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FSA FUTURE DIRECTIONS

RELIABILITY AND ENGINEERING SCIENCES FY85-FY86 ACTIVITIES AND PLANS

JET PROPULSION LABORATORY

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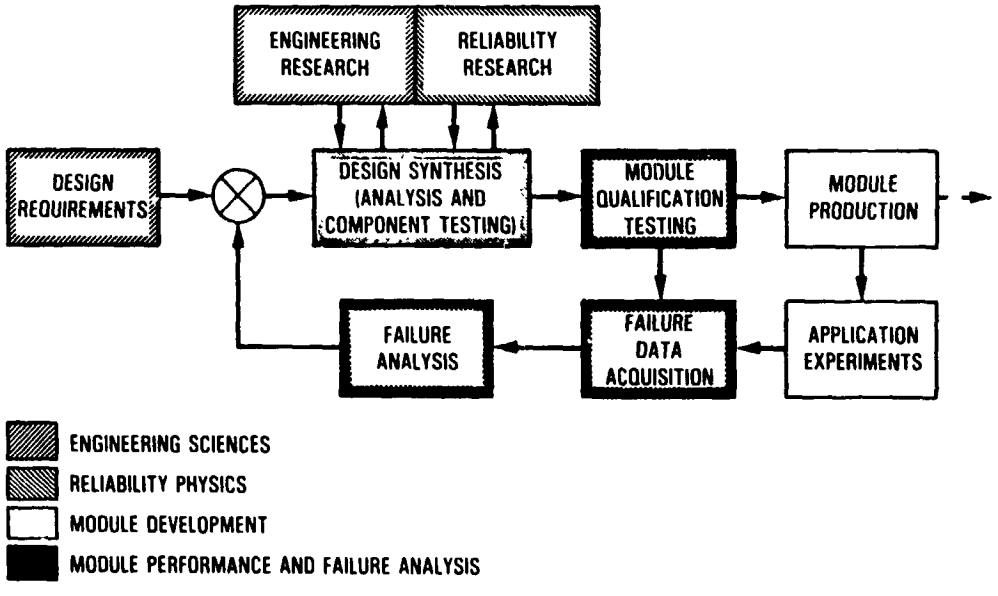
Reliability and Engineering Sciences Functional Organization



Engineering Sciences Objective and Approach

- Develop module design requirements associated with future large-scale PV applications
  - Performance
  - Safety
  - Reliability
  - System interface
- Develop generic design and construction technology base required to achieve the above-defined safety and performance requirements
  - Module encapsulant materials
  - Thermal design methods
  - Electrical connection means
  - Module safety design practices
  - Array electrical circuit analysis methods
  - Module flammability considerations

Engineering Sciences Current Status and Problems

- Status
  - Most module requirements for large-scale applications are in place for both c-Si and thin-film modules
  - Module-engineering technology base nearly complete for crystalline-Si but needs updating for thin films
- Problems
  - Possible problem with reliability of present rear-surface materials (Tedlar)
  - Unknown reliability of fire-resistant rear-surface materials
  - Need to update 1981 Block V Module Specification for c-Si to incorporate learning of past four years
  - Need to develop generic (thin-film) module specifications to focus thin-film module development and assist industry
  - Need for thin-film encapsulant development

Engineering Sciences FY85-FY86 Research Activities

- Drafting of Block VI Module Design Specification for c-Si:
  - New NOCT test method
  - New reference spectrum
  - Bypass diode qual test
  - Expanded hot-spot test
  - Revised hipot test procedure
  - UV exposure test
- Initial development of generic (including thin-film) module design specification
- Identification/development of environmentally durable and safe rear-surface materials for c-Si and thin-films
  - Conventional constructions (films)
  - Flame-resistant constructions
  - Special materials for thin films
- Identification/development of new encapsulants suitable for thin-film modules
  - Lower-processing-temperature pottants
  - Transparent front covers

Reliability Physics Objective and Approach

- Develop the technology base required for 30-year-life modules
  - Establish mechanism-specific reliability goals
    - Identify key degradation mechanisms
    - Determine system energy-cost impacts
    - Allocate system-level reliability
  - Quantify mechanism parameter dependencies
    - Understand mechanism physics
    - Governing materials parameters
    - Governing environmental-stress parameters
  - Develop degradation prediction methods
    - Quantitative accelerated tests
    - Life-prediction analysis methods
  - Identify cost-effective solutions
    - Component design features
    - Circuit redundancy and reliability features

Reliability Physics Current Status and Problems

- 30-year module design technology available for
  - Glass fracture (c-Si)
  - Hail impact (c-Si)
  - Interconnect fatigue (c-Si)
  - Soiling (c-Si and T-F)
  - Cell fracture (c-Si)
  - Hot-spot heating (c-Si)
  - Bypass diodes (c-Si and T-F)
- 30-year technology available except for some important unknowns
  - Electrochemical corrosion w/EVA (unknown encapsulant water concentration)
  - Photothermal degradation of EVA (unknown synergism with moisture)
- Significant technology gap for 30-year life
  - Voltage breakdown (basic mechanism unknown)
  - Delamination (time-stress dependence unknown)
  - Integrity of rear surface materials
  - Unknown reliability of new high-efficiency c-Si cells
  - Unknown reliability of thin-film solar cells and modules

Reliability Physics FY85-FY86 Research Activities

- Water-module interaction studies
- Electrochemical corrosion studies
- Photothermal degradation of polymers (EVA, Tedlar and T-F encapsulants)
- Delamination of bonded interfaces
- Voltage breakdown of polymers
- Hot-spot testing of thin-film modules
- Glass strength and impact resistance of thin-film modules
- Development of mechanism-specific reliability allocations for thin-film modules
- Cell and module life testing (Clemson, Wyle)
- Bypass diode qual test development

Module Development Objective and Approach

- Objective
  - Facilitate the transfer of DOE-sponsored technology developments into PV manufacturers and their products
  - Facilitate the evaluation of recent technology developments in the context of the manufacturing and operating performance of complete modules
- Approach
  - Prepare module specifications reflecting the most advanced PV technology and requirements for future large-scale applications
  - Contract for module design and fabrication by industry
  - Conduct design reviews and technical discussions
  - Evaluate electrical and reliability performance in laboratory and field tests
  - Employ failure analysis to analyze module deficiencies
  - Iterate design, design reviews, manufacture and tests until successful module qualification

Module Development Current Status and Problems

- Status
  - Maintained continual advance in module performance over 10-year period by implementation of five successive development programs (Blocks I through V) and transferred majority of crystalline-silicon module technology to manufacturers
  - Resultant design features have been adopted internationally
- Problems
  - Dendritic-web module development and technology transfer incomplete
  - High-efficiency module development and technology transfer incomplete
  - Rear-surface material development and technology transfer incomplete
  - Significant need for development of thin-film modules

Module Development FY85-FY86 Activities

- Technology evaluations
  - Dendritic web (Westinghouse)
  - High-efficiency cells (Spire)
- Fire-resistant encapsulants (Solavolt, ARCO)
- Thin-film modules
  - ARCO
  - Hughes
  - Chronar
  - Others(?)

Module Performance and Failure Analysis Objective and Approach

- Objective
  - Accurately quantify PV module performance
  - Identify areas of needed development
  - Assess suitability for large-scale application
- Approach
  - Perform qualification testing on state-of-the-art modules incorporating latest technologies (Block Program modules and commercial modules)
  - Develop equipment, procedures and techniques for accurate measurement of the electrical performance of PV modules
  - Perform failure analysis to determine exact cause of observed anomalies

Module Performance and Failure Analysis Current Status and Problems

- Status
  - Most current U.S. and foreign production-module designs have been evaluated (SMUD PV2 modules in work)
  - Block V qualification testing, performance evaluation and failure analysis completed February 1985
- Problems
  - National and international electrical performance measurements capability in poor shape
    - Limited facilities for module measurements
    - Recent change of AM1.5 Global spectrum
    - Poor international agreement on measurements
  - Limited international qualification test capability
    - Major problem is electrical performance measurement accuracy

Module Performance and Failure Analysis FY85-FY86 Activities

- Module qualification testing (increasing international demand for JPL qualification)
- Performance measurement of SMUD PV2 modules (ARCO, Solarex and Mobil)
- Establishment of AM1.5 Global module measurement standards
  - Reference cell calibration procedures
  - Simulator spectrum modifications
  - International round robins
- Continuing failure analysis
- Possible contract for continuation of qual testing by private testing laboratory