

MODULE DEVELOPMENT AND ENGINEERING SCIENCES

N86-29403

AMORPHOUS-SILICON MODULE HOT-SPOT TESTING

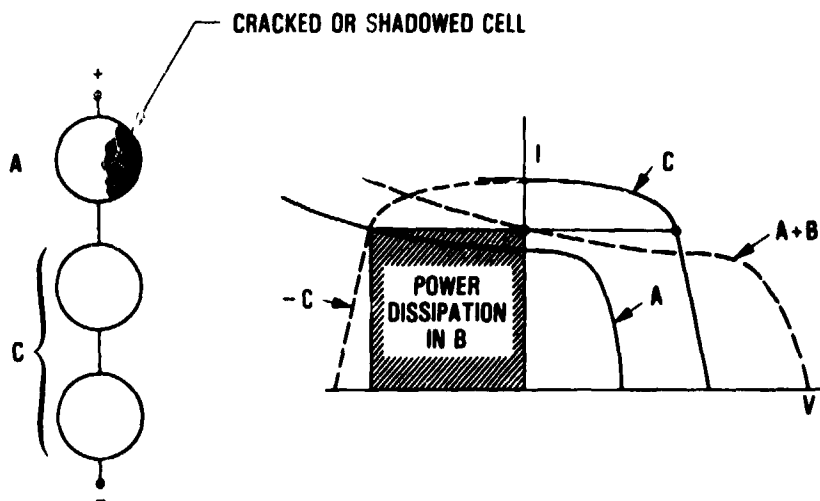
JET PROPULSION LABORATORY

C. C. Gonzalez

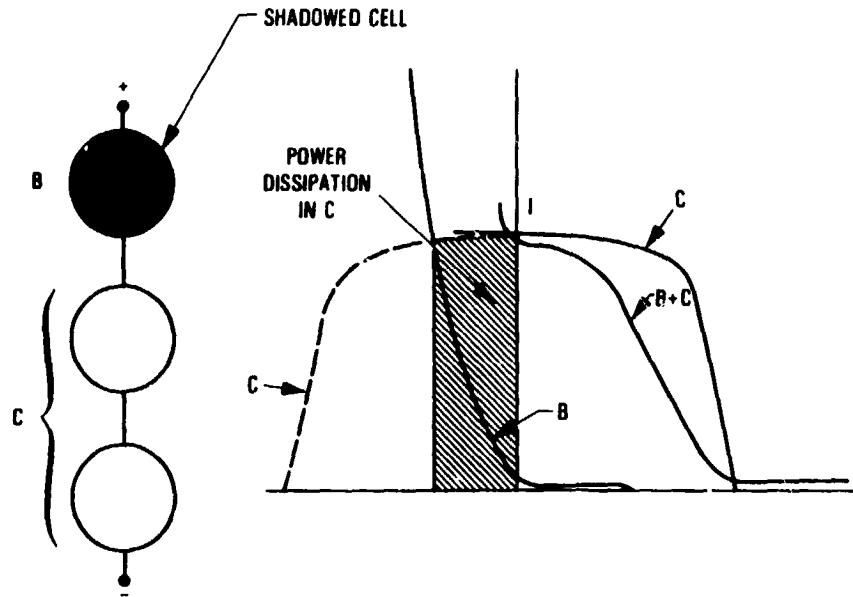
Background

- Hot-spot heating occurs when cell short-circuit current is lower than string operating current
 - Cell goes into reverse bias and absorbs power (= reverse-bias voltage x cell current)
 - Reverse-bias voltage is proportional to the number of cells in series with the affected cell
 - It is necessary to limit reverse-bias voltage by means of bypass diodes
- Nonuniform heating over cell area leads to increased temperature for same power dissipation

Visualization of Hot-Spot Cell Heating with High-Shunt Resistance Cell



Visualization of Hot-Spot Cell Heating
with Low-Shunt Resistance Cell



Key Lessons from Crystalline Silicon

- **Maximum allowable temperature for encapsulants: 120°C to 140°C**
- **Temperature very dependent on cell-to-cell shunt-resistance differences**
- **Lateral heat transfer from hot spot is important**
- **Common failure at high heat levels is cell shorting**
- **Typical crystalline-silicon module requires bypass diodes around every 12 to 18 cells**
- **Heating is highly non-linear function of applied current and voltage**
 - **Non-linear reverse I-V characteristic**
 - **Changing shunt-resistance with temperature**
 - **Changing hot-spot area with temperature**

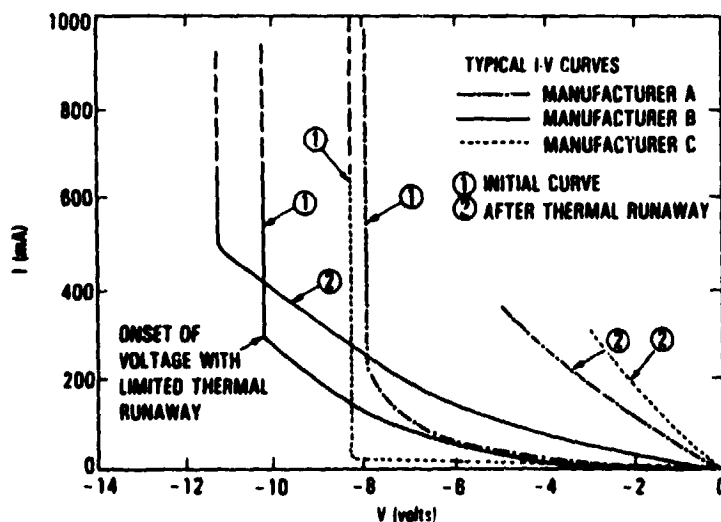
Amorphous-Cell Hot-Spot Testing Objectives

- To develop the techniques required for performing reverse-bias testing of amorphous cells
- To quantify the response of amorphous cells to reverse biasing
- To develop guidelines for reducing hot-spot susceptibility of amorphous modules
- To develop a qualification test for hot-spot testing of amorphous modules

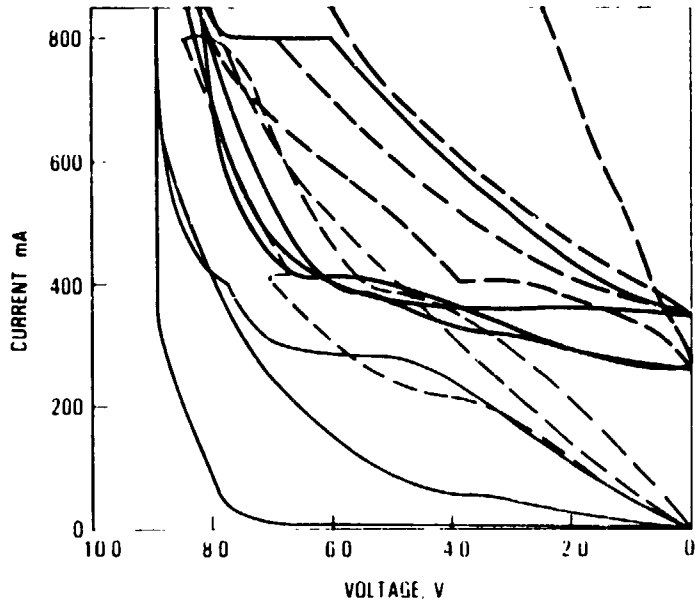
Approach

- Amorphous cells tested using two techniques
 - First is equivalent to that used in hot-spot testing of crystalline cells
 - Hot-spot temperature monitored using IR camera
 - Reverse-bias I-V curve plotted as test is conducted
 - Second consists of pulsed reverse-bias voltage ranging in duration from 0.01 to 100 milliseconds
 - I-V curve plotted after each pulse

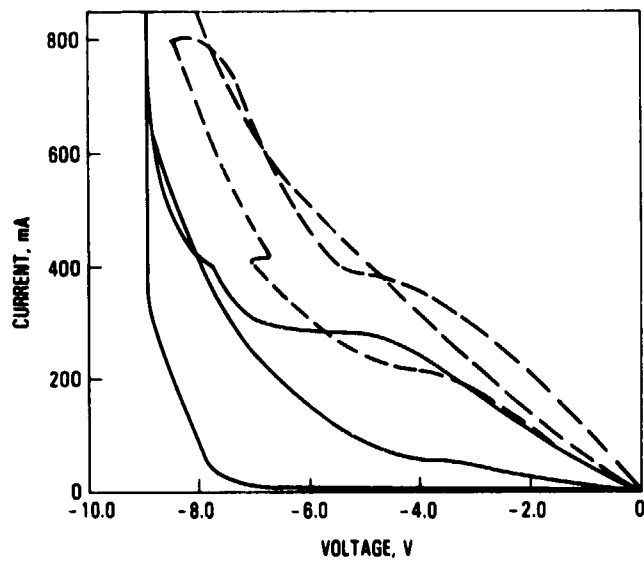
Amorphous-Cell Second-Quadrant I-V Curves



Amorphous-Module Cell-Reverse Quadrant I-V Curves
Illuminated Cells

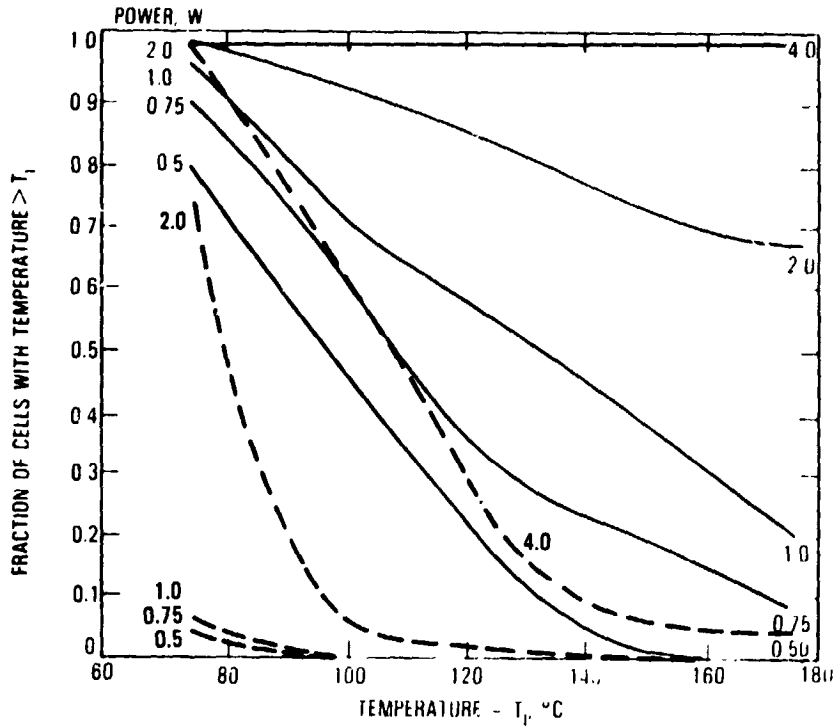


Amorphous-Module Cell-Reverse Quadrant I-V Curves
Unilluminated Cells

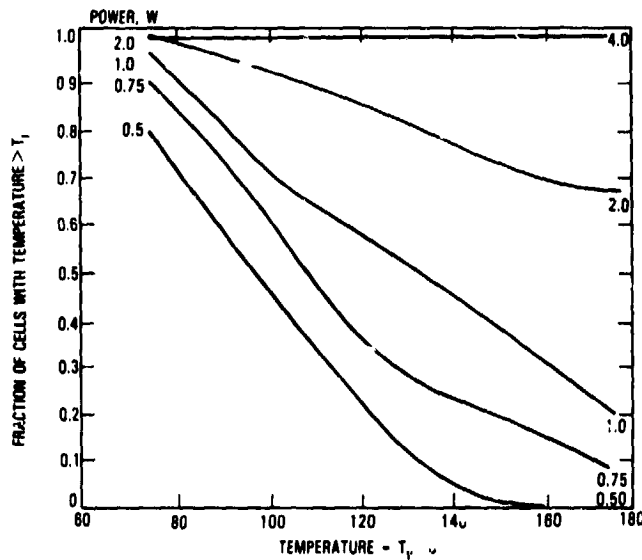


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Fraction of Cells Reaching a Given Temperature as a Function of Power Dissipated (Modules)

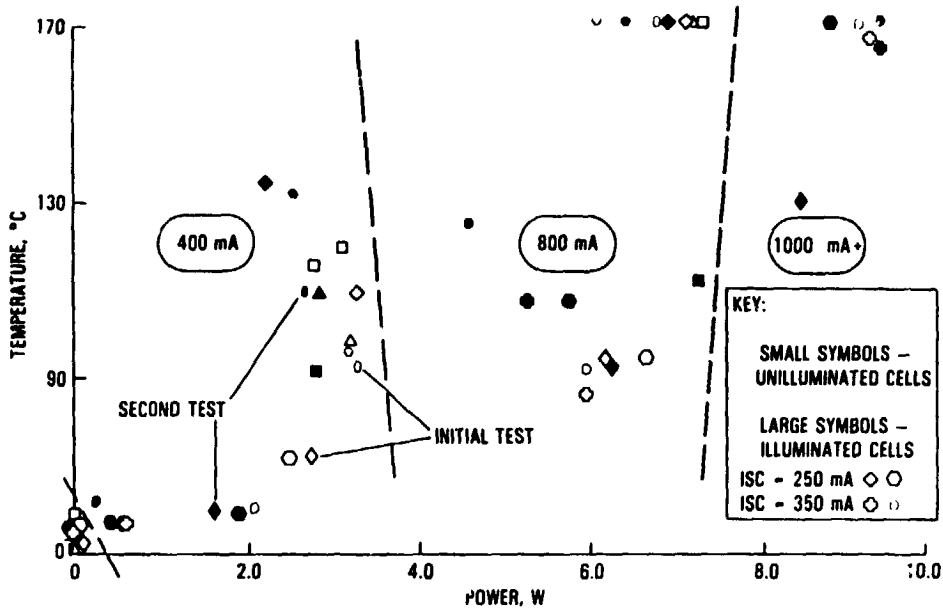


Fraction of Cells Reaching a Given Temperature as a Function of Power Dissipated (Submodules)

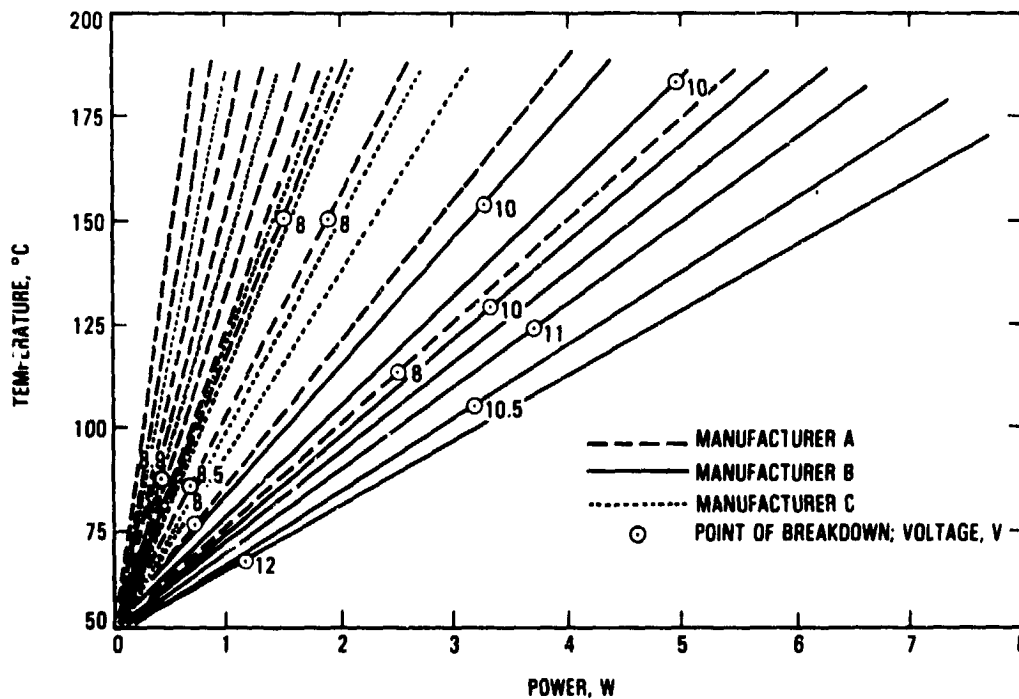


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Hot-Spot Temperature Versus Power for Cells in Encapsulated Module
(Test Current Equal to 1, 2, and 2 + Cell I_{SC})



Hot-Spot Temperature Versus Power
(Unencapsulated Amorphous-Silicon Submodules, No Illumination)



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Hot-Spot Qualification Test

- **Hot-spot qualification test performed on one module type**
- **Same procedure and equipment as for crystalline cells**
 - **100-hour cyclic test**
 - **Treated as low-shunt-resistance cell (Type B)**
 - **Test performed in absence of illumination**
 - **Test current is module short-circuit current**
 - **Module temperature raised to field environment (45°C to 50°C)**

Results and Conclusions

- **Amorphous cells undergo hot-spot heating similarly to crystalline cells**
 - **Shunt resistance levels similar**
 - **Tolerance to heating level similar**
- **Comparison of results obtained with submodules versus actual module indicate heating level lower in latter**
 - **Module structure contains thick (relative to front surface) glass substrate not present in submodules**
- **Module design must address hot-spot heating**
 - **Heat-sinking cells**
 - **Use of bypass diodes**
 - **Use of smaller solar cells (lower maximum current)**
- **Hot-spot qualification test conducted on module**
 - **Module passed test with no instabilities**
 - **Minor cell erosion occurred that is characteristic of amorphous cells**

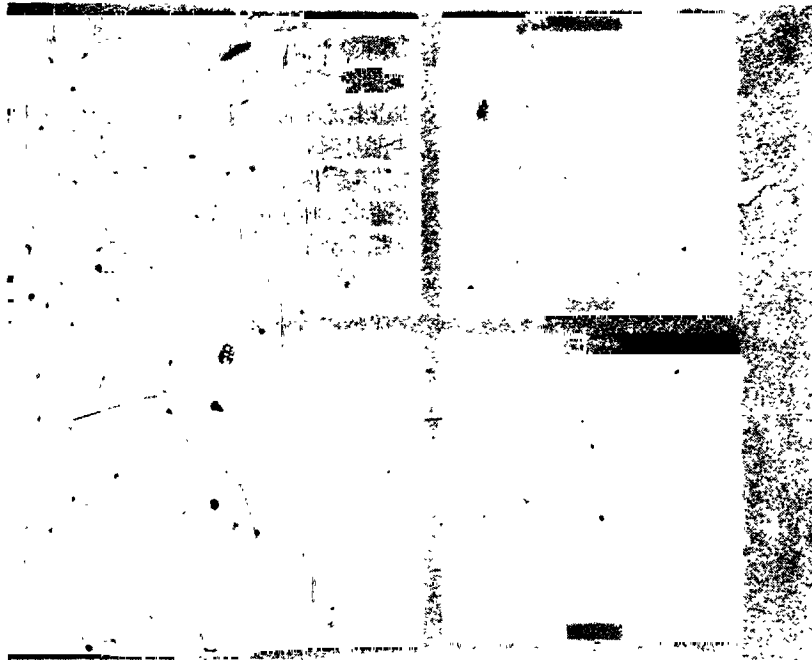
Hot-Spot Test Set-Up



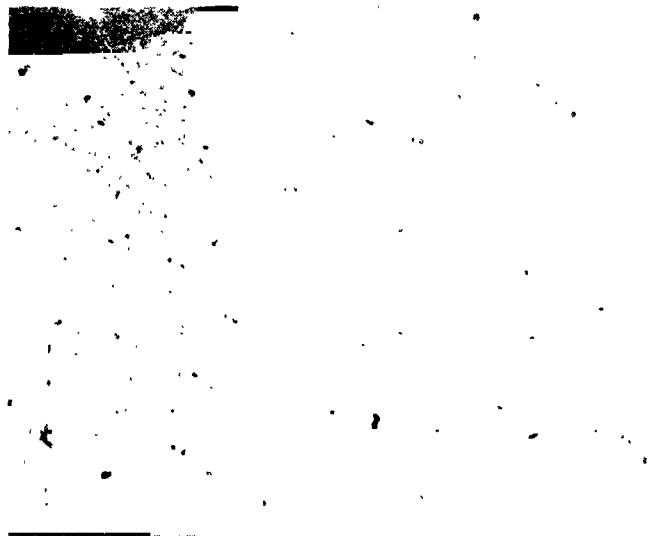
Test Set-Up for Submodule Using Conductive Elastomeric Material



Results of Hot-Spot Testing of Four Submodules



Close-up View of Hot-Spot Area

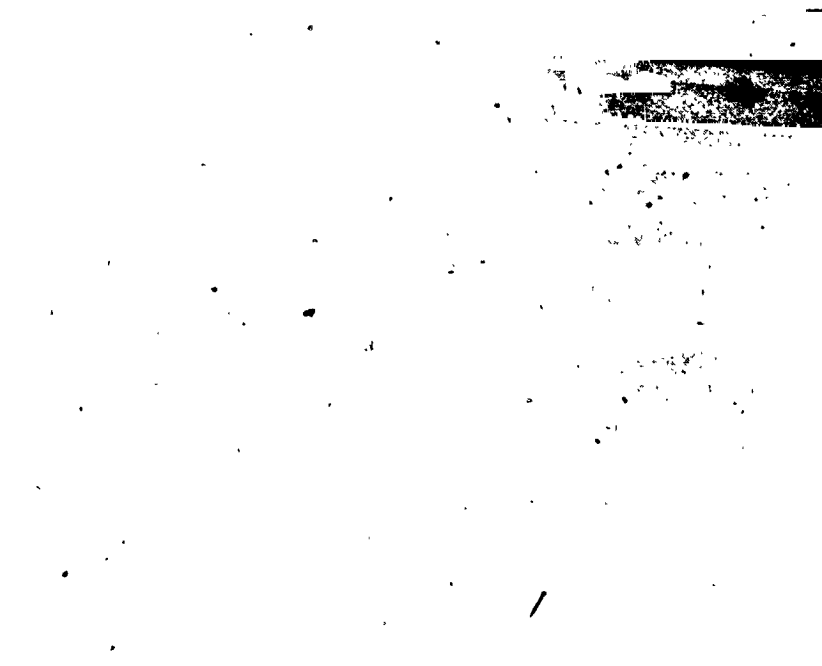


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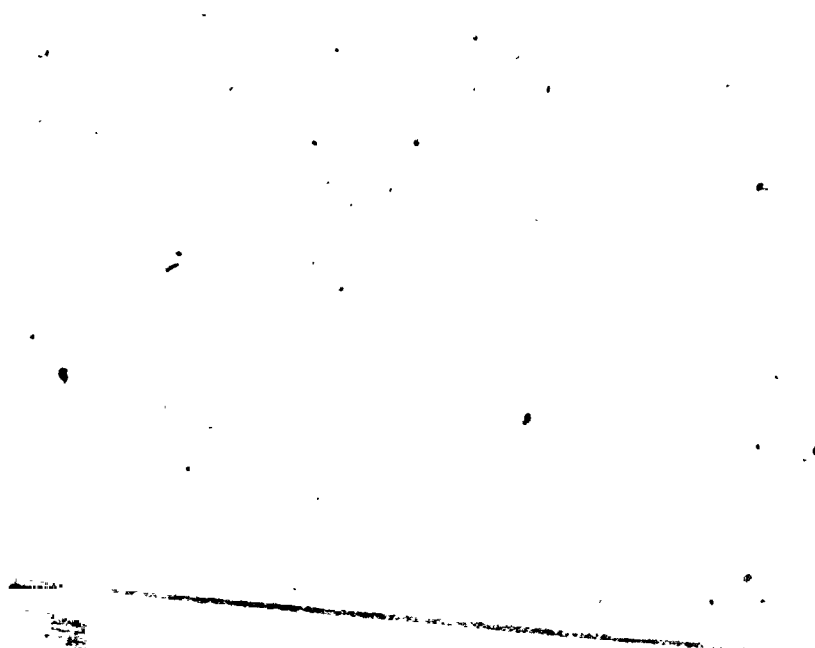
Front Side of Arco Test Module



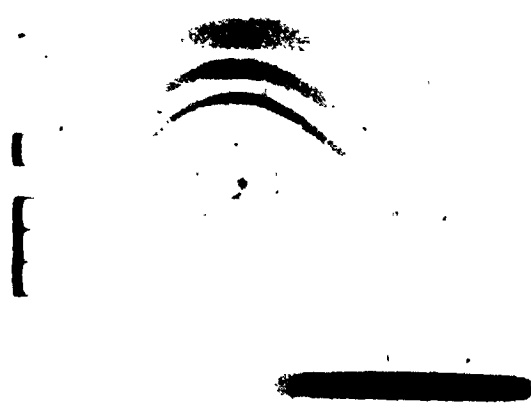
**Back Side of Arco Test Module Showing
Added Conductive Ribbon Attached with Conductive Epoxy**



Close-up of Arco Test Module Showing Results of Hot-Spot Testing



Hot-Spot Recorded on IR Monitor Using Time-Lapse Photography



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Ocilloscope Trace of Pulse-Reverse Bias Testing

A 704 A cell 13

+25V

500NS

+ 500mV

50 V

IV curve # 18

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