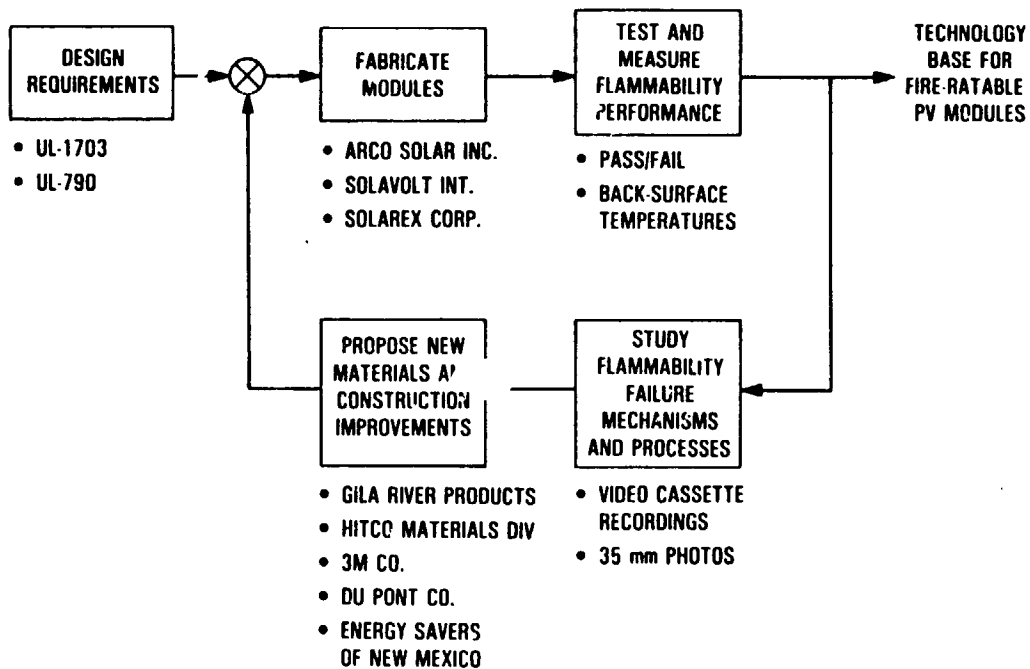


MODULE FLAMMABILITY RESEARCH

JET PROPULSION LABORATORY

R. S. Sugimura
D. H. Otth

Approach



Tests for Fire Resistance of Roof Covering Materials (UL-790)

Fire Rating	Spread-of-Flame Test			Burning-Brand Test		
	Flame Temperature, °F	Flame Application Time, min	Allowable Flame Spread Distance, ft	Brand Size, in.	Brand Ignition Temperature, °F	Approximate Peak Module Temperature, °F
Class A	1400	10	< 6	12 x 12 x 2½	1630	1900
Class B	1400	10	< 8	8 x 8 x 2½	1630	1400
Class C	1300	4	< 13	1½ x 1½ x 25/32	-	-

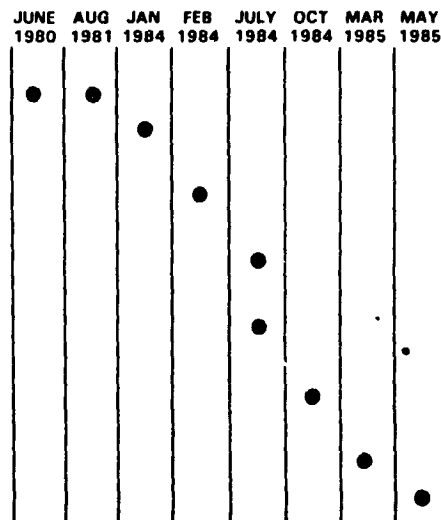
Spread-of-flame test – distance that flame has spread. No flaming or glowing brands of roof material

Burning-brand test – until flame, glow and smoke disappear. No sustained flaming on underside, production of flaming, or glowing brands of roof material

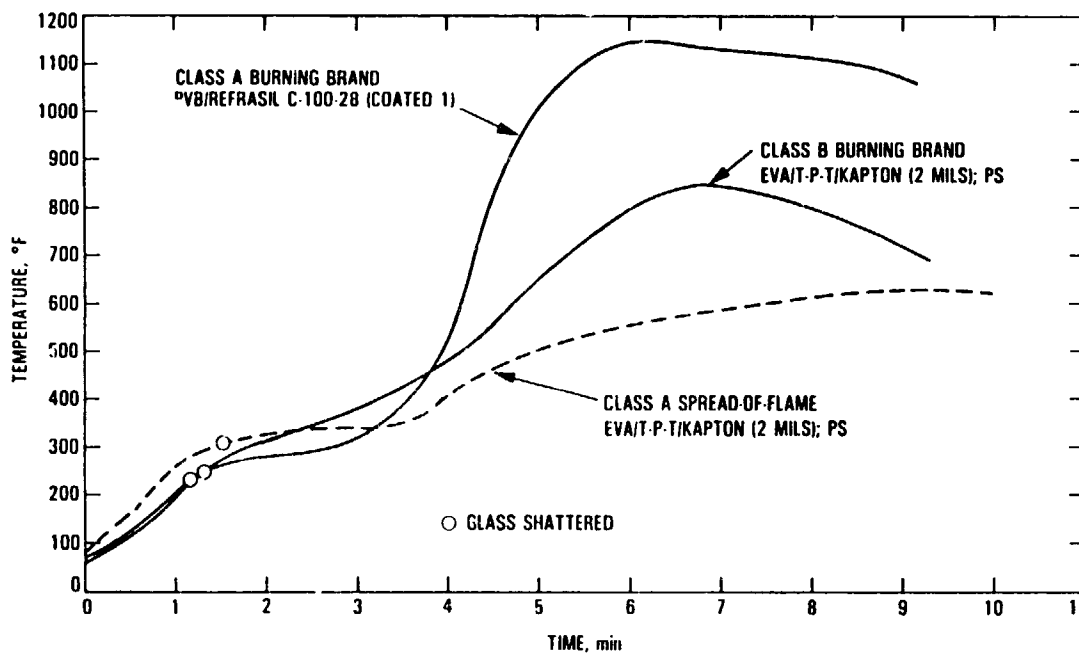
Chronological Overview

Test phases

- Exploratory (uninstrumented)
- Diagnostic (instrumented)
- Experimental modules:
 - Characterize Burning Brand, Class B
 - Identify lower-cost materials, Burning-Brand, Class B
 - Characterize Spread-of-Flame, Classes A and B
 - Characterize Burning-Brand, Class A
 - Identify lower-cost materials, Burning-Brand, Class A
 - Assess impact on module edges



Module Back-Surface Temperature History



Flammability Test Highlights

Pottant ^a	Back-Cover Configuration ^b	Flame	"B" Brand	"A" Brand
EVA EVA	T-P-T/Kapton (2 mils); PS T-P-T/Kapton (2 mils); TS	●	● ○	○
EVA PVB	Kapton (2 mils) Kapton (2 mils)	●	● ○	
EVA EVA	Al (3 mils) in. 4-layer laminate T-P-T/SS (2 mils)		● ●	○ ●
EVA EVA EVA EVA	T-P-T/FG; TS T-P-T/FG; PS FG - Silicone rubber (1 side) FG - Neoprene rubber (1 side)	● ●	● ○ ● ●	
EVA, PVB	Refrasil FG (15 mils) - Z-mix (1 side)			●
EVA, S, PVB EVA, S, PVB	FG (24 mils) - Z-mix (1 side) FG (13 mils) - Z-mix (1 side)			● ●
EVA, S, PVB	FG (7 mils) - Z-mix (2 sides)			●

● = passed ○ = failed

^aEVA - ethylene vinyl acetate; PVB - polyvinyl butyral; S - Pottant S (Solavolt Int.)

^bT-P-T - Tedlar-polyester-Tedlar; PS - pressure sensitive; TS - Thermoset; SS - stainless steel;

FG - fiberglass; Al - aluminum; Z-mix - proprietary HITCO coating

Candidate Materials for Fire-Ratable Modules

Back-Cover Material Description ^a	Manufacturer	≈ \$/ft ²
Class B		
Kapton (2 mils)	DuPont 200H	0.75
Vonar/Surmat/Conbond 1560/T (4 mils)	DuPont	—
FG (4 mils) — red silicone rubber (1 side)	3M SRG-0607 1/c	1.08-0.76
FG (4 mils) — Neoprene rubber (1 side)	3M FGN-0605 1/c	0.80-0.64
Mylar/Al (0.7 mils)/rubberized back coat	Spire Block IV	—
Al (3 mils) in 4-layer laminate	—	—
T (1½ mils) — Mylar (5 mils) — Al (0.5 mils) — EVA (4 mils)	Gila River — Solar 2	0.80
T (1½ mils) — FG (8 mils — epoxy) — T (1½ mils) ^b	Gila River — Solar 5	—
Class A		
Refrasil (15 mils) — Z-mix (1 side)	HITCO C100-28 w/Z-mix	2.22
FG (24 mils) — Z-mix (1 side)	HITCO 1584 w/Z-mix	1.42
FG (13 mils) — Z-mix (1 side)	HITCO 1582 w/Z-mix	1.12
FG (7 mils) — Z-mix (2 sides)	HITCO Solar-Tex	0.83-0.73 ^c
Stainless steel foil (2 mils)	—	0.45

^a T — Tedlar; FG — fiberglass; Al — aluminum; EVA — ethylene vinyl acetate

^b Possible candidate for Class A. ^c Price varies according to color: black/black; white/white; black/white

Summary

- Fire-resistant module designs require special high-temperature materials and constructions to achieve Class B and Class A ratings
- Synergisms exist between back-surface materials and module configuration
 - Amount of pottant
 - Type of adhesive
 - Edge seals

Future Work

- Test durability and reliability performance of selected candidates
- Test module edge-seal materials and configurations

