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LONG-TERM STABILITY OF AMORPHOUS-SILICON MODULES

JET PROPULSION LABORATORY

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Amorphous Silicon Module Test Program Objectives

Objective

- **Assess reliability characteristics of amorphous silicon modules**
- **Assess attributes of various test methods**
- **Establish research priorities**

Approach

- **Establish strawman mechanism-specific reliability goals**
- **Test a number of first-generation amorphous silicon modules using a wide variety of tests**
  - **Block V qualification tests**
  - **Field aging (various electrical loading points)**
  - **Field aging (at elevated temperatures)**
  - **Dark oven aging (various electrical biases)**
  - **Photothermal oven aging**

Life-Cycle Cost Impacts and Allowable Degradation Levels for Thin-Film Modules

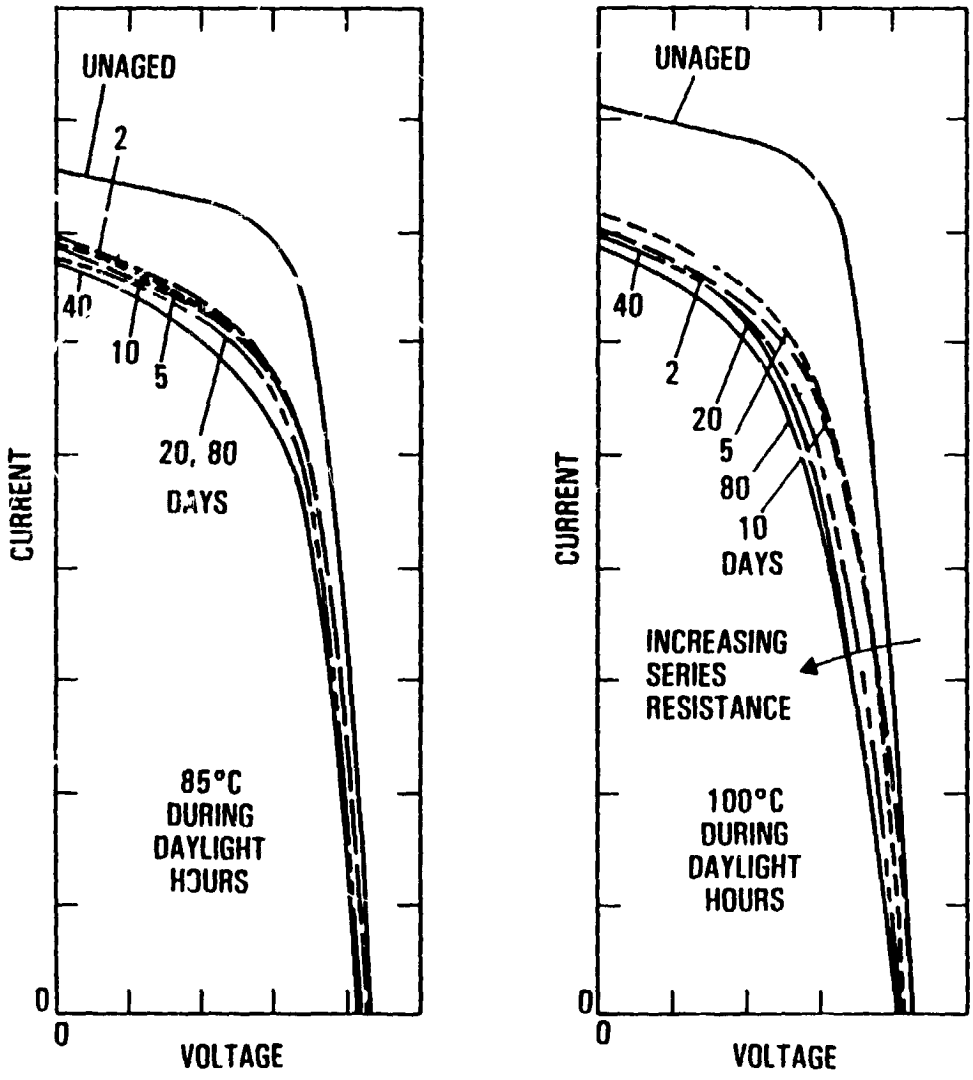
Type of Degradation	Failure Mechanism	Units of Degrad.	Level for 10% Energy Cost Increase*		Allocation for 30-Year Life Module	Economic Penalty
			k = 0	k = 10		
Component failures	Open-circuit between cells	%/yr	0.08	0.13	0.02	Energy
	Short-circuit cells	%/yr	0.24	0.40	0.05	Energy
Power Degradation	Light induced effects	%	10	10	5	Energy
	Cell gradual power loss	%/yr	0.67	1.15	0.20	Energy
	Module optical degradation	%/yr	0.67	1.15	0.02	Energy
	Front surface soiling	%	10	10	3	Energy
Module failures	Module glass breakage	%/yr	0.33	1.18	0.1	O&M
	Module open circuits	%/yr	0.33	1.18	0.1	O&M
	Module hot-spot failures	%/yr	0.33	1.18	0.1	O&M
	Bypass diode failures	%/yr	0.70	2.40	0.05	O&M
	Module shorts to ground	$\%/yr^2$	0.022	0.122	0.01	O&M
	Module delamination	$\%/yr^2$	0.022	0.122	0.01	O&M
Life-limiting wearout	Encapsulant failure due to loss of stabilizers	Years of life	27	20	35	End of life

*k = Discount rate

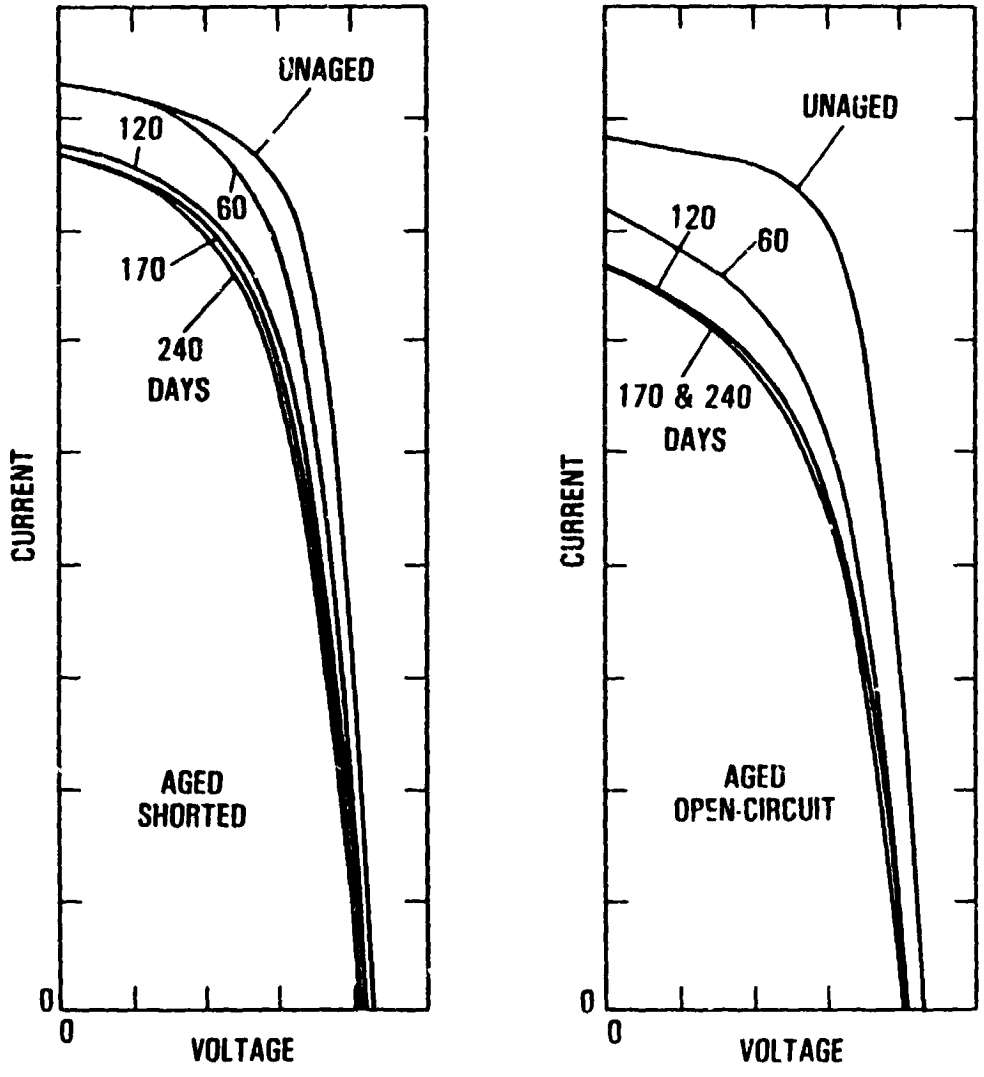
Block-V Qual Testing of Amorphous Silicon Modules

- Good performance in mechanical loading tests
  - Mechanical cycling at 50 psf
  - Hail impact with 1 in. ice balls
- Slight degradation (10%) in thermal cycle and humidity tests
  - Corrosion of monolithic interconnects
  - Some open-circuiting of monolithic interconnects
- Good performance in hot-spot test
- Mixed performance with encapsulant system
  - Frame softening
  - Some delamination of non-EVA systems

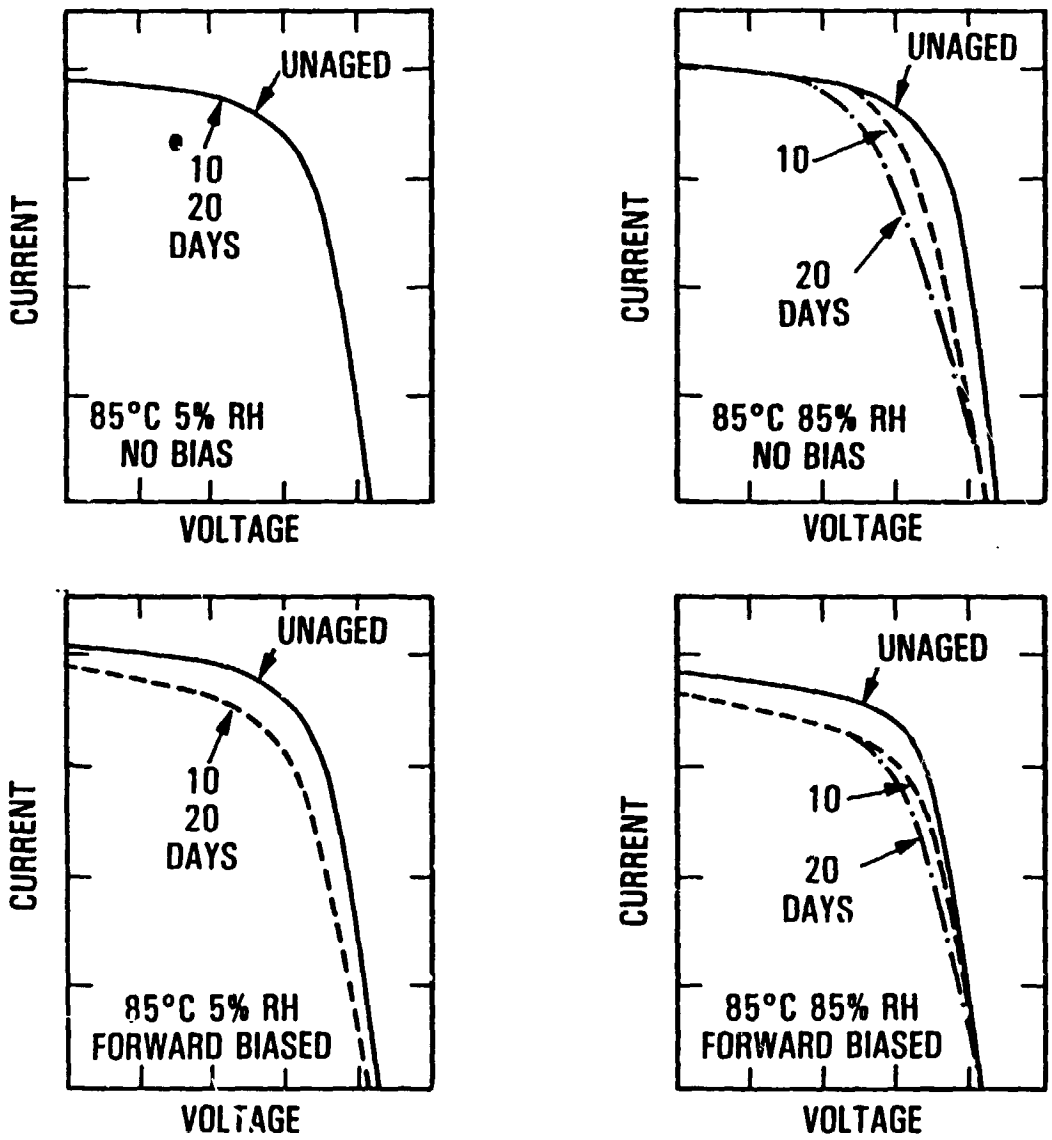
Amorphous-Silicon Module Field Performance (Ambient-Temperature Aging)



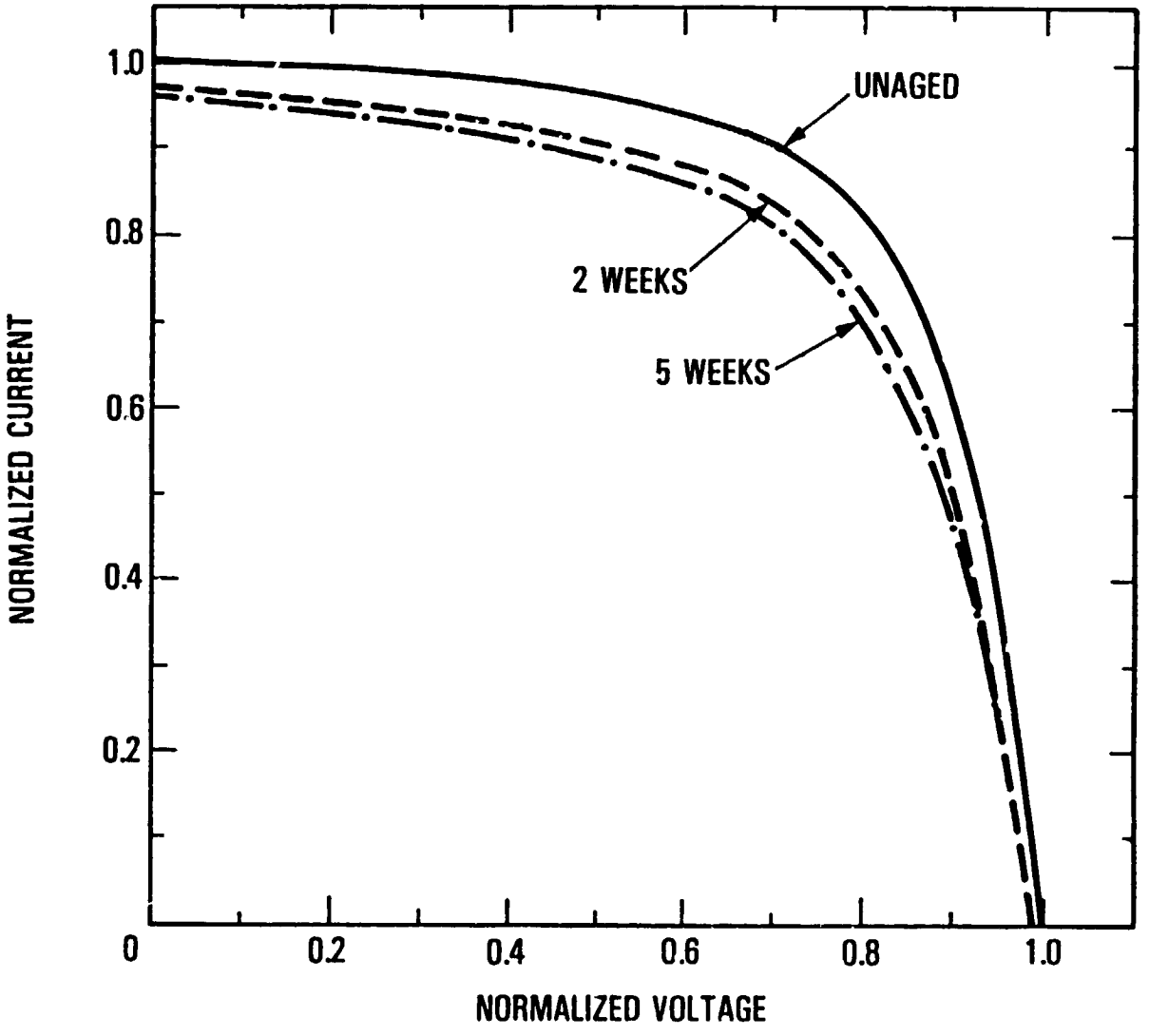
Amorphous-Silicon Field Performance (Elevated-Temperature Aging)



Amorphous Silicon Module I-V Performance
(Dark Oven Aging)



Amorphous Silicon Cell Photothermal Aging Performance
(85°C, 5% RH, 1 Sun UV)



Summary

- Block V crystalline-silicon qualification test insufficient for amorphous silicon modules
  - Good indicator of mechanical and hot-spot endurance
  - Poor indicator of electrical stability of amorphous silicon
- Electrical stability of amorphous silicon modules is very complex
  - Light induced effects
    - Sensitive to electrical loading point (Voc, Isc, Pmp)
    - Complex temperature dependency
  - Corrosion induced effects
    - Strong (Arrhenius) temperature dependency
    - Strong humidity dependency
- Accelerated laboratory and field testing must address the complex parameter dependencies
- Tests appropriate for amorphous silicon procurement specifications do not exist at this time

Present Research Thrusts

- Developing useful accelerated test for amorphous silicon electrical stability
- Developing solutions to corrosion-induced effects
- Continuing broad-spectrum testing to identify research priorities