5th Triennial International Fire and Cabin Safety Research Conference

Laboratory & Full-Scale Testing of Lightweight Aircraft Seat Cushion Materials

Presented to: Session on Materials Fire Safety

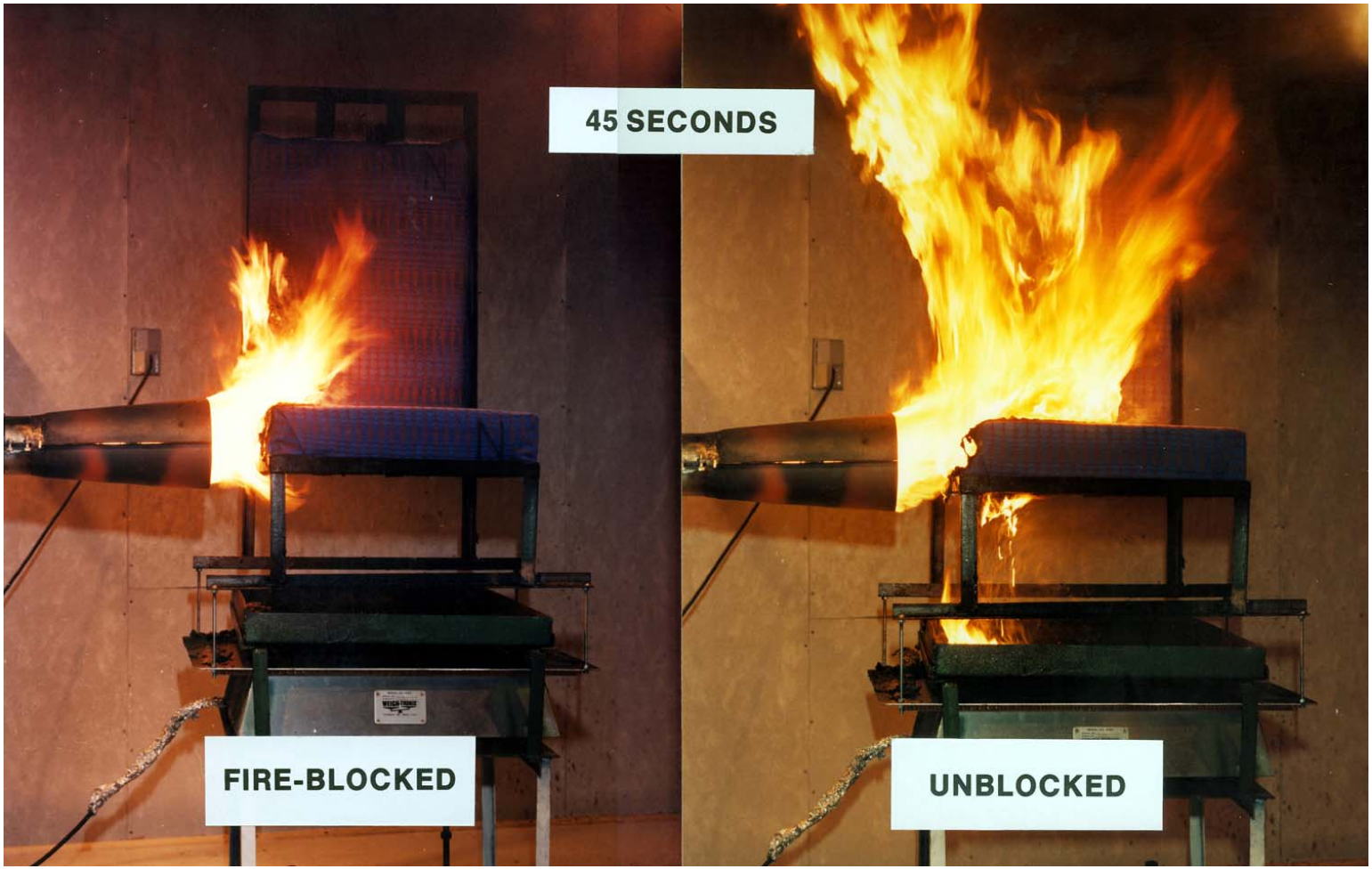
By: Tim Marker, FAA Technical Center

Date: October 30, 2007

Federal Aviation Administration

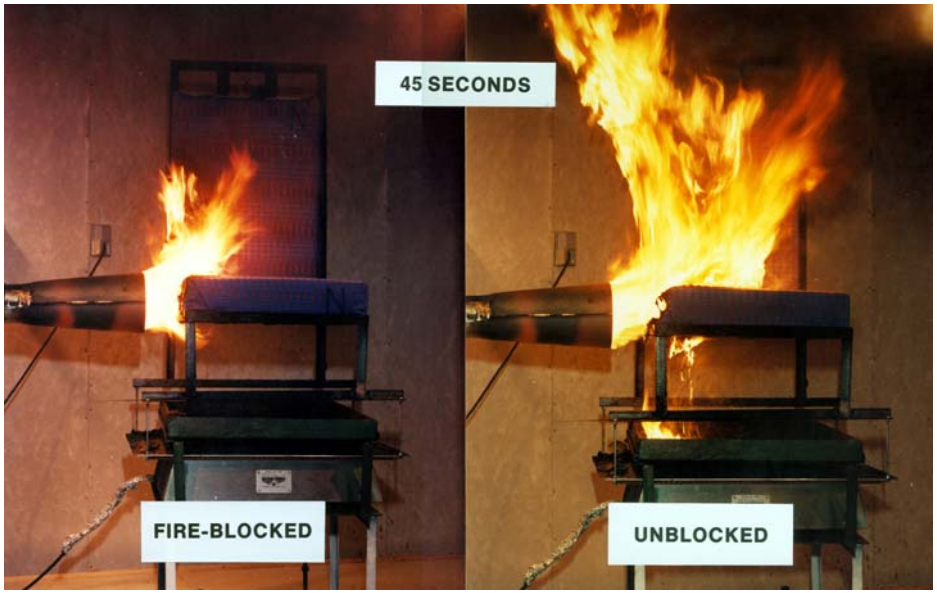
Early Full Scale Testing in C-133

FAA Flammability Test for Seat Cushions



Performance test based on results of full-scale tests

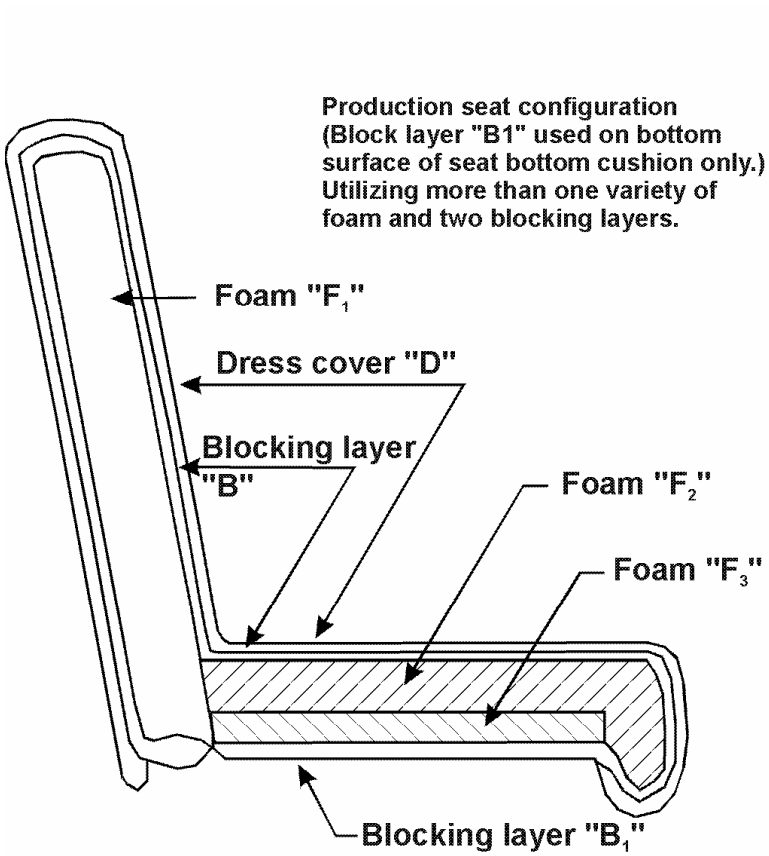
Seat Cushion Flammability Test Acceptance Criteria

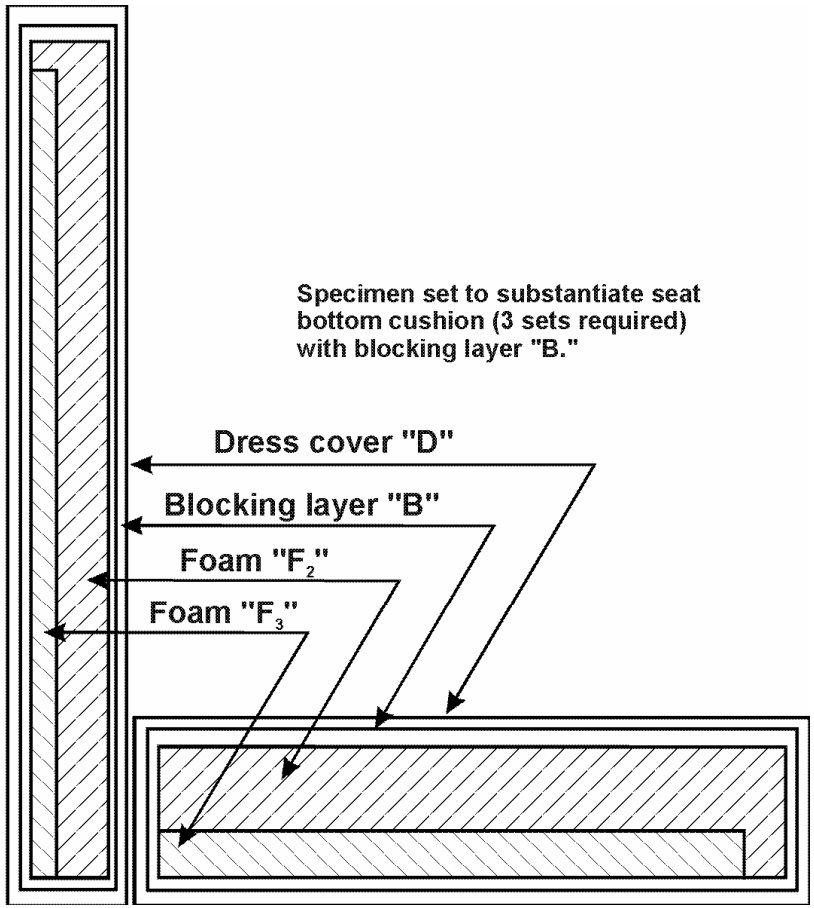


Burn length on any surface not to exceed 17 inches

Percentage weight loss not to exceed 10%

Test Specimen Fabrication





How is Standard Met?

Manufacturers historically used urethane foam and lightweight fire blocking layer to meet performance standard

Weight Loss Criteria

Problem: Next Generation aircraft seats utilizing lighter materials in their construction are unfairly restricted by the FAR-mandated 10% weight loss criteria.

% Weight Loss = (initial weight – final weight) / (initial weight) x 100

Example: 5 lb seat [(5.0-4.6) / 5.0] x 100 = 8.0% PASS

Example: 3 lb seat [(3.0-2.6) / 3.0] x 100 = 13.3% FAIL

Should standard be adjusted to reflect performance of new materials?

Proposed Testing: Evaluate performance of lightweight seat cushions under realistic conditions.

Testing Proposed by FAATC June 2002

Participants to supply 18 sets of test cushions to FAATC

Test cushion construction per FAR 25.853(c) Appendix F, Part II (or Handbook)

Back: 18 W x 25 H x 2 T Bottom: 18 W x 20 D x 4 T

FAATC randomly selects 6 sets of cushions to conduct lab-scale tests (oil burner)

Confirm seats exceed 10% weight loss ***If Yes,***

Proceed with full-scale evaluation using remaining 12 sets

Description of Materials

Baseline Seat 1 (6 tests)

Standard fire retardant foam, 2.75 lb/ft^3 density

PBI felt fire blocking fabric, 290 g/m^2

Standard 90/10 wool/nylon blend dress cover

Baseline Seat 2 (3 tests)

Standard fire retardant foam, 2.75 lb/ft^3 density

PBI felt fire blocking fabric, 290 g/m^2

Standard 90/10 wool/nylon blend dress cover

Description of Materials (con't)

Lightweight Seat A (6 tests)

Fire hardened foam, 0.62 lb/ft^3 density, no blocking layer

Dress Cover: Wool 91% / PA 9%, 375 g/m^2

Lightweight Seat B (6 tests)

Fire hardened foam, 2.2 lb/ft^3 density, no blocking layer

Dress Cover: Wool 90% / PA 10%, 380 g/m^2

Lightweight Seat C (6 tests)

Fire hardened foam 3.0 lb/ft^3 + lightweight foam 0.59 lb/ft^3, no blocking layer

Dress Cover: Wool 91% / PA 9% 380 g/m^2

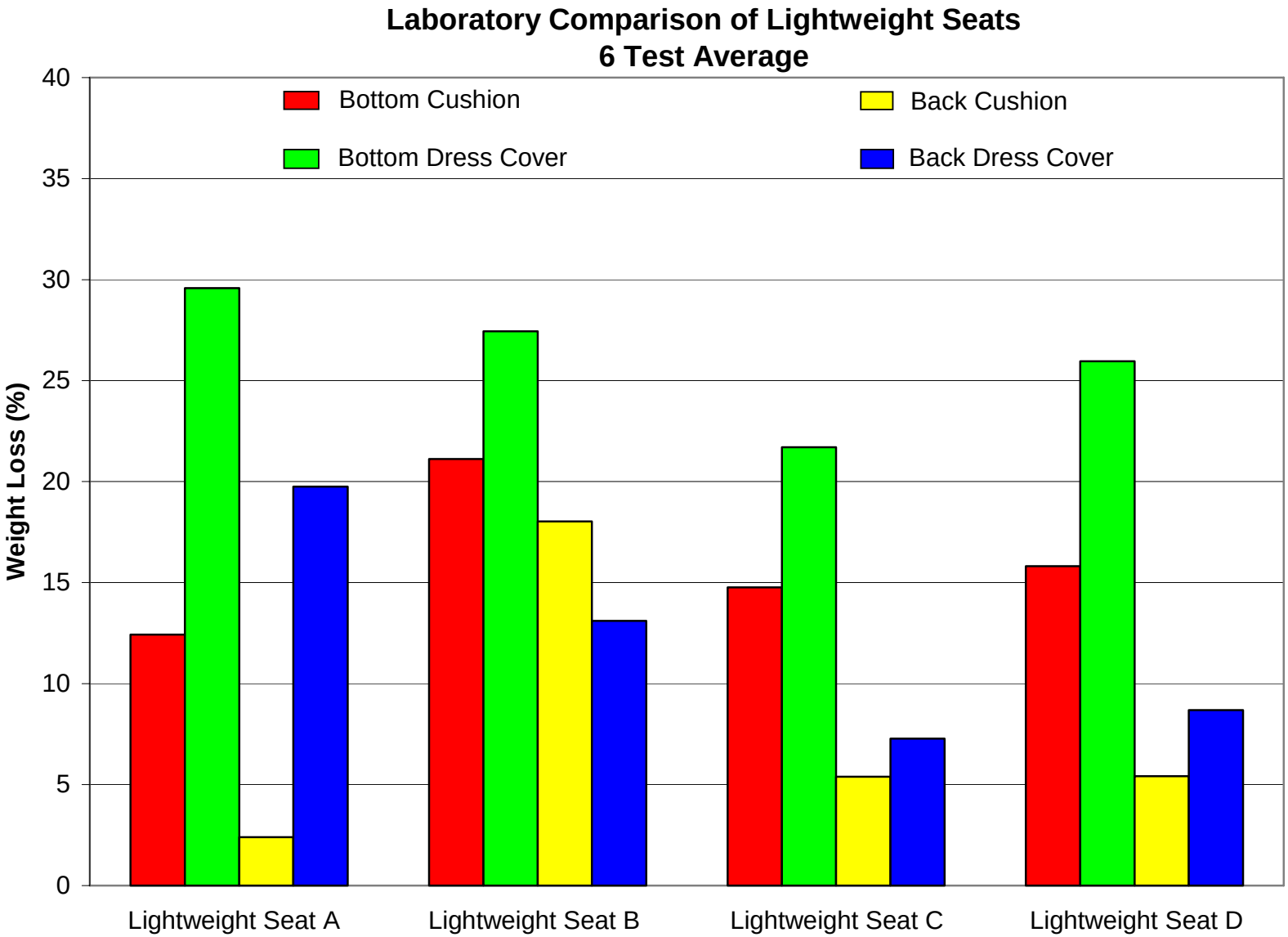
Lightweight Seat D (6 tests)

Lightweight foam 0.59 lb/ft^3, no blocking layer

Dress Cover: Wool 91% / PA 9% 380 g/m^2

Lab-Scale Test Results

Seat	Initial Weight Bottom Cushion (lbs)	Initial Weight Bottom Cover (lbs)	Initial Weight Back Cushion (lbs)	Initial Weight Back Cover (lbs)	Initial Weight Total (lbs)	Final Weight Total (lbs)	Weight Loss (%)	Avg Weight Loss (%)	
Baseline 1	2.25	0.75	1.48	0.78	5.26	4.94	6.03	7.96	PASS
	2.25	0.75	1.48	0.78	5.26	4.81	8.54		
	2.25	0.75	1.48	0.78	5.26	4.73	10.04		
	2.19	0.72	1.47	0.78	5.16	4.75	7.95		
	2.19	0.72	2.08	0.78	5.77	5.35	7.28		
	2.21	0.80	1.5	0.78	5.29	4.87	7.94		
Baseline 2	2.21	0.72	1.5	0.78	5.21	4.790	8.06	6.65	PASS
	2.22	0.74	1.52	0.79	5.27	4.970	5.69		
	2.22	0.75	1.56	0.79	5.32	4.990	6.20		
Lightweight A	0.55	0.71	0.42	0.77	2.45	2.07	15.50	18.00	FAIL
	0.54	0.69	0.41	0.75	2.39	2.01	15.89		
	0.54	0.69	0.41	0.75	2.39	1.96	17.99		
	0.54	0.70	0.41	0.75	2.40	1.80	25.00		
	0.54	0.70	0.41	0.76	2.41	1.98	17.78		
	0.54	0.70	0.41	0.75	2.40	2.02	15.86		
Lightweight B	1.86	0.74	1.19	0.78	4.56	4.06	10.96	12.11	FAIL
	1.83	0.74	1.18	0.78	4.54	4.01	11.67		
	1.83	0.74	1.15	0.78	4.50	3.98	11.56		
	1.86	0.74	1.15	0.78	4.55	3.98	12.53		
	1.86	0.74	1.18	0.78	4.58	4.02	12.23		
	1.83	0.74	1.17	0.78	4.52	3.90	13.72		
Lightweight C	1.48	0.56	1.05	0.60	3.68	3.07	16.62	11.94	FAIL
	1.46	0.55	1.06	0.57	3.64	3.23	11.21		
	1.46	0.54	1.06	0.60	3.65	3.28	10.10		
	1.46	0.54	0.95	0.57	3.52	3.10	11.84		
	1.42	0.55	1.05	0.58	3.60	3.21	10.95		
	1.44	0.55	1.03	0.58	3.60	3.21	10.95		
Lightweight D	1.01	0.55	0.80	0.60	2.97	2.57	13.33	13.41	FAIL
	0.98	0.55	0.79	0.58	2.91	2.52	13.41		
	0.99	0.54	0.83	0.58	2.94	2.54	13.70		
	0.99	0.54	0.83	0.58	2.94	2.54	13.70		
	1.00	0.56	0.83	0.57	2.97	2.58	12.99		
	0.99	0.55	0.84	0.58	2.97	2.57	13.33		


Laboratory Comparison of Lightweight Seats
6 Test Average
Bottom Cushion
Back Cushion
Bottom Dress Cover
Back Dress Cover
Weight Loss (%)
40
35
30
25
20
15
10
5
0
Lightweight Seat A
Lightweight Seat B
Lightweight Seat C
Lightweight Seat D

Analysis of Lab Tests, Lightweight Seats

- Bottom dress cover yields higher % weight loss than bottom cushion in all cases

- Back dress cover yields higher % weight loss than back cushion in all cases except B

- Ratio of total cushion weight to total dress cover weight ranged from .65 to 2.2

Lightweight Seat A ratio = 0.65

Lightweight Seat B ratio = 1.99

Lightweight Seat C ratio = 2.19

Lightweight Seat D ratio = 1.60

Full-Scale Test Parameters

Test Article

B707 fuselage, fully fire hardened interior

Instrumentation

Continuous gas analysis at 2 locations, 2 heights

Temperature measurement: 3 thermocouple trees + individual seat thermocouples

Smoke measurement: smoke-meters at 2 locations, 3 heights each

4 interior video cameras, 2 external

Interior Materials

0.25-Inch thick crushed-core Nomex honeycomb panels, meets 65/65

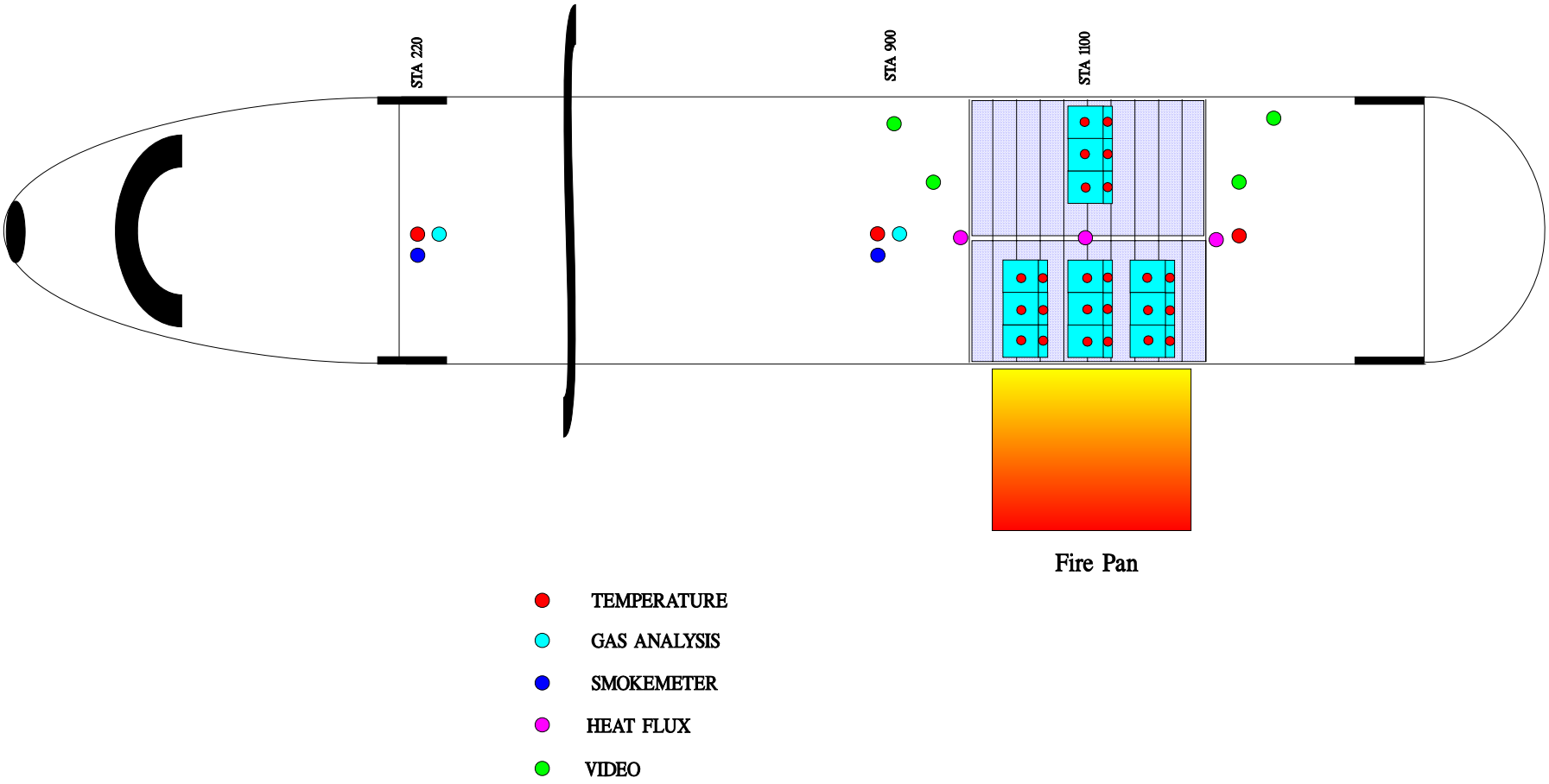
Aircraft-grade carpet, meets VBB

Test Execution

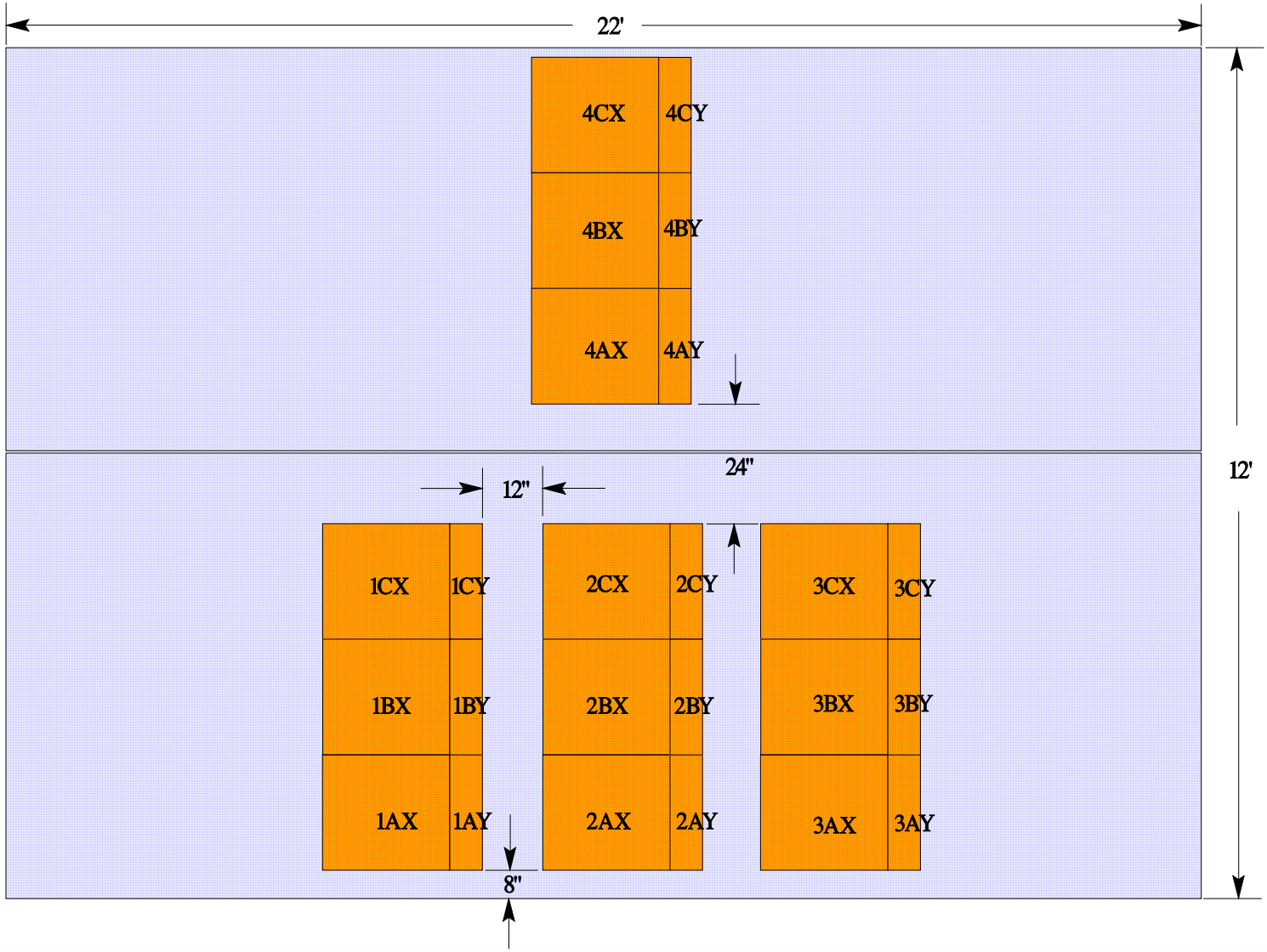
55 gallon JP8 fuel fire in 8’ by 10’ pan adjacent to fuselage

External fuel fire extinguished following noticeable flashover

Full-Scale Test Apparatus



Seat Layout & Thermocouple Location



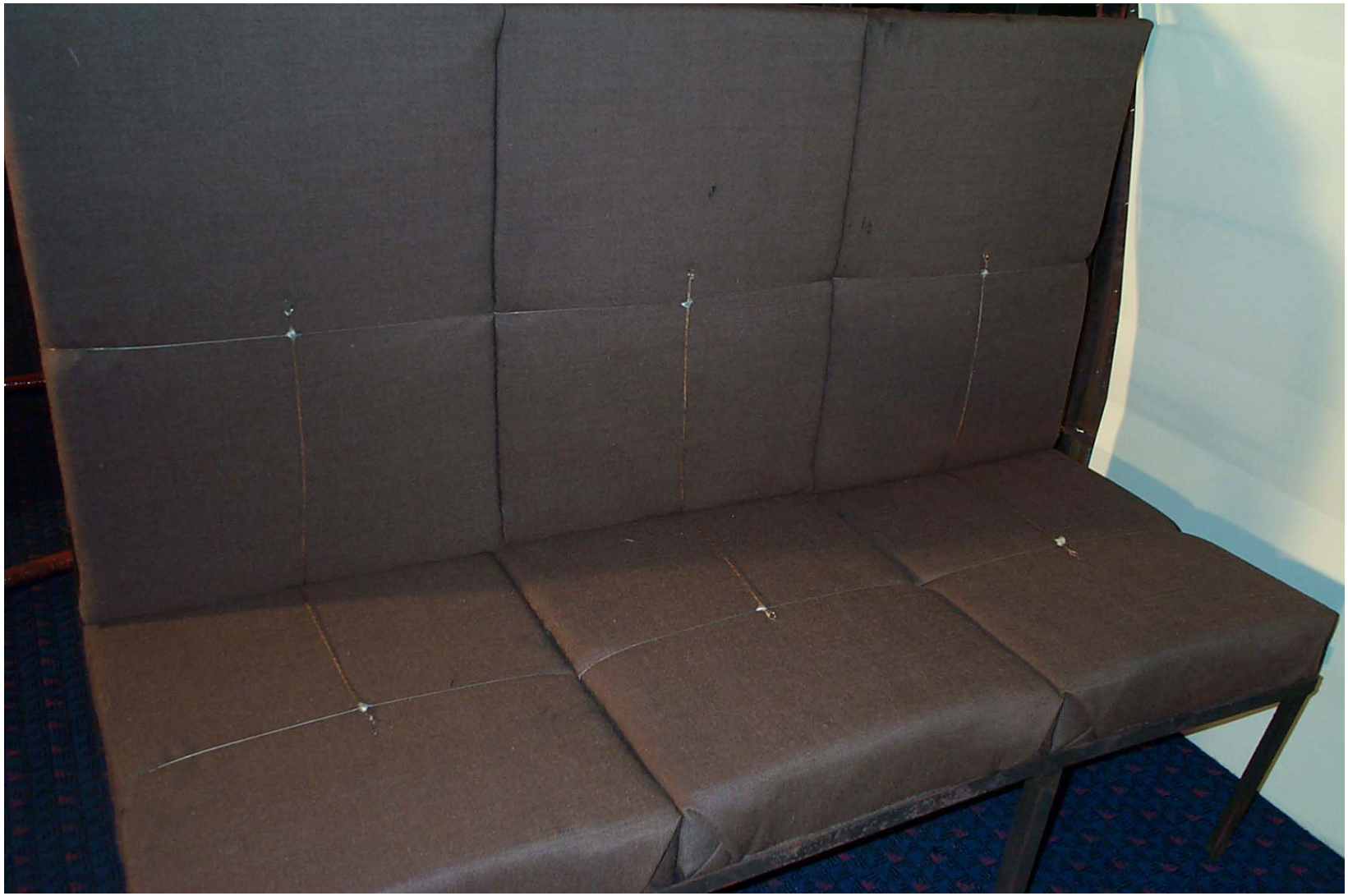
Full-Scale Test Configuration in 707

Full-Scale Test Configuration in 707

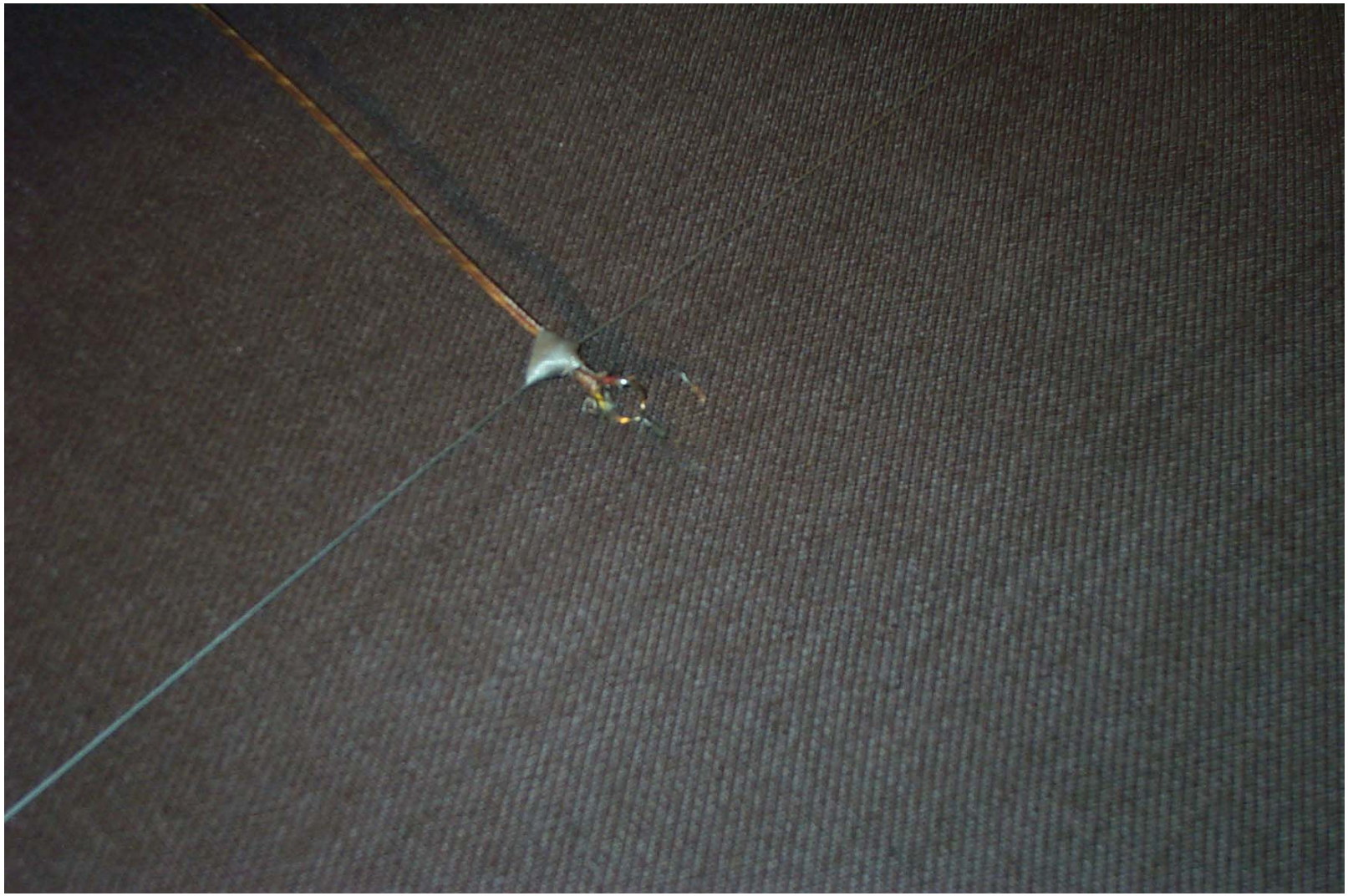
Full-Scale Test Configuration in 707

View Into Fire Door in 707

Thermocouple Placement on Seats



Close-up of Seat Thermocouple



Typical Cabin Fire @ 1:00

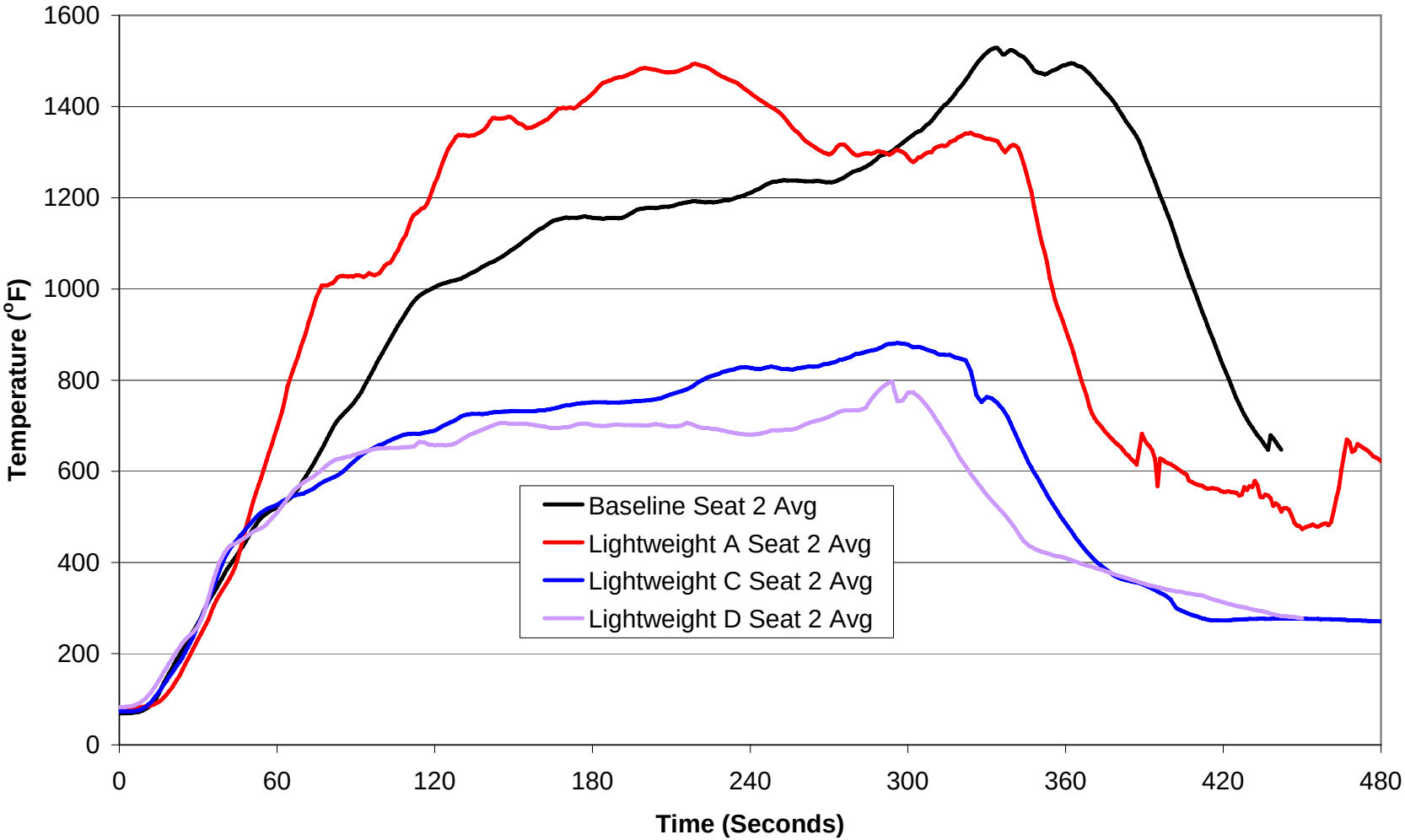
Typical Cabin Fire @ 2:00

Typical Cabin Fire @ 3:00

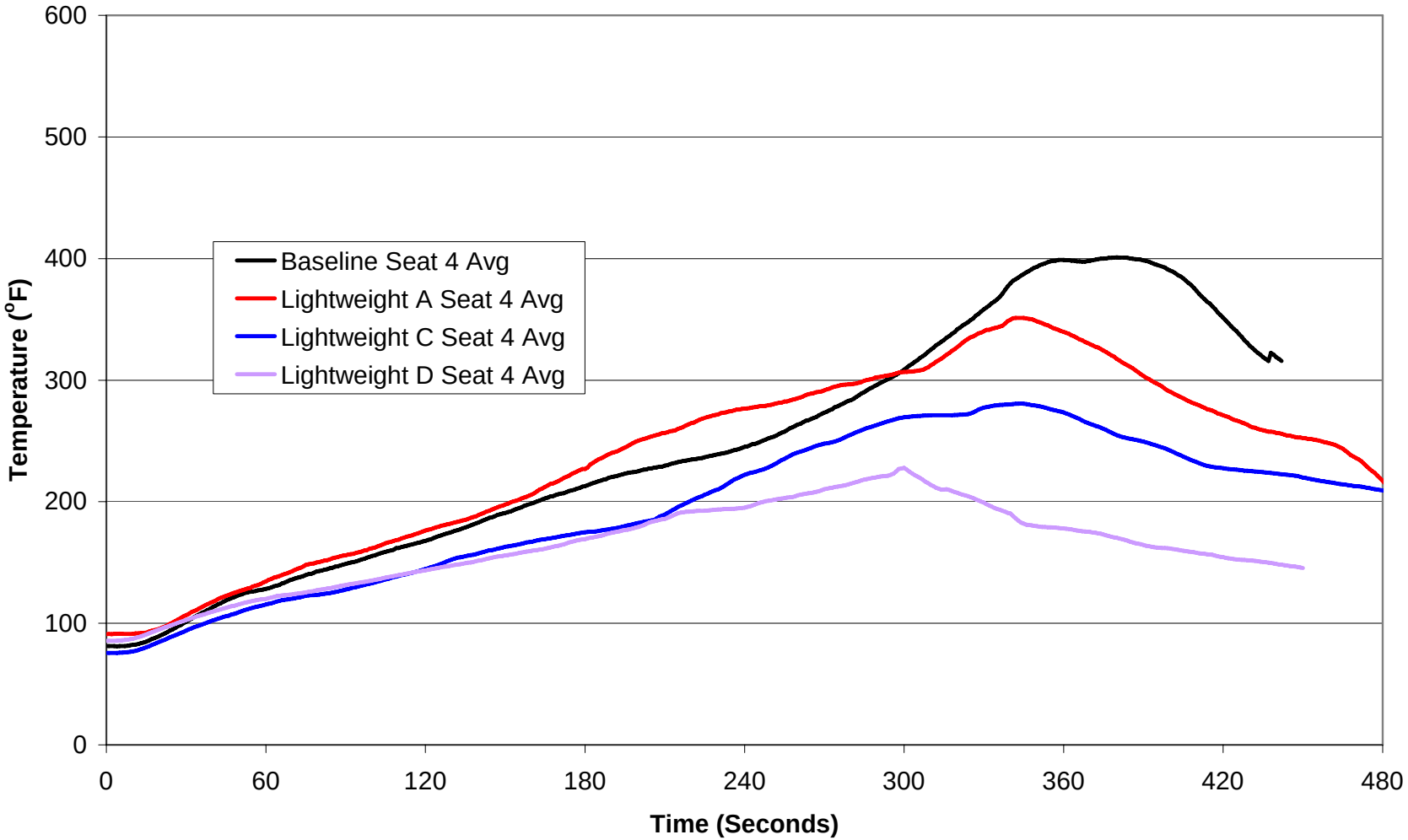
Typical Post Event

Full-Scale Test Results

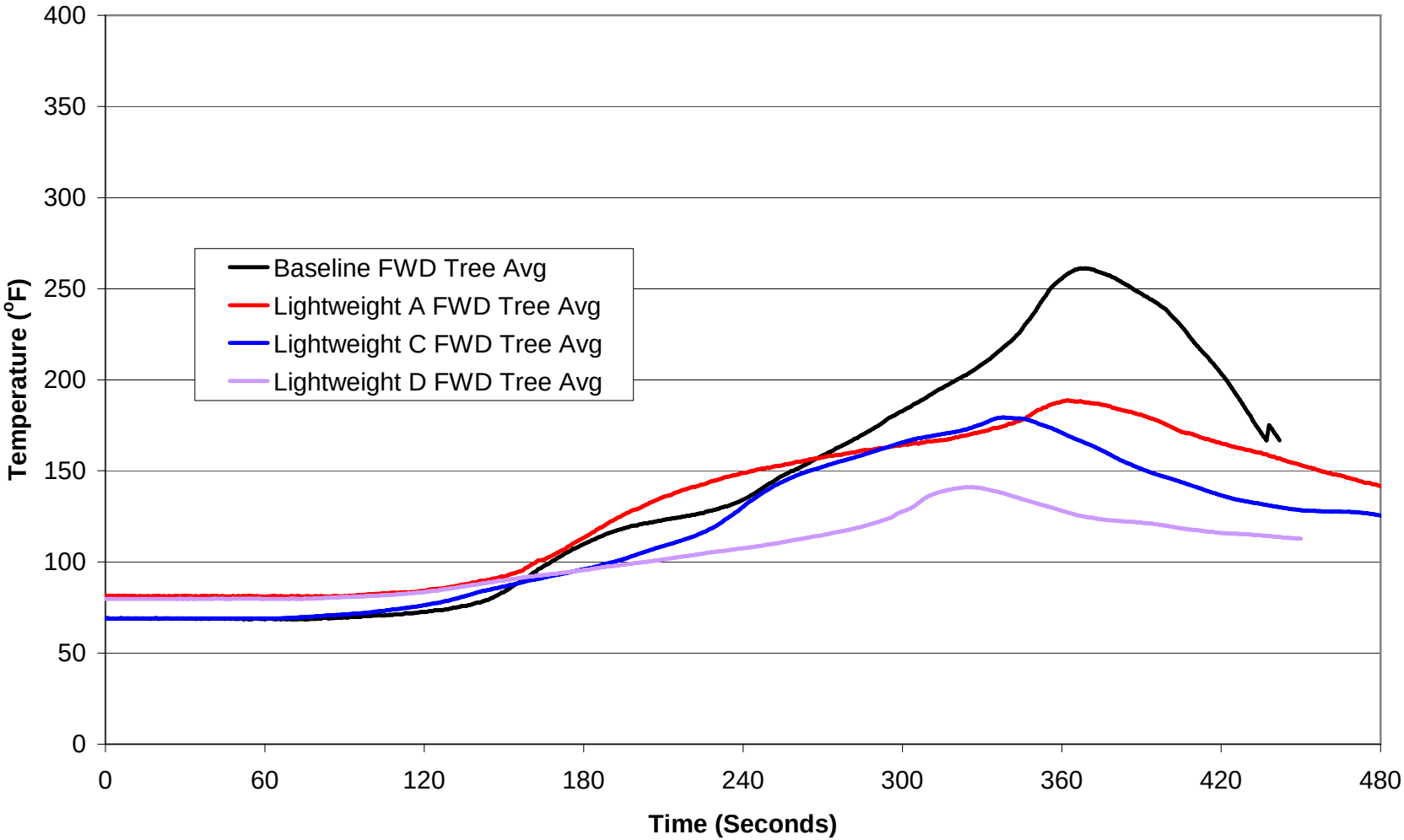
Seat 2 Temperatures



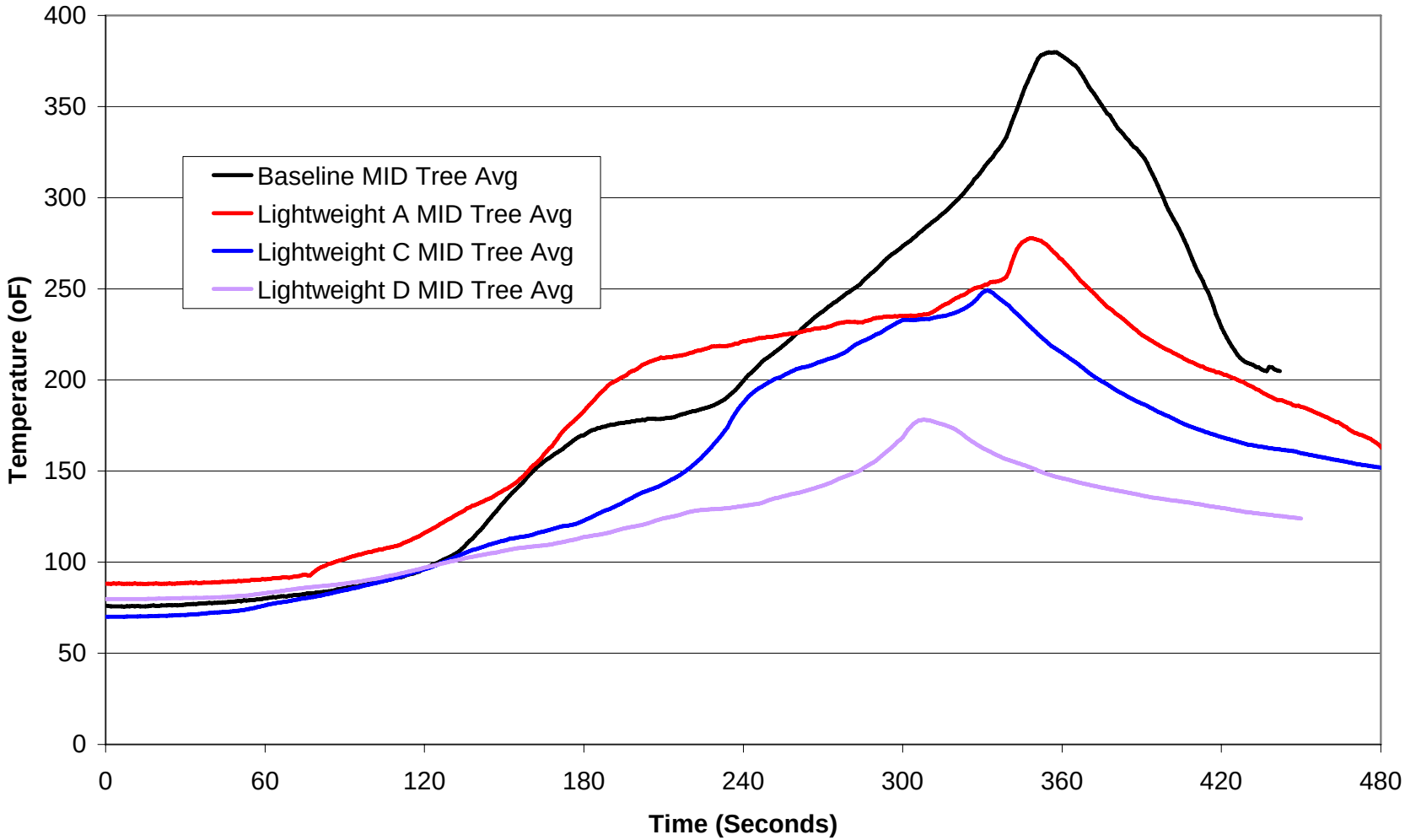
Seat 4 Temperatures



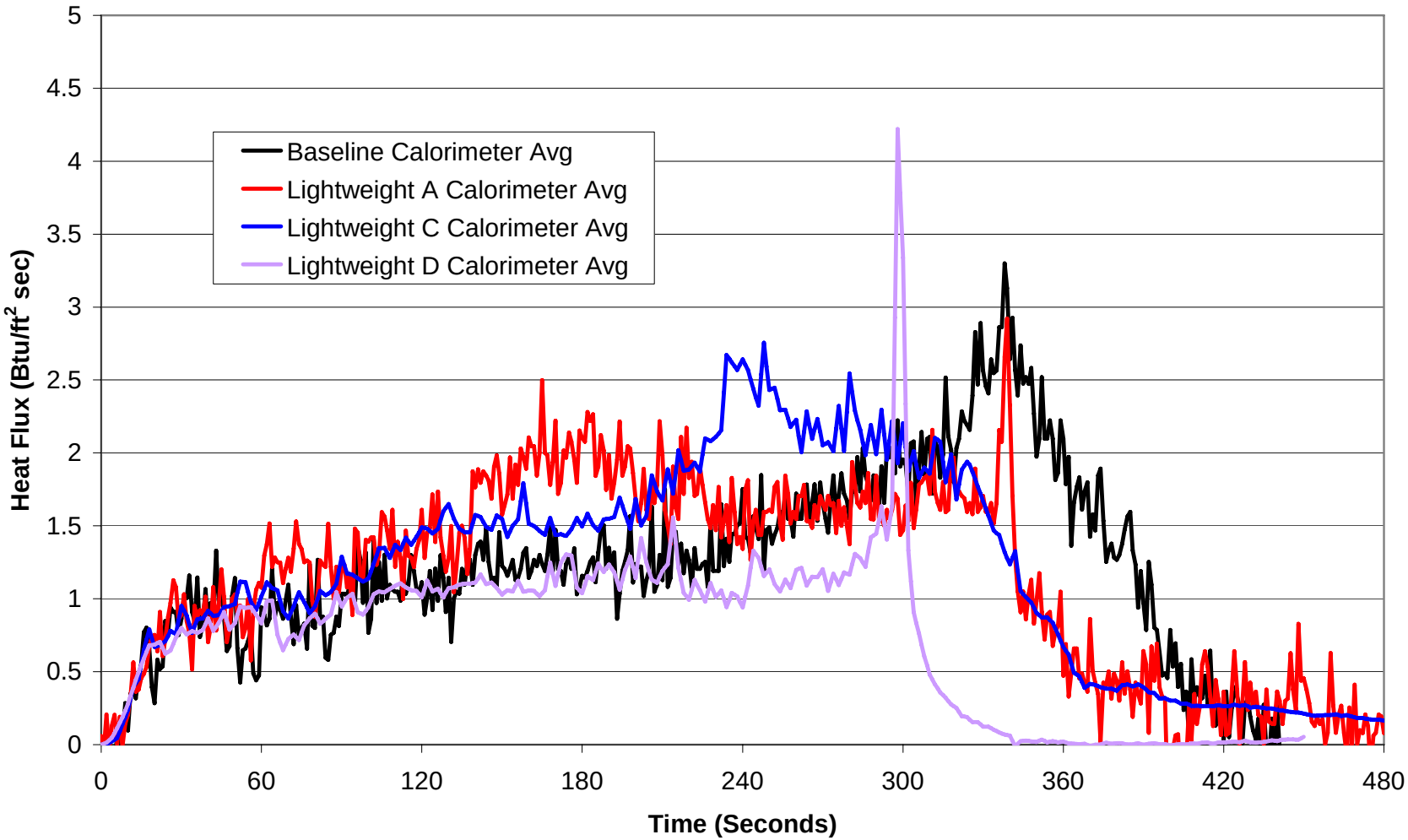
Forward Cabin Temperatures



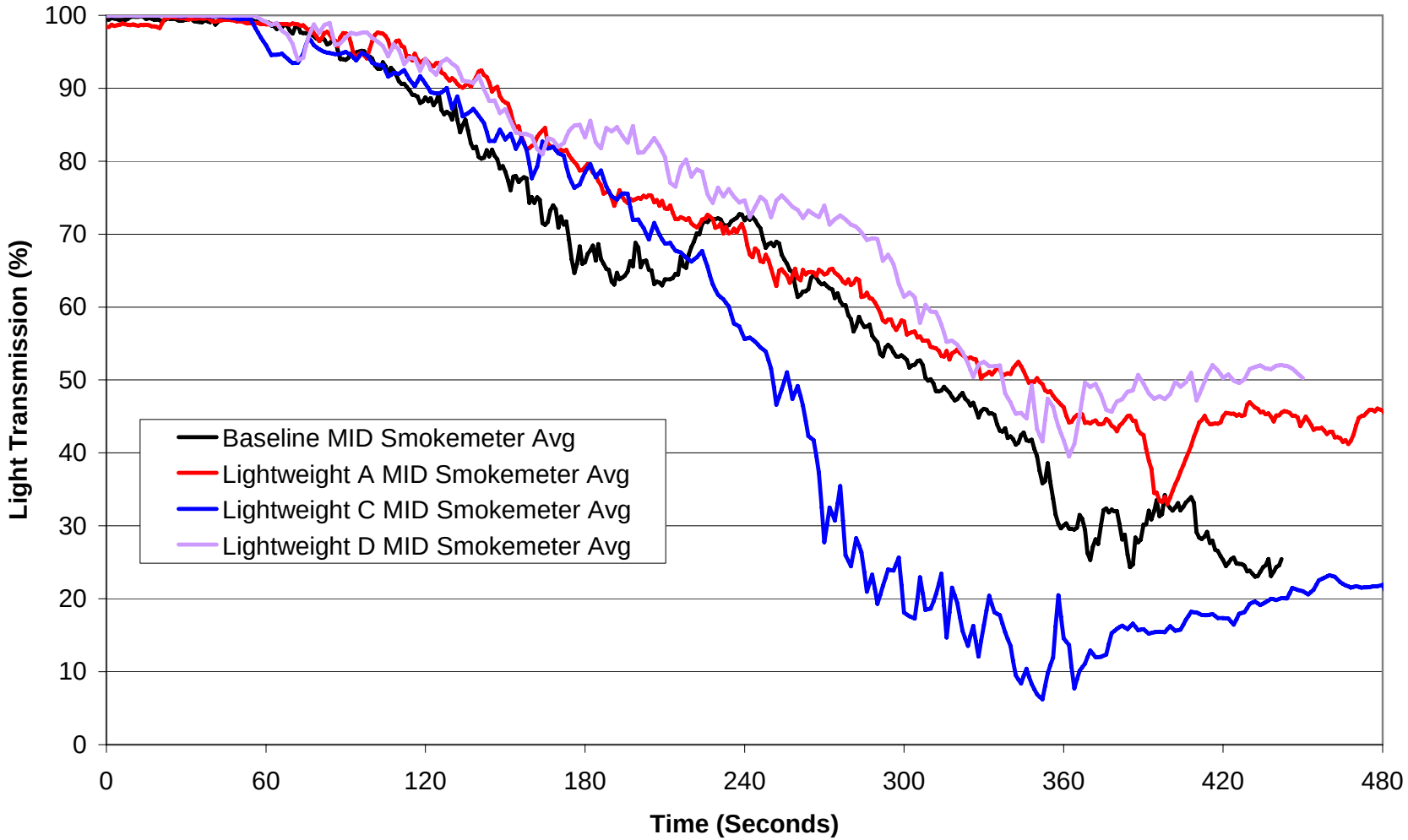
Mid Cabin Temperatures



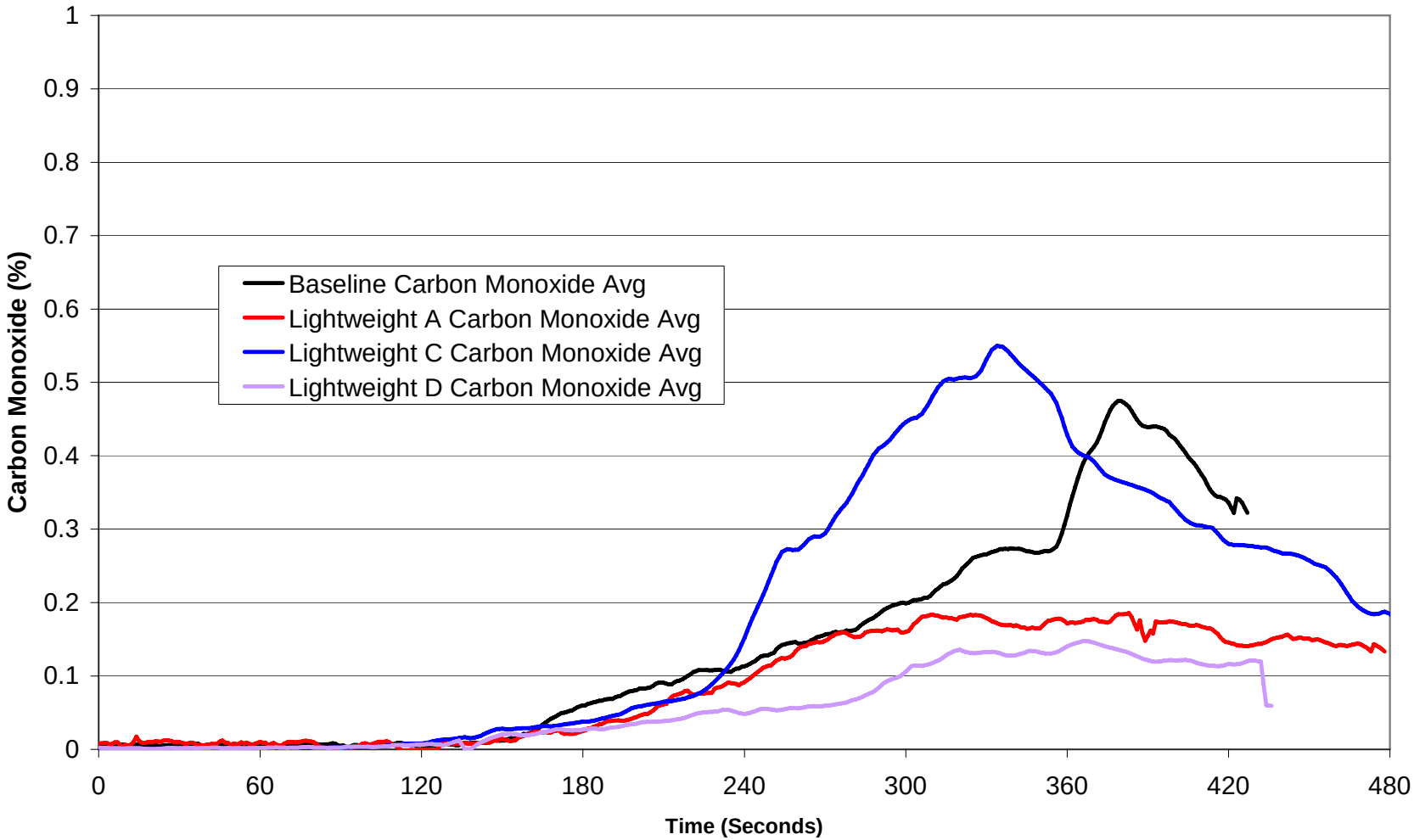
Cabin Area Heat Flux Level



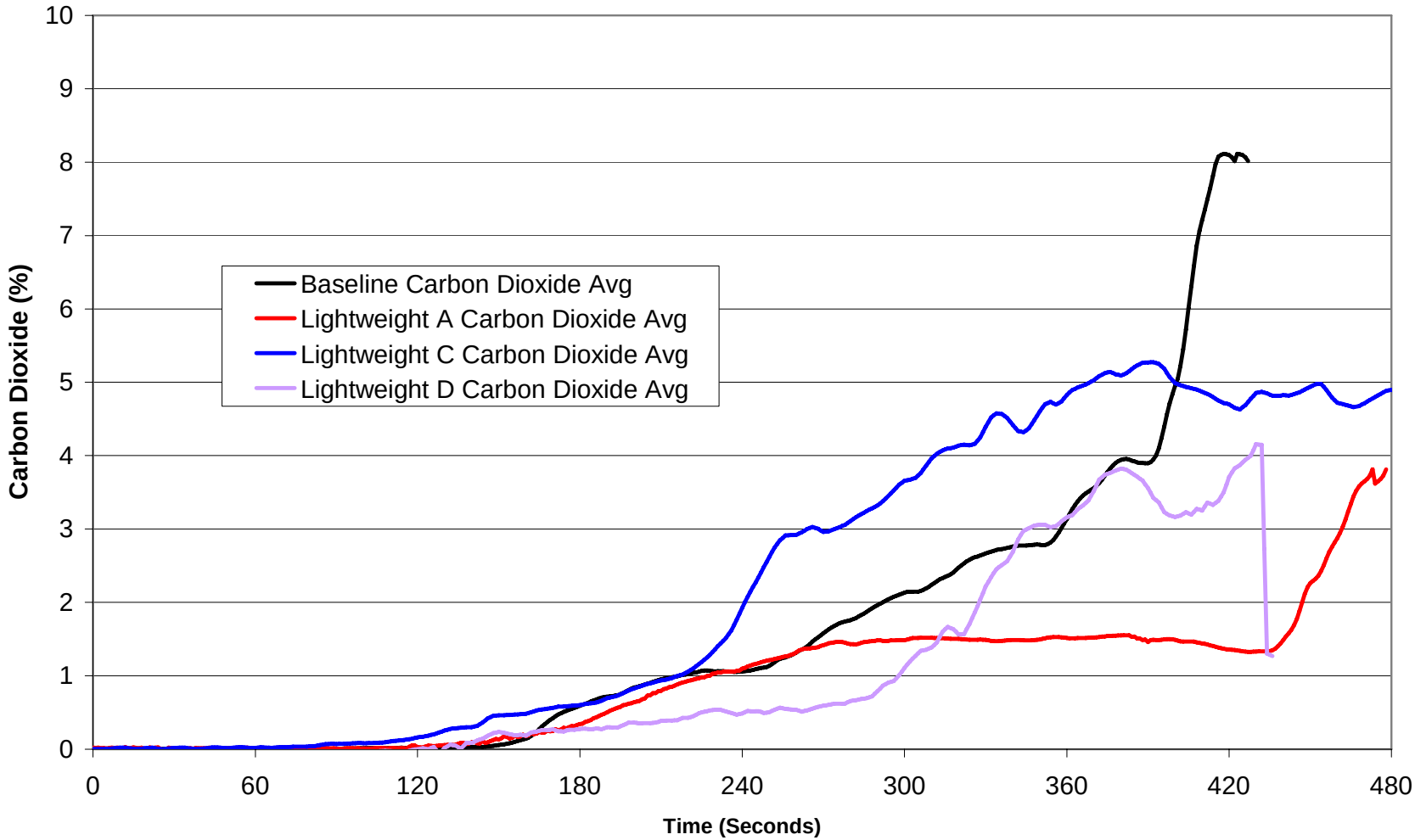
Mid Cabin Smoke Level

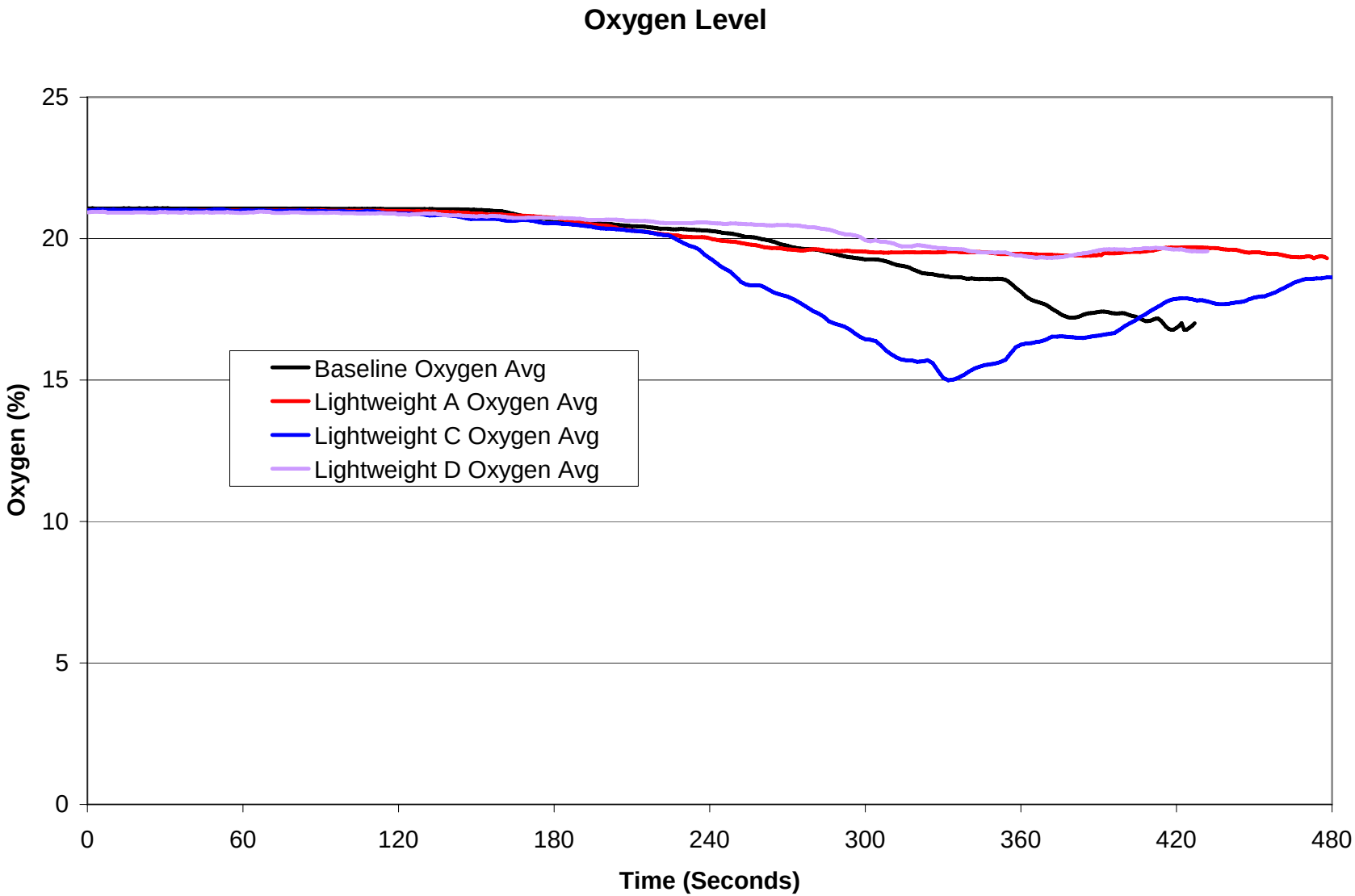


Carbon Monoxide Level



Carbon Dioxide Level




Oxygen Level
25
20
15
10
5
0
Oxygen (%)
0
60
120
180
240
300
360
420
480
Time (Seconds)
Baseline Oxygen Avg
Lightweight A Oxygen Avg
Lightweight C Oxygen Avg
Lightweight D Oxygen Avg

Full-Scale Test Analysis

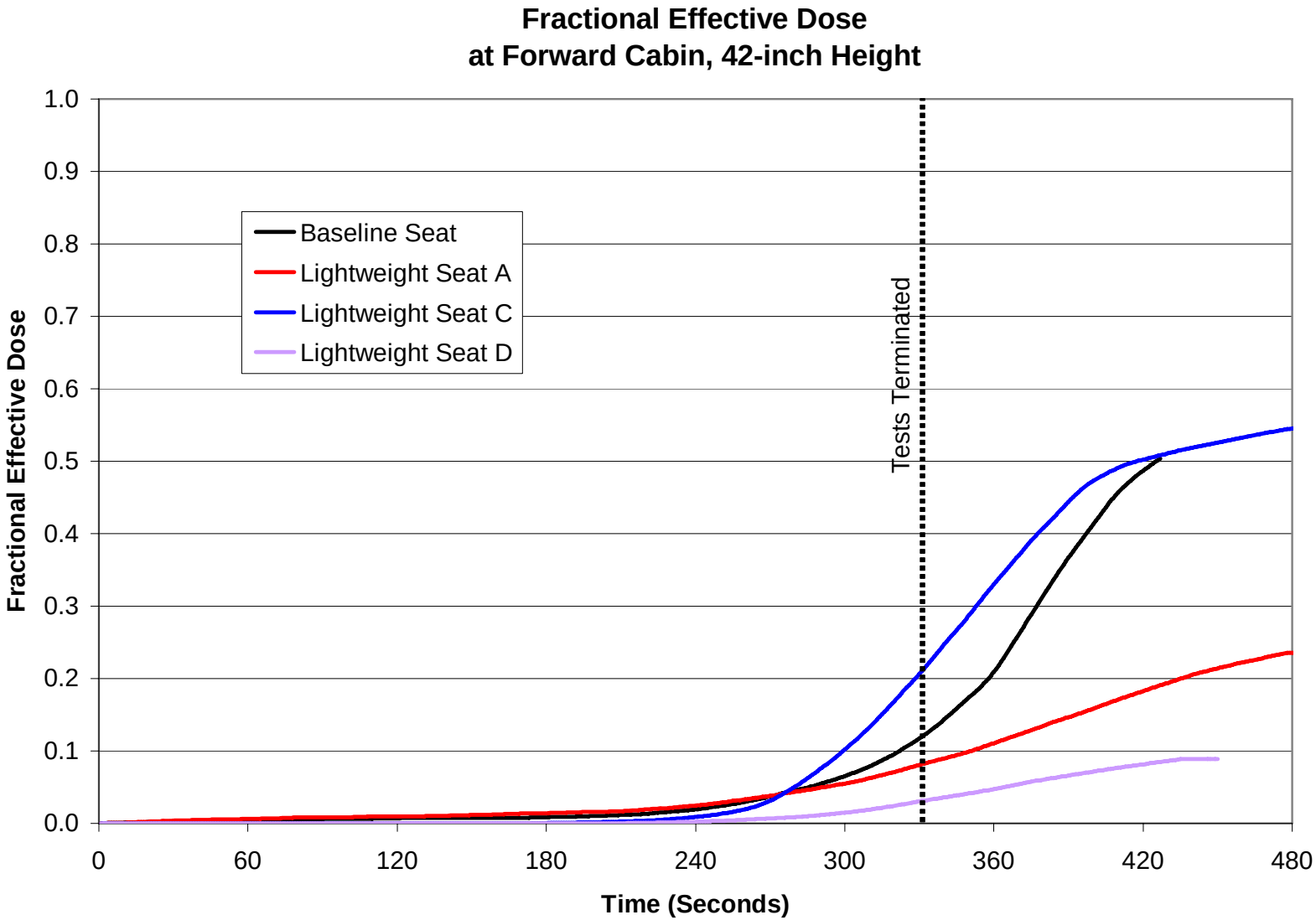
•Baseline test using traditional fire-blocked seats resulted in a flashover condition at approximately 5:00 minutes.

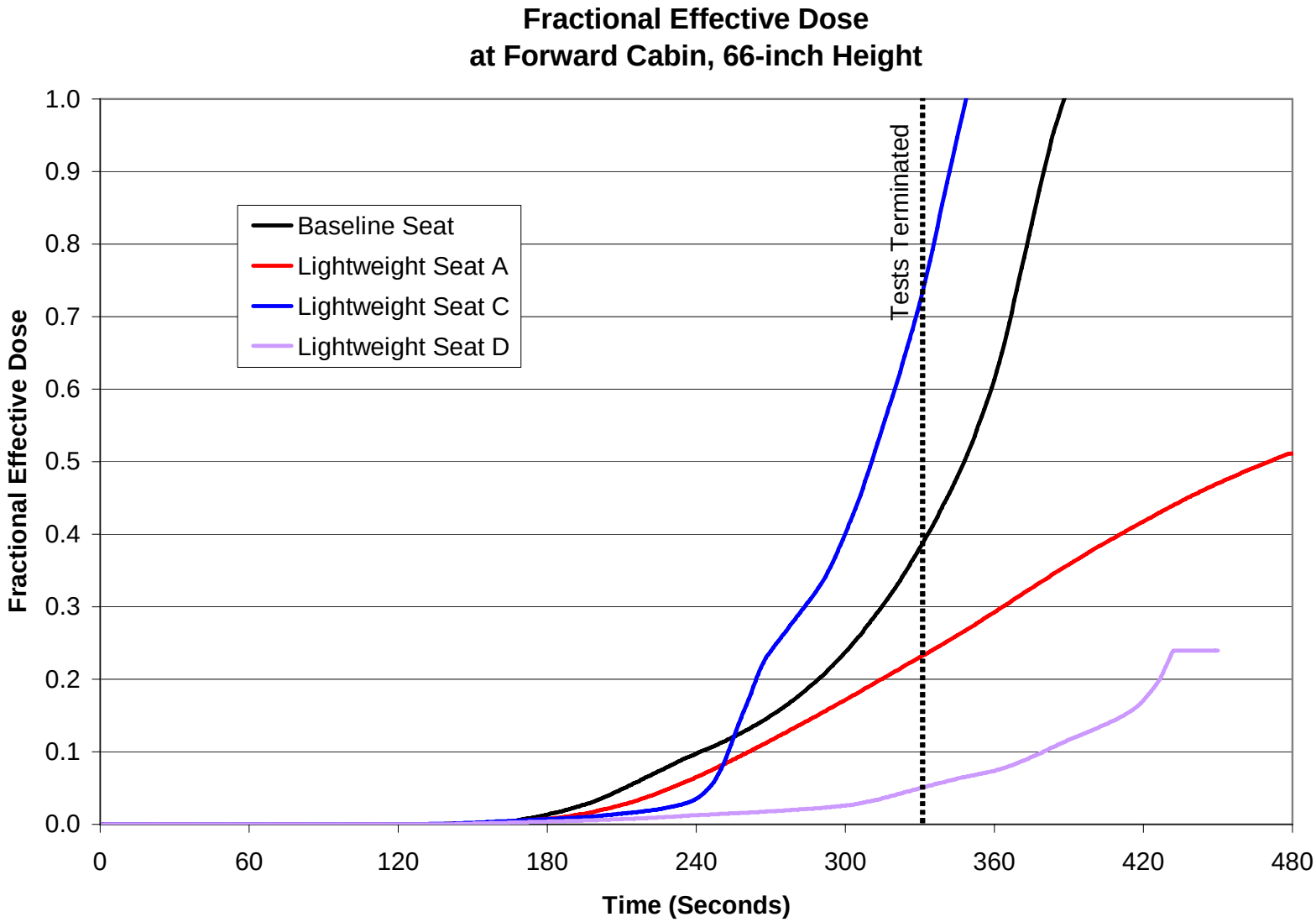
•Lightweight seats A, C, and D resulted in a more subtle flashover condition, occurring slightly later, approximately 5:00 to 5:30 minutes.

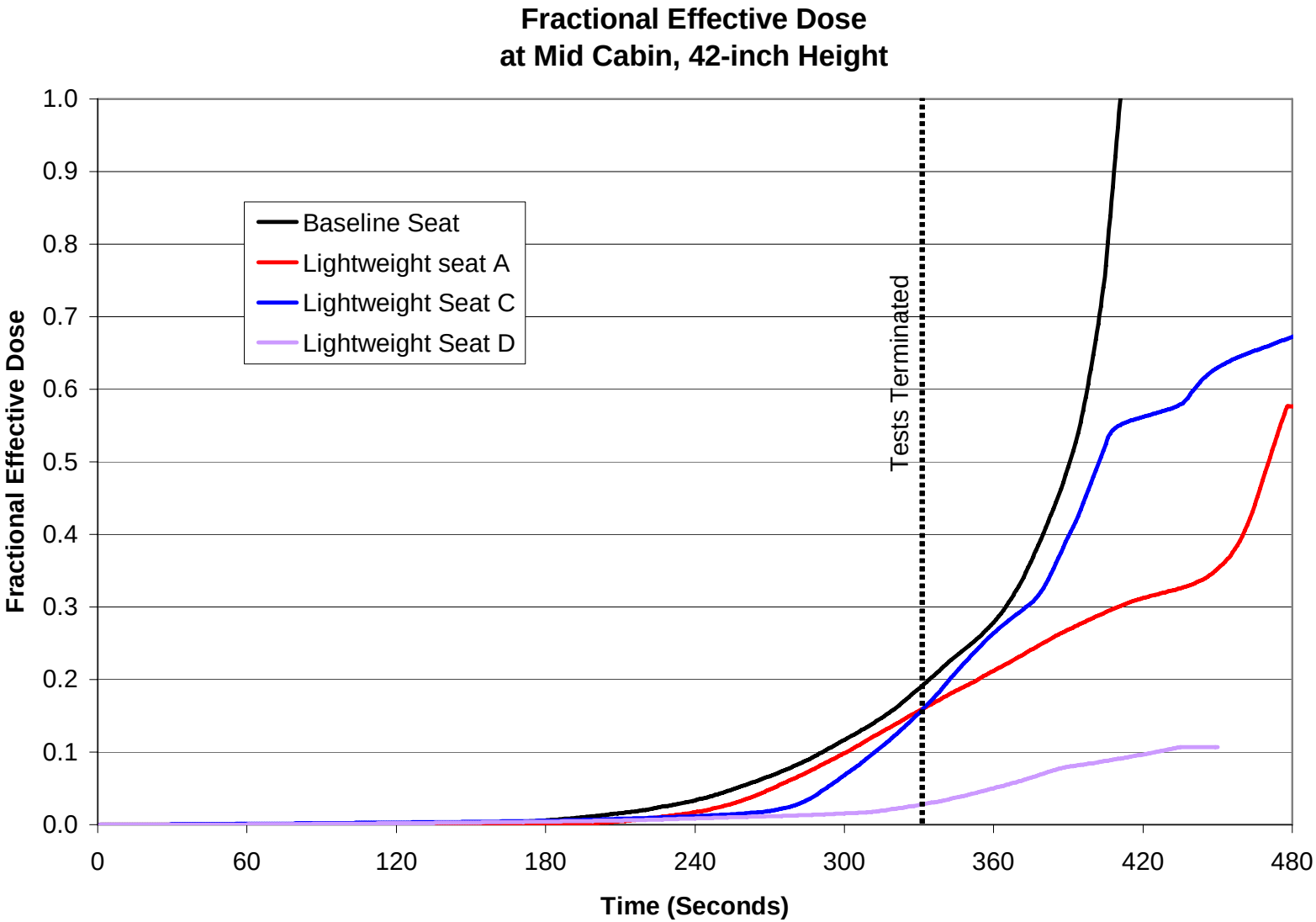
•Lightweight B resulted in a quicker flashover condition, approximately 3:30 from start.

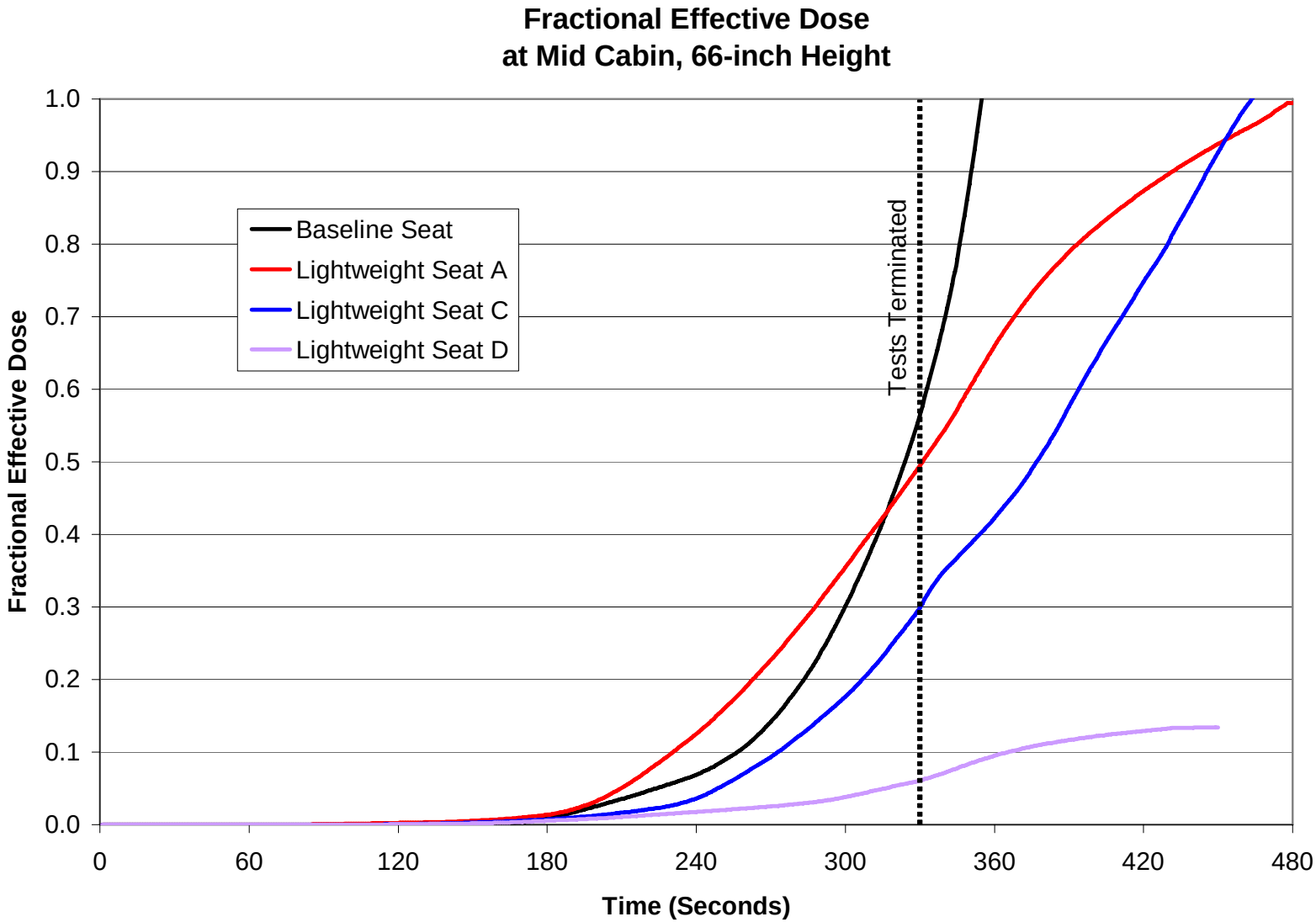
•Lightweight C produced more smoke and higher gas levels than all others.

•Lightweight D resulted in lowest temperatures, smoke, heat flux, and gas levels.


Fractional Effective Dose
at Forward Cabin, 42-inch Height
Fractional Effective Dose
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Baseline Seat
Lightweight Seat A
Lightweight Seat C
Lightweight Seat D
Tests Terminated
0
60
120
180
240
300
360
420
480
Time (Seconds)


Fractional Effective Dose
at Forward Cabin, 66-inch Height
Fractional Effective Dose
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
60
120
180
240
300
360
420
480
Time (Seconds)
Baseline Seat
Lightweight Seat A
Lightweight Seat C
Lightweight Seat D
Tests Terminated


Fractional Effective Dose
at Mid Cabin, 42-inch Height
Fractional Effective Dose
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
60
120
180
240
300
360
420
480
Time (Seconds)
Baseline Seat
Lightweight seat A
Lightweight Seat C
Lightweight Seat D
Tests Terminated


Fractional Effective Dose
at Mid Cabin, 66-inch Height
Fractional Effective Dose
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
60
120
180
240
300
360
420
480
Time (Seconds)
Baseline Seat
Lightweight Seat A
Lightweight Seat C
Lightweight Seat D
Tests Terminated

$$$$ What is Lightweight? $$$

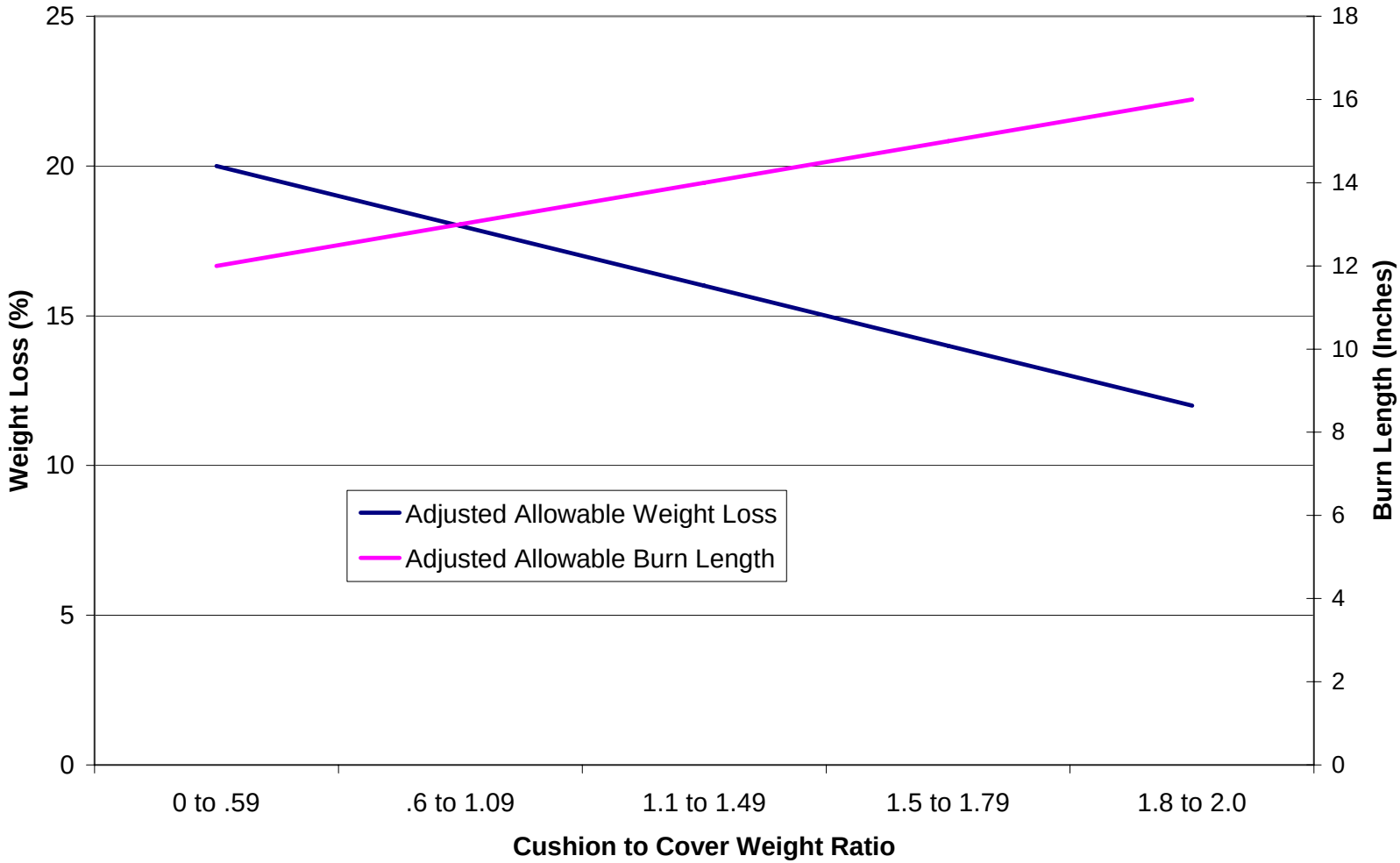
New Acceptance Criteria

Total Seat Weight (lbs)	Average Ratio of Cushion Weight to Cover Weight	Corrected Allowable Weight Loss (%)	Corrected Allowable Burn Length (Inches)
Less than 3	1.8 to 2.0	12	16
	1.5 to 1.79	14	15
	1.1 to 1.49	16	14
	.60 to 1.09	18	13
	0 to .59	20	12

Results When Applying New Criteria

Seat	Initial Weight Bottom Cushion (lbs)	Initial Weight Bottom Cover (lbs)	Initial Weight Back Cushion (lbs)	Initial Weight Back Cover (lbs)	Initial Weight Total (lbs)	Final Total (lbs)	Weight Loss (%)	Avg Weight Loss (%)	Ratio Cushion Weight to Cover Weight	Average Ratio	Corrected Allowable Weight Loss (%)	Pass/Fail
Baseline 1	2.25	0.75	1.48	0.78	5.26	4.94	6.03	7.96	2.44	2.49	10	Pass
	2.25	0.75	1.48	0.78	5.26	4.81	8.54		2.44			
	2.25	0.75	1.48	0.78	5.26	4.73	10.04		2.44			
	2.19	0.72	1.47	0.78	5.16	4.75	7.95		2.44			
	2.19	0.72	2.08	0.78	5.77	5.35	7.28		2.85			
	2.21	0.80	1.5	0.78	5.29	4.87	7.94		2.35			
Baseline 2	2.21	0.72	1.5	0.78	5.21	4.790	8.06	6.65	2.47	2.46	10	Pass
	2.22	0.74	1.52	0.79	5.27	4.970	5.69		2.44			
	2.22	0.75	1.56	0.79	5.32	4.990	6.20		2.45			
Lightweight B	1.86	0.74	1.19	0.78	4.56	4.06	10.96	12.11	2.01	1.99	10	Fail
	1.83	0.74	1.18	0.78	4.54	4.01	11.67		1.98			
	1.83	0.74	1.15	0.78	4.50	3.98	11.56		1.96			
	1.86	0.74	1.15	0.78	4.55	3.98	12.53		1.98			
	1.86	0.74	1.18	0.78	4.58	4.02	12.23		2.00			
	1.83	0.74	1.17	0.78	4.52	3.90	13.72		1.97			
Lightweight C	1.48	0.56	1.05	0.60	3.68	3.07	16.62	11.94	2.18	2.19	10	Fail
	1.46	0.55	1.06	0.57	3.64	3.23	11.21		2.24			
	1.46	0.54	1.06	0.60	3.65	3.28	10.10		2.21			
	1.46	0.54	0.95	0.57	3.52	3.10	11.84		2.16			
	1.42	0.55	1.05	0.58	3.60	3.21	10.95		2.17			
	1.44	0.55	1.03	0.58	3.60	3.21	10.95		2.17			
Lightweight D	1.01	0.55	0.80	0.60	2.97	2.57	13.33	13.41	1.59	1.60	14	Pass
	0.98	0.55	0.79	0.58	2.91	2.52	13.41		1.56			
	0.99	0.54	0.83	0.58	2.94	2.54	13.70		1.62			
	0.99	0.54	0.83	0.58	2.94	2.54	13.70		1.62			
	1.00	0.56	0.83	0.57	2.97	2.58	12.99		1.61			
	0.99	0.55	0.84	0.58	2.97	2.57	13.33		1.61			
Lightweight A	0.55	0.71	0.42	0.77	2.45	2.07	15.50	18.00	0.65	0.65	18	Pass
	0.54	0.69	0.41	0.75	2.39	2.01	15.89		0.65			
	0.54	0.69	0.41	0.75	2.39	1.96	17.99		0.65			
	0.54	0.70	0.41	0.75	2.40	1.80	25.00		0.65			
	0.54	0.70	0.41	0.76	2.41	1.98	17.78		0.65			
	0.54	0.70	0.41	0.75	2.40	2.02	15.86		0.65			

Cushion/Cover Ratio Vs. Weight Loss and Burn Length



What is the next step?

ANM-114 to release Policy Memo on the formalization of this new acceptance criteria, November 2007.