

RELIABILITY PHYSICS

N86-29363

“(RH + t)” AGING CORRELATION

JET PROPULSION LABORATORY

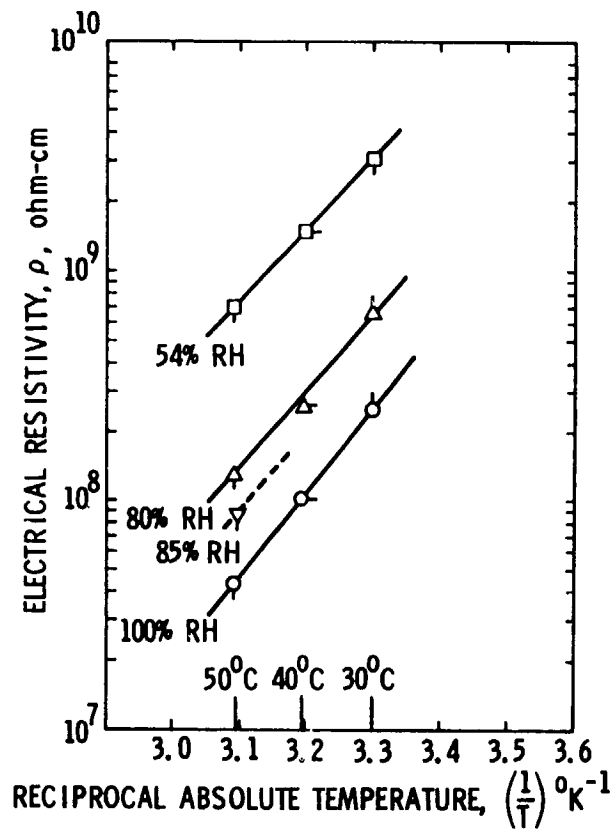
E. F. Cuddihy

Electrical Resistivity of PVB at Various
Temperatures and Relative Humidities
(Experimental Data Measured by Prof. John Orehtsky)

<u>RH, RELATIVE HUMIDITY, %</u>	<u>t, TEMP °C</u>	<u>ρ, RESISTIVITY, OHM-CM</u>	<u>DATA SYMBOL</u>
100	30	$2.53 \cdot 10^8$	o
	40	$9.86 \cdot 10^7$	o
	50	$4.44 \cdot 10^7$	o
85	50	$8.86 \cdot 10^7$	o
80	30	$6.24 \cdot 10^8$	Y
	40	$2.60 \cdot 10^8$	Δ
	50	$1.35 \cdot 10^8$	Δ
54	30	$3.02 \cdot 10^9$	+
	40	$1.51 \cdot 10^9$	o
	50	$7.07 \cdot 10^8$	o

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Electrical Resistivity of PVB



EQUATION

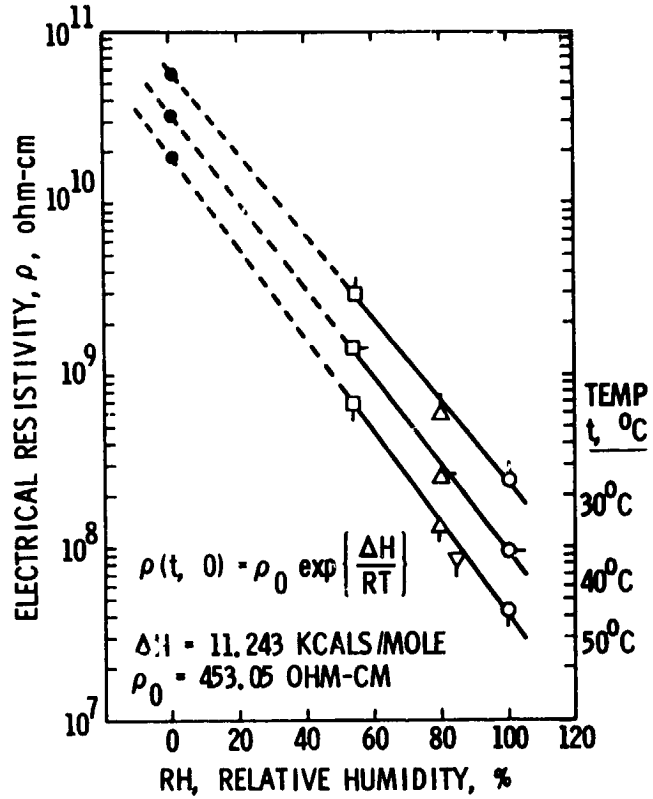
$$\rho(t, RH) = \rho_0(RH) \exp \left\{ \frac{\Delta H}{RT} \right\}$$

$$\left\{ T (^{\circ}K) = t (^{\circ}C) + 273 \right\}$$

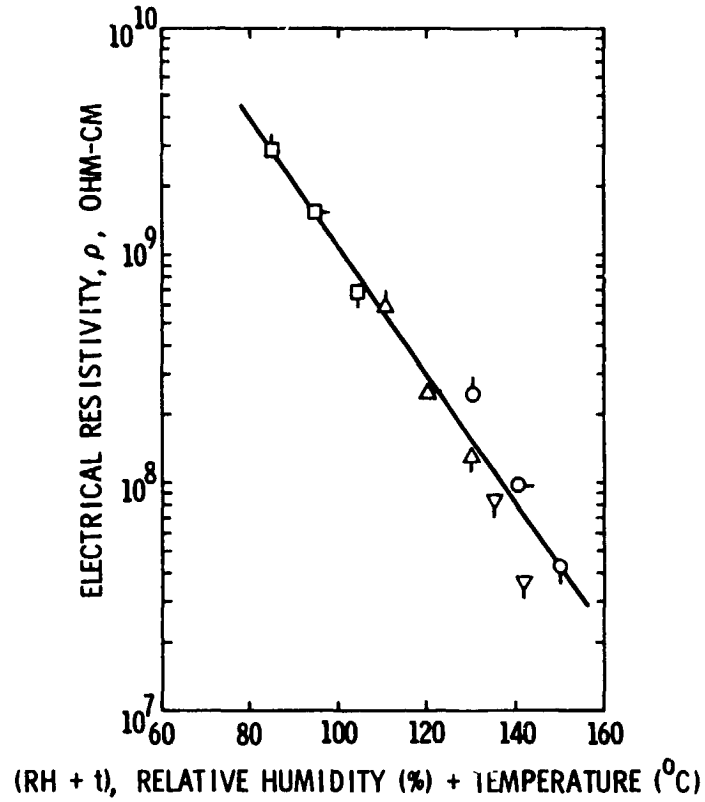
Electrical Resistivity of PVB as a Function of Relative Humidity

ρ AT 0% RH
(FROM LINEAR EXTRAPOLATION)

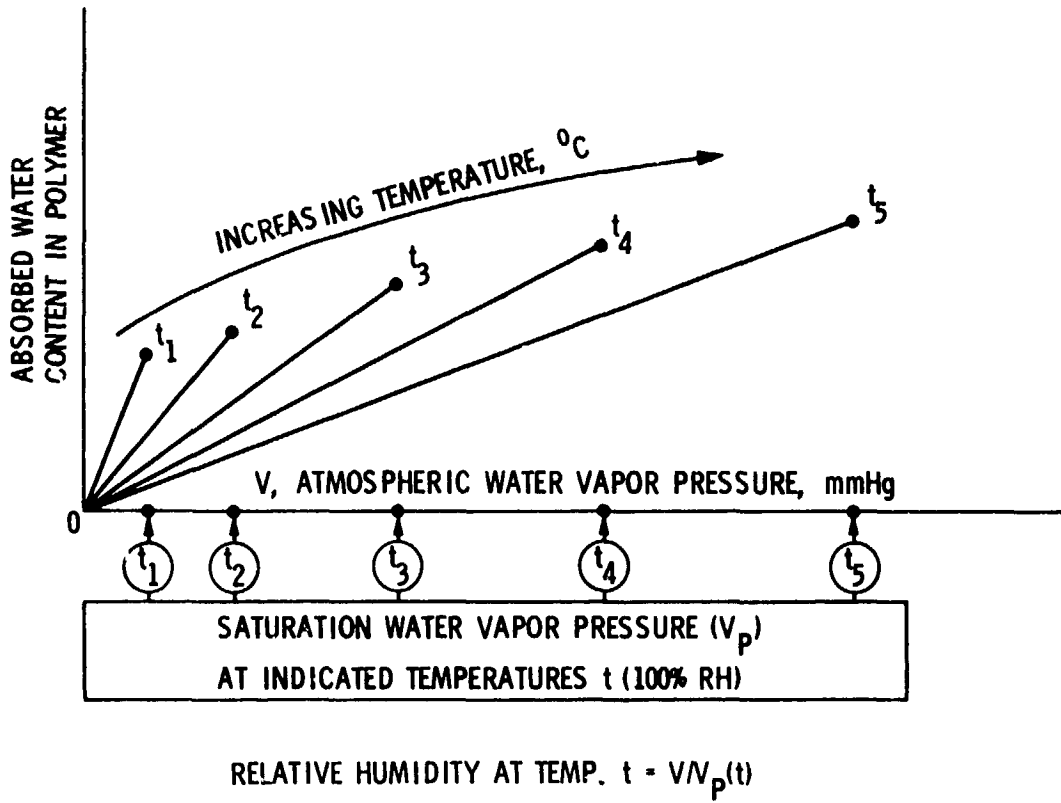
TEMP. °C	ρ , ohms-cm
30	$5.8 \cdot 10^{10}$
40	$3.3 \cdot 10^{10}$
50	$1.8 \cdot 10^{10}$



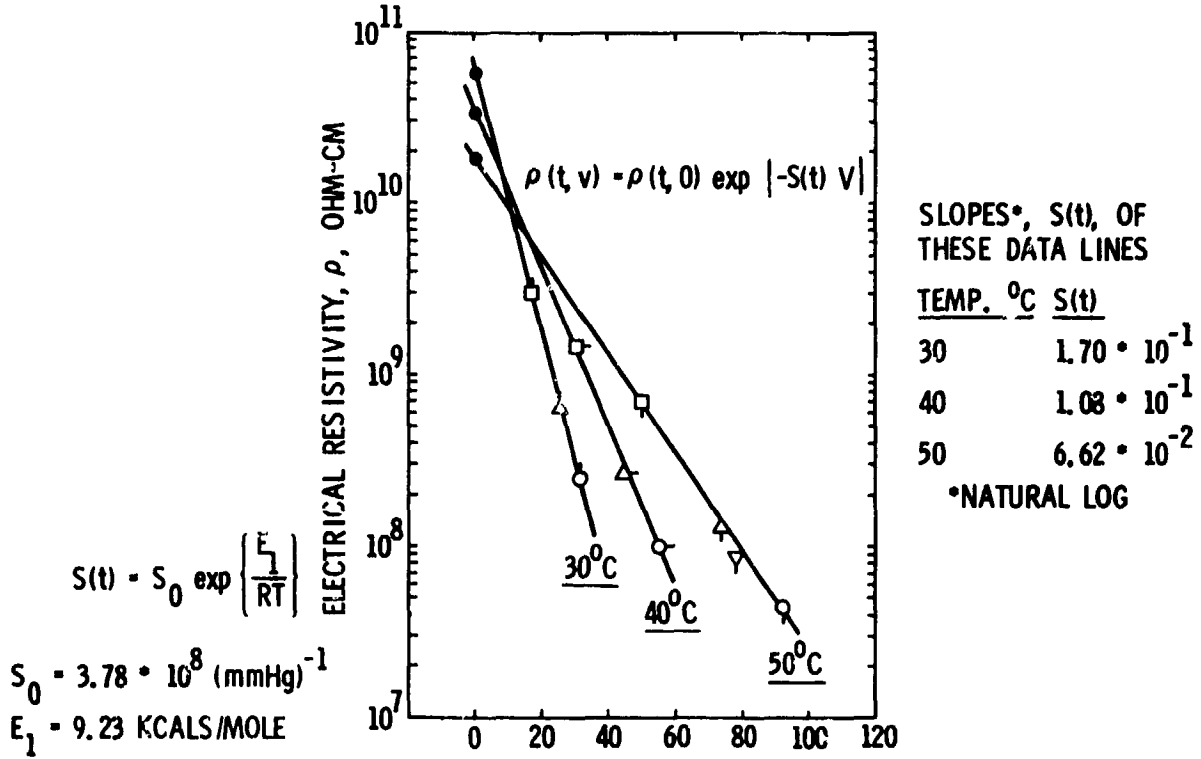
Electrical Resistivity of PVB as a Function of the Variable (RH + t)



Generalized Hygroscopic Behavior of Polymeric Materials



Electrical Resistivity of FVB Versus Atmospheric Water Vapor Pressure (Absolute Humidity)



The Basic Equations

SLOPES OF ρ VERSUS V

$$S(t) = S_0 \exp\left\{\frac{E_1}{RT}\right\}$$

$$S_0 = 3.78 \cdot 10^{-8} \text{ (mm.Hg)}^{-1}$$

$$E_1 = 9.23 \text{ KCALS/MOLE}$$

SATURATION VAPOR PRESSURE

$$V_p(t) = V_0 \exp\left\{\frac{-E_2}{RT}\right\}$$

$$V_0 = 1.031 \cdot 10^9 \text{ mm.Hg}$$

$$E_2 = 10.41 \text{ kcals/mole}$$

RELATIVE HUMIDITY

$$RH(t) = 100 \cdot V/V_p(t) : V = \left(\frac{V_0}{100}\right) (RH) \exp\left\{\frac{-E_2}{RT}\right\}$$

RESISTIVITY AT 0% RH

$$\rho(t, 0) = \rho_0 \exp\left\{\frac{\Delta H}{RT}\right\}$$

$$\rho_0 = 453.05 \text{ OHM-CM}$$

$$\Delta H = 11.243 \text{ kcals/mole}$$

(R = 1.987 CAL/DEG-MOLE)

Derivation of the "(RH + t)" Variable

$$1) \rho(t, V) = \rho(t, 0) \exp \{-S(t) V\}$$

$$2) \rho(t, V) = \rho_0 \exp \left\{ \frac{\Delta H}{RT} \right\} \exp \{-S(t) V\}$$

$$3) \ln \rho(t, V) = \ln \rho_0 + \frac{\Delta H}{RT} - S(t) V$$

$$\rightarrow V = \left(\frac{V_0}{100} \right) (RH) \exp \left\{ \frac{-E_2}{RT} \right\}$$

$$\rightarrow S(t) = S_0 \exp \left\{ \frac{E_1}{RT} \right\}$$

$$4) \ln \rho(t, RH) = \ln \rho_0 + \frac{\Delta H}{RT} - \frac{S_0 V_0}{100} \exp \left\{ \frac{E_1 - E_2}{RT} \right\} (RH)$$

$$\rightarrow \frac{\Delta H}{RT} = \frac{\Delta H}{R} \left\{ \frac{1}{T_0} + \frac{t}{T_0^2} + \frac{t^2}{T_0^3} - \dots \right\}$$

a) TAYLOR'S EXPANSION

$$b) T_0 = 273 : T (^{\circ}K) = 273 + t (^{\circ}C)$$



Derivation of the "(RH + t)" Variable (Cont'd)

$$5) \quad \ln \rho(t, RH) = \ln \rho_0 + \frac{\Delta H}{RT_0} - \frac{\Delta H}{RT_0^2} (t) - \frac{S_0 V_0}{100} \exp \left\{ \frac{E_1 - E_2}{RT} \right\} (RH)$$

DEFINE

$$A = \ln \rho_0 + \Delta H/RT_0$$

$$k_1 = \Delta H/RT_0^2$$

$$k_2 = \frac{S_0 V_0}{100} \exp \left\{ \frac{E_1 - E_2}{RT} \right\}$$

$$6) \quad \ln \rho(t, RH) = A - k_1 t - k_2 (RH)$$

$$\rightarrow k_1 = (11, 243) / (1.987) (273)^2 = 0.0759$$

$$\rightarrow k_2 \quad \text{TEMP. } ^\circ\text{C}$$

$$0.0548 \quad 30$$

$$0.0584 \quad 40$$

$$0.0619 \quad 50$$

$$7) \quad \ln \rho(t, RH) = A - k (t + RH)$$

Least Squares Analysis

- $\ln \rho(t, RH) = A - k_1 t - k_2 (RH)$

- $A = 25.9468$

- $k_1 = 0.08033$

- $k_2 = 0.0568$

- $k_1 = \frac{\Delta H}{RT_0^2}$

- $\Delta H = 11.89$ kcals/mole (FROM LEAST SQUARES)

- $\Delta H = 11.24$ kcals/mole (FROM DATA CURVES)

- $\ln \rho(t, RH) = A - k_2 \left\{ \frac{k_1}{k_2} t + RH \right\}$

- $k_1/k_2 = 1.414$



Electrical Resistivity of PVB Versus
the Variable (1.414 t + RH)

