

Fire Testing of 3M™ Nextel™ Ceramic Fabrics for Aerospace Applications

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Abstract

An experimental investigation is performed to compare the thermal and flame performance of alternative fabrics made from ceramic fibers with different deniers. Commercially available Nextel™ 312 AF-10 is currently used in many flame barrier applications. This fabric design is based on lower denier input (600 d) that makes the manufacturing process slow and increases the fabric cost. Different fabric designs using high denier fiber (e.g. 900 d, 1800 d) are evaluated in comparison to commercially available Nextel™ 312 AF-10 fabric. An optimized fabric design is proposed that can be considered as an alternative in high temperature applications including where AF-10 is currently used. New fabric design and properties are presented alongside properties of commercial fabric(s) including AF-10. Comparative flame propagation and burn through resistance are also presented per FAR 25.856-a and FAR 25.856-b (fabric only, exposure for 5 min) and development test simulating performance per ISO2685 (fabric only, exposure for 15min).

Outlines

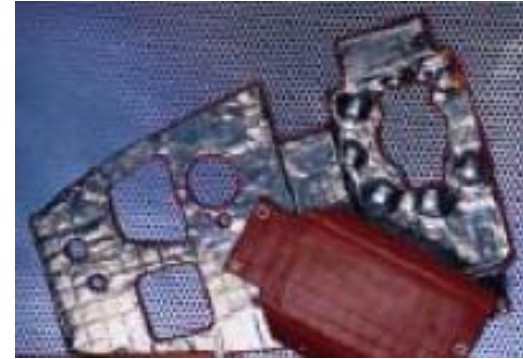
- Background
 - 3M™ Nextel™ Fiber
 - Fire Barrier Applications
- Fabrics Flammability Test
 - FAR 25.856-a and b
 - ISO 2685
- 3M™ Nextel™ Ceramic Fabrics Flammability Test Results
- Summary

Background

Commercial 3M™Nextel™ Ceramic Fabrics (e.g. AF-10, AF-12, AF-14) are used in Fire Barriers; They provide a combination of fire performance, lightweight and flexibility.

These fabrics are a key element in some fire proof structures (gaskets, seals, ducts, firewall).

3M has developed new fabric products in response to customers need for: lower cost while maintaining product performance.



3M™ Nextel™ Ceramic Fiber Products

Flexible Continuous Ceramic Fibers :

High Temperature Textiles

Reinforcement fibers for Composites



3M™ Nextel™ Ceramic Fiber Compositions

Property	Units	High Temperature		Structural	
		Nextel 312	Nextel 440	Nextel 610	Nextel 720
Chemical Composition	wt. %	62.5 Al ₂ O ₃ 24.5 SiO ₂ 13 B ₂ O ₃	70 Al ₂ O ₃ 28 SiO ₂ 2 B ₂ O ₃	>99 Al ₂ O ₃	85 Al ₂ O ₃ 15 SiO ₂
Crystal Phase		Distorted Mullite + Amorphous	gamma-Al ₂ O ₃ + Amorphous	alpha-Al ₂ O ₃	alpha-Al ₂ O ₃ + Mullite
Filament Diameter ¹	μm	8 – 12	10 - 12	11 - 13	12 - 14
Use Temperature ²	°C	1200	1300	1000	1150
Filament Tensile Strength (25.4 mm gauge)	MPa	1630	1840	2800	1940
Filament Tensile Modulus	GPa	150	190	370	250
Thermal Expansion (100-1100°C)	ppm/°C	3 (25-500°C)	5.3	8.0	6.0
Density	g/cc	2.8	3.0	3.9	3.4

¹ Measurement done on fiber micrograph, ² For N 312 and N 440 : 40% fiber strength retention tested at room temperature after 100 hours soak; N 610 and N 720 : Single filament ≤1 % strain under 69 MPa after 1000 hours. Typical property data not for specification use.

3M™ Nextel™ Fabrics : Typical Data Properties

Fabrics	Input Yarn	Weave	Thread Count (per inch) Warp/Fill	Weight (oz/yd ²) Sized/HC	Thickness (inch) Sized/HC	Breaking Strength (lb/inch)-HC Warp/Fill	Air Permeability
AF-9*	900 D	4 HS	31/31	7.3/7.2	0.014/0.012	160/160	Med
AF-10	600 D	5 HS	46/46	8.6/7.2	0.016/0.011	140/140	Med
AF-12	1200 D	5 HS	25/25	8.0/7.9	0.014/0.011	120/130	Med
AF-14	900 D ½ yarn	Plain Weave	20/17	9.0/8.8	0.015/0.014	120/120	High

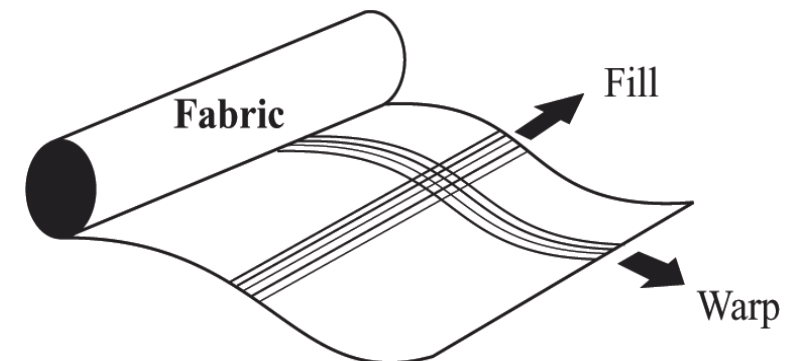
**Experimental Product*

HS : Harness satin, HC: Heat Cleaned

Air permeability (cfm/ft²) : Low (20), Med (20-70); High (> 70)

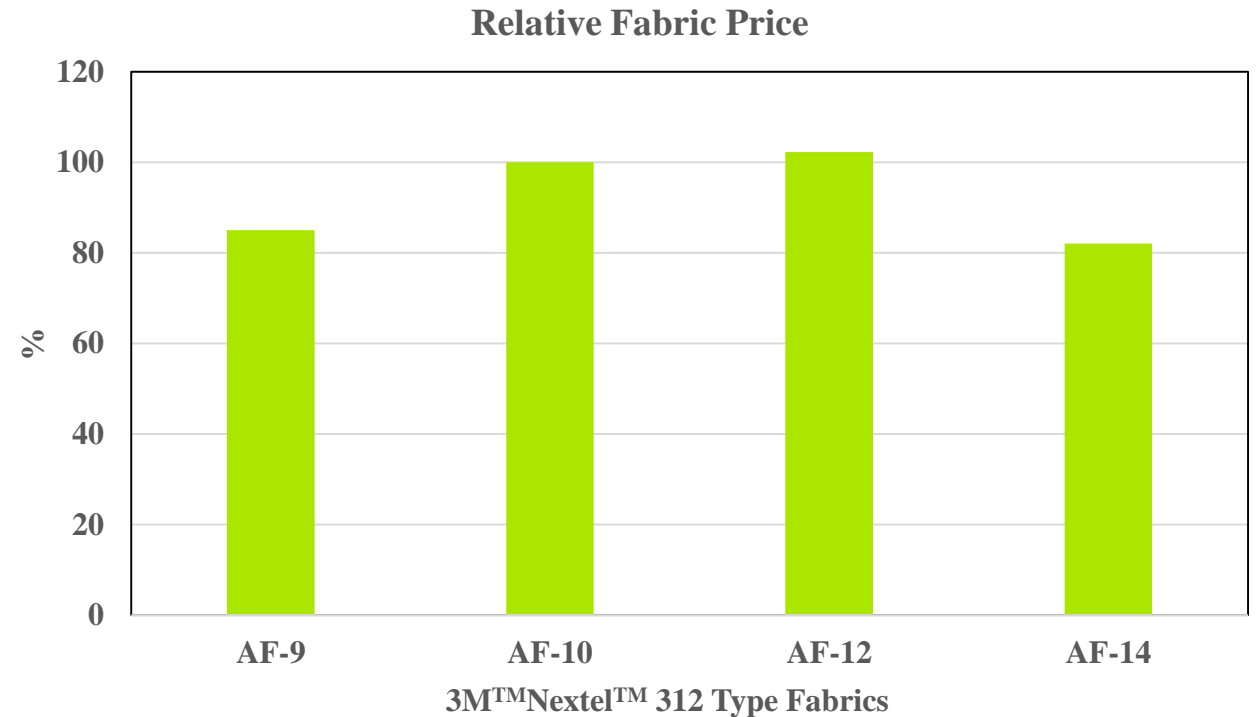
Fill – Ends that run crosswise in a fabric.

Warp – Ends that run lengthwise in a fabric.



Benefits of Higher Denier Product

- Lower cost
- Simpler weave
- Design challenge: comparable weight (AF-10 vs AF-9)



Incorporation of High Denier and Smart Weave Design can help to reduce the cost

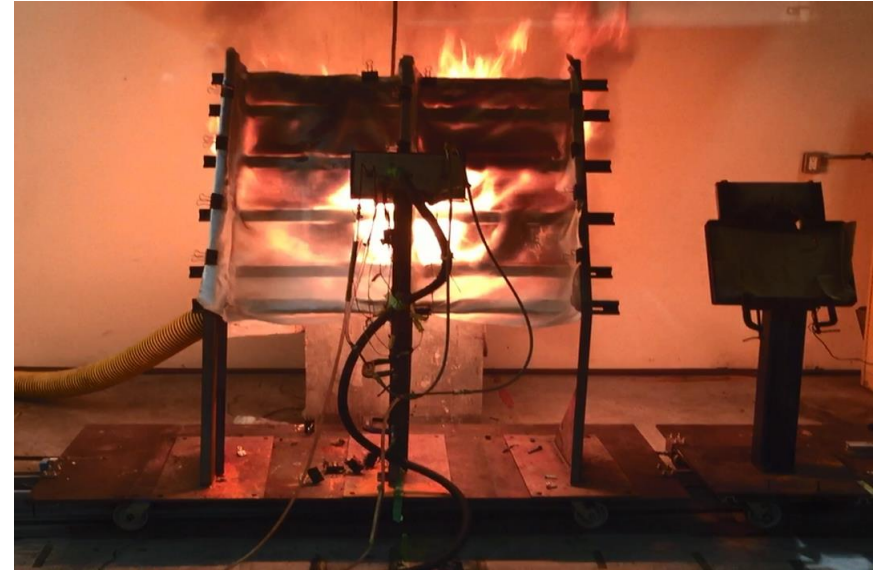
Flammability Test Lab (3M Canada Lab)

In house flammability testing capabilities for aerospace applications:

- Vertical / Bunsen Burner 12/60sec (FAR 25.853)
- Flame Propagation / Radiant Panel (FAR 25.856-a)
- Flame Penetration/Burn-trough (FAR 25.856-b)
- Fire Protection/Self Extinguishing (ISO 2685)

3M Canada Flammability Lab is listed in Appendix F of The Aircraft Materials Fire Test Handbook

3M Canada Flammability Lab set ups for both 25.856-a and -b have been found compliant by the FAA and Transport Canada in 2007, and since then used for certification testing by various OEMs and their suppliers.



3M™ Nextel™ Fabric Flammability Testing

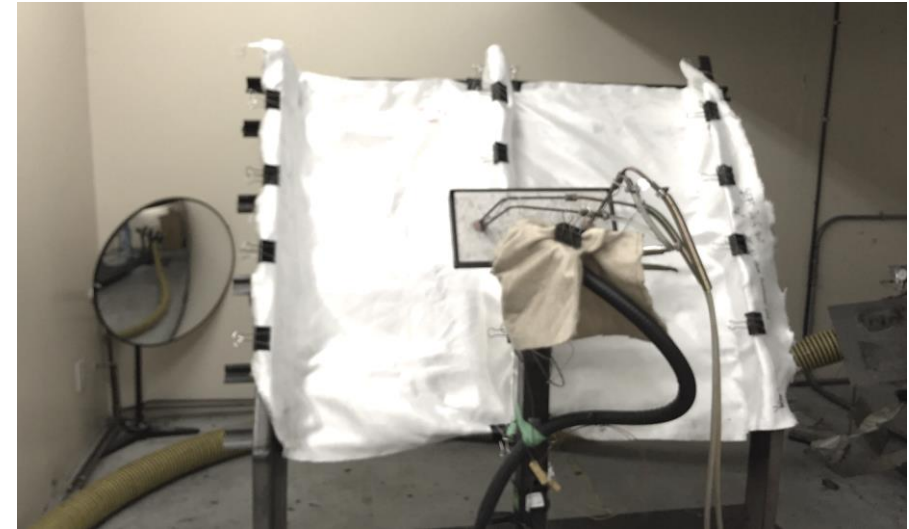
Application in Thermal/Acoustic Insulation :

- Evaluation of 3M Nextel fabrics to show compliance to FAA requirements for Thermal/Acoustic insulation blankets for flame propagation and burn-through, per FAR 25.856 a/b;

Application in all components, equipment and structures located in zones designated as "fire zones" :

- Evaluation of two 3M Nextel fabrics as fire barrier elements when exposed to fire test conditions corresponding to the requirements in ISO 2685 standard;

FAR 25.856 a/b

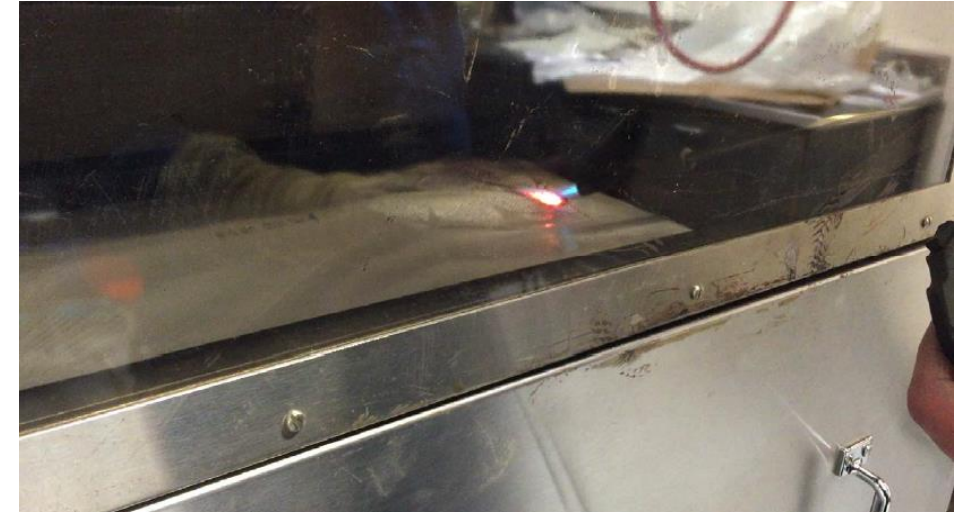


ISO 2685

Test Results: FLAME PROPAGATION 14 CFR 25.856(a)

- ZERO after flame (AF) and propagation (P), both configurations
- Samples retained undamaged appearance and were visibly comparable to themselves prior to testing

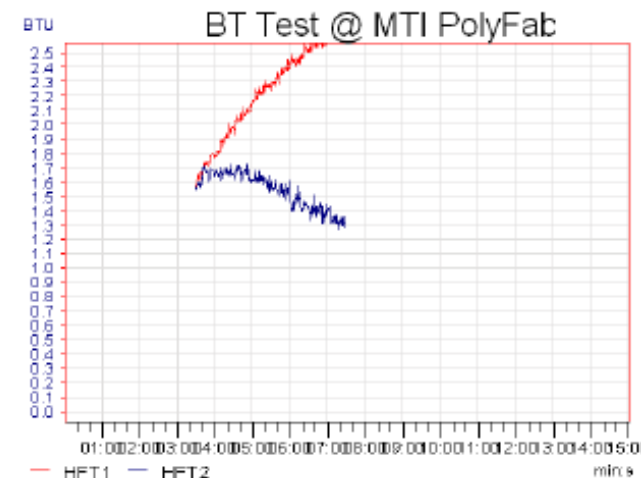
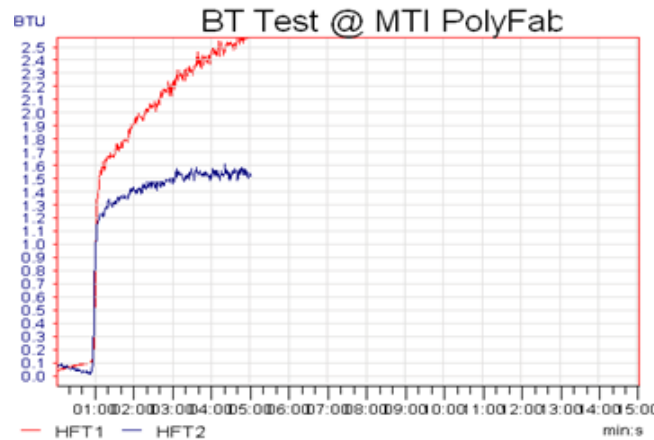
Test Configuration	After flame (sec)	Propagation (inches)	Pass/ Fail
1 layer AF-10	0	0	Pass
1 layer AF-10 bagged in film	0	0	Pass
1 layer AF-9	0	0	Pass
1 layer AF-9 bagged in film	0	0	Pass



Test Results : BURN-THROUGH 14 CFR 25.856(b)

Nextel™ Fabric Only

- Heat Flux of 2.7 BTU recorded at 4min
- No burn-through, no damage to sample observed
- 3 lots of AF-10 and 1 lot of AF-9 tested

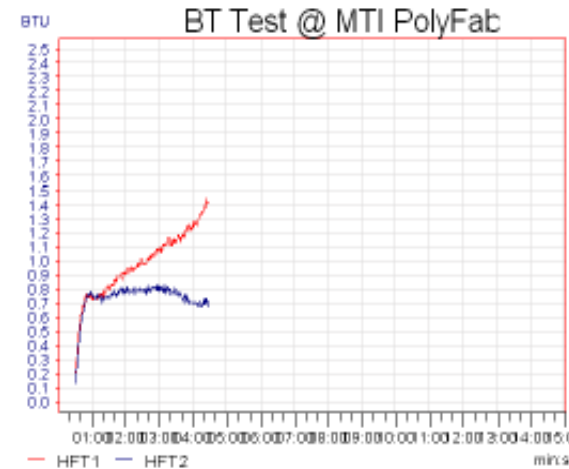


Test Configuration	Heat Flux@4 min (BTU)	Burn-through
1 layer AF-10	2.5-2.7	No
1 layer AF-9	2.7	No

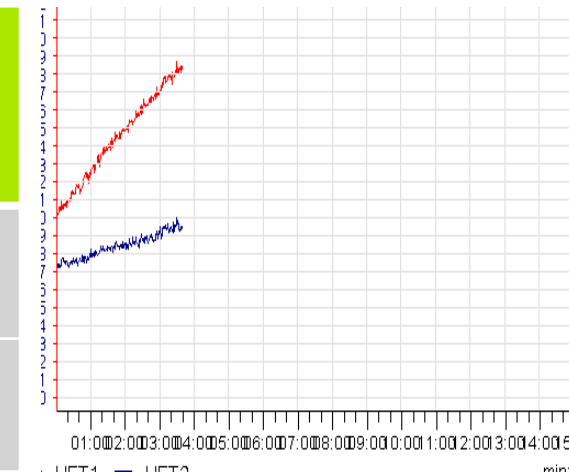
Test Results: BURN-THROUGH 14 CFR 25.856(b)

Nextel™ Fabric with 0.5" Fiber Glass

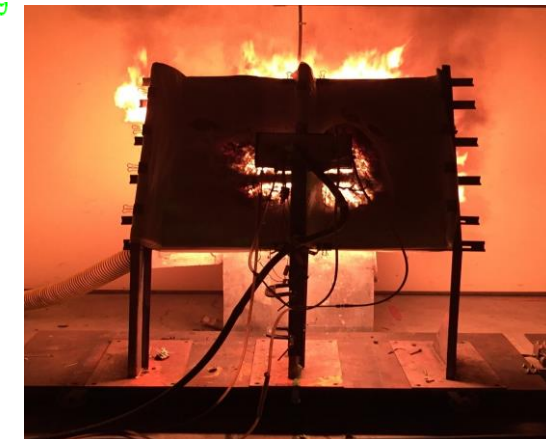
- After 4 min Heat Flux recorded on right side
- No burn-through, no damage to sample observed
- Each configuration : 3 samples were tested



Total Time
00:04:00
HFT1
1.40 BTU
HFT2
0.72 BTU



00:03:33
HFT1
1.82 BTU
HFT2
0.96 BTU



Test Configuration	Heat Flux @4min (BTU)	Burn-through	Pass/Fail
(1 layer AF-10 + 0.5" 0.6pcf FG) bagged in film	1.7-1.9	No	Pass
(1 layer AF-9 + 0.5" 0.6pcf FG) bagged in film	1.2-1.4	No	Pass

ISO 2685: Environmental test procedure for airborne equip.

Resistance to fire in designated fire zones

Application in all components, equipment and structures located in zones designated as “fire zones”:

Region of an aircraft, for example compartments containing main engines and auxiliary power units, designated as such by the aircraft designer in accordance with the requirements of the approving authority.

Fireproof Grade:

Grade designating components, equipment and structures capable of withstanding the application of heat by a standard flame for 15 min.

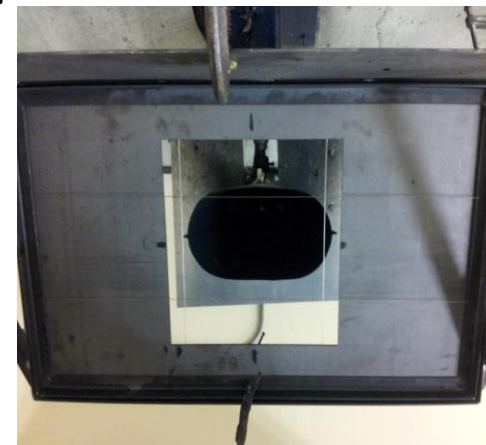
Self-extinction requirement in this test is characterized by after flame of not more than 10sec.

Standard Flame temperature: $1100\text{ }^{\circ}\text{C} \pm 80\text{ }^{\circ}\text{C}$ (same burner as in burn-through test)

Test Procedure Simulating ISO 2685

Existing FAR25.856-b test set up was modified to achieve conditions outlined in ISO 2685 test. This test set up was then used to measure if tested material is capable of withstanding the application of heat by standard flame for 15 min, with after flame of not more than 10sec after flame was shut off.

- Each sample 18"x32", was installed in picture frame making fabric area exposed to the flame (window opening) of 12"x12";
- Sample was positioned at 4" distance from the burner cone edge;
- Temperature was recorded continuously during the test (15min) using two thermocouples at the back side of tested fabric (cold side).

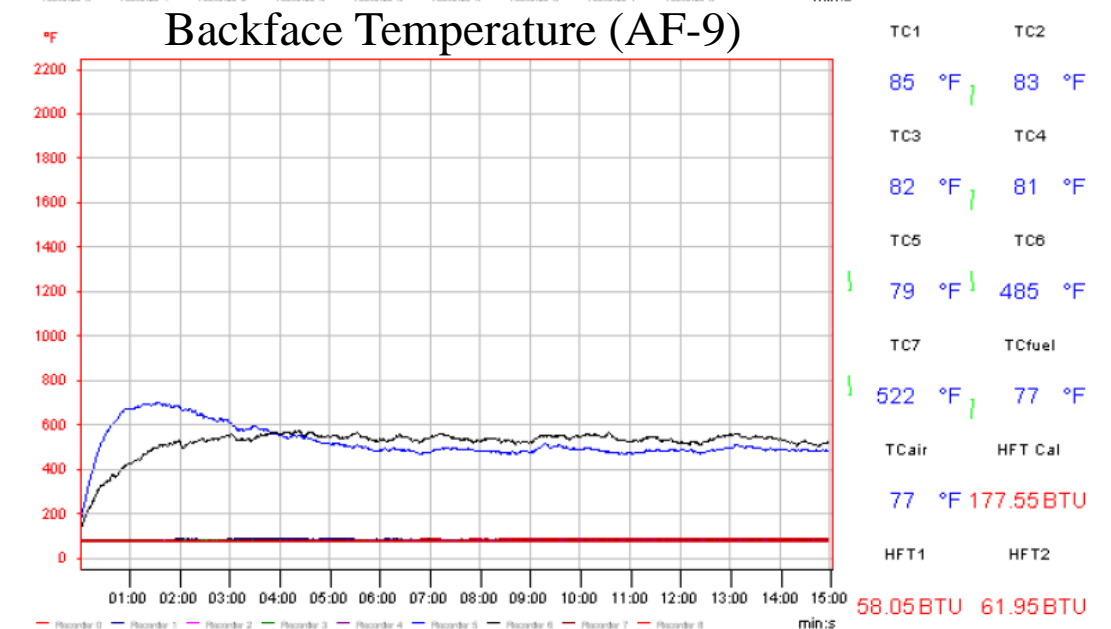
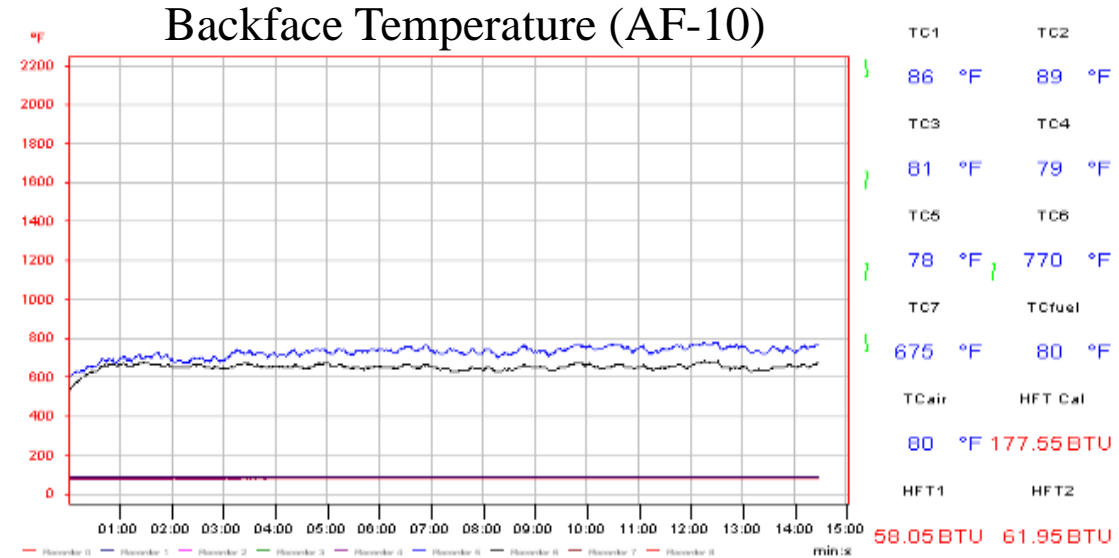


Test Results: ISO 2685

COMPLIANT per ISO2685 fire proof test requirements:

- No flame penetration after 15min exposure
- No after flame
- 2 samples of AF-10 and 1 sample of AF-9 tested

Material	Max observed blackface temp (°F)	After Flame (sec)	Observed material damage
AF-10	675	0	None
AF-9	522	0	None



Summary

FLAME PROPAGATION 14 CFR 25.856(a) : Pass: AF-10 and AF-9 ; 3 tests completed

BURN-THROUGH 14 CFR 25.856(b) : Pass as AF-10 (1 layer) + 0.5” FG min ; AF-9 (1 layer) + 0.5” FG min ; Fail as AF-10 (1 layer) , AF-9 (1 layer)

ISO 2685: Pass: AF 10; AF-9 (all 1 layer)

- AF-9 and AF-10 fabrics
 - Compliant to FAR 25.856-a
 - Compliant to FAR 25.856-b when tested with min 0.5" FG (HF< 2 BTUs)
 - 1 layer tested per FAR 25.856-b: 4min exposure at 2000F, no flame penetration (no BT)
 - 1 layer tested per ISO2685: 15 min exposure at 2000F, no flame penetration, no after flame

Based on these results, AF-9 can be evaluated for new applications. Contact 3M for sample.

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