N86-29406

# AMORPHOUS-SILICON MODULE HOT-SPOT TESTING

JET PROPULSION LABORATORY

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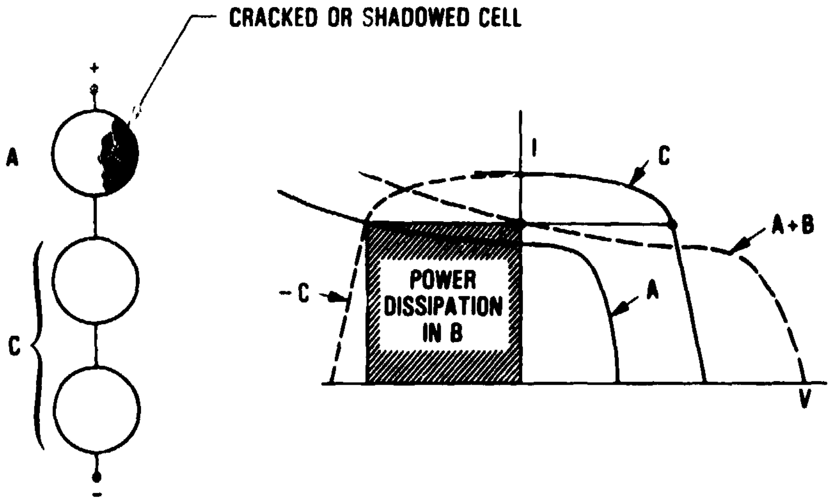
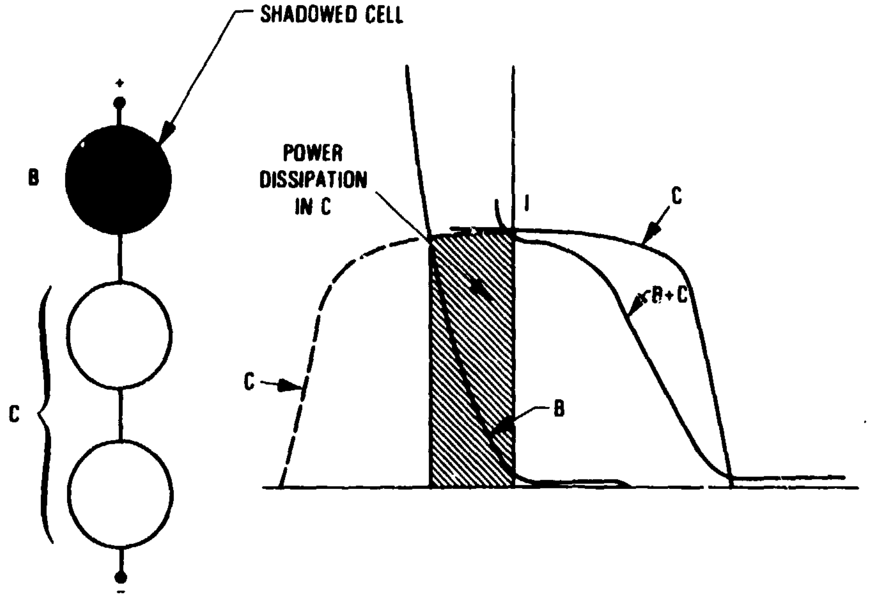
## Background

- **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**

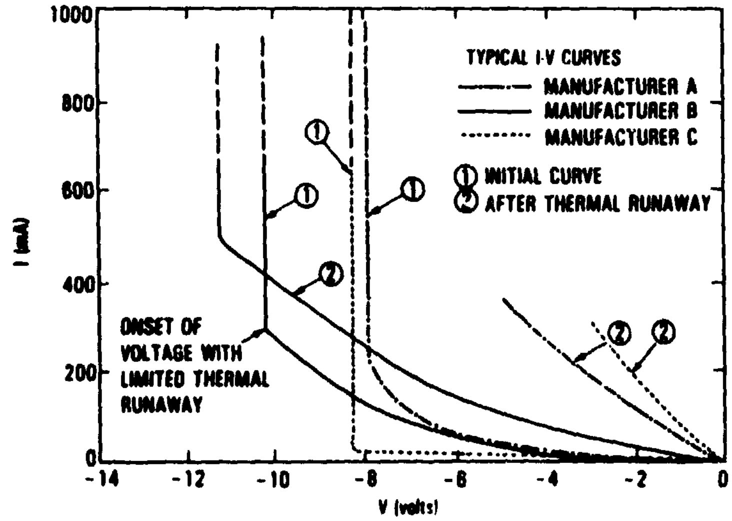
## Amorphous-Cell Hot-Spot Testing Objectives

- **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**

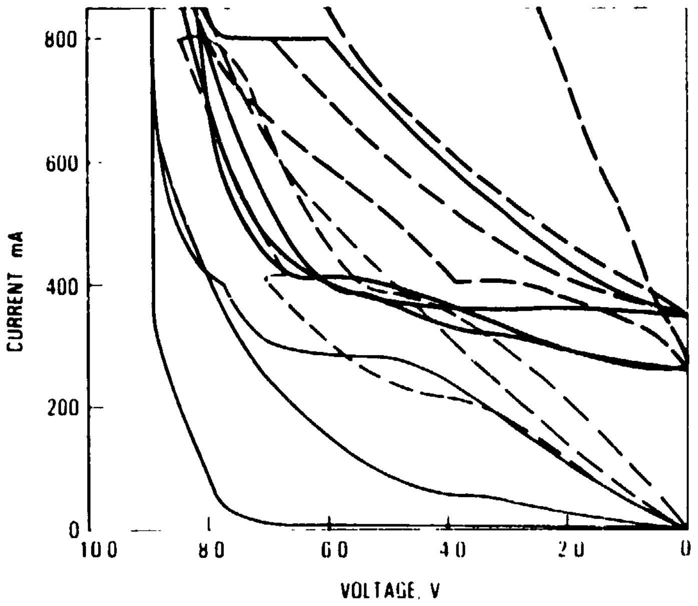
## Approach

- **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**

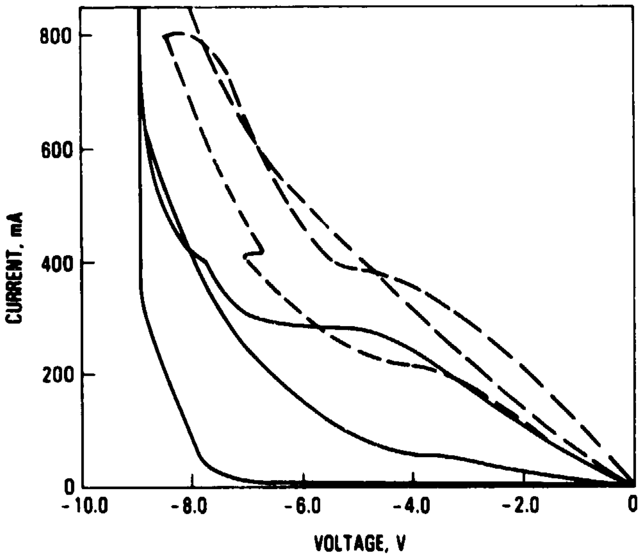
## Amorphous-Cell Second-Quadrant I-V Curves



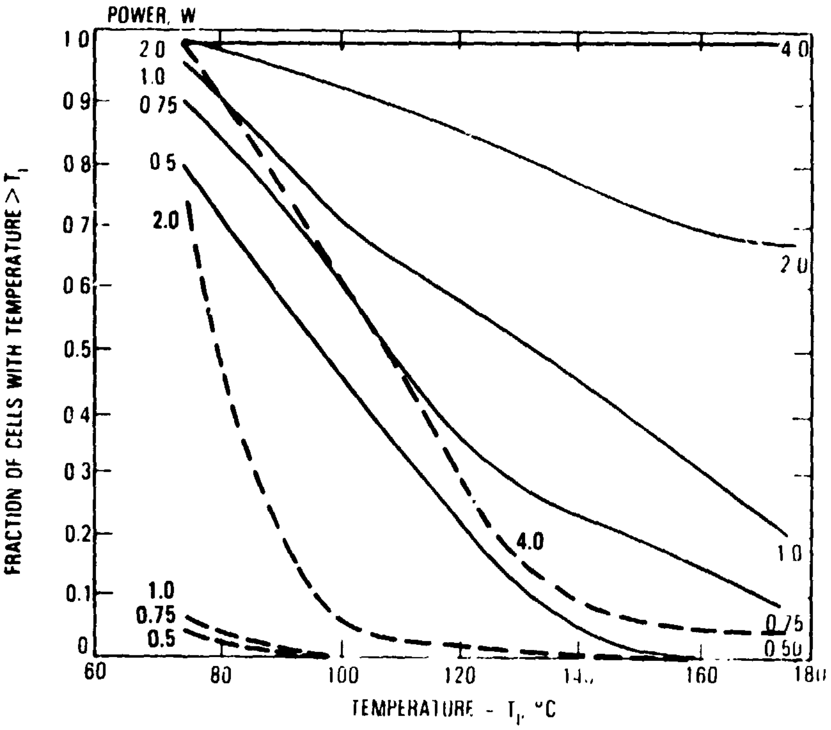
## Amorphous-Module Cell-Reverse Quadrant I-V Curves
## Illuminated Cells



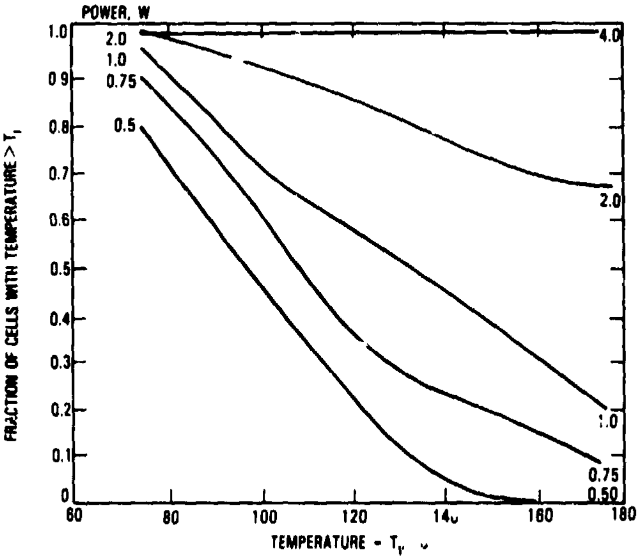
## Amorphous-Module Cell-Reverse Quadrant I-V Curves
## Unilluminated Cells



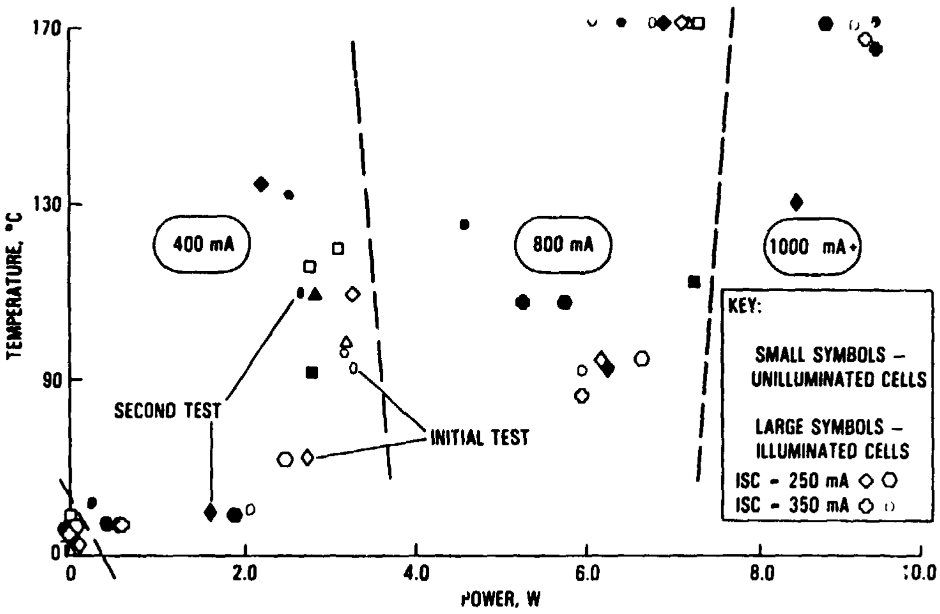
## Fraction of Cells Reaching a Given Temperature as a Function of Power Dissipated
## (Modules)



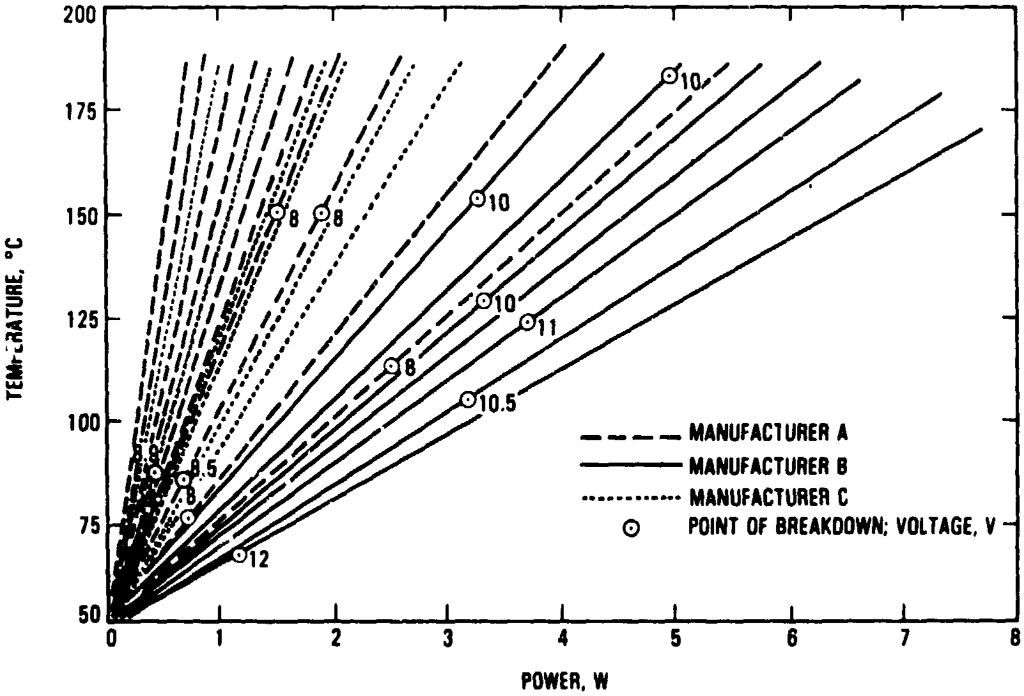
## Fraction of Cells Reaching a Given Temperature as a Function of Power Dissipated
## (Submodules)



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)



## 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**

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Hot-Spot Test Set-Up

Test Set-Up for Submodule Using Conductive Elastomeric Material

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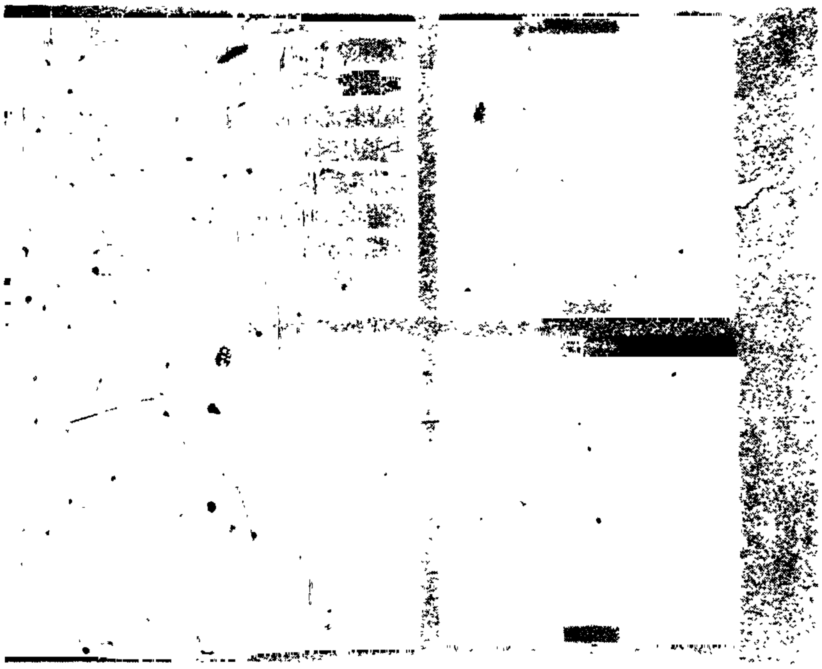
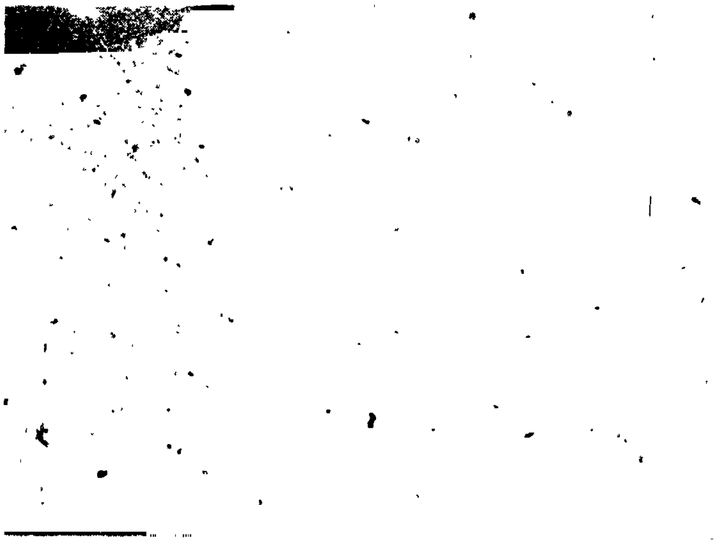
Results of Hot-Spot Testing of Four Submodules

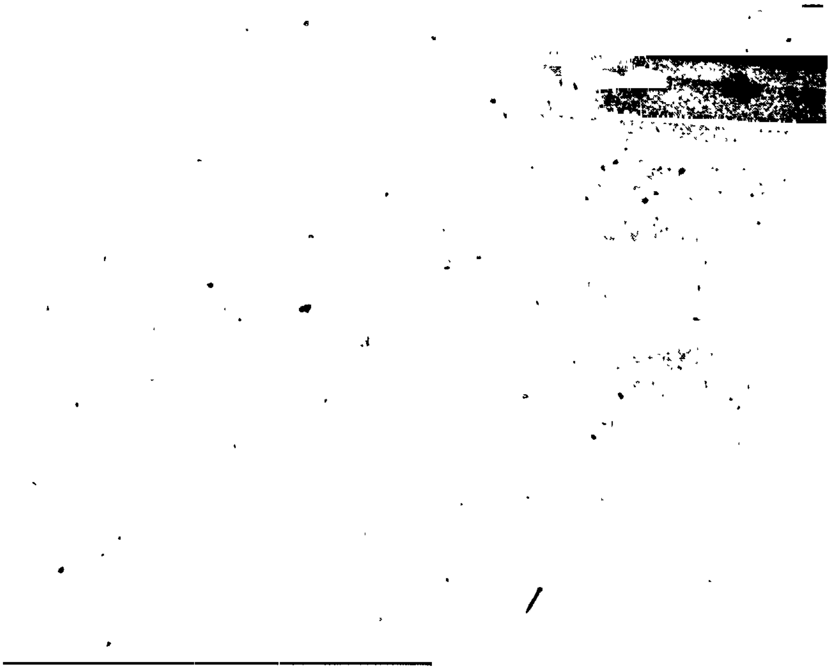


Close-up View of Hot-Spot Area



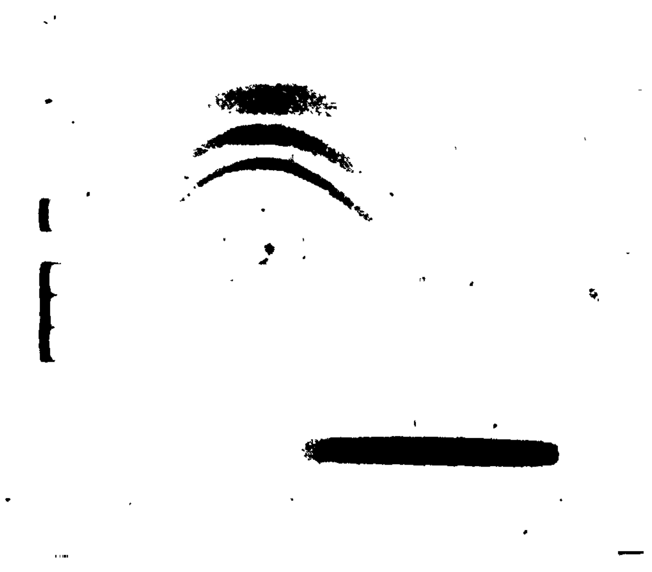
Front Side of Arco Test Module

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



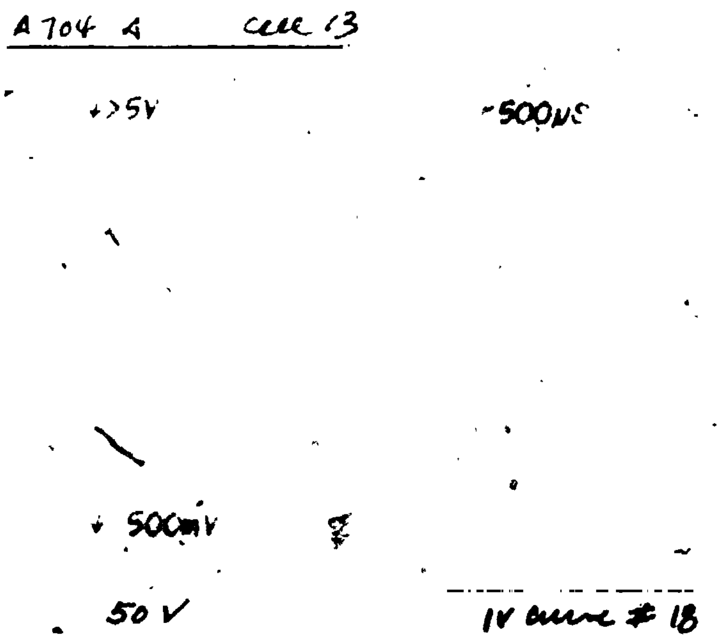
Close-up of Arco Test Module Showing Results of Hot-Spot Testing

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



## MODULE DEVELOPMENT AND ENGINEERING SCIENCES

### Ocilloscope Trace of Pulse-Reverse Bias Testing



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