N86-29361

PRELIMINARY STUDY: MOISTURE-POLYMER INTERACTION

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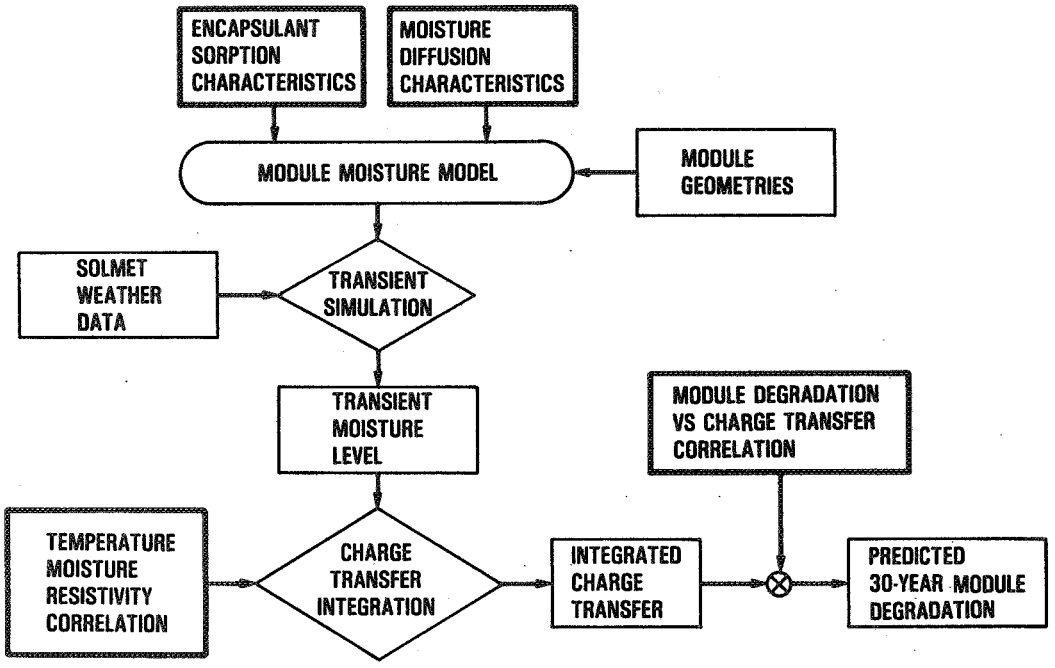
Study Objectives

To develop methodology for predicting module temperature, humidity and surface moisture level versus time in field environment

- **Water sorption**
- **Moisture diffusion**
- **Simulation using SOLMET weather tape**

To apply the above temperature-moisture prediction methodology together with electrochemical corrosion temperature-moisture dependence to predict module corrosion lifetime in the field

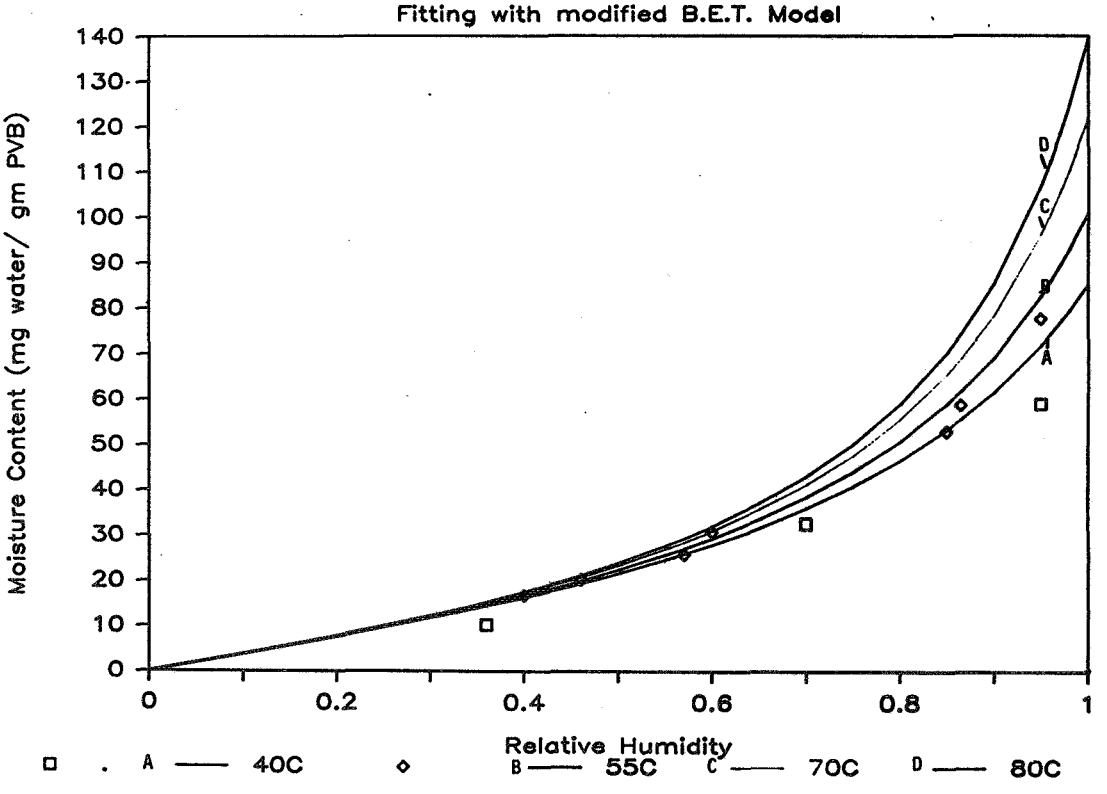
Simulation Flow Diagram



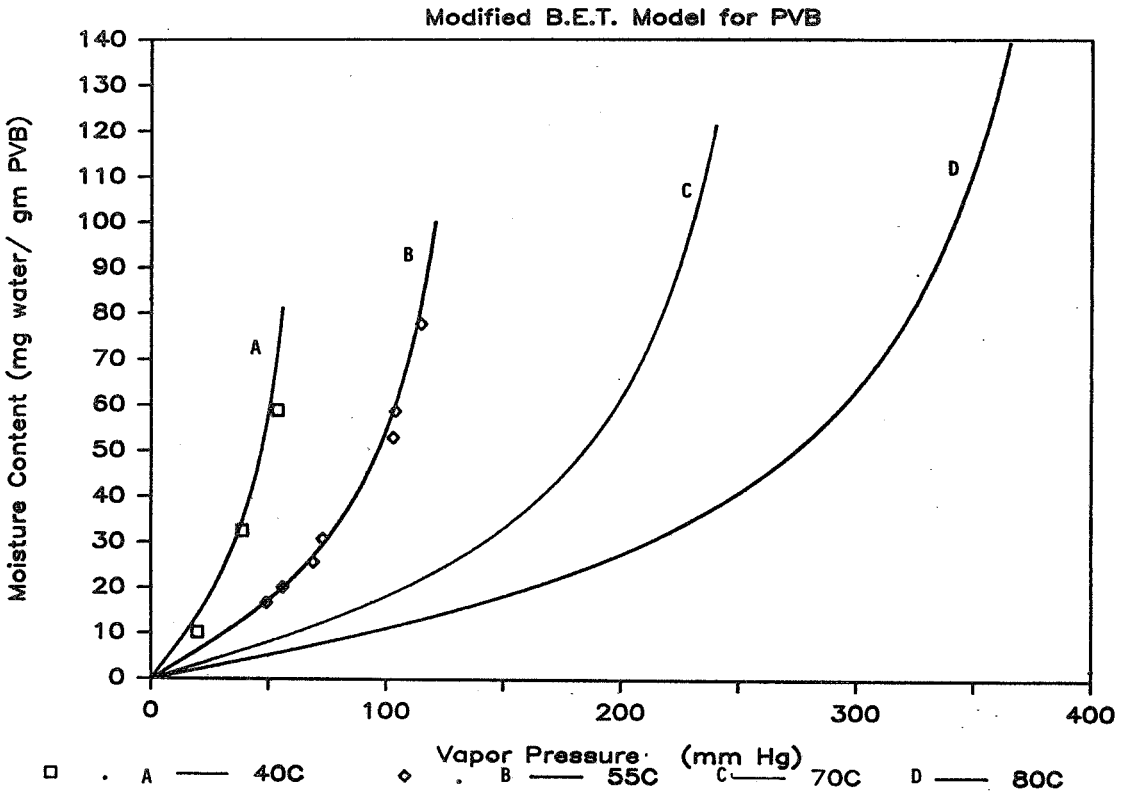
Sorption Study

- **Objective**
  - **To establish an analytical model for predicting moisture sorption isotherms for relevant polymers**
- **Approach**
  - **Gravimetric measurements using a Cahn balance**
  - **Isothermal system: humidity chamber**
  - **Relative humidity from 40% to 95%, no liquid water**
  - **Data fitting with an analytical model (modified B.E.T. equation)**

Water Sorption for PVB



Water Sorption Isotherms



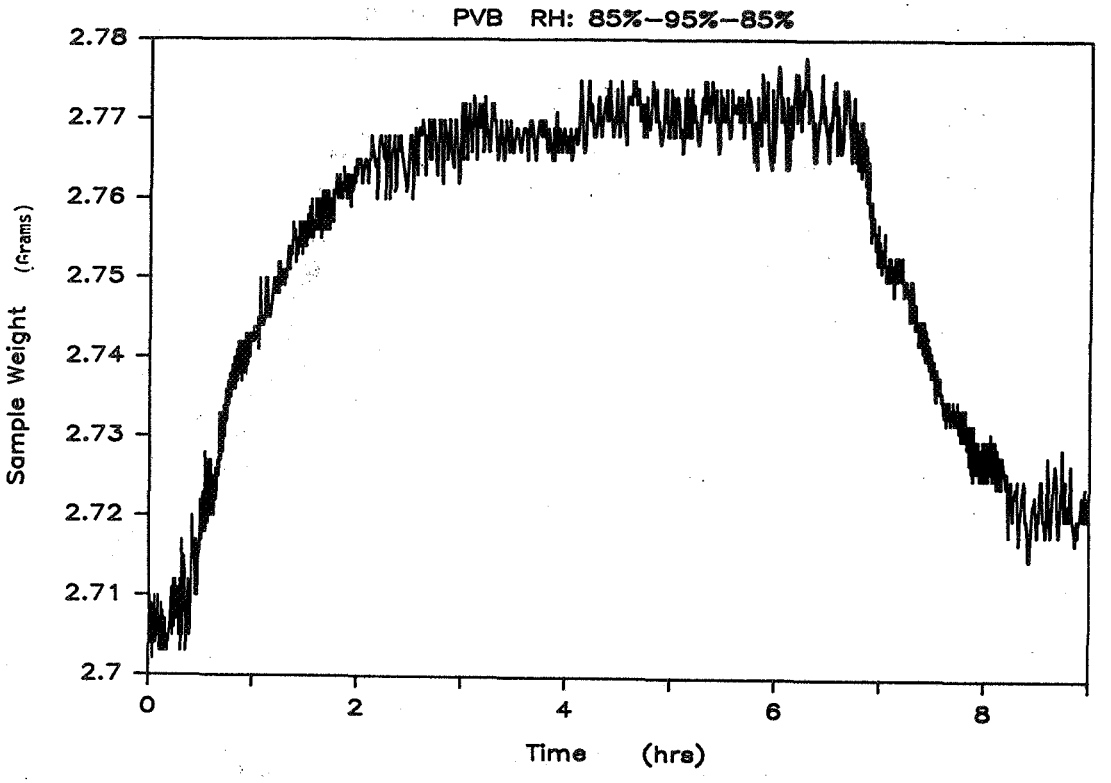
Moisture Sorption

- **Status**
  - **Limited samples were used (PVB)**
  - **Reasonable data fitting with a modified B.E.T. equation**
- **Required R&D**
  - **Expanded sorption data base for different materials, composite layers and conformal coatings**
  - **Sorption-desorption in non-isothermal conditions**
  - **Kinetics and thermodynamics of adsorption/absorption (both liquid and vapor water)**
  - **Factors influence moisture sorption in polymer; plasticizer, cross-linking agent**
  - **Free-to-bound water transformation**

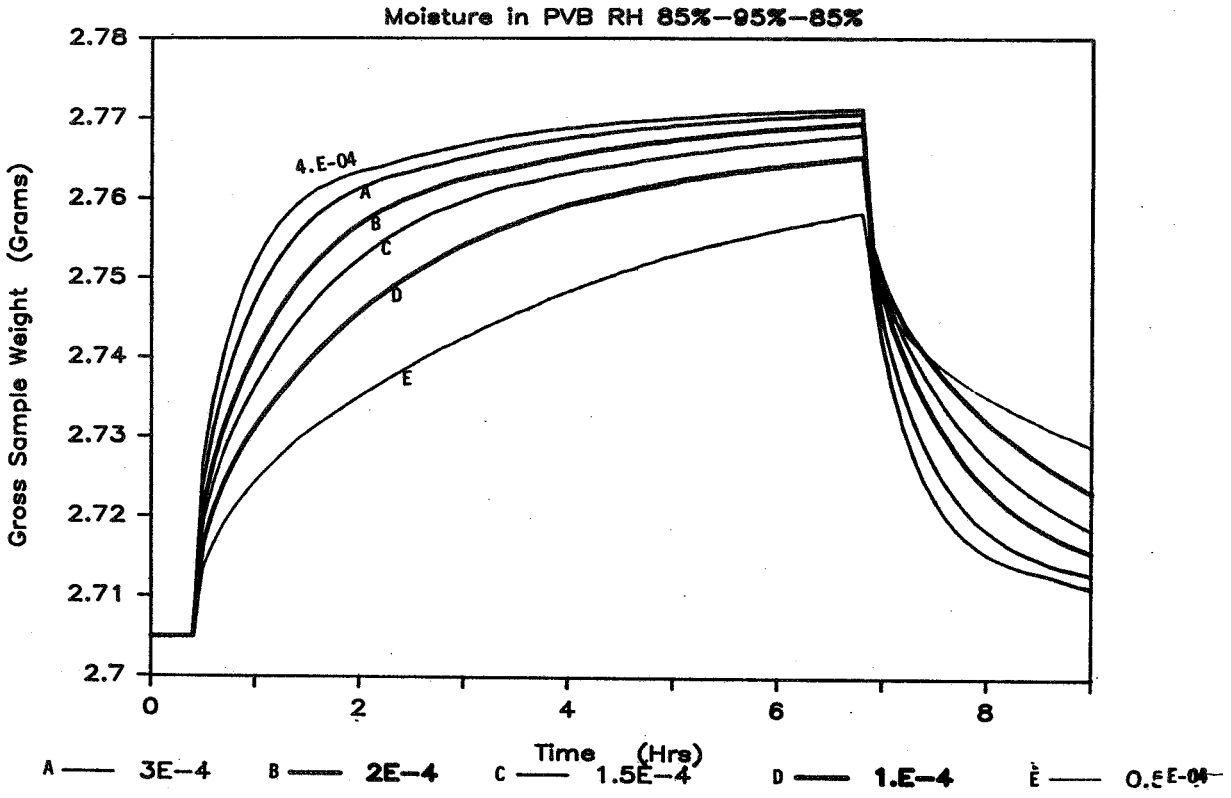
Moisture Diffusion

- Objective
  - To develop a moisture transport model and diffusion/permeation parameters
- Approach
  - Transient experimental data based on sorption measurements
  - Nodal network representation of Fick's diffusion model
    - 100-layer model
    - Isothermal system
    - Parametric iteration of constant diffusivity levels
  - Determination of diffusivity based on transient data
  - To establish equations to correlate diffusivity/permeability as a function of temperature and moisture content
- Status
  - Diffusivity increases with moisture content in PVB
  - Arrhenius-type variation with temperature
  - Good correlations between data and model
- Required R&D
  - Moisture diffusion in composite encapsulants
  - Diffusion of unbound water
    - Bulk water movement
    - Transition of bound and unbound water
    - Apparent diffusivity
  - Non-isothermal system
    - Models for simultaneous heat and mass transfer
    - Thermal diffusion
  - Factors affecting moisture diffusion and permeation

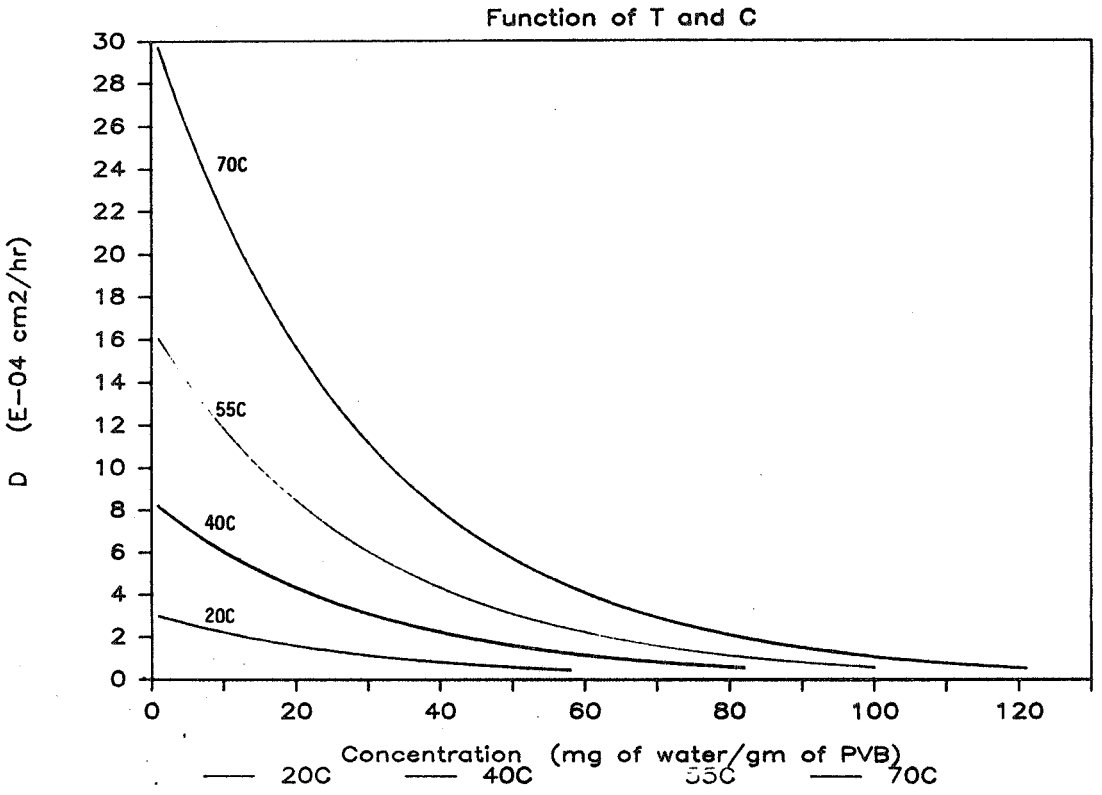
Moisture Sorption-Desorption



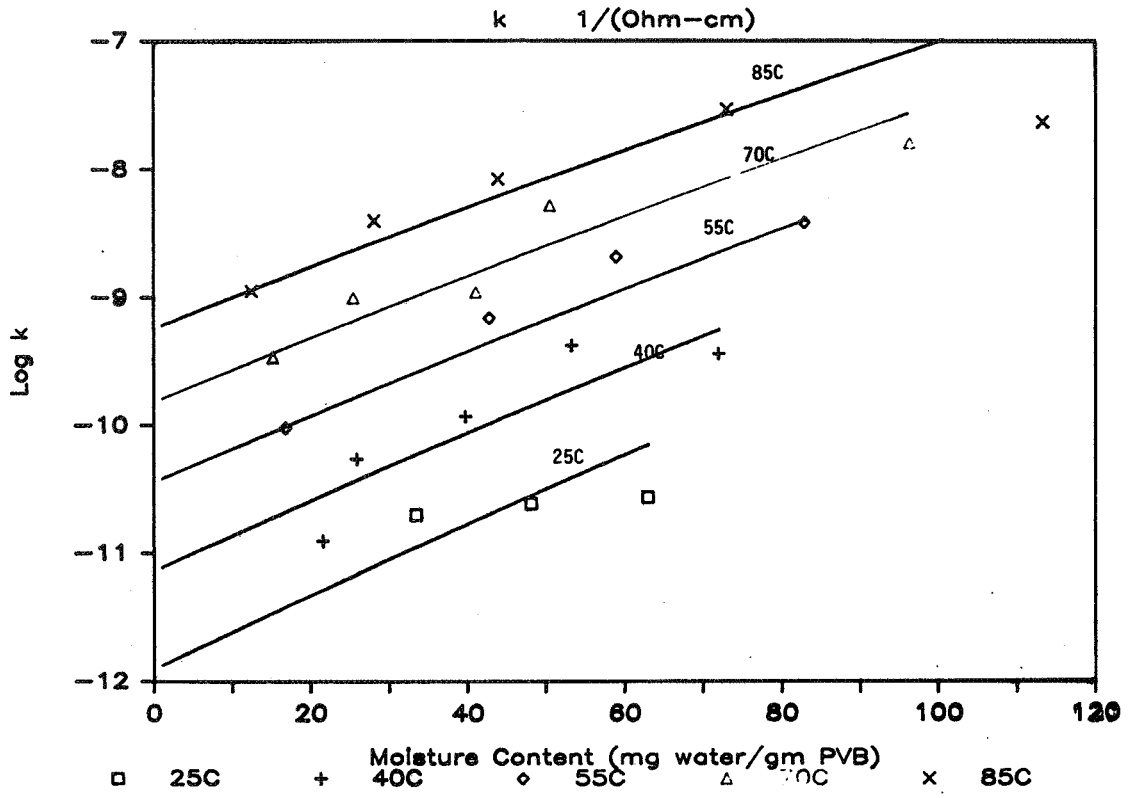
Diffusivity Simulation at 55°C



Diffusivity of Moisture in PVB



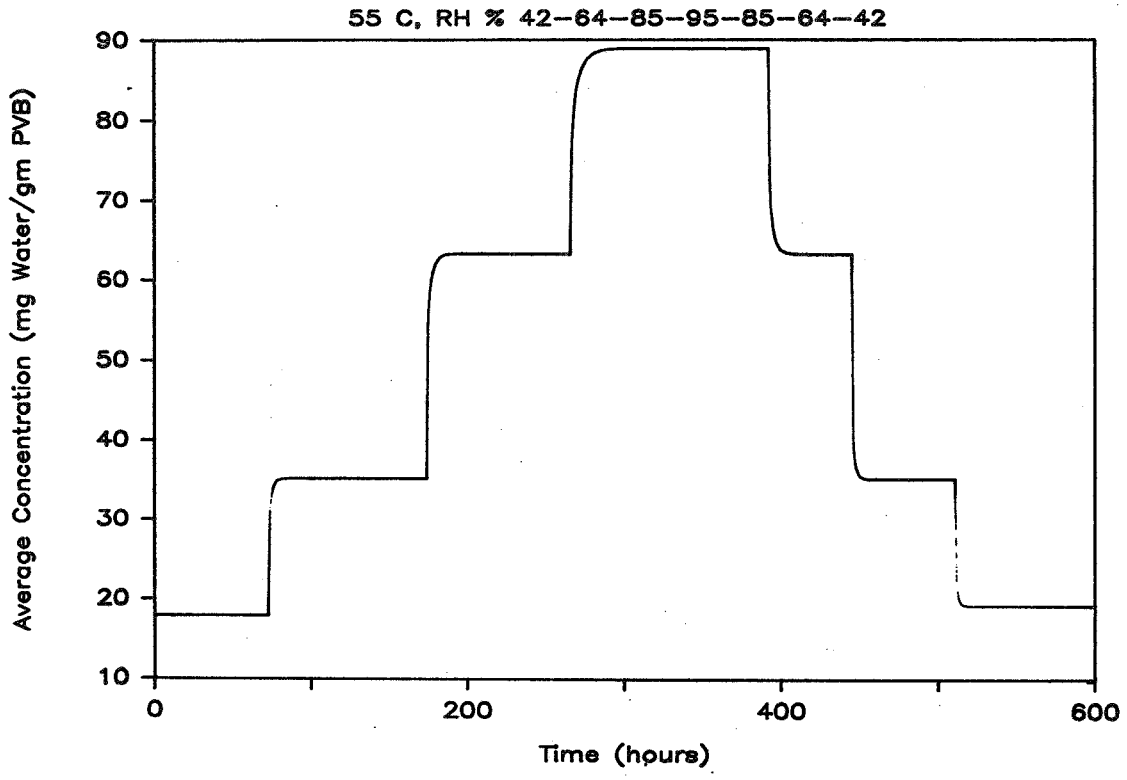
Bulk Conductivity of PVB

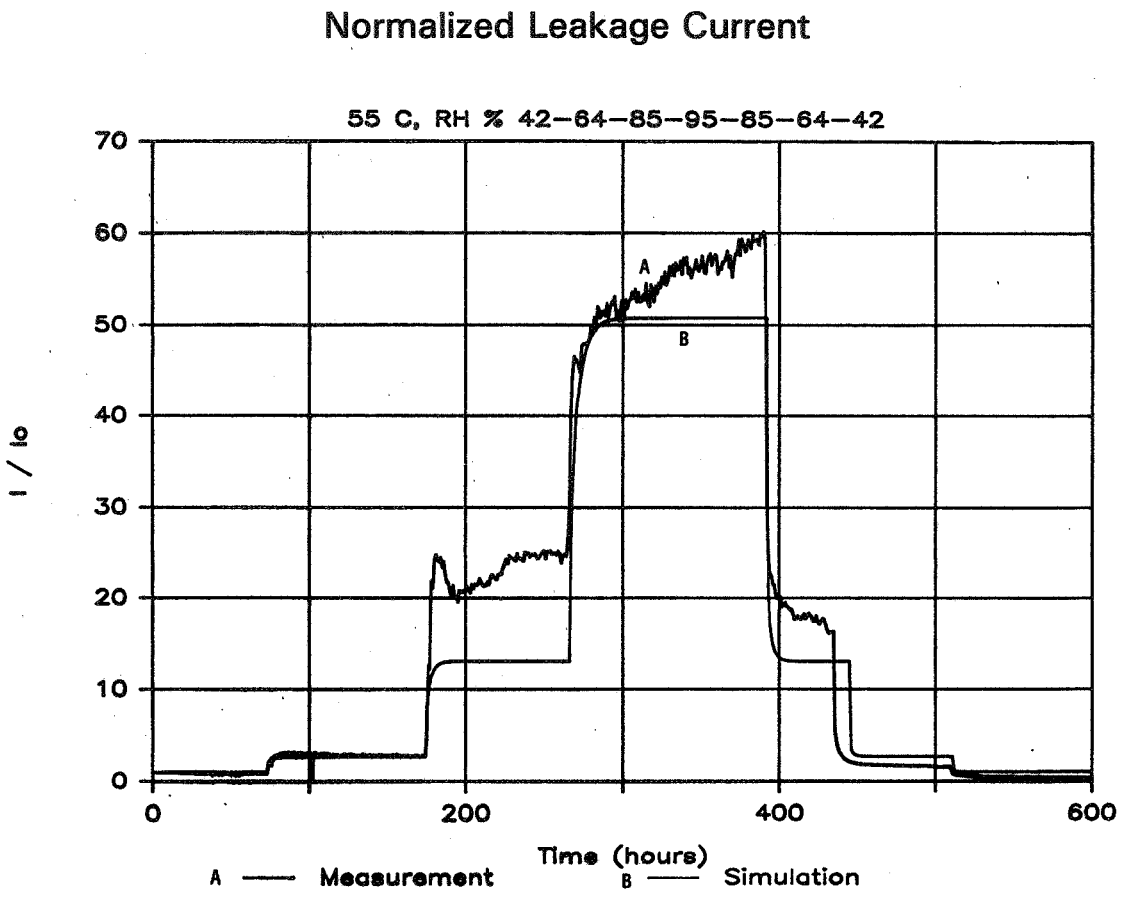


Electrochemical Corrosion

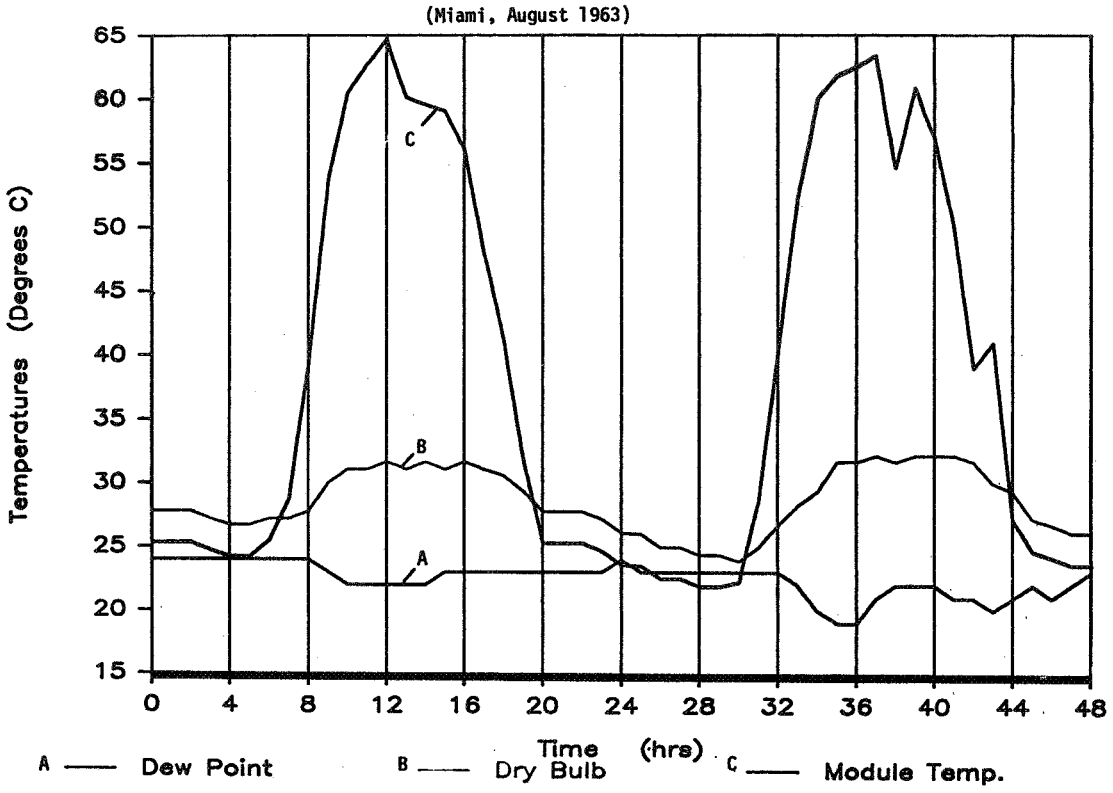
- **Objective**
  - **To simulate module leakage current vs time in operating environment**
- **Approach**
  - **Construct preliminary analytical model**
    - **Conduction across encapsulant**
    - **No surface resistance, no lateral volumetric conduction**
    - **Include equations for sorption and diffusivity**
    - **Nodal network analysis using thermal analyzer SINDA**
    - **Equation to represent bulk ionic conductivity as a function of temperature and moisture content**
  - **Exercise model with transient chamber boundary conditions**
  - **Exercise model with SOLMET field data**

Moisture Content, PVB

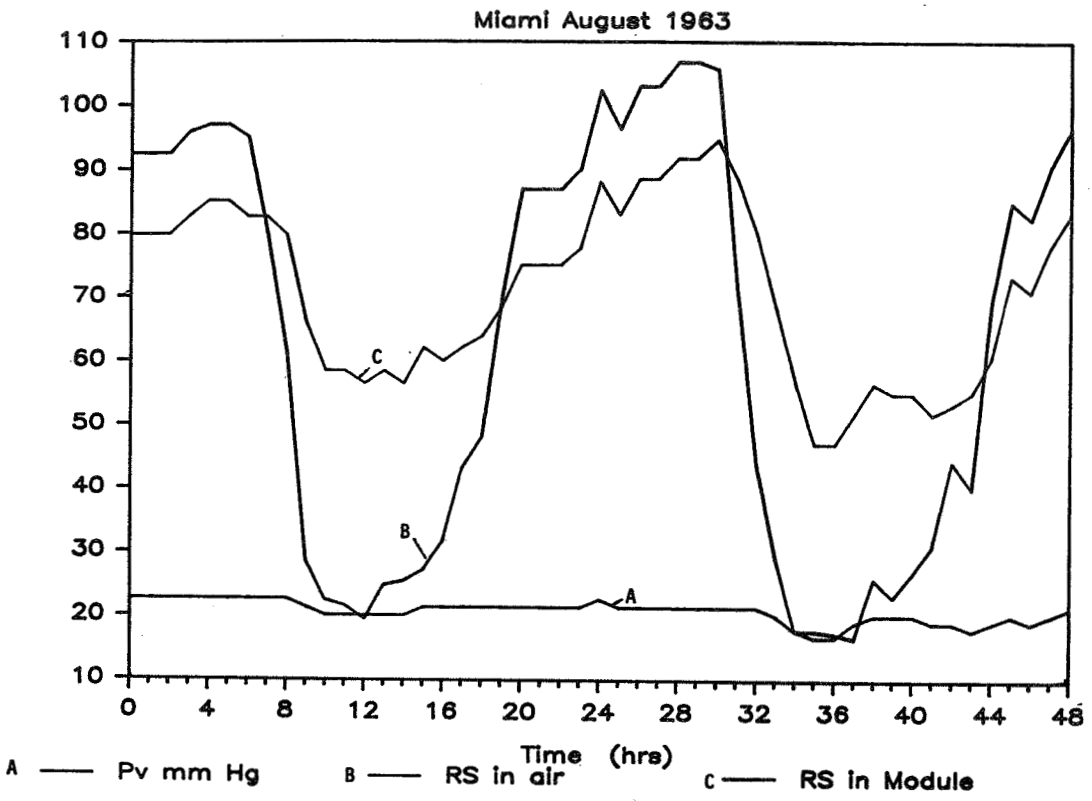



Normalized Leakage Current
55 C, RH % 42–64–85–95–85–64–42
70
60
50
40
30
20
10
0
I / Io
A
B
0
200
400
600
Time (hours)
A —— Measurement
B —— Simulation

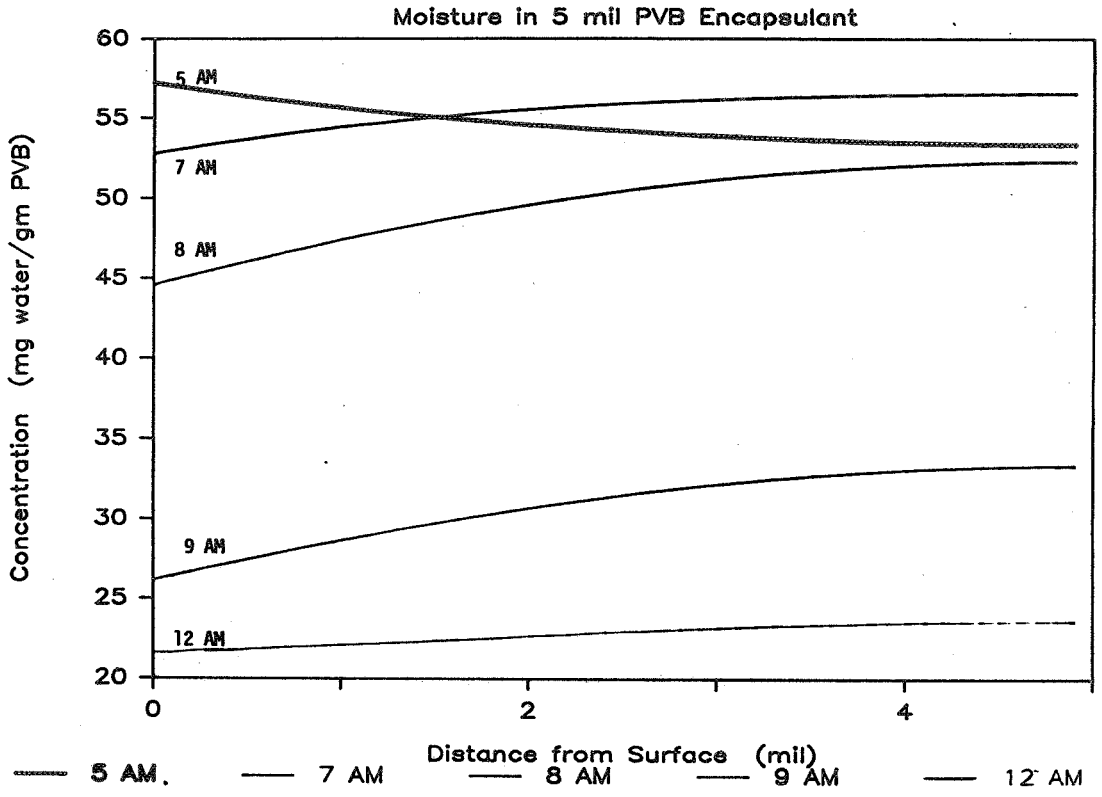
Temperature Profiles

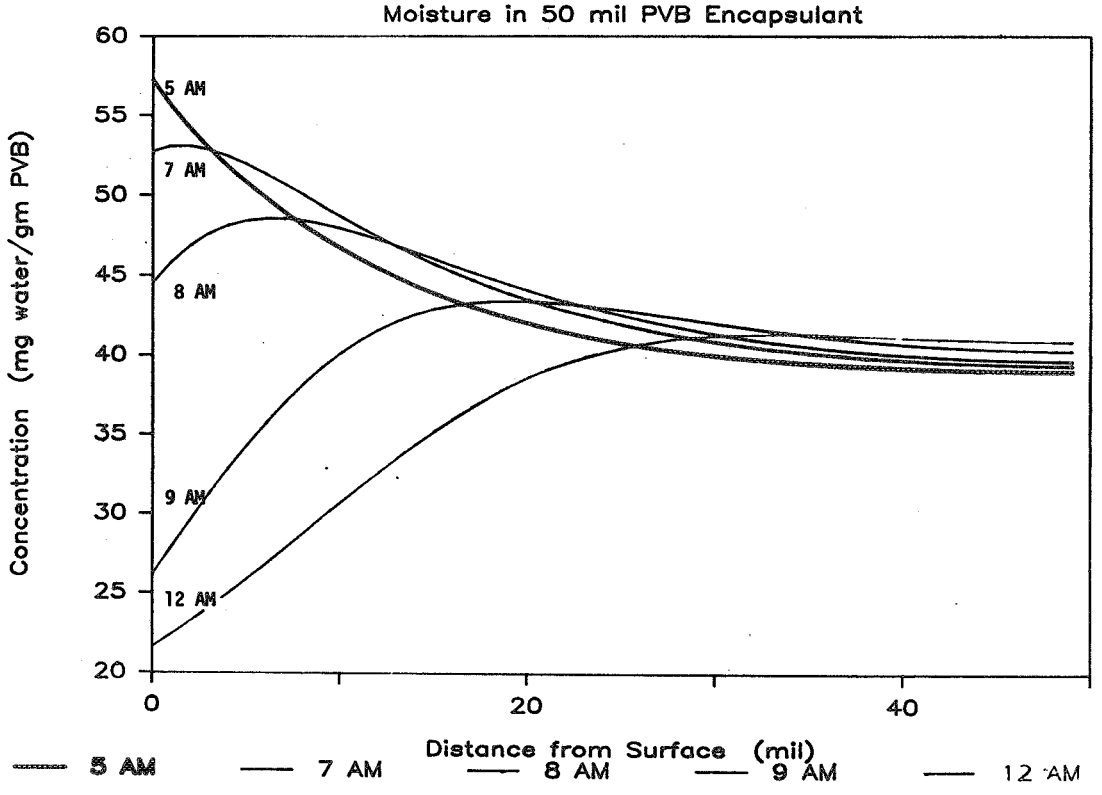


Vapor Pressure and Relative Saturation

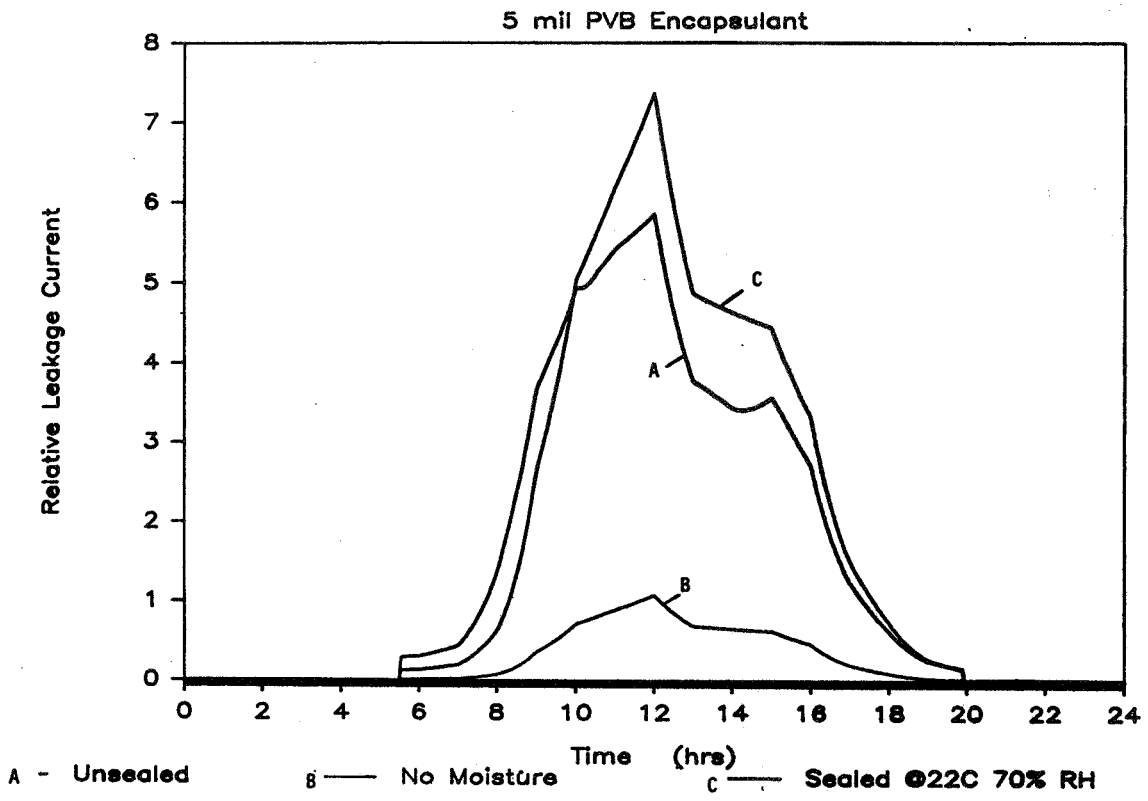


Concentration Distribution

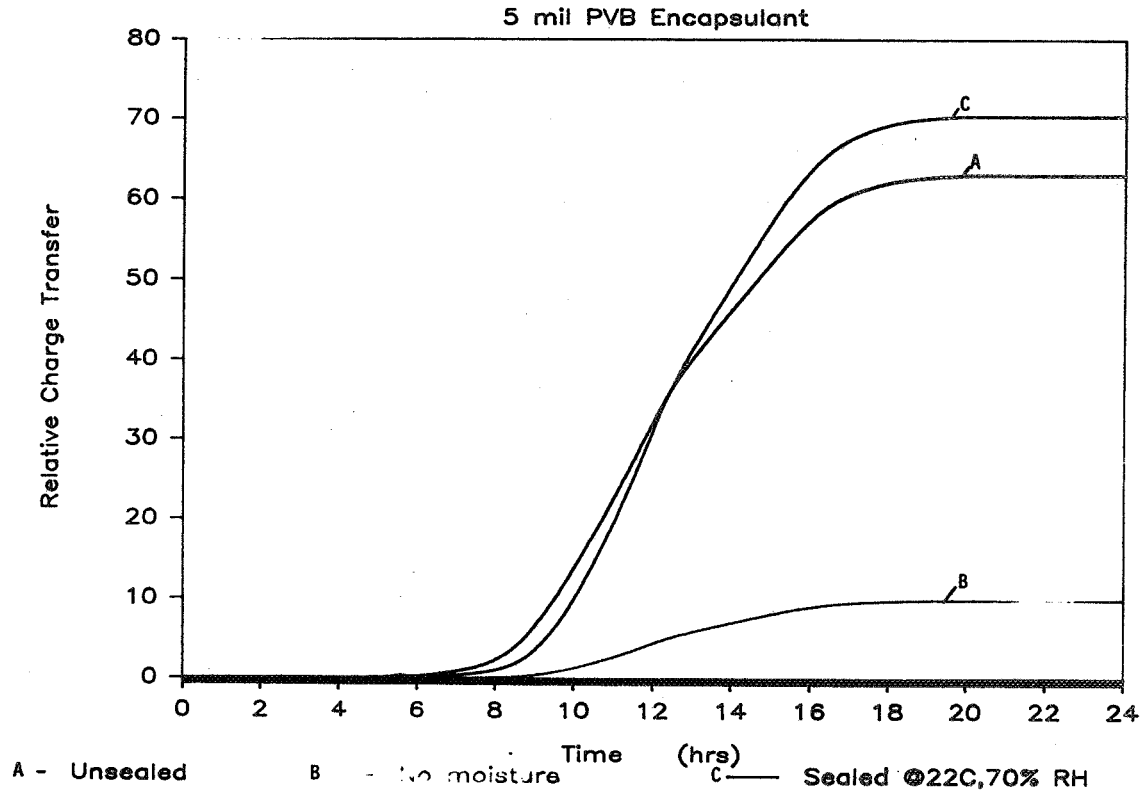


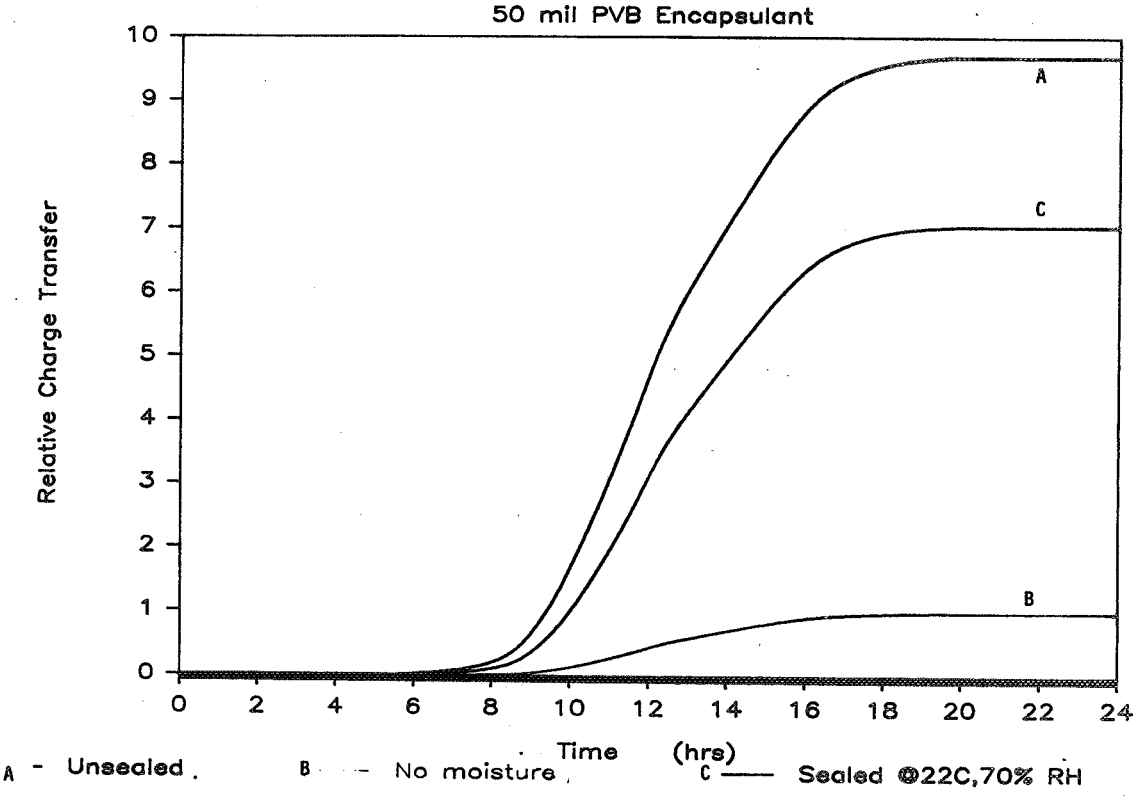


Leakage Current in Field



Charge Transfer in Field





Summary

- **Realistic lifetime prediction appears to be feasible**
- **Refinements in prediction techniques are required**
- **Research areas:**
  - **2-dimensional ionic conduction model**
  - **Composite layers**
  - **Non-isothermal system**
  - **Effects of liquid water**
  - **Interfacial adsorption/absorption**