The Ohio State University Release Rate apparatus has been evaluated extensively at many laboratories including Boeing, the FAA and McDonnell Douglas. The basic apparatus and a proposed procedure are described in reference 4. Unfortunately, the operating procedures for airplane materials have not been established, and much of the equipment has been modified to unique testing concepts of the individual laboratories. There were significant differences in the OSU testing procedures used by Boeing, the FAA Technical Center and McDonnell Douglas. Some of the more significant differences are obvious in Table 7. Because of these differences, correlation of absolute values of heat and smoke release would not be expected. Figures 8 through 13 summarize accumulated release values for specific times as related to the release from configuration No. 1 (baseline) expressed as 100%.

It should be noted that McDonnell-Douglas did not test configuration Nos. 3, 7, 10 and 11 and tested other configurations at only 2.5 W/cm^2 and 5.0 W/cm^2. Other blank charts on the figures occur because data were not reduced for all specific times by each participant. The absolute OSU data expressed in appropriate units are in Appendix 10.2.

First examination of the OSU heat release data in Figures 8 through 10 does not reveal a great deal of consistency of ranking between testing agencies. However, it must be remembered that a means is being sought for screening materials with relative level of fire resistance rather than ranking the eleven configurations in absolute order.

If it is assumed, as the FAA preliminary large scale tests indicate, that neoprene foam blocking layers provide one level of fire resistance, fire resistant fabrics a lower level of resistance and the replacement foams another level, then the configurations can be grouped and coded to demonstrate this. The Figures 8 through 13 have been coded to group configurations 2, 3, 4, and 8 as neoprene foam blocking layers, configurations 5, 6, 7 and 9 as fabric blocking layers and configurations 10 and 11 as replacement foams.

TABLE 7

OHIO STATE UNIVERSITY (OSU) RELEASE RATE CALORIMETER OPERATING PARAMETERS

	BOEING	DOUGLAS	FAA
SAMPLE SIZE	6" x 6" (15.2 cm x 15.2 cm)	10" x 10" (25.4 cm x 25.4 cm)	6" x 6" (15.2 cm x 15.2 cm)
RADIANT FLUX	2.5, 5.0 & 7.5 W/cm^2	2.5 & 5.0 W/cm^2	2.5, 5.0 & 7.5 W/cm^2
TYPE IGNITION	SAMPLE LOWER EDGE	SAMPLE LOWER EDGE	EVOLVED GASES
PRIMARY AIRFLOW	21 FT^3/MIN (0.01 m^3/SEC)	15 FT^3/MIN (0.0071 m^3/SEC)	21 FT^3/MIN (.01 m^3/SEC)
MIXING AIRFLOW	63 FT^3/MIN (0.03 m^3/SEC)	45 FT^3/MIN (0.021 m^3/SEC)	63 FT^3/MIN (.03 m^3/SEC)
THERMOPILE	COMPENSATED	UNCOMPENSATED	COMPENSATED

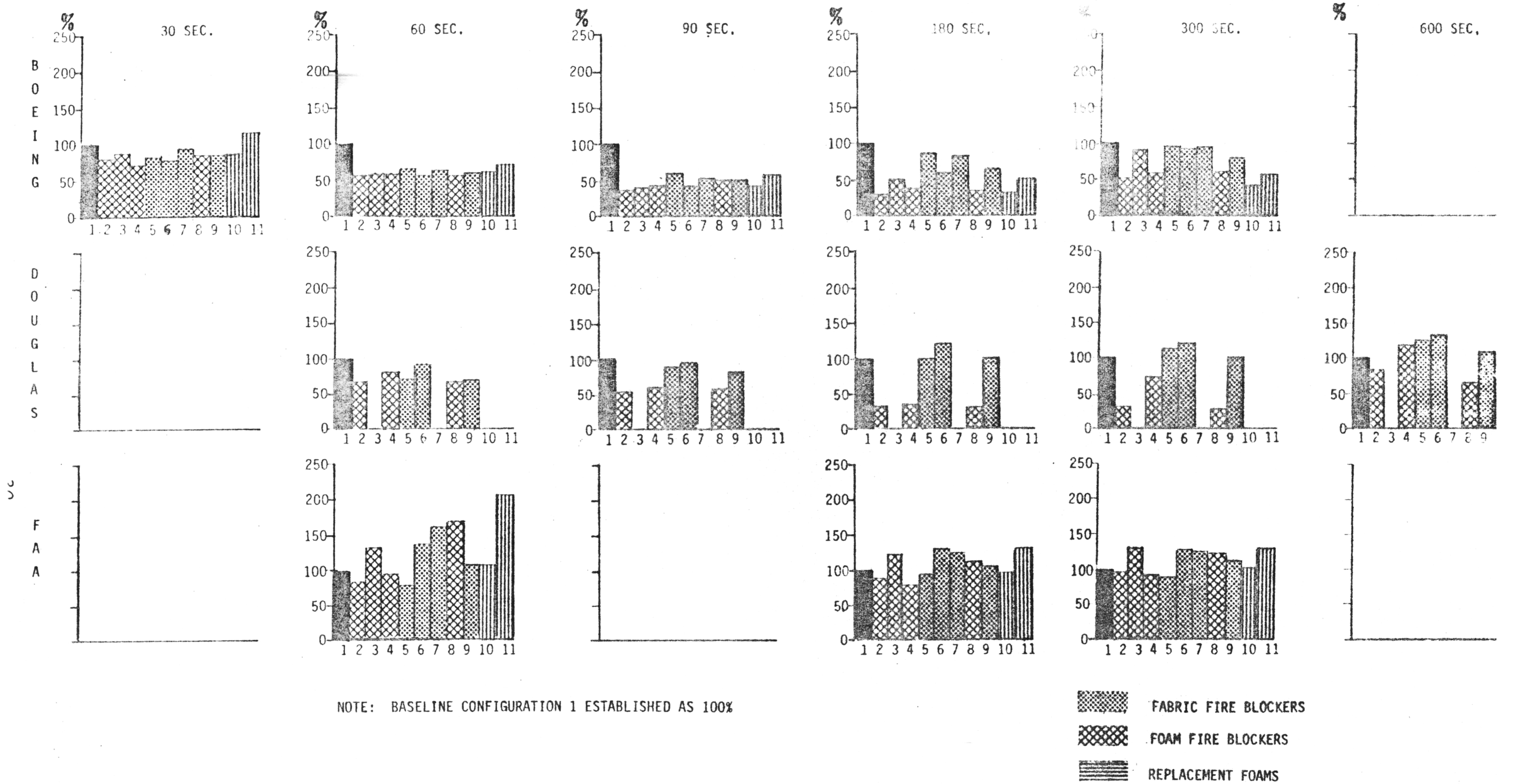


FIGURE 8 COMPARISON OF OSU HEAT RELEASE AT 2.5 W/cm^2

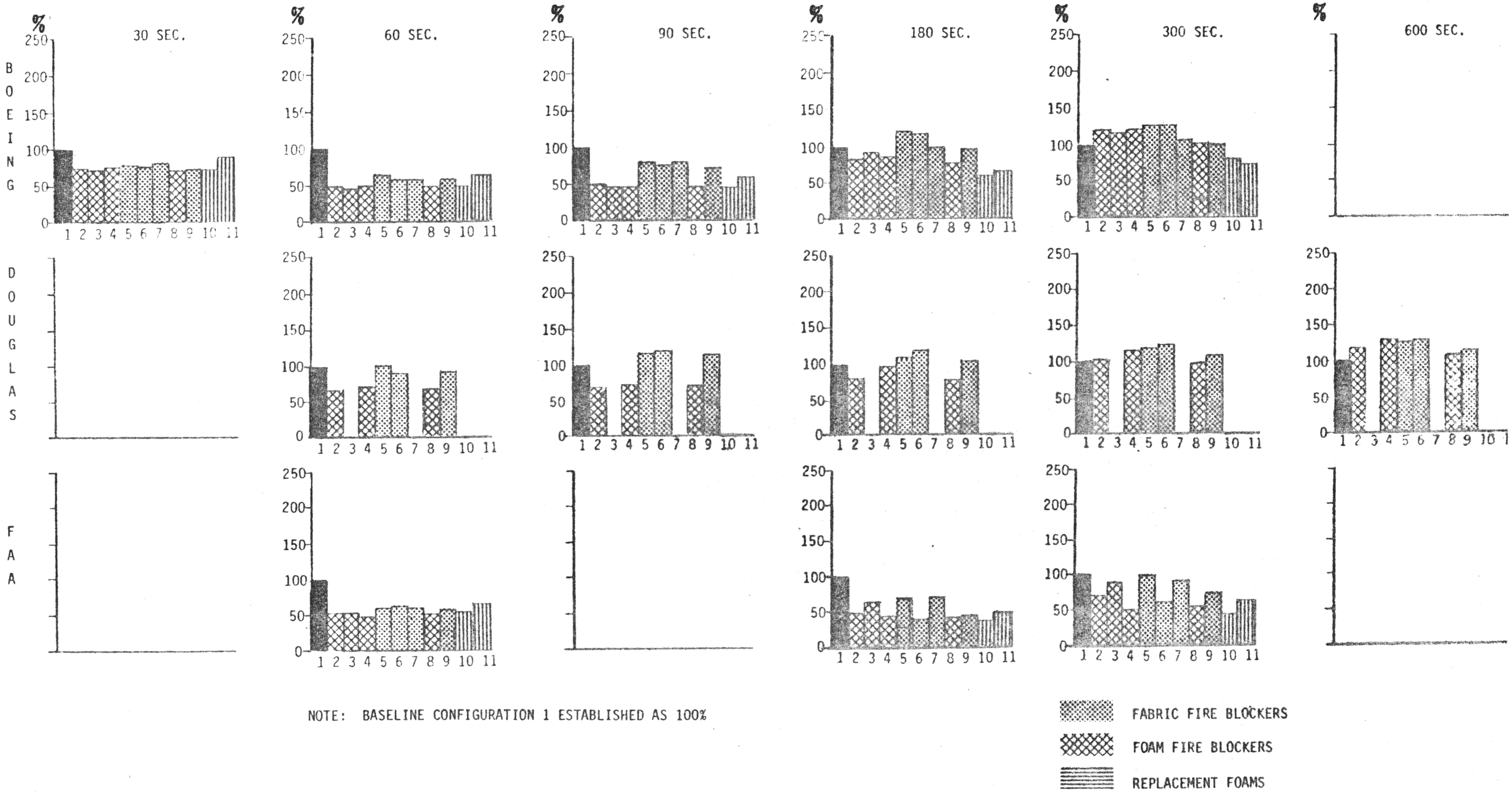
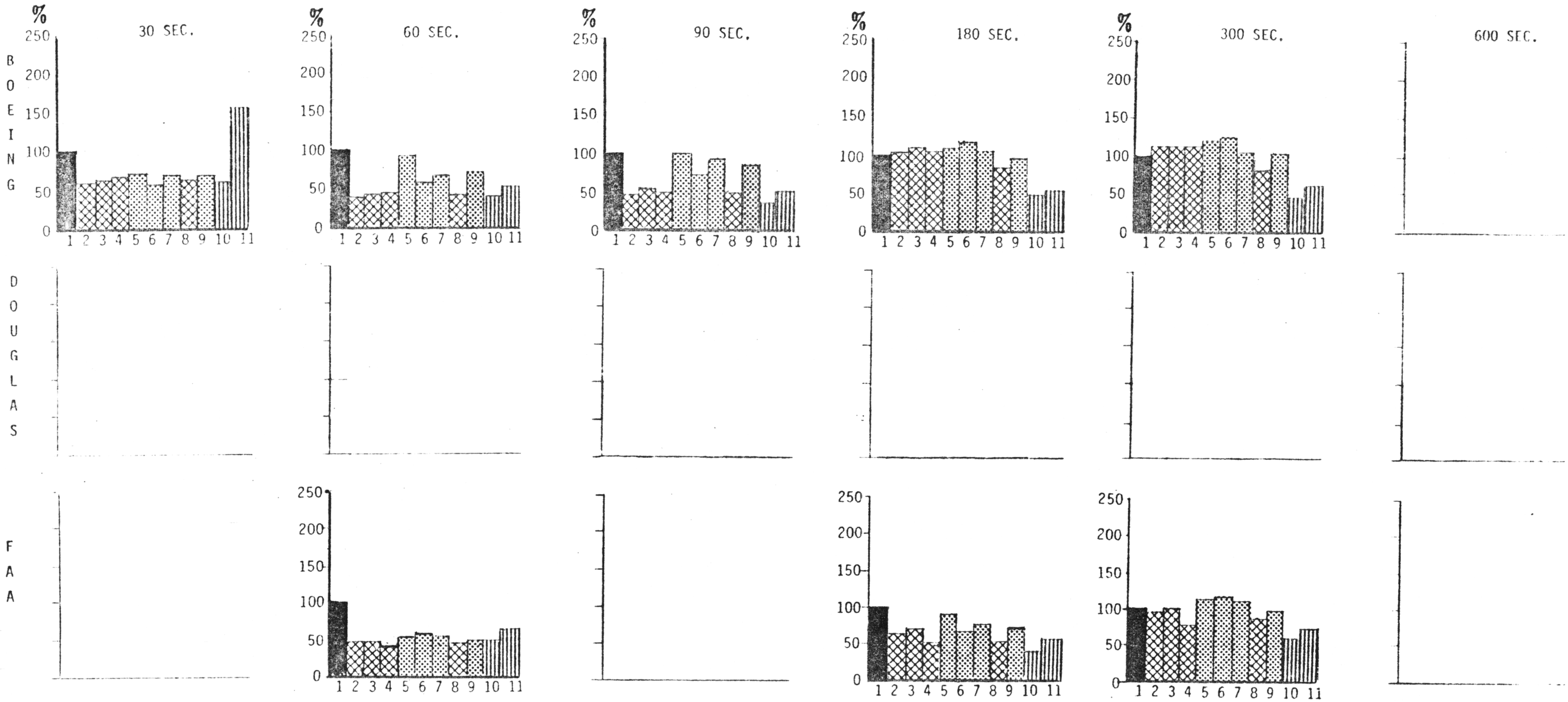


FIGURE 9 COMPARISON OF OSU HEAT RELEASE AT 5.0 W/cm^2



NOTE: BASELINE CONFIGURATION 1 ESTABLISHED AS 100%

FABRIC FIRE BLOCKERS
FOAM FIRE BLOCKERS
REPLACEMENT FOAMS

FIGURE 10 COMPARISON OF OSU HEAT RELEASE AT 7.5 W/CM^2

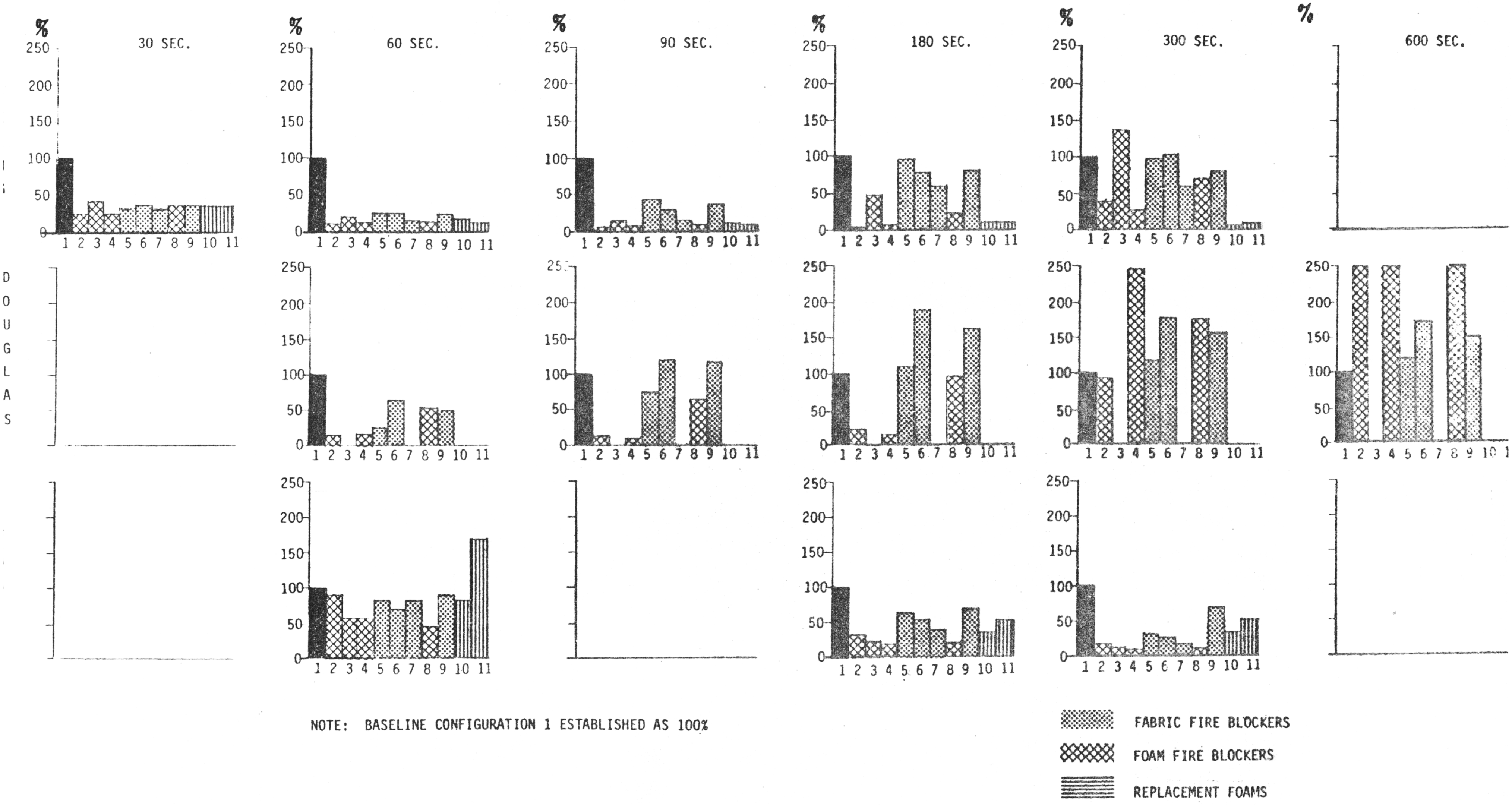


FIGURE 11 COMPARISON OF OSU SMOKE RELEASE AT 2.5 W/CM^2

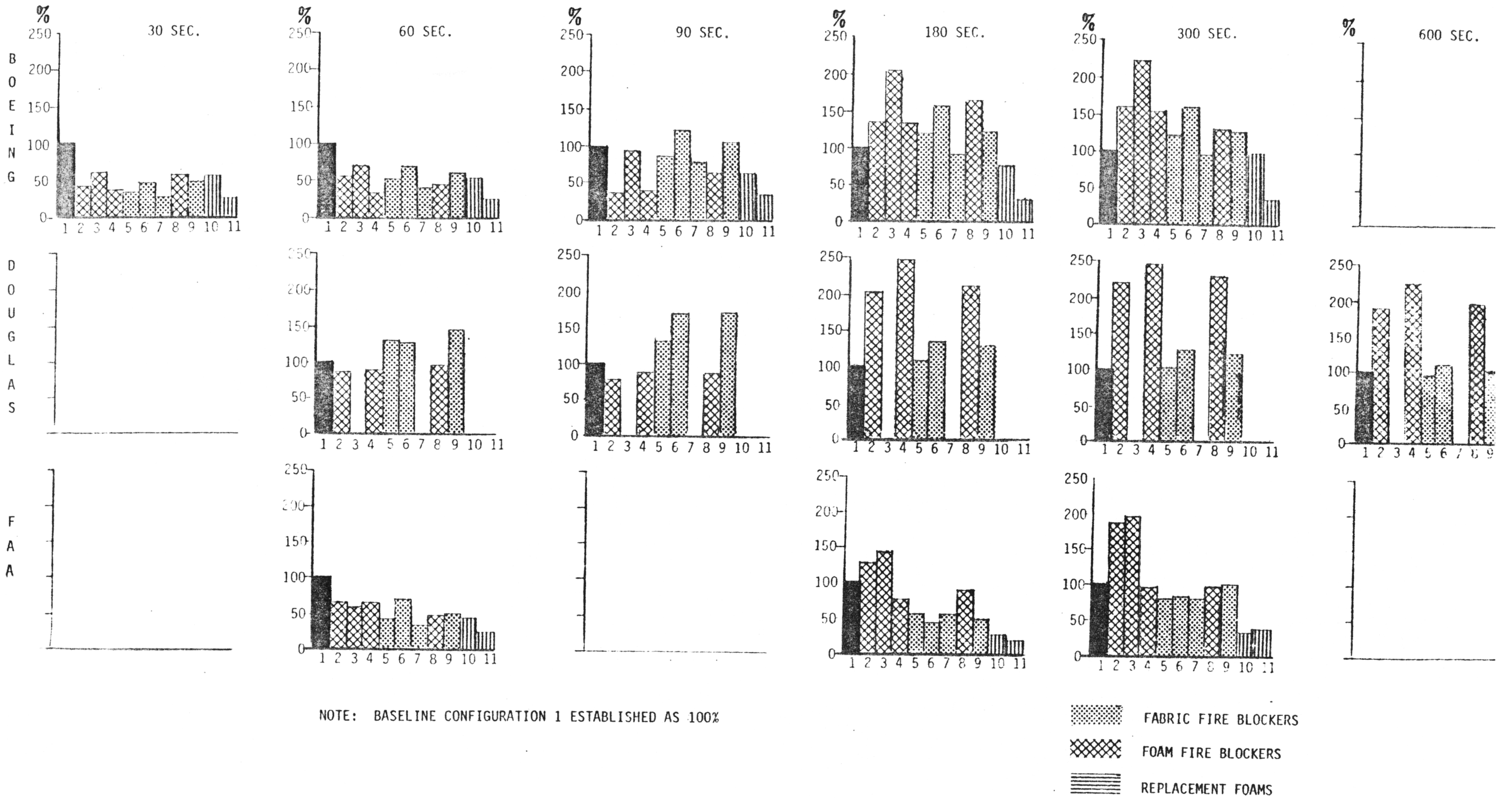


FIGURE 12 COMPARISON OF OSU SMOKE RELEASE AT 5.0 W/cm^2

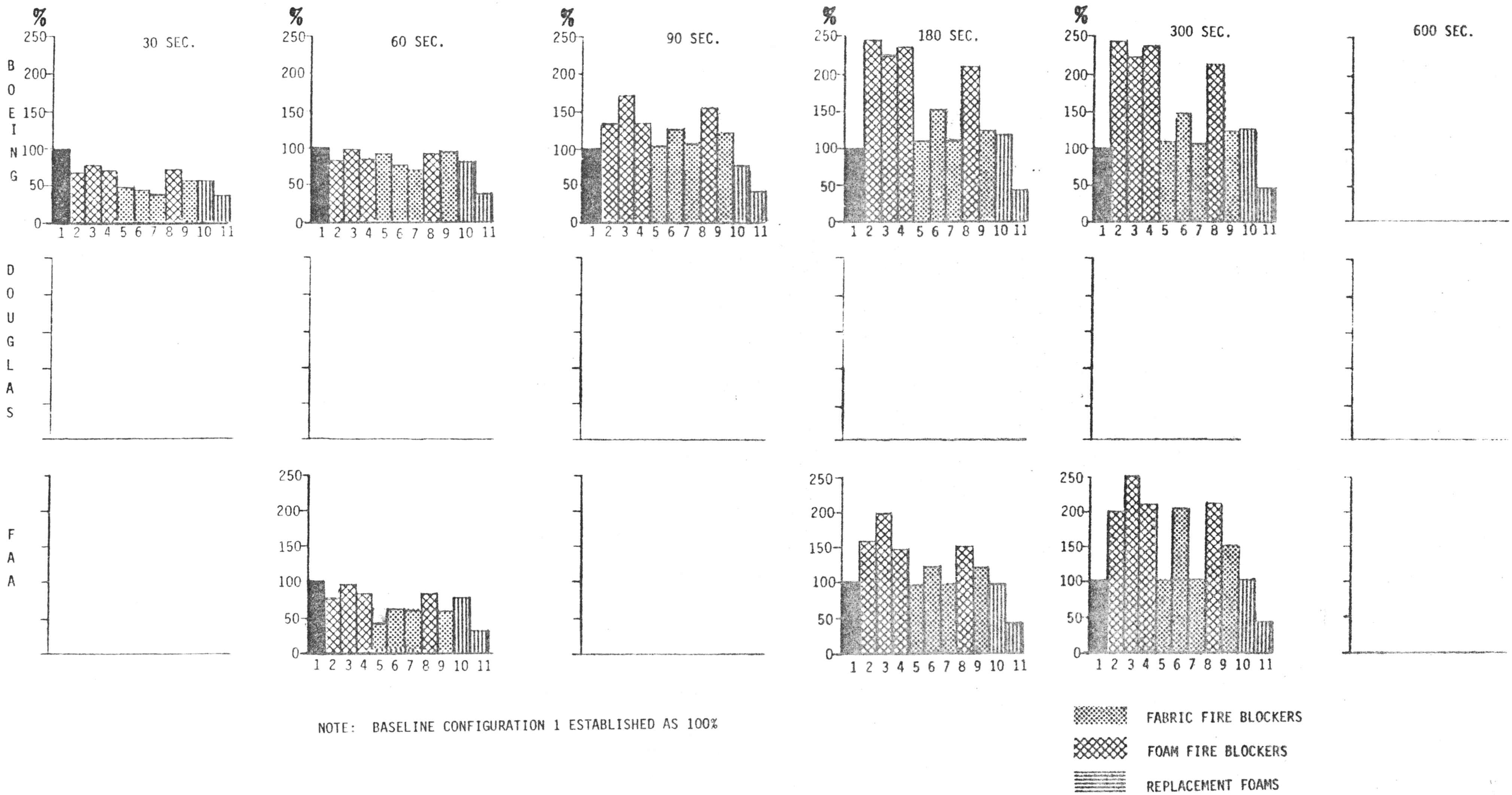


FIGURE 13 COMPARISON OF OSU SMOKE RELEASE AT 7.5 W/cm^2

7.0 COMPARISON OF LABORATORY AND FULL SCALE FIRE TEST RESULTS

From the full scale fire tests conducted in the FAA C-133 fuselage (Reference 1) it appears that the fabric fire blocking layers tested are effective in preventing the spread of probable ramp and in-flight seat cushion fires.

A minimum amount of testing with simulated post-crash fires showed a fabric fire blocking layer beneficial in slowing the spread of fire, but less effective than the thicker and heavier neoprene foam fire blocking layer. These results are consistent with technical reasoning. Barring the use of metallic or other non-organic materials with high melting and burning temperatures, it is to be expected that the thicker non-porous materials would provide the better initial thermal protection for the urethane foam. These same materials could be less permeable to vaporized or liquified flammable foam products than the fabrics.

The photographic data of the closely controlled simulated-fire radiant heat tests conducted by McDonnell Douglas generally confirmed the results of the FAA full-scale, high-thermal-threat, post-crash fire tests. The weight loss data requires more than casual examination because each fire blocking layer added a unique weight increment to the baseline seat weight. Use of cushion foams other than urethane also resulted in changes in the specimen weight. Percent weight loss may be indicative of the extent of fire spread; however, total heat released is a parameter which cannot be ignored. Weight loss data is related to heat release only (1) if all material lost is burned and (2) if the heat of combustion for the material is known or if it can be assumed that all applicable materials have the same heat of combustion. Neither of these two points can be readily assumed for these experiments.

Generally, based on limited test data from each of several different fire threats, it may be said that the fabrics tested provide a significant level of fire blocking, the foam layers provide a greater level of protection and the replacement foams reduce the fire involvement to an even lower level. Examination of all the laboratory tests shows the same trend. The time to elevated foam temperatures in the T-3 burner exhibited the desired trend, although the data may have been difficult to interpret, and the method not applicable to evaluation of replacement cushion foam benefits.

The results of the mass injection rate experiments also predicted the large scale fire test results, and indicated the superiority of the foam blocking layer protection at high heating rates found in the post crash fire condition. The results at 5.0 W/cm^2 in the laboratory tests probably are most predictive of the overall protection offered by the blocking layers. Evaluation by only the specific mass injection rate assumes (as does evaluation by weight loss) that all material injected is combustible and has the same heat of combustion.

The Meeker burner tests gave the same performance trend when the amount of foam burned is examined and, in addition, confirmed some large scale test results (see 5.2 and reference 2) not predicted by other laboratory tests: viz, polyimide foam by itself is quite fire resistant, but when used with some upholstery materials will burn significantly more, resulting in increased heat release and fire spread.

The OSU heat release data gives the most quantitative data of all the laboratory tests. However, the variety of conditions employed by the round robin participants demonstrates the lack of standardization of the equipment and methods used in the aircraft field. It appears that the results of FAA and Boeing OSU tests taken at 5.0 W/cm^2

between 30 and 180 seconds test time correlates well with large scale test results. This time period and test flux also are representative of the values found important for those parameters in the full scale FAA-C133 post-crash tests. The protection given by the fire blocking layers is not so apparent in the Douglas OSU test results. However, good correlation to the FAA and Boeing data can be found if it is assumed that Douglas' recorded heat release for the baseline configuration is low. This assumption would lessen the relatively greater than expected heat release values of the fire-blocked configurations.

As an observation, much of the OSU smoke release data show the fire blocked configurations produce measurably more smoke than the baseline configuration, with the fabrics producing less than the neoprene foam layers. The increase in smoke is probably not significant when compared to the benefits from the decreased fire spread and lower heat release.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

8.1.1 Full Scale Tests

The AIA Project 210-9 bases the following conclusions on the full scale fire test results:

1) Both the fabric and the foam fire blocking layers tested show significant and beneficial improvements in seat fire resistance for many ramp and in-flight fire conditions.

2) Both the fabric and the foam fire blocking layers tested show a measurable and beneficial delay and/or limitation in fire spread from simulated post-crash fire sources. In the more severe threats, neoprene foam blocking layers appear to offer more protection than do the fabrics tested.

3) The aluminized fabric tested reduced the seat foam involvement more than did the same fabric without the aluminum coating.

4) As replacements for aircraft seat cushioning foam both polyimide and LS-200 neoprene foams offer a high fire resistance. The former has not yet demonstrated satisfactory functional properties and use of the latter incurs an unreasonable weight penalty.

5) Fire-retardant urethane foam can be replaced with non fire-retardant urethane foam in aircraft seat cushions covered with a blocking layer material without loss in fire protection.

8.1.2 Comparison of Laboratory Test Data to Full Scale Test Results

The results of the laboratory fire tests and the comparison of laboratory and full scale data support the following conclusions.

1) Any one of the laboratory tests can screen fire blocking materials for retarding the burning of the polyurethane foam.

2) The Meeker burner test method indicates configuration-dependant characteristics not evident in other laboratory tests which constrain the entire boundary of the sample and expose it to uniform heating across the entire face.

3) The 181 E-glass fire blocking did show fire blocking performance similar to the aluminized fabric materials under the laboratory test conditions.

4) No laboratory test has had sufficient trial to establish a unique and acceptable fire blocking value for configuration selection.

8.2 Recommendations

The AIA TARC Project 210-9 makes the following recommendations for improving airplane seat fire resistance and for setting a standard for fire resistance control:

1) Airlines, airplane manufacturers, and seat manufacturers should develop seat cushions in airplanes that display as a minimum the fire resistance demonstrated by NORFAB® 11HT-26-AL (an aluminized fabric) used as a fire blocking layer on FAR 25.853b foam. To prevent seam splitting and barrier rupture from pressure of evolved gases, a pressure relief must be provided without destroying the fire blocking function.

2) Laboratory tests discussed in this report may be used as screening devices for fire blocking layers or for fire resistant seat cushions.

3) Full scale fire testing of E-181 glass fabric should be conducted by the FAA in an attempt to confirm its use as a readily available and consistent fire blocking layer standard for minimum fire resistance.

4) A fire test on simulated full size seat cushions (bottom and back) including venting should be conducted to confirm the fire resistance of a selected configuration. The radiant heat/propane ignition test set up used by McDonnell Douglas as reported herein has been found adequate. A 2 gallon per hour oil burner test developed by the FAA Technical Center will be evaluated by industry.

   The degree of seat destruction, foam consumption and fire spread as compared to the NORFAB® 11 HT-26-AL wrapped cushion (or E 181 glass fabric, if confirmed acceptable) should be a subjective criteria for acceptability.

   Quality Control of seat construction components other than the fire blocking materials should be by current FAR 25.853 test methods. A QC test method for blocking materials must be developed.

5) Although demonstrating a high fire resistance, neither polyimide nor LS-200 neoprene foam is recommended as a replacement for urethane foam in aircraft seat cushioning.

9.0 REFERENCES

1. Hill, R. G. and Sarkos, C. P., "Effectiveness of Seat Cushion Blocking Layer Materials Against Cabin Fires". FAA Technical Center presentation at 1982 SAE Aerospace Congress and Exposition, October 25-28, 1982 at Anaheim, California.

2. Duskin, Fred E. and Schutter, Kenneth J., "Study for the Optimization of Aircraft Seat Cushion Fire-Blocking Layers - Full Scale - Test Description and Results", McDonnell Douglas Corporation, Final Report for Contract NASA 2-11095, May 1982.

3. Kourtides, D. A., Parker, J. A., Ling, A. C., and Hovatter, W. R., "Optimization of Aircraft Seat Cushion Fire Blocking Layers", U. S. Department of Transportation Final Report No. DOT/FAA/CT-82-132 (July 1982).

4. American Society for Testing Materials, ASTM Committee E-5 on Fire Standards, Working Paper titled "Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products" currently in committee review.

10.0 APPENDICES

10.1 Industry and Government Correspondence

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

1725 DE SALES STREET N.W. WASHINGTON, D.C. 20036 TEL 347-2315

August 7, 1981

Mr. Jerry M. Chavkin
Chief, Aircraft Engineering Division, AWS-100
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, D. C. 20591

Mr. Roy E. Reichenbach
Chief, Aircraft Safety Development Division, ACT-300
Federal Aviation Administration Technical Center
Atlantic City Airport, New Jersey 08405

Subject: Improved Fire Resistant Aircraft Seat Cushions

Gentlemen:

In November 1980, AIA formed Project 210-9 within the Transport Airworthiness Requirements Committee (TARC) to study the implementation of requirements for improved fire resistant seat cushions for airplanes. Eventual project objectives include definition for AIA members of the following:

1) Current cushion functional characteristics

2) Functional performance guidelines for new cushions

3) Current cushion fire performance

4) Guidelines for improved fire performance within the capability of available materials meeting functional guidelines

The early approach to the objectives included a review of current programs (government and industry) relating to improved cushion fire resistance. To this end, AIA representatives met with FAA Technical Center personnel January 14, 1981 to discuss the large scale fire test program underway there. Also, AIA technical representatives attended a February 10-11, 1981, NASA-sponsored meeting reporting the status of the several NASA-funded development projects for fire resistant seat cushions and an up-date of the FAA Technical Center progress. The TARC Project contacted seat manufacturers and others associated with cushion development. Based on this review, AIA offers the following comments on current status:

(1) Extensive laboratory and full scale testing has narrowed the list of available materials that could be employed to improve the fire resistance of passenger seats of conventional design. Since the density of neoprene is unacceptable and polyimide is not yet developed, polyurethane is the only available cushion material. Fire blocking elements may be Vonar, LS-200 neoprene, Kermel or PBI batting in combination with various fabric layers such as Nomex, PBI (if available) or other suitable fire resistant materials.

(2) A protective blocking layer on the surface of the urethane foam will add substantial weight and labor cost to the seat. The blocking materials are presently available but their optimum configuration for fabricability is not established. Commercial fabrication capability must be established. Once a given blocking construction is established, there will still be a substantial (6 months to a year) lag before installation of such seats could be initiated in aircraft.

(3) The extensive testing of seat cushion configurations and interior lining against several fire sources in the C-133 fuselage at FAA-ACT has yielded voluminous data supporting fire safety benefits from possible changes in seat cushion configuration. However, test condition decisions, test plans, baseline calibration data for the tests, method of test data analysis, and results have not been documented.

(4) The feasibility of one seat cushion fire blocking concept has been demonstrated by limited service tests. An FAA-sponsored optimization program is underway to minimize the impact (wieght) on airplane performance for a similar concept.

(5) FAA planning to establish small scale and/or laboratory tests for certification (regulations) and quality control should be established.

(6) The larger AIA member companies (Lockheed, Boeing, and McDonnell Douglas) are participating in seat cushion and fire test methods development with independent studies.

The AIA wishes to continue use of the best available fire resistant materials in aircraft cabins within reasonable economic and fabrication constraints. The AIA is in full support of a passenger seat cushion fire blocking development program. However, the AIA does have some concerns about the FAA test and development program and wish to address these:

(1) The AIA agrees that seat cushion contribution to cabin fires and the degree of improvement possible within the state of the art must be confirmed by large scale fire tests. The FAA C-133 fire test facility at the Technical Center is the best available instrument to establish these important performance properties quantitatively to maintain program perspective. The AIA recognizes that the current test configuration (large fuselage opening, large fire, minimum fire source entry) was selected to obtain maximum specimen exposure to heat with minimum combustion products from the source to interfere with evaluation of the specimen behavior. However, this condition, while possible, certainly is not typical of post-crash fire incidents in past fatal accidents. The use of only this scenario to evaluate the possible reduction in post crash fire hazard with interior material changes may be misleading. For instance, as the Technical Center has experienced, decreasing the size of the fuselage simulated "rupture" can reduce the effect of seat cushion involvement while increasing significantly the hazard contribution of the fire source.

To obtain a proper perspective of interior material post-crash fire contribution, the AIA recommends that the FAA examine again the accident statistics for past survivable post-crash fire scenarios. With an inert fuselage interior, several scenarios could be tested to determine the threat to interior materials and the life hazard contribution by the fire source. The results obtained from the specific material tests then could be evaluated in light of the likelihood for such a fire condition.

(2) The AIA understands the desire of the FAA to show feasibility for the fire blocking concept by development of a configuration "optimized" for minimum weight, cost, etc. using state of the art materials. However, in the short FAA program it is not possible to evaluate all aspects of design and fabrication. Improvements in passenger seat fire safety standards must not be accomplished by the mandating of particular materials or design. It is recommended that the FAA emphasize the development of small scale and laboratory test methods and standards for seat cushion certification and to assure quality control of configuration and materials employed. The AIA believes the ultimate solution for improved seat cushion fire resistance lies in development of new cushioning concepts eliminating, most certainly, polyurethane foam and possibly all foams. A standard mandating particular materials and design would stifle this development.

The AIA recognizes the time constraints placed upon the FAA Technical Center program and the limitations of the FAA budget and technical staff; however, the impact of a mandated standard configuration could be difficult to justify. The AIA urges the FAA to reconsider the current program emphasis and to consider alternatives possible with coordinated FAA and AIA technical expertise. These alternatives should include reconsideration of the current C-133 design fire condition and the establishment of a plan for development of new fireworthiness criteria and standards for seat cushions.

Very truly yours,

AEROSPACE TECHNICAL COUNCIL

J. P. Reese - Director
Airworthiness Programs
for

U.S. Department
of Transportation
Federal Aviation Administration

800 Independence Ave., S.W.
Washington, D.C. 20591

October 16, 1981

Mr. J. P. Reese
Director, Airworthiness Programs
Aerospace Industries Association
of America, Inc.
1725 De Sales Street, NW.
Washington, D.C. 20036

Dear ~~Mr. Reese~~ Jack:

This is in reply to your letter of August 7 to this office and to Mr. Roy Reichenbach of the Technical Center, regarding the research and development program for improved fire resistant seat cushions. Mr. Reichenbach, the co-addressee, will reply to your letter separately on those particular program aspects of concern to the Technical Center.

Your expression of support of the program is most welcome. Your comments on page 2 largely reflect our understanding of the program as it stands today. We take some exception to your items 1 and 2. Fire blocking materials may not necessarily be limited to those you have mentioned and they may not increase the weight of the cushion. We are working toward publication of the information mentioned in item 3.

We fully appreciate your concerns with the technical areas discussed on page 3. Considering the advancements which have been made in the program to date, we believe your concerns are being taken into consideration, and that the program will progress to a satisfactory resolution of these issues. On August 25 and 26, subsequent to your letter, an informal meeting was held at the Technical Center with several representatives of the Federal Aviation Administration, the National Aeronautics and Space Administration (NASA), and industry to review the major technical aspects of the research and development work. It was the consensus of that meeting that the evaluation of improved fire resistant cushions should be based on credible fire scenarios, as you have suggested. Work is continuing on the investigation of fire scenarios.

We agree with you that criteria for a cushion should be based on performance rather than on the specification of a particular material or design. Performance criteria which fosters design innovation can promote both the use of fire blocking construction for polyurethane foam and the use of advanced foam materials such as polyimide, and thus give the designer an opportunity to optimize the materials and the cushion design. We are working currently with the NASA and several aircraft manufacturers on the evaluation of a small scale test which will be suitable as a basis for performance criteria. A round-robin test series is being conducted which we hope will guide us in this area.

We believe as the program progresses and you become more familiar with the details, that you will find the objectives of the program more to your liking. We invite you and your member companies to inquire informally at this office or the Technical Center at your convenience regarding the progress and status of the program.

Sincerely,

Jerry

Jerry Chavkin
Chief, Aircraft Engineering Division
Office of Airworthiness

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
ATLANTIC CITY AIRPORT, N.J. 08405

sources, we can prevent the occurrence of a self-sustaining cabin fire by using a cushion blocking layer.

On page 2 of your letter, you indicate that C-133 test results have not been documented. In this regard, our current plan is for a draft report in January 1982, and a published report in April or May 1982. A similar report date is planned for the FAA-sponsored optimization work at NASA Ames (item 4, page 2).

We share your concern that blocking layer materials should be selected based on a small-scale/laboratory test, not through the mandating of particular materials or design. Subsequent to your letter a working meeting was held at the Technical Center with representatives from FAA, NASA, and industry who agreed to participate in a round-robin test series to evaluate existing test procedures. The cooperation expressed by the parties involved was, I believe, unprecedented in a matter of this kind. A round-robin study is necessary to develop suitable test procedures for materials selection. Although it has been time consuming to secure ample quantities of the 11 material configurations agreed upon at the meeting, we expect these materials to have been delivered during November to the participating laboratories. Testing should be completed by February 1982, and a working meeting will follow as quickly as the data can be tabulated and analyzed.

We appreciate your interest and comments on our seat cushion fire blocking layer test program. If we can be of further assistance, please feel free to contact us at any time.

Sincerely,

R. E. Reichenbach

R. E. Reichenbach
Chief, Aircraft Safety Development
Division

10.2 OSU Test Results

SUMMARY OSU EVALUATION

HEATING RATE: 2.5 W/cm^2

AGENCY: DOUGLAS

CHARACTERISTIC: HEAT

CONFIG NO.	Q - $KW\text{-}MIN/m^2$					MAX. dQ/dt - KW/m^2	
	60 sec.	90 sec.	180 sec.	300 sec.	600 sec.	dQ/dt	Time - sec.
1	25.2	53.9	104.4	141	160	83 35	59 150
2	17.3	28.1	35.7	47	135	37.5 27.5	55 300
3	-	-	-	-	-	-	-
4	21.5	32.0	38.2	105	188	42.5 43.0	50 231
5	19.1	46.2	105.8	161	202	62.2 40.0	84 200
6	23.2	49.6	126.0	172	213	47 70.1	55 92
7	-	-	-	-	-	-	-
8	17.9	28.9	35.3	41	109	39.2 22.5	51 300
9	18.8	41.9	106.8	145	177	42.0 54.1	58 109
10	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-

SUMMARY OSU EVALUATION

AGENCY: BOEING

HEATING RATE: 2.5 W/cm^2

CHARACTERISTIC: HEAT

CONFIG. NO.	Q - J/cm^2					MAX dQ/dt - W/cm^2	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dQ/dt	Time - Sec.
1	263.	753.	1235	1898	2107	17.75 17.57	50 90
2	221.	411.	469	622	1133	13.67 5.65	25 270
3	231.	425.	524	955	1895	13.34 8.90	25 275
4	192.	420.	531	787	1241	14.29 4.81	25 300
5	215.	475.	714	1607	1977	12.56 10.81	25 150
6	205.	407.	539	1279	1956	12.32 10.27	25 205
7	243.	467.	638	1546	1983	13.78 11.99	20 155
8	224.	408.	463	745	1274	12.81 5.40	25 205
9	224.	429.	626	1338	1736	13.78 8.38	25 140
10	232.	447.	539	698	929	13.27	25
11	306.	536.	704	1005	1243	17.84	20

SUMMARY OSU EVALUATION　　AGENCY: BOEING

HEATING RATE: 5.0 W/cm^2　　CHARACTERISTIC: HEAT

CONFIG. NO.	Q - J/cm^2					MAX dQ/dt - W/cm^2	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dQ/dt	Time - sec.
1	499.	1219.	1541	1806	1930	21.59 26.38	10 35
2	355.	562.	733	1513	2326	18.19 12.04	10 150
3	347.	551.	724	1691	2273	18.24 13.32	10 125
4	378.	578.	730	1550	2325	20.55 13.75	10 160
5	390.	773.	1237	2214	2450	17.74 18.45	10 95
6	379.	700.	1192	2161	2446	21.23 18.17	10 110
7	393.	694.	1231	1834	2069	20.24 20.18	10 80
8	347.	567.	742	1419	1991	18.52 8.53	10 120
9	352.	644.	1108	1732	1975	18.73 16.73	15 80
10	354.	557.	712	1104	1546	18.71	10
11	450.	744.	942	1168	1387	26.69	10

SUMMARY OSU EVALUATION

HEATING RATE: 2.5 W/cm^2

AGENCY: FAA-ACT

CHARACTERISTIC: HEAT

CONFIG. NO.	Q - J/cm^2					MAX dQ/dt - W/cm^2	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dQ/dt	Time - sec.
1		13		54	109	.68	204
2		11		48	104	.63	236
3		17		66	143	.81	258
4		12		42	101	.81	260
5		10		50	99	.60	155
6		18		70	138	.95	227
7		21		68	136	.99	207
8		22		61	135	1.07	259
9		14		58	122	.99	211
10		14		52	114	.99	259
11		27		71	143	1.01	261

SUMMARY OSU EVALUATION

HEATING RATE: 5.0 W/cm^2

AGENCY: FAA-ACT

CHARACTERISTIC: HEAT

CONFIG. NO.	Q - J/cm^2					MAX dQ/dt - W/cm^2	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dQ/dt	Time - sec.
1		640		1542	1901	16.78	44
2		337		761	1273	15.16	23
3		341		993	1632	15.51	24
4		315		646	932	15.09	24
5		381		1055	1878	13.75	23
6		393		639	1102	14.30	24
7		383		1094	1735	14.80	24
8		339		695	1023	14.95	24
9		356		715	1362	14.88	25
10		346		628	832	15.30	23
11		410		808	1198	17.49	21

SUMMARY OSU EVALUATION

HEATING RATE: 5.0 W/cm^2

AGENCY: DOUGLAS

CHARACTERISTIC: HEAT

CONFIG NO.	Q - $KW\text{-}MIN/m^2$					MAX. dQ/dt - KW/m^2	
	60 sec.	90 sec.	180 sec.	300 sec.	600 sec.	dQ/dt	Time - sec.
1	51.1	68.2	117.7	139	151	75 40	36 120
2	34.6	46.1	97.2	141	182	55 50	22 125
3	-	-	-	-	-	-	-
4	36	49	114	162	201	59 62	17 115
5	51.9	80.7	132.7	165	197	57 79	25 57
6	46.3	81.9	141	175	200	58 77	25 68
7	-	-	-	-	-	-	-
8	35.4	47.8	96.0	132	164	58 47	22 125
9	47	80	127	155	174	55 72	25 66
10	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-

SUMMARY OSU EVALUATION — AGENCY: FAA-ACT

HEATING RATE: 7.5 W/cm^2 — CHARACTERISTIC: HEAT

CONFIG. NO.	Q - J/cm^2					MAX dQ/dt - W/cm^2	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dQ/dt	Time - sec.
1		837		1802	2042	20.79	48
2		409		1173	1880	16.90	15
3		408		1314	2036	17.69	18
4		379		967	1621	15.44	17
5		433		1632	2304	14.66	17
6		450		1247	2350	16.28	15
7		447		1487	2231	16.28	16
8		405		1040	1786	15.93	18
9		422		1349	1981	15.58	16
10		416		827	1187	17.02	17
11		486		1065	1437	21.08	15

SUMMARY OSU EVALUATION

HEATING RATE: 7.5 W/cm^2

AGENCY: BOEING

CHARACTERISTIC: HEAT

CONFIG. NO.	Q - J/cm^2					MAX dQ/dt - W/cm^2	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dQ/dt	Time - sec.
1	617.	1178.	1364	1556	1673	27.00 24.98	7 25
2	357.	524.	681	1618	1859	21.35 15.53	5 130
3	364.	547.	938	1710	1865	22.03 16.73	5 75
4	388.	549.	733	1653	1864	24.53 16.74	5 105
5	442.	1061.	1437	1729	1945	20.41 22.24	5 45
6	351.	682.	1110	1827	2013	15.06 18.91	20 95
7	406.	795.	1308	1654	1748	21.66 19.53	5 75
8	351.	496.	703	1223	1345	20.00 8.75	5 95
9	404.	848.	1215	1506	1700	22.89 18.00	5 55
10	342.	471.	556	718	768	20.82	10
11	954.	677.	773	887	986	31.49	5

SUMMARY OSU EVALUATION

HEATING RATE: 2.5 W/cm^2

AGENCY: DOUGLAS

CHARACTERISTIC: SMOKE

CONFIG. NO.	INTEGRATED SMOKE RELEASE - SMOKE					MAX SMOKE RELEASE RATE	
	60 sec.	90 sec.	180 sec.	300 sec.	600 sec.	Smoke/m^2	Time - sec.
1	10.3	13.6	21.1	23.3	25.4	39.4 7	52 150
2	1.4	2.1	4.7	21.9	73.9	53.3	302
3	-	-	-	-	-	-	-
4	1.5	1.7	2.7	56.7	69.4	4 41.8	45 223
5	2.7	10.9	23.1	27.5	30.6	27.7	87
6	6.6	16.7	39.8	41.3	42.8	21 31.4	55 81
7	-	-	-	-	-	-	-
8	5.7	9.2	19.5	40.8	96.1	9 47.2	45 302
9	5.2	16.0	35.4	36.5	38.1	18 28.9	60 85
10	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-

SUMMARY OSU EVALUATION   AGENCY: BOEING

HEATING RATE: 2.5 W/cm^2 CHARACTERISTIC: SMOKE

CONFIG. NO.	D_s					MAX dD_s/dt	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dD_s/dt	Time - sec.
1	20.	95.	122	147	147	2.92 1.23	40 80
2	5.	8.	8	8	59	.59 .75	30 240
3	8.	16.	20	73	203	.86 1.47	30 205
4	5.	9.	10	11	47	.52 .88	30 205
5	6.	23.	52	141	146	1.50 1.14	80 150
6	7.	23.	34	116	154	1.06 1.33	30 120
7	6.	12.	20	88	102	.55 .99	25 150
8	7.	11.	11	33	106	.63 .78	30 175
9	7.	20.	46	117	124	1.24 .87	115 140
10	7.	15.	15	15	16	.67	30
11	7.	10.	13	15	17	.66	25

SUMMARY OSU EVALUATION

HEATING RATE: 5.0 W/cm^2

AGENCY: BOEING

CHARACTERISTIC: SMOKE

CONFIG. NO.	D_s					MAX dD_s/dt	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dD_s/dt	Time - sec.
1	71.	122.	130	133	134	3.20 3.47	15 25
2	30.	68.	50	184	215	2.05 2.28	20 150
3	45.	84.	121	274	295	2.67 2.50	20 120
4	26.	43.	51	178	207	1.56 2.51	20 140
5	24.	65.	113	159	161	1.63 2.07	20 60
6	33.	84.	156	212	215	2.51 2.73	20 65
7	21.	51.	104	114	120	1.18 2.07	15 80
8	41.	59.	82	220	244	2.46 2.15	15 110
9	35.	75.	138	167	174	2.20 2.47	20 80
10	41.	68.	80	104	131	2.44	20
11	20.	35.	45	47	48	1.53	15

SUMMARY OSU EVALUATION

HEATING RATE: 2.5 W/cm^2

AGENCY: FAA-ACT

CHARACTERISTIC: SMOKE

CONFIG. NO.	D_s					MAX dD_s/dt	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dD_s/dt	Time - sec.
1		9		49	96	.97	156
2		8		16	18	.29	44
3		5		12	12	.26	52
4		5		10	10	.19	40
5		7		30	30	.68	72
6		6		26	26	.46	72
7		7		19	19	.29	50
8		4		11	11	.23	42
9		8		32	32	.46	56
10		7		17	17	.32	52
11		15		25	25	.71	50

SUMMARY OSU EVALUATION

HEATING RATE: 5.0 W/cm^2

AGENCY: FAA-ACT

CHARACTERISTIC: SMOKE

CONFIG. NO.	D_s					MAX d^{D_s}/dt	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	d^{D_s}/dt	Time - sec.
1		62		93	93	2.53	24
2		35		117	172	2.40	22
3		33		142	190	2.24	22
4		35		69	86	1.36	22
5		24		49	72	1.13	24
6		37		39	75	1.87	28
7		20		50	74	.74	30
8		27		82	87	2.01	24
9		29		46	88	1.78	28
10		26		28	28	1.23	24
11		14		19	33	1.04	16

SUMMARY OSU EVALUATION AGENCY: DOUGLAS

HEATING RATE: 5.0 W/cm^2 CHARACTERISTIC: SMOKE

CONFIG. NO.	INTEGRATED SMOKE RELEASE - SMOKE					MAX SMOKE RELEASE RATE	
	60 sec.	90 sec.	180 sec.	300 sec.	600 sec.	Smoke/m^2	Time - Sec.
1	23.1	28.3	40.9	44.4	53.2	57 15	22 100
2	19.8	22.32	83.9	97.2	99.7	53 84.4	25 121
3	-	-	-	-	-	-	-
4	20	24	102	114	118	44 109	20 112
5	29.3	37.1	44.5	45.0	46.8	53.3	30
6	28.9	46.8	55.6	56.5	59.5	56 58.2	30 65
7	-	-	-	-	-	-	-
8	21.4	24.1	86.4	100.9	103.4	53 85.3	26 125
9	34	48	54	54	55	65 49	24 55
10	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-

SUMMARY OSU EVALUATION

AGENCY: FAA-ACT

HEATING RATE: 7.5 W/cm^2

CHARACTERISTIC: SMOKE

CONFIG. NO.	D_s					MAX dD_s/dt	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dD_s/dt	Time - sec.
1		80		106	106	3.20	18
2		60		164	209	2.69	16
3		74		206	263	2.97	16
4		63		152	221	2.21	18
5		30		94	108	1.54	18
6		48		126	215	2.33	18
7		47		95	110	1.13	26
8		63		159	222	2.53	18
9		47		124	159	2.72	18
10		61		95	110	2.08	18
11		22		41	45	1.43	12

SUMMARY OSU EVALUATION

AGENCY: BOEING

HEATING RATE: 7.5 W/cm^2

CHARACTERISTIC: SMOKE

CONFIG. NO.	D_s					MAX dD_s/dt	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dD_s/dt	Time - sec.
1	98.	141.	142	143	144	4.75 5.00	15 25
2	66.	121.	192	352	354	3.20 3.66	15 100
3	78.	145.	246	329	331	4.39 4.12	10 80
4	68.	122.	192	340	349	3.13 4.06	10 100
5	45.	129.	149	155	161	1.70 3.61	10 40
6	43.	117.	181	216	216	2.69 2.30	25 90
7	38.	104.	153	158	158	2.94 2.51	40 65
8	71.	132.	220	303	309	3.84 3.30	15 80
9	56.	143.	174	178	182	3.22 3.46	15 40
10	56.	90.	112	168	188	3.31	15
11	36.	56.	58	62	68	2.62	10