# SELECTION OF THE SPACE STATION FREEDOM (SSF) FLAT COLLECTOR CIRCUIT (FCC) INSULATION MATERIAL

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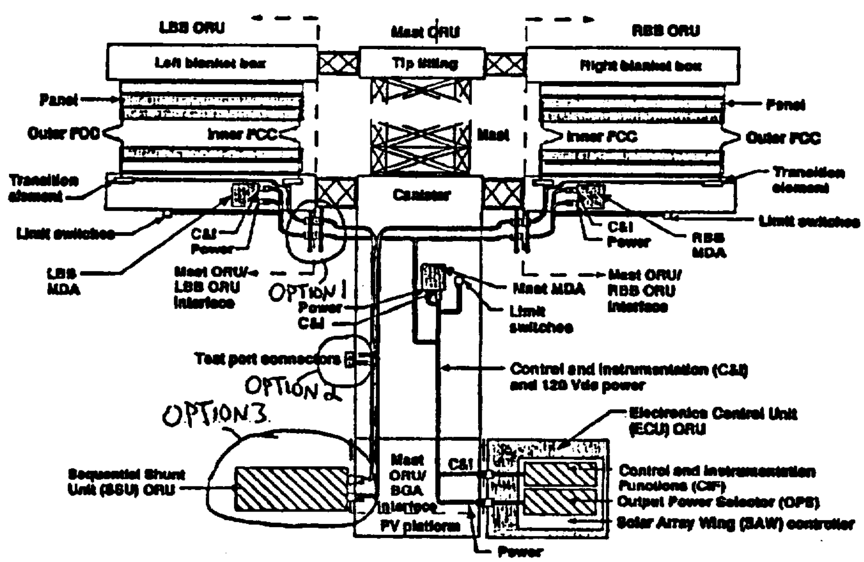
## FUNCTION OF FCC:

**A FLEXIBLE CABLE WHICH PROVIDES MULTIPLE ELECTRICAL PATHS FOR THE DISTRIBUTION OF ELECTRICAL POWER FROM CIRCUIT COMPONENTS ON THE SSF SOLAR ARRAY.**

**Array Power Deadfacing Option Locations**



## REQUIREMENTS OF THE FCC WHICH AFFECT THE SELECTION OF THE INSULATION MATERIAL

### THE FCC SHALL PERFORM AS SPECIFIED AFTER EXPOSURE TO THE FOLLOWING ENVIRONMENTS:

- ATOMIC OXYGEN EXPOSURE - TOTAL FLUENCE 5.4 x $10^{22}$ AO/$CM^2$. (15 YEARS OF EXPOSURE)
- ULTRAVIOLET RADIATION EXPOSURE - 10 SUN YEARS (2/3 OF ILLUMINATED ORBITAL TIME OVER 15 YEARS).
- THERMAL CYCLES - 87,000 THERMAL CYCLES BETWEEN ± 100°C.
- STORAGE LIFE - 5 YEARS SHELF LIFT UNDER FOLLOWING ENVIRONMENT:

    TEMPERATURE = +10, +40°C
    RELATIVE HUMIDITY - 20 TO 60%
    PRESSURE - 650 TO 810 TORR

### OTHER REQUIREMENTS:

- THE FCC SHALL NOT ADHERE TO ITSELF. (BLOCKING)
- THE SURFACE OF THE FCC SHALL HAVE A SOLAR ABSORPTIVITY ≤ .45 BOL.
- THE SURFACE OF THE FCC SHALL HAVE AN INFRARED EMISSIVITY ≥ .85 AT BOL.

DATA TO SUPPORT THE SELECTION OF THE FCC INSULATION MATERIAL WAS OBTAINED THRU DEVELOPMENT WORK ASSOCIATED WITH THE SA COVERLAY.

- o THE SAME MATERIAL IS USED FOR THE FCC INSULATION AND THE SA COVERLAY.

- o THE DEVELOPMENT WORK TO BE PRESENTED WAS DONE ON THE SOLAR ARRAY COVERLAY MATERIAL. THE FINDINGS ARE APPLICABLE TO THE FCC APPLICATION.

  - COVERLAY IS THE STRUCTURAL LAYER OF THE SOLAR ARRAY TO WHICH THE SOLAR CELLS ARE BONDED.

  - COVERLAY ALSO FUNCTIONS AS THE DIELECTRIC BETWEEN THE INTERCONNECTING CIRCUITRY ON THE SA AND THE LEO ENVIRONMENT.

## DEVELOPMENT HISTORY

INITIAL SELECTION (1989):
SiOx COATED 1 MIL THICK KAPTON H.

- INITIAL DESIGN WAS BASED ON MILSTAR AND SAFE FLEXIBLE SOLAR ARRAY DESIGNS AND MATERIAL DEVELOPMENT WORK PERFORMED BY LMSC UNDER LeRC CONTRACT.

TESTS PERFORMED:
SHORT EXPOSURE TO RF GENERATED OXYGEN PLASMA (1 WK).

TEST RESULTS:
SiOx COATED KAPTON EXHIBITED A DECREASE IN THE AO INDUCED MASS LOSS RATE RELATIVE TO BARE KAPTON (REDUCTION IN MASS LOSS RATE UP TO 100x).

TEST LIMITATIONS:
LONG DURATION TESTS NECESSARY FOR SSF APPLICATIONS WERE OUTSIDE THE SCOPE OF THE INITIAL MATERIAL DEVELOPMENT PROGRAM.

## INITIAL SELECTION (1989)

## FURTHER TESTING FOR SSF APPLICATIONS

**TESTS PERFORMED:**
SIMULATED LONG DURATION AO STABILITY TESTS (SIMULATED 15 YR EXPOSURE).

**TEST RESULTS:**

- o SiOx COATING ITSELF DISPLAYED SUPERIOR STABILITY AGAINST AO ATTACK.
- o ANY BREAKS INITIALLY PRESENT IN COATING RESULTED IN EROSION OF THE UNDERLAYING MATERIAL.
- o TENSILE STRENGTH OF THE COVERLAY DECREASES RAPIDLY DUE TO THE LOW TEAR PROPAGATION STRENGTH OF KAPTON.

**CONCLUSION:**

- o COVERLAY APPLICATION REQUIRED A MATERIAL WITH GREATER MECHANICAL STRENGTH RETENTION TO MEET SA LOAD REQUIREMENTS.
- o EROSION OF THE KAPTON INSULATION MATERIAL IN THE FCC APPLICATION MAY INCREASE THE PROBABILITY OF SHORT CIRCUIT

# MODIFIED DESIGN

## E-GLASS TESTING:

| ENVIRONMENT | DURATION/EXPOSURE | RESULTS |
|---|---|---|
| HUMIDITY | 30 DAY AT 90% RH 85°C | EXHIBITED ADEQUATE PROPERTIES FOR LONG TERM STORAGE. |
| SIMULATED ATOMIC OXYGEN ON UNSIZED E-GLASS | EFFECTIVE FLUENCE $1.5 \times 10^{22}$ AO/CM$^2$ 30% EXPECTED SSF EXPOSURE | NO CHANGE IN MATERIAL STRENGTH |
| SIMULATED AO ON SIZED E-GLASS (S-938* SIZING) | $.07 \times 10^{22}$ AO/CM$^2$ 1% EXPECTED SSF EXPOSURE | 30% LOSS IN TENSILE STRENGTH/ STRENGTH OF SIZED CLOTH REMAINED ABOVE STRENGTH OF UNSIZED CLOTH |

*SILANE SIZING (S-938) INCREASES THE TENSILE STRENGTH AND IMPROVES THE ADHESION OF FIBERS TO SILICONE.

## MODIFIED DESIGN (1990) BASELINE:

1300Å SiOx COATING
1 MIL KAPTON H
1300Å SiOx COATING
1.5 MIL THICK STYLE 106 E-GLASS IMPREGNATED WITH NUSIL TECHNOLOGY CV1-2502 SILICONE
1 MIL BARE KAPTON HN

## ADVANTAGES OF NEW DESIGN:

- o FIBERGLASS PROVIDES STRENGTH RETENTION (ASSUMES LOAD CARRYING ROLE).
- o 2 LAYERS OF SiOx COATING PROTECT THE FIBERS IN THE SILICONE MATRIX.
- o EVEN AFTER THE FIBERS IN THE SILICONE MATRIX ARE EXPOSED, STABILITY OF THE GLASS UNDER AO EXPOSURE WILL AID IN MAINTAINING TEAR RESISTANCE AND STRENGTH.
- o OUTER LAYER OF SiOx PREVENTS BLOCKING.

## COVERLAY TESTING - ASSUMED END-OF-LIFE CONFIGURATION

EOL CONFIGURATION REPRESENTS WORST-CASE CONDITION AFTER BOTH LAYERS OF KAPTON ARE ERODED AWAY. CONFIGURATION CONSIDERED TO PRODUCE CONSERVATIVE RESULTS.

| ENVIRONMENT | DURATION/EXPOSURE | RESULTS |
| --- | --- | --- |
| 1. AO | EFFECTIVE FLUENCE $2.9 \times 10^{22}$ AO/CM$^2$ 60% SSF EXPOSURE LEVEL | o* EMBRITTLED REGIONS<br>o LOSS OF TENSILE STRENGTH |

*RESULTS WERE NOT CONSIDERED WITH EXPECTED RESULT BASED ON LDEF DATA, WHICH INDICATED SILICONE HAS GOOD RESISTANCE TO AO EMBRITTLEMENT.

| | | |
| --- | --- | --- |
| UV | 8000 EQUIVALENT SUN HRS AT 2 SUNS INTENSITY | INCREASE IN TENSILE STRENGTH FROM 30-40 LB/IN<br>NO CRACKING OBSERVED.<br>SLIGHT DARKENING |

| ENVIRONMENT | DURATION/EXPOSURE | RESULTS |
| --- | --- | --- |
| 2. AO (RECENT DATA SEPARATE LOT) | 80% SSF EXPOSURE LEVEL | RETENTION OF TENSILE STRENGTH PROPERTIES ON BOTH BOL, EOL SPECIMENS |

*THE VARIATION IN TEST VALUES EXHIBITED IN AO TEST 1 COMPARED TO EARLIER DATA AND CURRENT DATA ARE ATTRIBUTED TO EITHER:

- o DEPENDENCE OF TEST CONFIGURATION
- o LOT TO LOT VARIATION

## CONCLUSION

THE MOST SIGNIFICANT ENVIRONMENTAL EXPOSURE EFFECTS ARE FROM ATOMIC OXYGEN.

THE MODIFICATION TO THE COVERLAY PROVIDE FOR GREATER ROBUSTNESS TO THE EFFECTS OF LONG LEO EXPOSURE.

## EFFECTS ON MODIFIED DESIGN ON FCC

o CHANGES TO THE COVERLAY DRIVEN BY THE NEED TO IMPROVE THE SA STRENGTH RETENTION SERVED TO BENEFIT THE FCC:

1. PROVIDES BETTER PROTECTION AGAINST THE OCCURRENCE OF EXPOSED COPPER CONDUCTOR.

   (INITIAL DESIGN - IMPERFECTIONS IN SiOx COATING RESULTED IN EROSION OF KAPTON AND SUBSEQUENT TEARING, LEADING TO EXPOSED CONDUCTOR.)

*2. A. TESTS INDICATE THE MODIFIED DESIGN IS MORE RESILIENT TO ARC TRACKING INITIATION.

   B. MODIFIED DESIGN ELIMINATED FLASH OVER.

* NASA CONTRACTOR REPORT 191106, THOMAS J. STUEBER

## ARC TRACKING TESTS PERFORMED ON FCC

CHARACTERISTIC OF KAPTON:

KAPTON POLYMIDE WIRING INSULATION IS VULNERABLE TO PYROLIZATION (CHARRING), ARC TRACKING AND FLASHOVER WHEN MOMENTARY SHORT CIRCUIT ARCS APPEAR.

- o ARC TRACKING OCCURS WHEN THE SHORT CIRCUIT ARC PROPAGATES DOWN THE WIRE THRU CONTINUED PYROLIZATION.
- o FLASHOVER OCCURS WHEN AN ARC INVOLVING ONE PAIR OF WIRES CHARS ADJOINING WIRING RESULTING IN MULTIPLE FAILURES.

ARC TRACKING TEST WERE CONDUCTED BY:

1. GENERATING A DEFECT LOCATED BETWEEN ONE OF THE SUPPLY LINES AND ITS CORRESPONDING RETURN LINE WHICH EXPOSES A SMALL AREA OF THE COPPER RETURN LINE.
2. SAMPLES WERE PREPYROLIZED BY CREATING A MOMENTARY SHORT CIRCUIT ARC. POWER WAS THEN TURNED OFF.
3. TEST WAS CONDUCTED TO DETERMINE THE MINIMUM OPEN CIRCUIT VOLTAGE AND SHORT CIRCUIT CURRENT NECESSARY TO RESTART THE ARC TRACKING EVENT.

FLASHOVER TESTS WERE CONDUCTED ON 3 SIDE-BY-SIDE ENERGIZED CHANNELS.

1. FLASHOVER TEST WAS CONDUCTED BY PROMOTING THE ARC TRACKING EVENT BY SHORTING THE MIDDLE CHANNEL WITH ADJOINING CHANNELS ENERGIZED.

## ARC TRACKING TEST RESULTS

ARC TRACKING:

A MOMENTARY SHORT CIRCUIT DID INITIATE KAPTON PYROLYSIS AT POWER LEVELS BELOW SSF OPERATING LEVELS. HOWEVER, NEW DESIGN WAS MORE RESILIENT TO ARC TRACKING INITIATION THAN PREVIOUS DESIGN.

PREVIOUS DESIGN:

ARC TRACKING WAS INITIATED AT THE EPOCH OF THE FIRST MOMENTARY SHORT CIRCUIT.

NEW DESIGN:

TYPICALLY SEVERAL MOMENTARY SHORT CIRCUITS WERE NEEDED TO PYROLIZE THE POLYIMIDE ENOUGH TO INITIATE ARC TRACKING.

FLASHOVER:

THE FLASHOVER EVENT OBSERVED IN EARLIER DESIGNS DID NOT OCCUR WITH THE MODIFIED DESIGN