N83 10521 D16-44

Environmental Isolation Task

C.D. Coulbert, Chairman

A review of the scope of PV module encapsulation technology made available to the industry through the various FSA-supported contracts and studies under the Flat-Plate Collector Research, Engineering Sciences, and Module Performance and Failure Analysis Areas shows it to be very broad (see p. 322). This technology has enabled the PV industry to respond with module designs and hardware with the potential of meeting module cost, performance and life goals. However, a review of these specific technology areas continues to stress the need for continuing module durability research to define module life-limiting degradation mechanisms so they can be quantified, predicted, and corrected. In these early days of PV module development, the great value of durability testing and failure analysis has been to identify design weaknesses; this has been used by industry to develop guidelines by which manufacturers could design and fabricate higher-quality hardware incorporating fault-tolerant design features.

Current FSA research activities are focused on identifying, modeling, and quantifying those long-term degradation mechanisms that would limit the ultimate service life of a PV module. At the same time, research is continuing on encapsulation materials and processes that have the greatest potential of increasing module life and efficiency and effectively reducing module cost.

The following visual presentations summarize significant progress in these areas during the reporting period.

Inasmuch as polymeric encapsulant material properties that may change with long-term field exposure do not necessarily result in a corresponding module damage or failure mode, it has become necessary to organize the failure-analysis process into a more specific set of long-term degradation steps so that material property change can be differentiated from module damage and module failure (see pp. 324-325). These categories allow separation, testing and modeling of the various degradation mechanisms with a clear distinction of which effects interact and which are sequential.

The polymeric aging computer model being developed by the University of Toronto will eventually predict what physical property changes may occur as a function of exposure time and environment. Additional analysis and experimental work are still required to relate polymer property change to module performance loss.

Encouraging developments in increasing module performance and life are indicated by the data on module surface treatments for soiling resistance, by improved bonding techniques and primers, by anti-corrosion treatments and by improved polymer stabilizers.

A new photoacoustic technique for very early detection of polymer surface reactions due to aging is being developed and evaluated at JPL. Such techniques are needed if the 20-year potential of modules is to be assessed and validated based on correlating field tests with accelerated tests over a limited number of months of durability testing.

ENVIRONMENTAL ISOLATION TASK

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ENCAPSULATION TECHNOLOGY AVAILABLE

JET PROPULSION LABORATORY

C.D. Coulbert

PV MODULE DESIGN	DESIGN ANALYSIS	FAILURE ANALYSIS
• PERFORMANCE REQ.	• PERFORMANCE EST.	• PERFORMANCE LOSS
• LOADS & HAZARDS	• PHYSICAL DURABILITY ANALYSIS	• WHAT FAILED
• AVAILABLE MATERIALS & PROCESSES	• PREDICTED PROPERTY CHANGES	• WHY FAILED
• DESIGN ANALYSES & GUIDELINES	• NOCT/HOT SPOT TEMP.	• PROPERTY CHANGE
• LIFE LIMITING MODES	• DESIGN OPTIONS	• PROGNOSIS
	• QUALITY CONTROL REQUIREMENTS	• CORRECTIVE ACTION
	• DAMAGE VS. PROPERTY CHANGE	• PREDICTABILITY
	• MODULE WEAK LINK	• ACCEPTABILITY

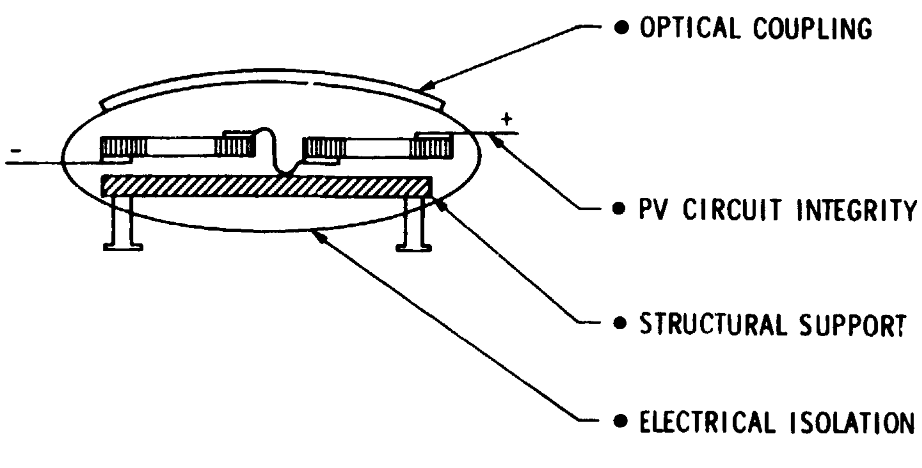
Encapsulation Materials and Processes

- SURFACE TREATMENTS BASED ON FLUOROCARBONS FOR LOW SOILING MODULE COVERS HAVE REDUCED OPTICAL LOSSES FROM 10% UNTREATED TO 3% OVER A TEN MONTH TEST PERIOD. (TESTING CONTINUES) (SPRINGBORN)
- NEW CURING AGENTS IDENTIFIED FOR EVA AND EMA TO REDUCE CURING TEMPERATURES AND TIMES. CURING TIMES MAY BE REDUCED FROM 15 MINUTES TO LESS THAN 5 MINUTES(SPRINGBORN)
- CORROSION RESISTANT COATINGS IDENTIFIED FOR MILD STEEL SUBSTRATE PANELS. TEST SPECIMENS HAVE SURVIVED SALT SPRAY FOR 3000 HOURS WITHOUT DETERIORATION. (SPRINGBORN)
- EXPERIMENTAL BONDING PRIMER SYSTEMS DEVELOPED AND BEING EVALUATED FOR BONDING EVA AND EMA TO POLYESTER FILMS AND ALSO PRIMERS FOR CORROSION INHIBITION OF MILD STEEL. (DOW CORNING)
- ION-PLATING AS METHOD FOR NON-FIRED METALLIZATION (Ti/Al-Cu) ON SOLAR CELL n-SURFACE DEMONSTRATED. POTENTIAL FEASIBILITY FOR p-SURFACE SHOWN EXPERIMENTALLY. (ITW)
- TWO NEW POLYMERIZABLE UV STABILIZERS FORMULATED FOR MODULE ACRYLIC COVER FILMS SHOW EXCELLENT UV CUT-OFF SPECTRAL CHARACTERISTICS. (UNIV. OF MASSACHUSETTS).

Encapsulant Material Stability

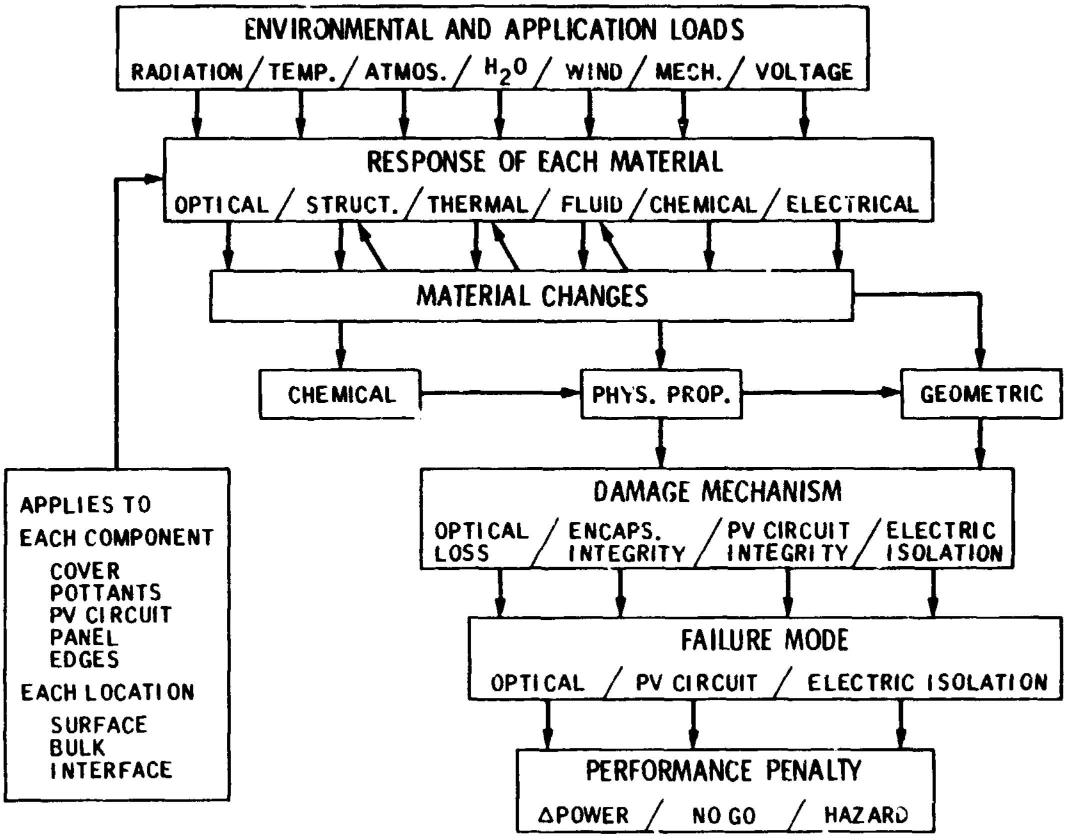
- EVA FORMULATION A9918 HAS SURVIVED > 30,000 HOURS (3.5 YR) OF RS/4 SUNLAMP 55°C EXPOSURE WITHOUT DAMAGE. (SPRINGBORN)
- ADVANCED ENCAPSULANT MATERIALS (EVA, PU, HARDBOARD, CONCRETE, ETC.) IN MINI-MODULE TESTS HAVE ALMOST TWO YEARS OF FIELD EXPOSURE AND PASSED JPL QUAL TESTS. (JPL)
- SUBSTRATE MODULES WITH EVA AND WOOD HARDBOARD SUBSTRATES PASS HAIL IMPACT TESTS. (JPL)
- NEW DIAGNOSTIC TECHNIQUE (LASER PHOTOACOUSTICS) MEASURES POLYMER SURFACE PHOTO OXIDATION AND CORRELATES 60-DAY FIELD EXPOSURE WITH 10-HOUR LAB TESTS. (JPL)
- FULL-SIZE MODULE TEST FACILITY FOR ACCELERATED UV THERMAL TESTING COMPLETED AND INITIAL TESTS IN PROCESS. (JPL)
- MATERIAL PROPERTY (MOLECULAR WEIGHT, STRENGTH, TOUGHNESS AND STABILITY) PREDICTION BY COMPUTER MODEL OF POLYMER MOLECULAR STRUCTURE DEVELOPED AND DEMONSTRATED. (ROCKWELL SCIENCE CENTER)
- MODULE RESPONSES TO ENVIRONMENT AS A FUNCTION ENCAPSULANT PROPERTIES AND THICKNESSES PREDICTABLE BY COMPUTER MODELING. REDUCED VARIABLE MASTER CURVES DEVELOPED FOR CELL STRESS PREDICTION FOR WIND AND TEMPERATURE. (SPECTROLAB AND JPL)
- COMPUTER MODEL OF EVA PHOTODEGRADATION YIELDS DEGRADATION PRODUCTS VS TIME. LONG INCUBATION PERIOD INDICATED (5 - 10 YEARS). (UNIV. OF TORONTO)
- REPORT ON EXPERIMENTAL PHOTOTHERMAL CHARACTERIZATION OF CANDIDATE POTTANTS AND COVER FILM MATERIALS EXPOSED TO UV AND AIR UP TO 105°C COMPLETED AND IN PUBLICATION. (JPL).

Encapsulation Requirements



WHEN ONE OF THESE IS VIOLATED
YOU HAVE DAMAGE AND POTENTIAL FAILURE

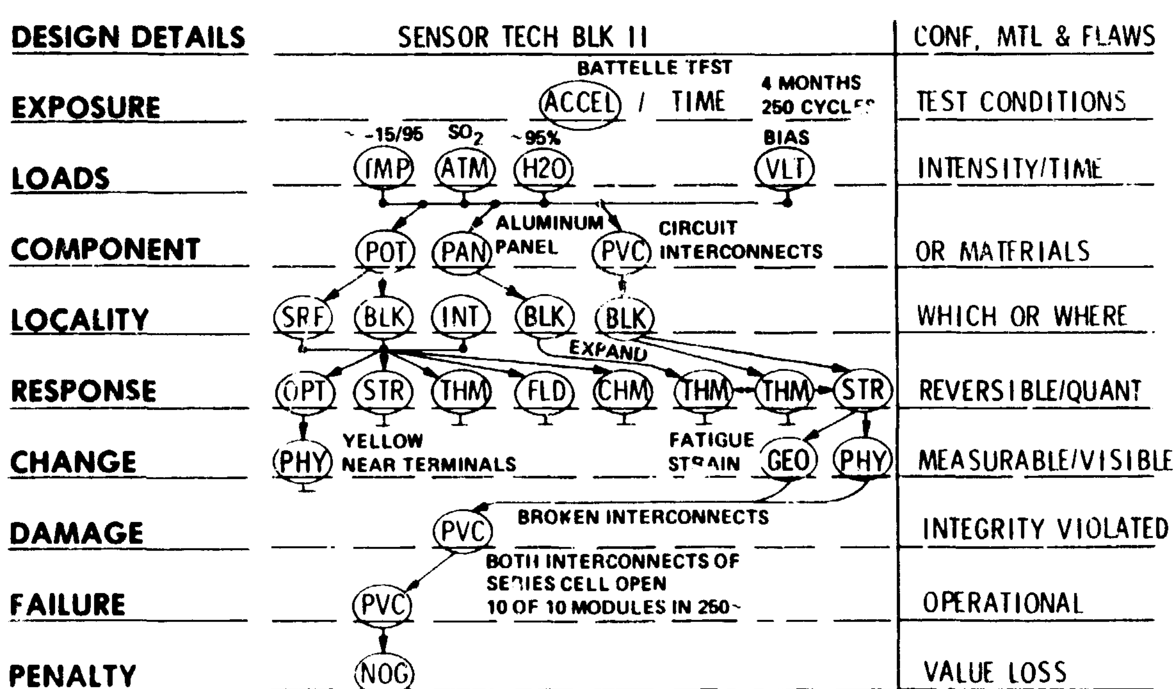
PV Module Failure Analysis Sequence



Durability Analysis Categories

DESIGN DETAILS									MT'L & CONFIG.
EXPOSURE	QUAL	FIELD	ACCEL / TIME						TEST CONDITIONS
LOADS	RAD	TMP	ATM	H2O	WND	MEC	VLT		INTENSITY/TIME
COMPONENT	COV	POT	PAN	EDG	PVC				OR MATERIALS
LOCALITY	SRF	BLK	INT						WHICH OR WHERE
RESPONSE	OPT	STR	THM	FLD	CHM	ELC			QUANTITATIVE
CHANGE	CHM	PHY	GEO						MEASURABLE/VISIBLE
DAMAGE	OPT	ENC	PVC	ISO					INTEGRITY
FAILURE	OPT	PVC	ISO						OPERATIONAL
PENALTY	PWR	NO?	HZD						VALUE LOSS

Example



MATERIAL RESEARCH AND EVALUATION

SPRINGBORN LABORATORIES, INC.

Candidate Pottant Materials

SHEET LAMINATION GRADES:

- EMA
- EVA

CASTING SYRUPS:

- POLYBUTYL ACRYLATE
- ALIPHATIC POLYURETHANE

PHASES:

- INDUSTRIAL EVALUATION GRADE
- TECHNOLOGY READINESS STAGE

CURRENT WORK:

- ADVANCED CURE SYSTEMS
- THERMAL AGING EVALUATION
- ADVANCED STABILIZATION

Pottants

INVESTIGATION OF PEROXIDE CURING AGENTS:

- CURE POLYMER TO HIGH GEL CONTENTS
- CURE IN THE RANGE OF 120°C TO 160°C WITH NO PREMATURE "SCORCH" AT 110°C MUST BE SOLUBLE IN THE RESIN AND NON-VOLATILE TO PREVENT LOSS
- MUST NOT SENSITIZE THE AGING OF THE RESIN (NON-AROMATIC) MUST BE COMPATIBLE WITH THE STABILIZERS AND OTHER INGREDIENTS
- MUST NOT PRODUCE CHEMICALLY ANTAGONISTIC BYPRODUCTS OR RESULT IN BUBBLING

GENERAL MECHANISM:

1. $RO\text{-}OR \xrightarrow{\Delta} 2\ RO\cdot$
2. $P\text{-}H + RO\cdot \longrightarrow P\cdot + ROH$
3. $2P\cdot \longrightarrow P - P$ (CROSSLINK)

- TERTIARY HYDROGENS ON THE POLYMER BACKBONE MOST READILY ABSTRACTED.
- CURING MUST BE CONDUCTED IN THE ABSENCE OF OXYGEN TO BE EFFECTIVE AND TO PREVENT OXIDATION OF THE RESIN.

Pottant Compounds

ADVANCED CURE SYSTEMS IN EVA

CURE TEMP.	TIME REQUIRED FOR 70% GEL CONTENT				
	120	130	140	150	160
LUPERSOL 101	N/A	N/A	45	15	6
LUPERSOL 99	30	20	12	8	2
LUPERSOL 331-80B	15	10	5	2	2
LUPERSOL TBEC	30	10	4	2	1

ALL PEROXIDES COMPOUNDED INTO STANDARD FORMULA, A9918.

. NO CURE OCCURS AT 110°C WITH ANY PEROXIDE: SHOULD SURVIVE EXTRUSION OK.

ADVANCED CURE SYSTEMS IN EMA

	TIME REQUIRED FOR 50% GEL CONTENT		
	130°C	140°C	150°C
LUPERSOL 101	N/A	60	30
LUPERSOL 99	30	15	5
LUPERSOL 331-80B	15	10	5
LUPERSOL TBEC	25	5	< 2

. ALL PEROXIDES TESTED IN STANDARD FORMULA NO. 13439.

. NO CURE AT 110°C IN ANY FORMULATION: SHOULD SURVIVE EXTRUDER OK.

NEW CURING AGENTS FOR EVA AND EMA

	% ACTIVE	ONE HOUR HALF-LIFE TEMPERATURE	FLASH POINT (VOLATILITY)
LUPERSOL 101	100%	138°C	43°C
LUPERSOL 331-80B	75%	111°C	40°C
LUPERSOL 99	75%	118°C	77°C
LUPERSOL TBEC [A.]	100%	120°C	101°C

- LUPERSOL TBEC CURING AGENT OF CHOICE:
- HIGHEST CURING EFFICIENCY
- 100% ACTIVE, NO DILUENT
- LOWEST VAPOR PRESSURE

TECHNOLOGY VOIDS:

- PLANT EXTRUSION RUNS
- SHELF LIFE DETERMINATION
- COMPATABILITY WITH ADHESION SYSTEM

A. LUPERSOL TBEC IS 0,0-T-BUTYL-0-(2-ETHYL HEXYL) PEROXY CARBONATE

ETHYLENE VINYL ACETATE, A9918
(COMMERCIAL FORMULATION)

CAVEAT:

- CURING AGENT (PEROXIDE) IS SLIGHTLY VOLATILE

  KEEP THE EVA IN ROLL FORM WHERE LOSS IS INHIBITED

- DO NOT USE CUT SHEET WHICH HAS BEEN OPENLY EXPOSED FOR OVER ONE DAY

ROLLS APPEAR TO HAVE INDEFINITE SHELF LIFE.

NEED TO DETERMINE PEROXIDE LOSSES VERSUS TIME AND STORAGE CONDITIONS

Butyl Acrylate Casting Syrup

FORMULA: BA 13870

- INDUSTRIAL SAMPLES AVAILABLE - (LABORATORY PROCESS)

CURE TIME GUIDE

	25°C	35°C	50°C	60°C	70°C
TIME TO ONSET OF CURE (MINUTES)	STABLE[A]	STABLE[A]	60	25	6.5

- PILOT PLANT QUANTITIES
- INITIATOR AND DATA SHEET SUPPLIED WITH EACH REQUEST
- PRIMER: TENTATIVE RECOMMENDATION
  SPRINGBORN 14588
  (DOW CORNING Z-6020 WITH TETRAETHYL SILICATE)
  ALSO PROVIDED WITH REQUEST

A. STABLE AT LEAST ONE WEEK, REFRIGERATION SUGGESTED.

Aliphatic Urethane Encapsulant

FORMULA: Z-2591

- AVAILABLE - DEVELOPMENT ASSOCIATES, INC.
  NORTH KINGSTOWN, R.I.
- COST: APPX. $3.00 PER POUND
  (MIXED SYSTEM)
- CONTACT: MR. BUD NANNIG
- PRIMER:
  - TENTATIVE RECOMMENDATION
    DOW CORNING Z-6020
    (10% SOLUTION IN METHANOL)
  - BAKE PRIMERS ALSO
    AVAILABLE - DEVELOPMENT
    ASSOCIATES, INC.

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RS/4 Exposures

POTTANT COMPOUNDS:

POTTANT	HOURS	% PROPERTY RETAINED TENSILE	ELONGATION
URETHANE Z-2591	4,000	82%	91%
EMA 23439	7,600	120%	119%
EMA 11877	15,000	130%	117%
EMA 2205 (UNCOMPOUNDED)	15,000	5% REMOVED	5%
BUTYL ACRYLATE 13870	7,[illegible]	60%	88%
EVA W/UV-2098	JUST STARTED		
EVA W/5-VINYL TINUVIN REACTED IN	15,000	77%	78%

REFERENCE:

POLYETHYLENE UNSTABILIZED	500	10%
POLYPROPYLENE UNSTABILIZED	500	0%

OUTER COVER AND BACK COVER FILMS:

OUTER COVER FILM	HOURS	% PROPERTY RETAINED TENSILE	% PROPERTY RETAINED ELONGATION
ACRYLAR X-22417	12,000	54%	100%
TEDLAR 100 BG 30 UT	14,000	94%	98.5%
TEDLAR 4662	10,800	140%	38%
TEDLAR 05VT (W/VINYL TINUVIN)	10,800	67%	1%
FLUOREX-A	10,800	70%	30%
BACK COVER FILMS			
TEDLAR 200 BS 30 WH	10,800	98%	93%
SCOTCHPAR 20CPW	6,600	95%	74%
KORAD 63000	6,600	94%	71%

- TEDLARS (BOTH CLEAR AND PIGMENTED) APPEAR TO BE MOST STABLE.

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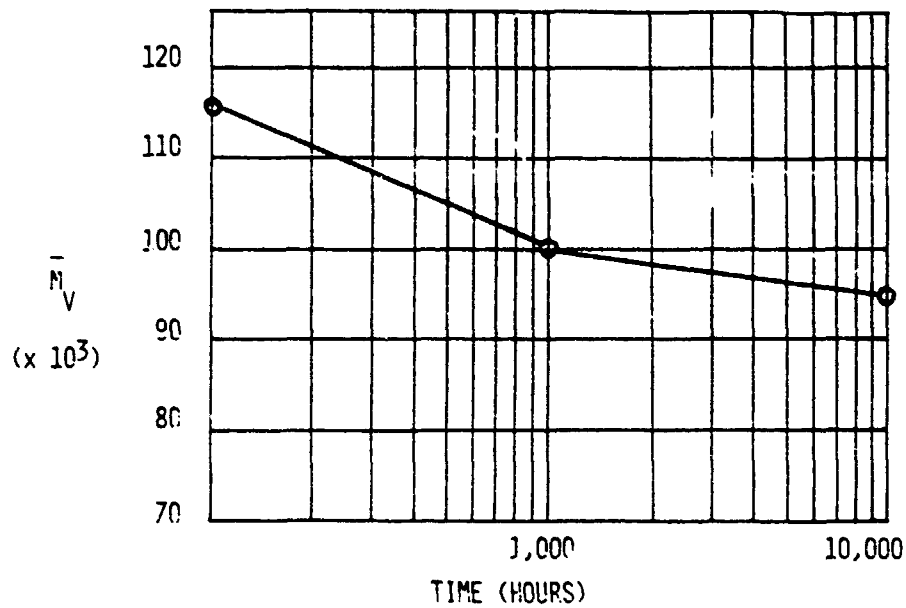
"ACRYLAR" BIAXIALLY ORIENTED

ACRYLIC FILM

(3M X 22417)

DECREASE IN VISCOSITY AVERAGE MOLECULAR WEIGHT WITH EXPOSURE TIME.



MOLECULAR WEIGHT DECREASES FROM 116,000 TO 94,800 IN 10,000 HOURS TIME.

ENVIRONMENTAL ISOLATION TASK

EVA POTTANT
(NO COVER FILM)

. CLEAR STABILIZED EVA EXPOSED 30,000 HOURS, LITTLE CHANGE.

	TOTAL INTEGRATED TRANSMISSION (%)	ULTIMATE* ELONGATION (%)	TENSILE* STRENGTH (PSI)
CONTROL	91	510	1890
EXPOSED 30,000 HRS.	90	480	1450
% CONTROL	99%	94%	77%[A.]

UNSTABILIZED ELVAX 250 (EVA) BECOMES SOFT, TACKY, - LOSES PHYSICAL PROPERTIES IN LESS THAN 1,000 HOURS.

*ASTM D-638

A. FIRST SIGN OF CHANGE NOTICES THROUGHOUT EXPOSURE PERIOD

Substrate Materials

CURRENT CANDIDATES

MATERIAL	¢/FT^2	\$/M^2
COLD ROLLED MILD STEEL, 28 GAUGE	15.5	1.67
SUPER DORLUX HARDBOARD (MASONITE CORP.)	14.0	1.51
DURON TEMPERED HARDBOARD (US GYPSUM COMPANY)	14.5	1.56

- SUBSTRATE ALLOCATION APPROX. 70¢/FT^2
- COST INCREMENT WILL APPEAR FOR PROTECTIVE TREATMENT

PROTECTIVE COATINGS OR TREATMENTS REQUIRED FOR LONG OPERATING LIFE IN OUTDOOR ENVIRONMENT

POSSIBILITIES:

- ENCAPSULATE ENTIRE SUBSTRATE WITH WEATHERABLE POTTANT
- LAMINATION WITH OCCULSIVE FOIL:[A.]
  - E.G.: "HOT-FOIL" TREATMENT
    (ALUMINUM FOIL WITH HOT MELT ADHESIVE)
- LAMINATE WITH ORGANIC FILMS
- COATING WITH WEATHERABLE ENAMEL[B.] OR PAINT
- COMBINATIONS OF THESE
- CHEMICAL MODIFICATION (WOOD)

A. TECHNIQUE BEING DEVELOPED BY U.S. GYPSUM AND OTHERS.

B. RECOMMENDATIONS FROM:

DOW CORNING CORPORATION

DEXTER - MIDLAND CORPORATION
STEEL STRUCTURES PAINTING
COUNCIL (SSPC)

<u>TESTING</u>

TEST "MODULES" PREPARED WITH COATED STEEL PANEL, BUTYL SEALANT AND GASKET

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Corrosion Experiments

MILD STEEL SUBSTRATES
SALT SPRAY EXPOSURE
(ASTM B-117)

COATING	ADHESIVES	HOURS	CONDITIONS
ACRYLAR	ACRYLIC	2,000	R
SCOTCHPAR	ACRYLIC	2,000	R
ALUM. FOIL	ACRYLIC	1,500	R
KORAD (WHITE)	ACRYLIC	2,000	R
EVA	SILANE	1,500	R
CLEAR KORAD	ACRYLIC	2,000	R
ACMITITE	ACRYLIC	2,500	R
WHITE TEDLAR	ACRYLIC	2,000	R
302 STAINLESS	ACRYLIC	2,500	R
EVA/SCOTCHPAR	SILANE	4,500	I
EVA/STAINLESS	SILANE	2,500	R
EVA/TEDLAR	SILANE	2,500	R
SCOTCHCLAD	NONE	2,000	R
EVA	CHROMATE/SILANE	4,000	II
VINYLIDENE/FLUORIDE	EPOXY	3,500	III
SILICONE/POLYESTER	EPOXY	3,100	II
ACRYLIC AUTO TOPCOAT	EPOXY	3,100	III

I NO OBSERVABLE CHANGE
II SOME SIGNS OF DETERIORATION (CORROSION, DELAMINATION)
III NOTICEABLE DETERIORATION
R SPECIMEN FAILED, REMOVED

MILD STEEL SUBSTRATES

OUTDOOR EXPOSURE, ENFIELD, CT.

COATING	ADHESIVES	HOURS	CONDITIONS
ACRYLAR	ACRYLIC	4,500	II
SCOTCHPAR	ACRYLIC	4,500	II
ALUM. FOIL	ACRYLIC	4,500	I
KORAD (WHITE)	ACRYLIC	4,500	II
EVA	SILANE	4,500	II
CLEAR KORAD	ACRYLIC	1,500	R
ACMITITE	ACRYLIC	4,500	I
WHITE TEDLAR	ACRYLIC	4,500	I
302 STAINLESS	ACRYLIC	4,500	II
EVA/SCOTCHPAR	SILANE	4,500	I
EVA/STAINLESS	SILANE	4,500	II
EVA/TEDLAR	SILANE	4,500	II
SCOTCHCLAD	NONE	4,500	II
EVA	CHROMATE/SILANE	4,000	II
VINYLIDENE FLUORIDE	EPOXY	3,400	II
SILICONE/POLYESTER	EPOXY	3,100	II
ACRYLIC AUTO TOPCOAT	EPOXY	3,100	II

I NO OBSERVABLE CHANGE
II SOME SIGNS OF DETERIORATION (CORROSION, DELAMINATION)
III NOTICEABLE DETERIORATION
R SPECIMEN FAILED, REMOVED

Hardboard Protection Experiments

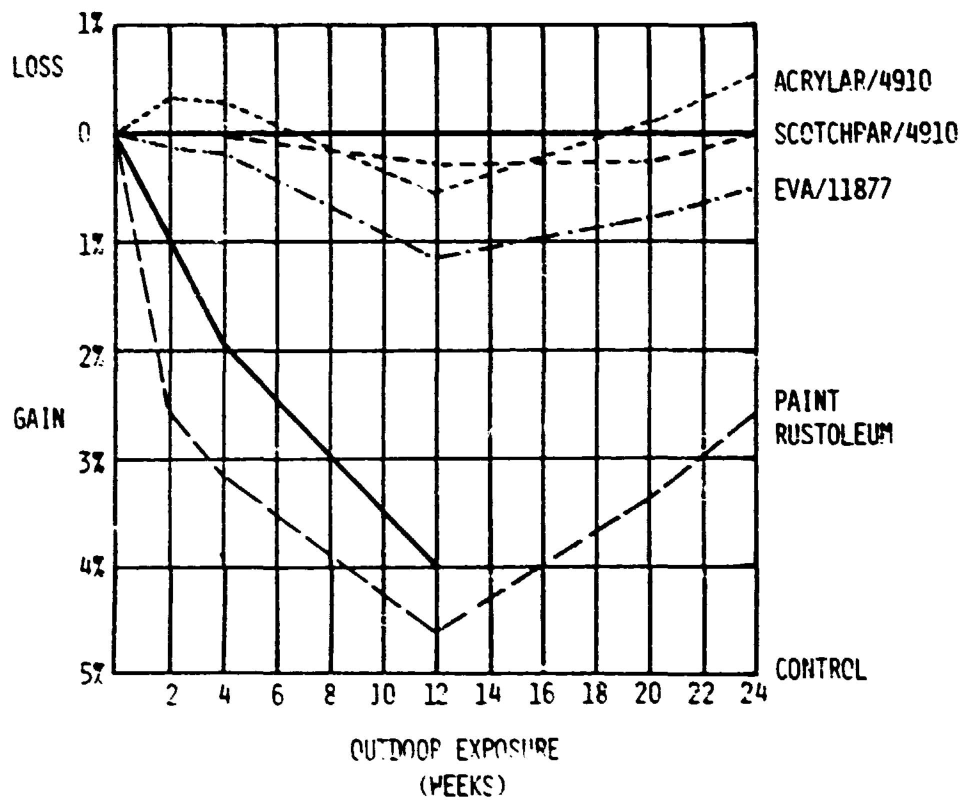
"SUPER DORLUX" - MASONITE CORPORATION

"MODULES" PREPARED WITH BUTYL EDGE SEAL AND
GASKET - SIX MONTHS OUTDOORS,
ENFIELD, CONNECTICUT

COATING	ADHESIVE	% CHANGE MODULE	% CHANGE HARDBOARD
ACRYLAR	3M 4910	-.40	-.53
KORAD 63000	3M 4910	-.58	-.75
PAINT (RUSTOLEUM)	-	+1.98	+2.57
302 STAINLESS	3M 4920	-.03	-.05
ALUM. FOIL	3M 4910	+.07	+.09
SCOTCHPAR 20CP	3M 4910	+.03	+.05
EVA 9918	A 11861	+.36	+.53
TEDLAR, WHITE	68070	-.26	-.34
MELAMINE "SHOWER COATING" AND EVA 9918 WITH A 11861	-	+2.56	+3.26
HARDBOARD	UNCOATED	-	+3.36

. NO SIGNS OF DELAMINATION OR EDGE SEAL DETERIORATION
. RAINFALL, 12.6 INCHES TOTAL
. BEST PERFORMANCE TO DATE WITH METAL FOIL COVERS
. BEST ORGANIC FILM, SCOTCHPAR POLYESTER

"SUPER DORLUX" MODULES PREPARED
WITH BUTYL EDGE SEAL AND GASKET



Soiling Effects

DECAY IN OPTICAL TRANSMISSION
SITE: ENFIELD, CONNECTICUT

	% TRANSMISSION[A.]		
MATERIAL	CONTROL	4 WEEKS	8 WEEKS
PYREX GLASS	92	90	90
SODA LIME GLASS	87	84	87
TEDLAR 100BG30UT	84	72	77
RTV 615	79	65	65
Q1-2577	74	65	64
SYLGARD 184	82	81	54

A. DIRECT TRANSMISSION FROM 350 NM TO 900 NM.

JPL SOILING THEORY SUGGESTS THAT SOIL RESISTANT SURFACES HAVE THE FOLLOWING PROPERTIES

- HIGH SURFACE HARDNESS
- HYDROPHOBIC
- OLEOPHOBIC
- ION FREE
- LOW SURFACE ENERGY
- SMOOTH

Antisoiling Experiments

SURFACE UNDER INVESTIGATION:

- SUNADEX GLASS
- 3M ACRYLIC FILM, X-22417
- TEDLAR 100BG30UT - DU PONT

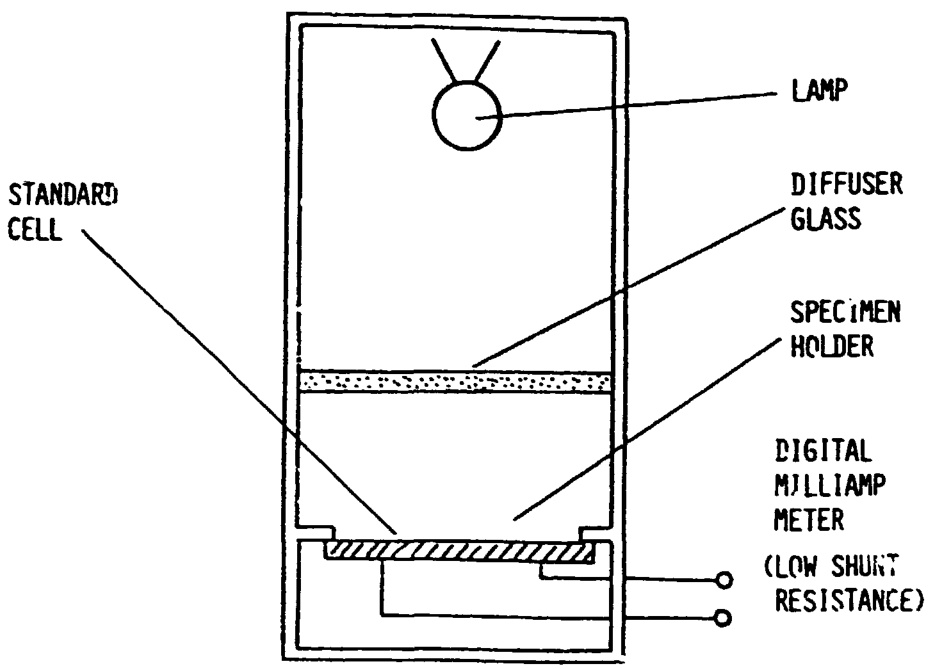
SURFACE TREATMENTS UNDER INVESTIGATION:

- 3M FLUOROSILANE TREATMENT L-1668[A.]
- PERFLUORODECANOIC ACID BASED COATING[A.]
  DOW CORNING E-3820
- OWENS ILLINOIS GLASS RESIN 650
- GENERAL ELECTRIC SHC - 1000
- ROHM & HAAS WL-81 ACRYLIC COATING

A. ALSO USED WITH OZONE TREATMENT TO COUPLE TO ORGANIC SURFACES.

Antisoiling Program

SHORT CIRCUIT MEASUREMENT DEVICE



$$\frac{\text{CURRENT W/SPECIMEN}}{\text{SHORT CIRCUIT CURRENT}} \times 100 = \%\ \text{CHANGE IN SHORT CIRCUIT CURRENT}$$

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Antisoiling Test Results

TEN MONTH EXPOSURE
ENFIELD, CONN.

TREATMENT	SUNADEX		ACRYLIC X-22417		TEDLAR 100 BG 30 UT	
	INITIAL	△%	INITIAL	△%	INITIAL	△%
CONTROL NO TREATMENT	90.5	-3.2	84.0	-10.8	87.7	-8.8
L-1668	89.7	-2.3	80.3	-6.6	88.4	-5.3
L-1668/OZONE	A.	A.	84.5	-6.1	88.1	-5.0
PFDA E-3820	90.0	-2.7	80.0	-6.8	86.0	-3.8
PFDA E-3820/OZONE	A.	A.	84.1	-4.9	86.0	-6.4
GLASS RESIN 650	91.0	-5.7	81.1	-7.4	89.0	-6.5
SHC - 1000	91.9	-4.5	82.1	-7.6	89.0	-5.6
ML-81	90.7	-5.1	83.6	-6.3	87.7	-5.2

A. NOT PREPARED

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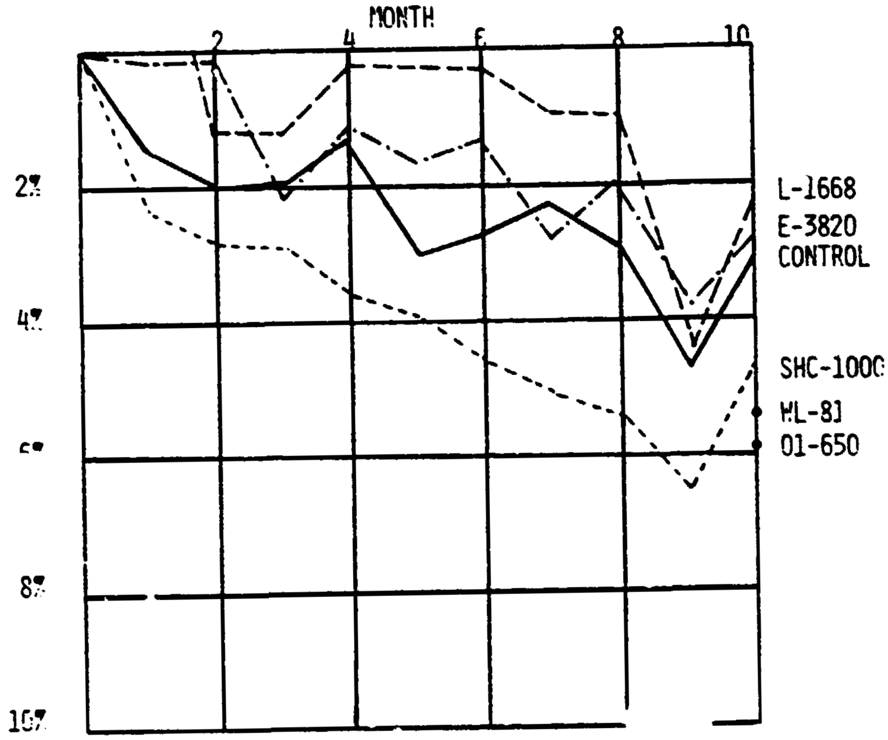
Antisoiling Experiments

TEN MONTHS EXPOSURE, ENFIELD, CONNECTICUT

% LOSS IN I_{SC} WITH STANDARD CELL

TREATED SUNADEX GLASS



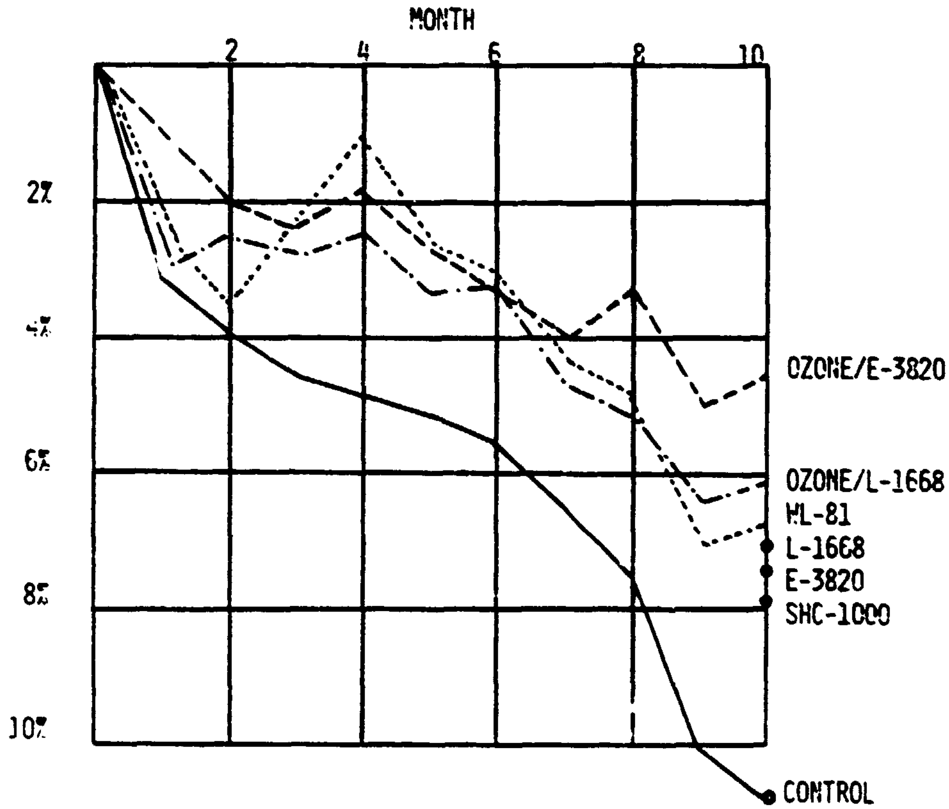
. BEST TREATMENT, L-1668

TEN MONTHS EXPOSURE, ENFIELD, CONNECTICUT

% LOSS IN I_{SC} WITH STANDARD CELL

TREATED ACRYLAR

(SUPPORTED ON GLASS)



- BEST TREATMENT, OZONE WITH E-3829 (FLUOROSILANE)

ENVIRONMENTAL ISOLATION TASK

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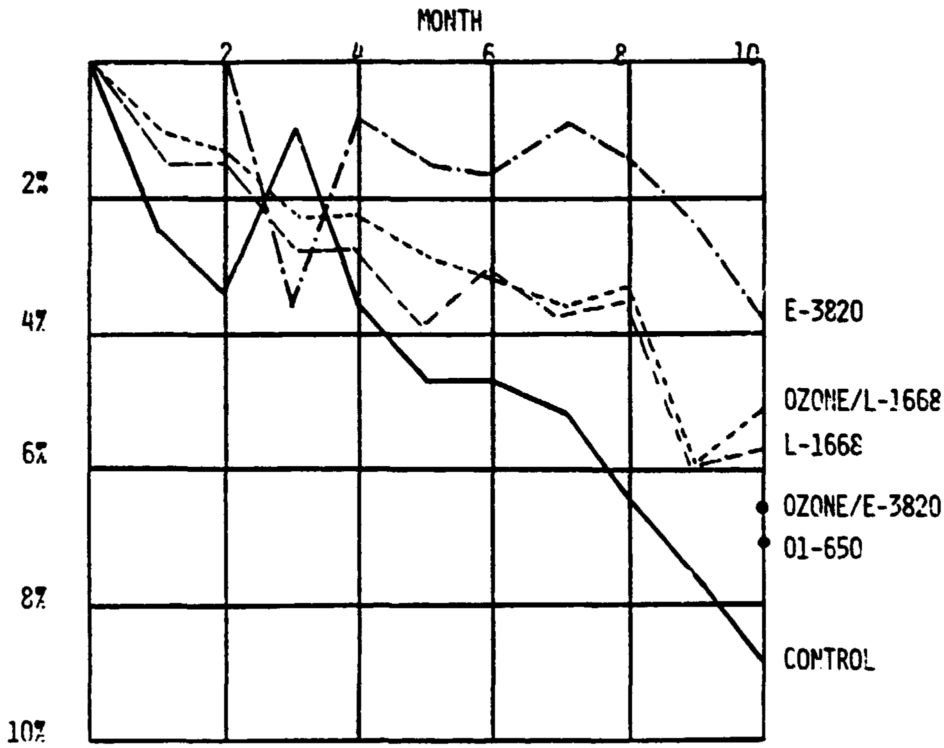
TEN MONTHS EXPOSURE, ENFIELD, CONNECTICUT

% LOSS IN I_{SC} WITH STANDARD CELL

TREATED TEDLAR 100BG30OUT
(SUPPORTED ON GLASS)



BEST TREATMENT, E-3820

ENVIRONMENTAL ISOLATION TASK

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GENERAL OBSERVATIONS:

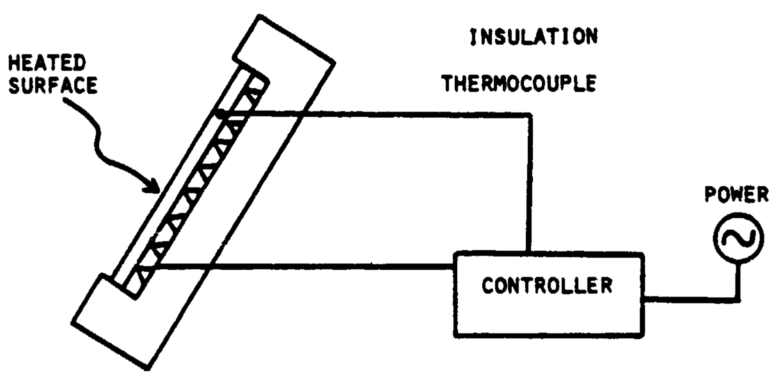
- SUNADEX HAS BEST CONTROL VALUES (-3.0%)
- SUNADEX: BEST COATING, L-1668 (-0.5%)
- TEDLAR: BEST COATING, E-3820 (-1.5%)
- ACRYLAR: BEST COATING, OZONE + E-3820 (-2.4%)
- GOOD CORRELATION WITH NATURAL "CLEANING" CONDITIONS

NEW MATERIALS:

- NEW FLUOROSILANE (SPRINGBORN):
  PERFLUORO-OCTYL TRIETHOXYSILANE
- REACTIVE POLYMER SURFACE TREATMENT (SPRINGBORN):
  PERFLUOROBUTYL ACRYLATE COPOLYMERIZED
  WITH DOW CORNING Z-6030 SILANE

Accelerated Aging Test Program: Outdoor Photothermal Aging

- USE NATURAL SUNLIGHT, AVOIDS SPECTRAL DISTRIBUTION PROBLEMS WITH ARTIFICIAL LIGHT SOURCES
- USES TEMPERATURE TO ACCELERATE THE PHOTOTHERMAL REACTION
- INCLUDES DARK CYCLE REACTIONS
- INCLUDES DEW/RAIN EXTRACTION
- SILICONE RUBBER HEATERS - IN OPERATION ONLY DURING SUNLIT HOURS



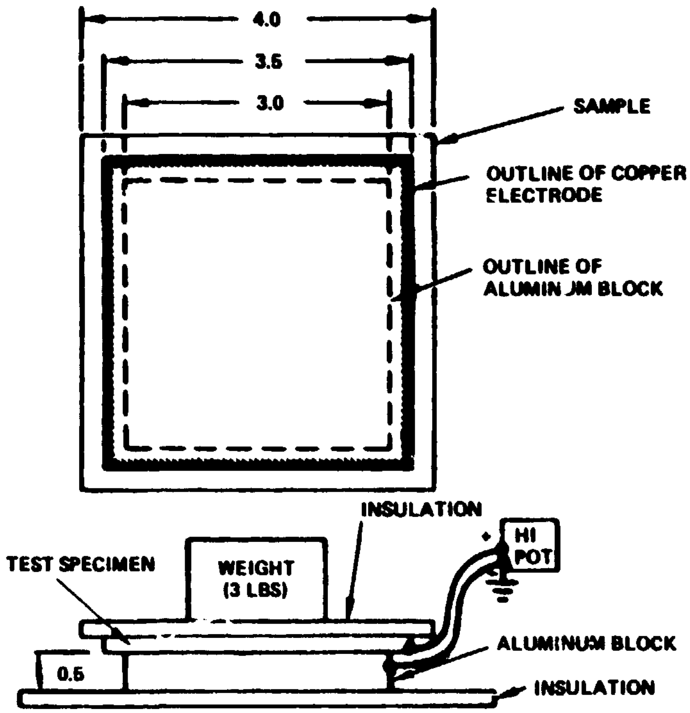
- TEMPERATURES OF INTEREST,
  70°, 90°, 110° C
- TEST MATERIALS:
  - 4 POTTANTS: EVA, EMA, BA, PU
  - 3 OUTER COVERS: SUNADEX, TEDLAR, ACRYLIC
  - COMBINATIONS OF POTTANTS/OUTER COVERS
- TESTS:
  - DIELECTRIC STRENGTH
  - CHEMICAL INERTNESS (COPPER CORROSION)
  - OPTICAL TRANSMISSION
  - STANDARD CELL OUTPUT
  - GEL CONTENT
  - YOUNG'S MODULUS
  - TENSILE STRENGTH
  - ULTIMATE ELONGATION
- DUPLICATE SPECIMENS - PHOENIX AND FLORIDA

ENCAPSULANT DESIGN ANALYSIS AND VERIFICATION

SPECTROLAB, INC.

C.P. Minning (Hughes Aircraft Co.)

Electrical Test Setup



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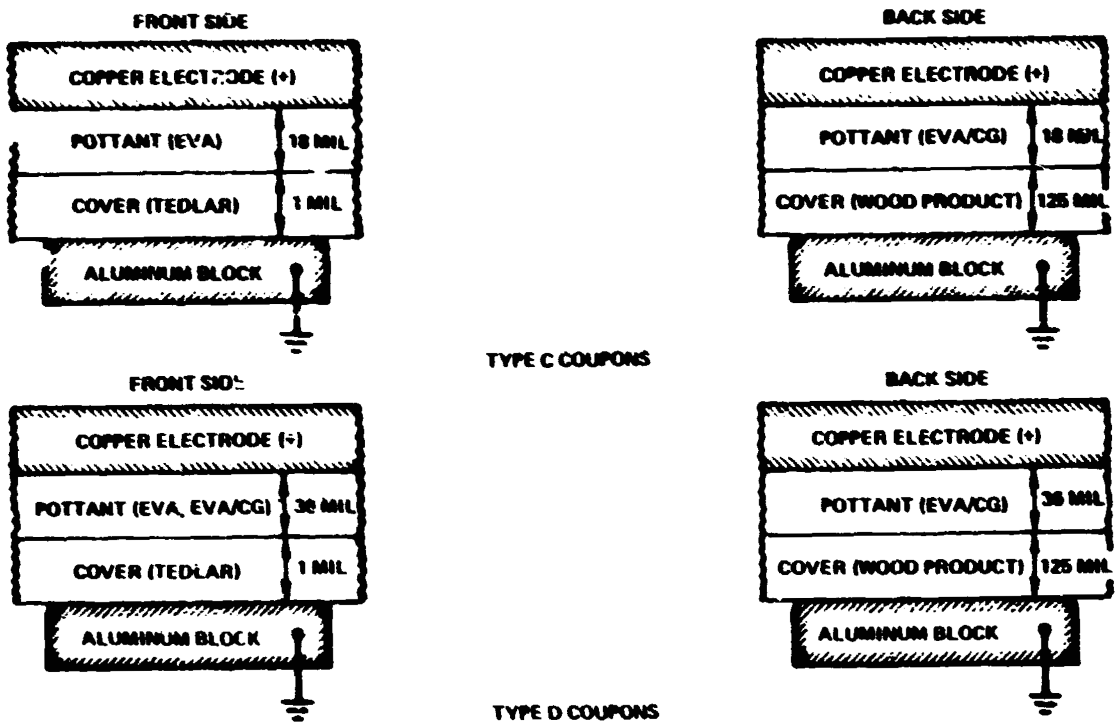
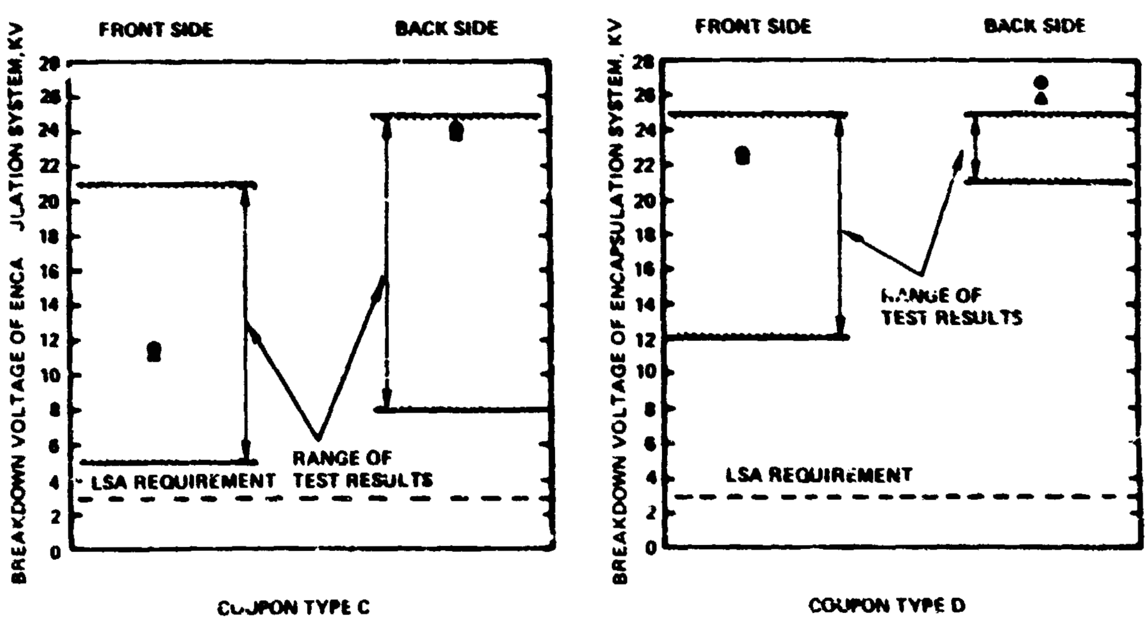
ENVIRONMENTAL ISOLATION TASK

Electrical Isolation Models (Typical)



Electrical Isolation Test Results



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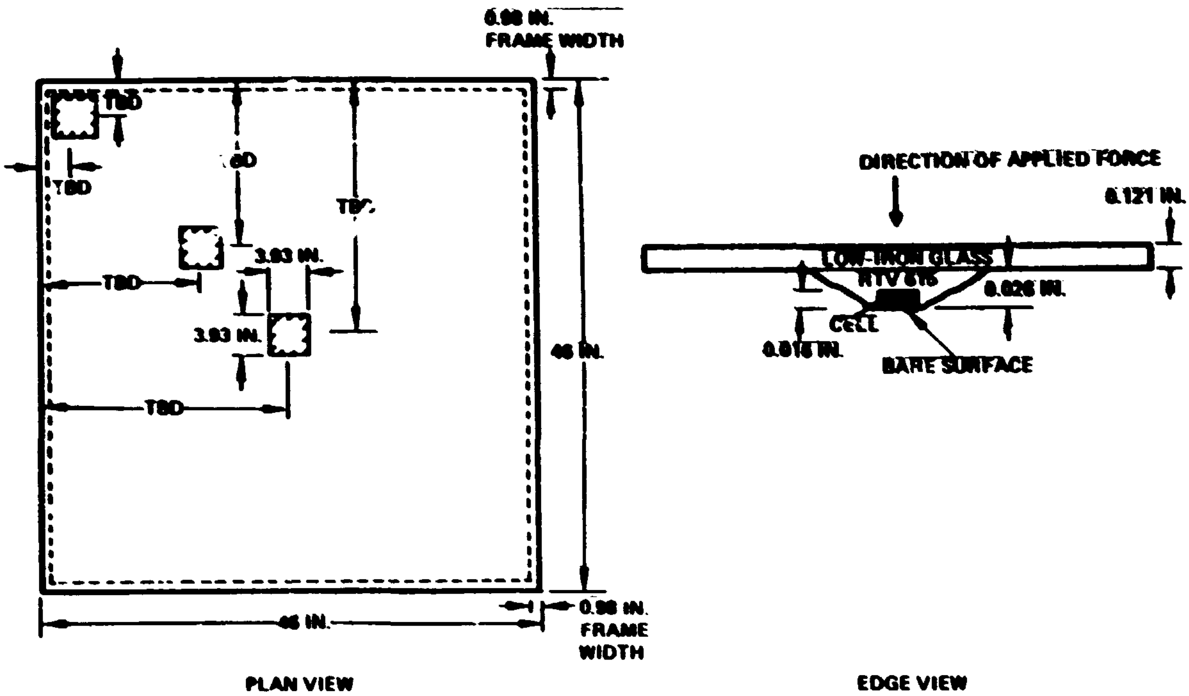
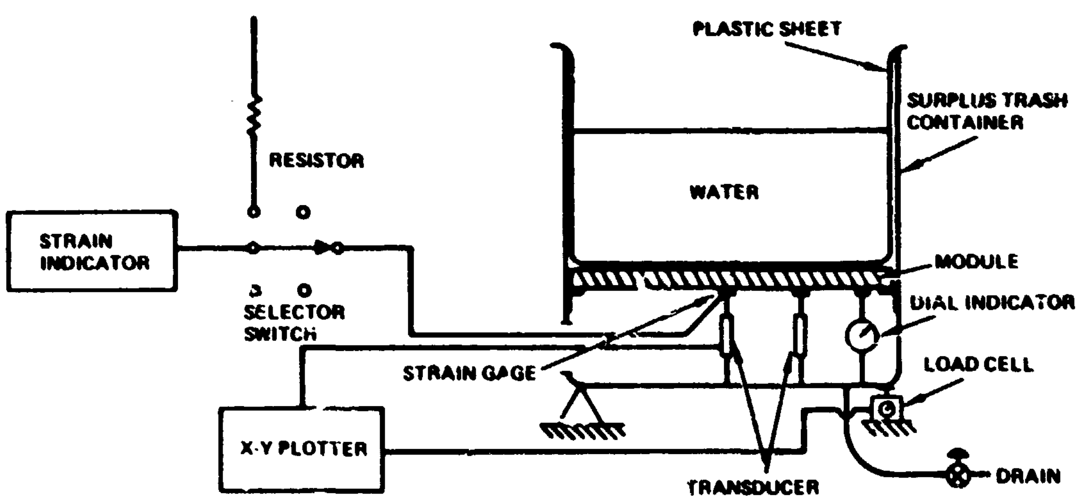
Typical Test Article: Structural/Deflection Test



Structural Deflection Test Setup



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Structural Deflection Test Results

LOAD-BEARING MEMBER DEFLECTION AND STRESS

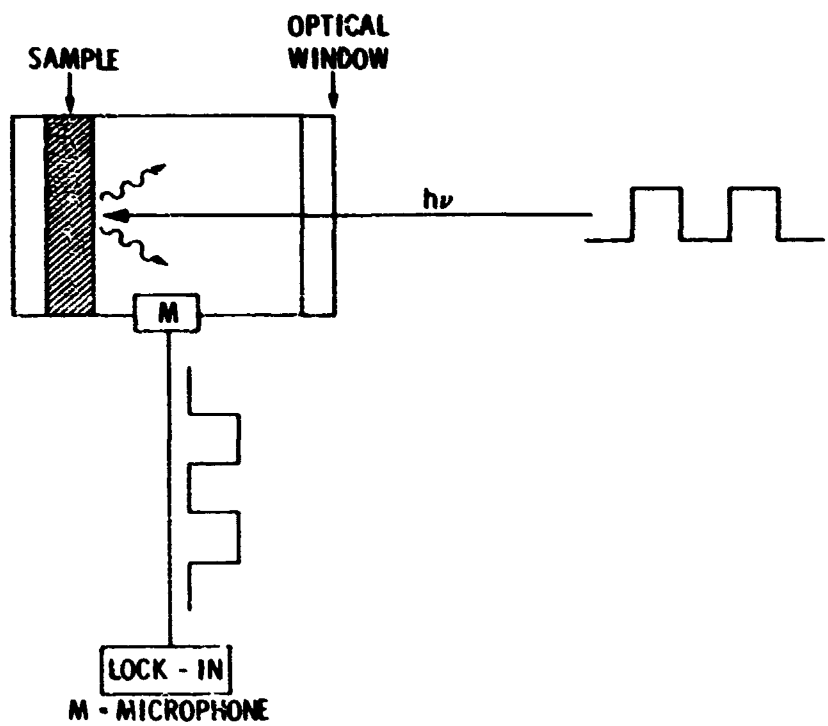
TEST MODULE	DESCRIPTION	DEFLECTION, INCHES		STRESS, PSI	
		TEST	ANALYSIS	TEST	ANALYSIS
SDM -1	GLASS SUPERSTRATE	0.615	0.67	3216	5381
2	GLASS SUPERSTRATE	0.62	0.65	4571	4946
3	GLASS SUPERSTRATE	0.61	0.67	2571	5100
4	GLASS SUPERSTRATE	0.58	0.65	2749	4236
5	PLAIN WOOD SUBSTRATE	1.42	1.33	817	752
6	PLAIN WOOD SUBSRTATE	1.36	1.27	766	741
7	RIBBED WOOD SUBSTRATE	FAILURE	–	–	–
8	STEEL SUBSTRATE	0.42	0.5	2357	4395
9	RIBBED WOOD SUBSTRATE	0.37	0.36	NA	NA

PHOTOACOUSTIC TECHNIQUE

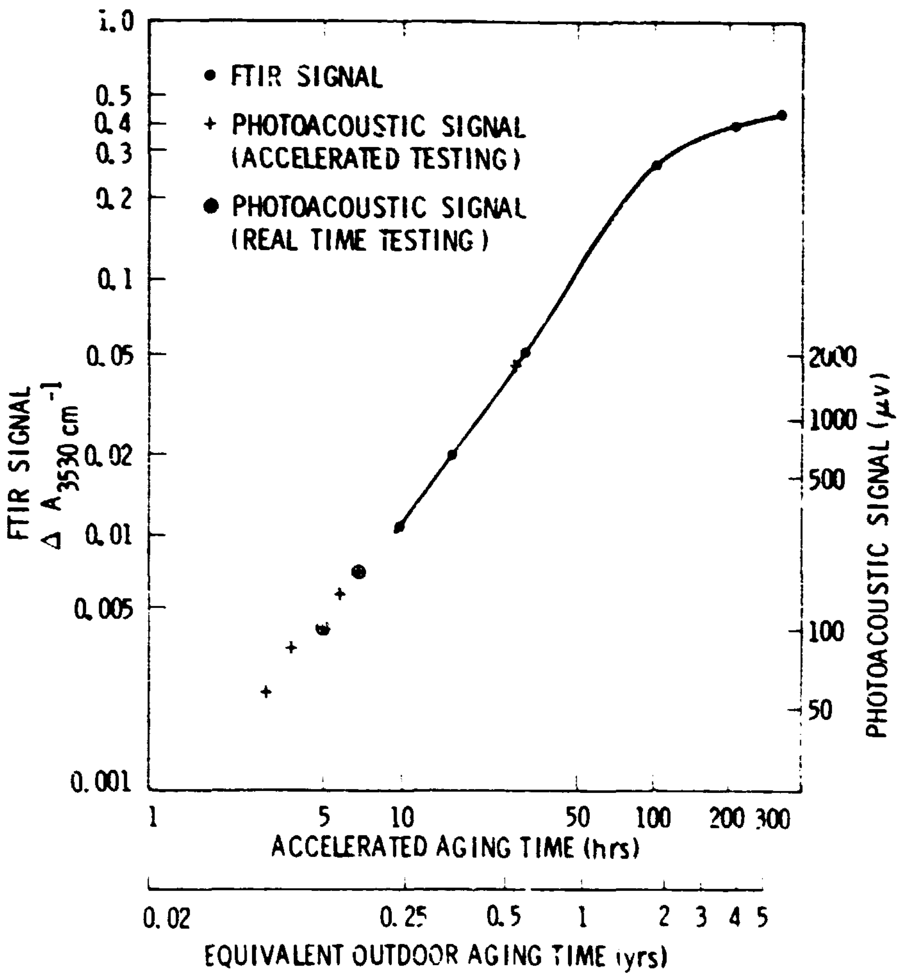
JET PROPULSION LABORATORY

R.H. Liang

Photoacoustic Setup



Formation of (OH) as a Function of Accelerated and Real-Time Aging



ENVIRONMENTAL ISOLATION TASK

MINIMODULE ENCAPSULANT FIELD TESTING

JET PROPULSION LABORATORY

P. Frickland

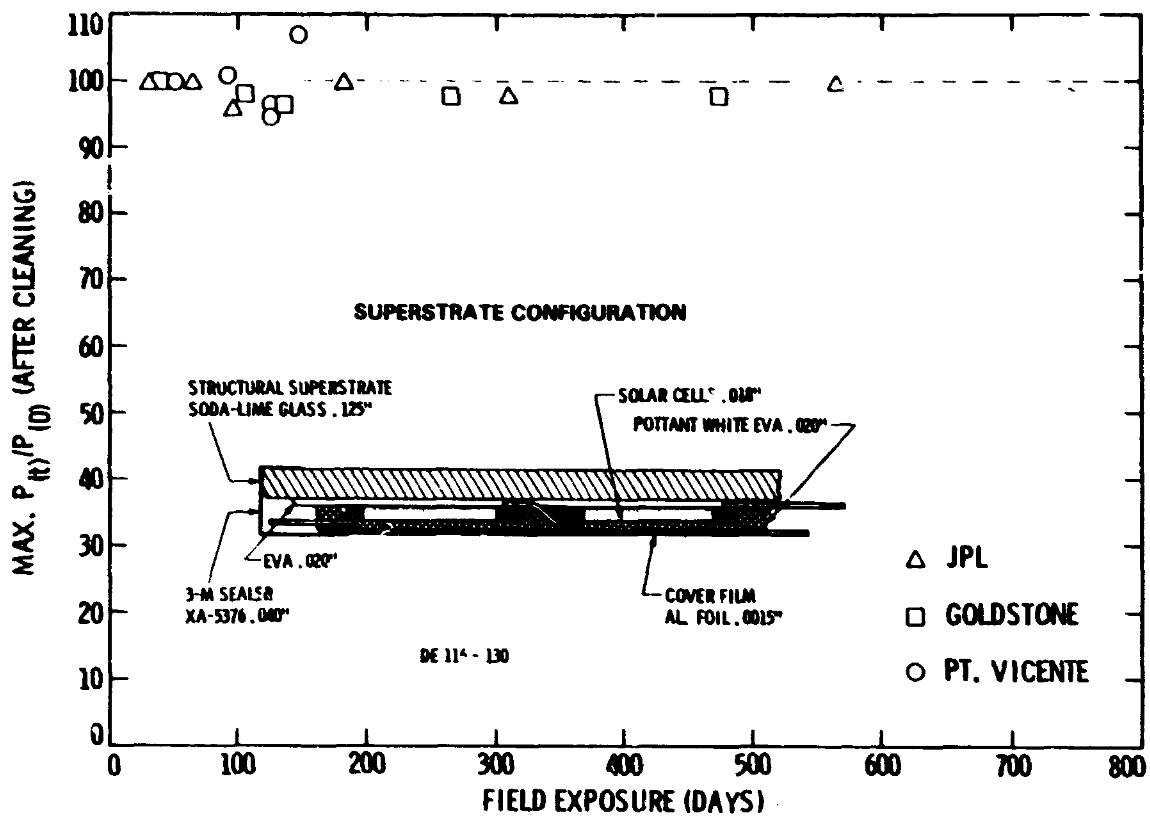
Summary of Minimodule Temperature and Humidity-Freeze Testing

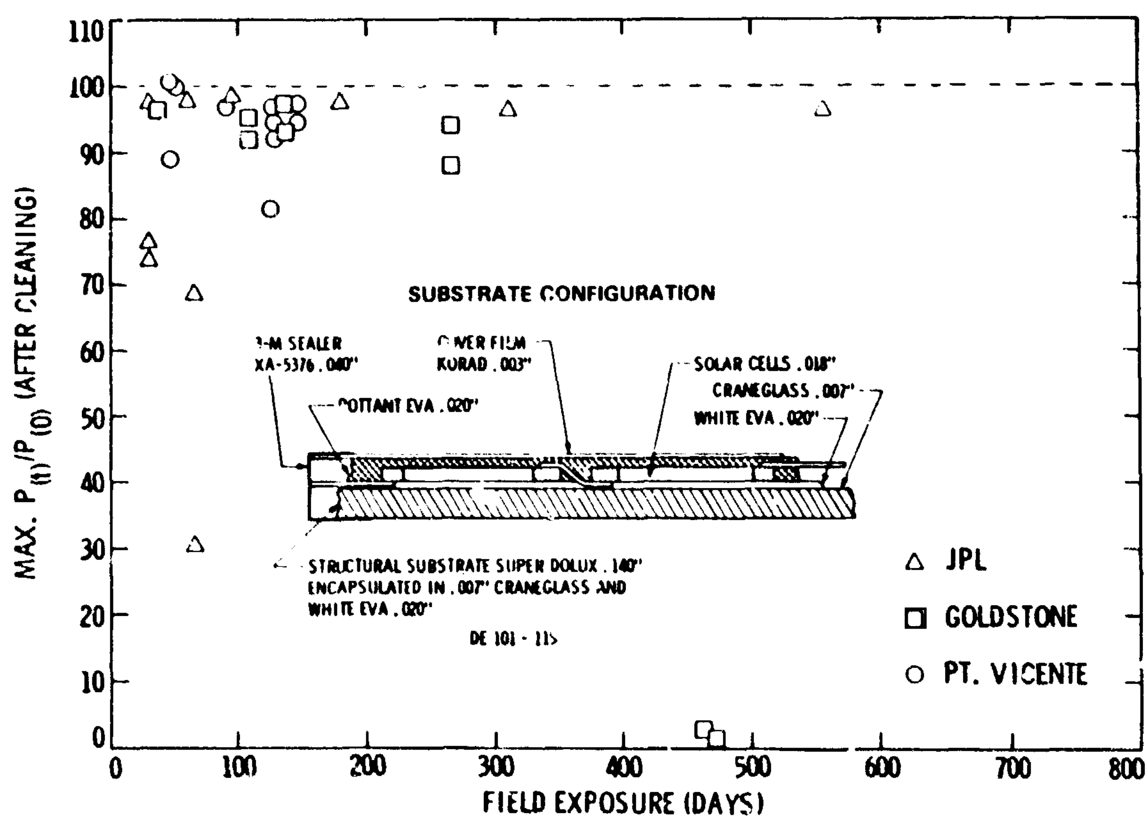
SUBSTRATE	$\Delta P_{(T)}/P_{(0)}$ % TEMP	$\Delta P_{(T)}/P_{(0)}$ % HUMID/FREEZE
Korad/EVA/Galvanized Steel (DE 131-145)	- 4	- 6
Tedlar/EVA/Glass Reinforced Concrete (MB 110-124)	- 0	-11
Korad/EVA/Super Dorlux (DE 101-115)	-25	-59
SUPERSTRATE (GLASS)		
Soda-lime Glass/Polyurethane (PW 101-115)	+ 5	+ 1
Soda-lime Glass/Polyurethane/Acmetite (PW 116-130)	+ 2	+ 1
Soda-lime Glass/EVA/White EVA/Craneglass/Al foil (DE 116-130)	- 4	- 6
Sunadex Glass/EVA/Acmetite (CE 131-145)	+ 2	+ 1
Sunadex Glass/EVA/Craneglass/Acmetite (CE 116-130)	- 2	- 1
Sunadex Glass/EVA/Craneglass/Mylar (CE 101-115)	- 2	- 2
Sunadex Glass/RTV Silicone/Craneglass/Acmetite (GE 101-105)	+ 1	+ 2
7070 Borosilicate Glass (ESB)/EVA/Acmetite (SE 101-110)	+ 1	0,-100

Summary of Minimodule Hail Testing

SUBSTRATE	RESULTS
KORAD/EVA/GALVANIZED STEEL (DE 131-145)	OK
TEDLAR/EVA/GLASS REINFORCED CONCRETE (MB 110-124)	OK
KORAD/EVA/SUPER DORLUX (DE 101-115)	OK
SUPERSTRATE (GLASS)	
SODA-LIME GLASS/POLYURETHANE (PW 101-115)	OK
SODA-LIME GLASS/POLYURETHANE/ACMETITE (PW 116-130)	OK
SODA-LIME GLASS/EVA/WHITE EVA/CRANEGLASS/AL FOIL (DE 116-130)	OK
SUNADEX GLASS/EVA/ACMETITE (CE 131-145)	OK
SUNADEX GLASS/EVA/CRANEGLASS/ACMETITE (CE 116-130)	*
SUNADEX GLASS/EVA/CRANEGLASS/MYLAR (CE 101-115)	OK
SUNADEX GLASS/RTV SILICONE/CRANEGLASS/ACMETITE (GE 101-105)	OK
7070 BOROSILICATE GLASS (ESB)/EVA/ACMETITE (SE 101-110)	BAD (4 @ 25 MPH)

* CRACKED AT EDGE ONLY, 3RD IMPACT 52 MPH


SUPERSTRATE CONFIGURATION
STRUCTURAL SUPERSTRATE
SODA-LIME GLASS .125"
SOLAR CELLS .018"
POTTANT WHITE EVA .020"
EVA .020"
3-M SEALER
XA-5376 .040"
COVER FILM
AL FOIL .0015"
JPL
GOLDSTONE
PT. VICENTE
MAX. $P_{(t)}/P_{(0)}$ (AFTER CLEANING)
FIELD EXPOSURE (DAYS)


SUBSTRATE CONFIGURATION
3-M SEALER
XA-5376 .040"
COVER FILM
KORAD .003"
POTTANT EVA .020"
SOLAR CELLS .018"
CRANEGLASS .007"
WHITE EVA .020"
STRUCTURAL SUBSTRATE SUPER DOLUX .140"
ENCAPSULATED IN .007" CRANEGLASS AND
WHITE EVA .020"
JPL
GOLDSTONE
PT. VICENTE
MAX. $P_{(t)}/P_{(0)}$ (AFTER CLEANING)
FIELD EXPOSURE (DAYS)

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