N86-29363

"(RH + t)" AGING CORRELATION

JET PROPULSION LABORATORY

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

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

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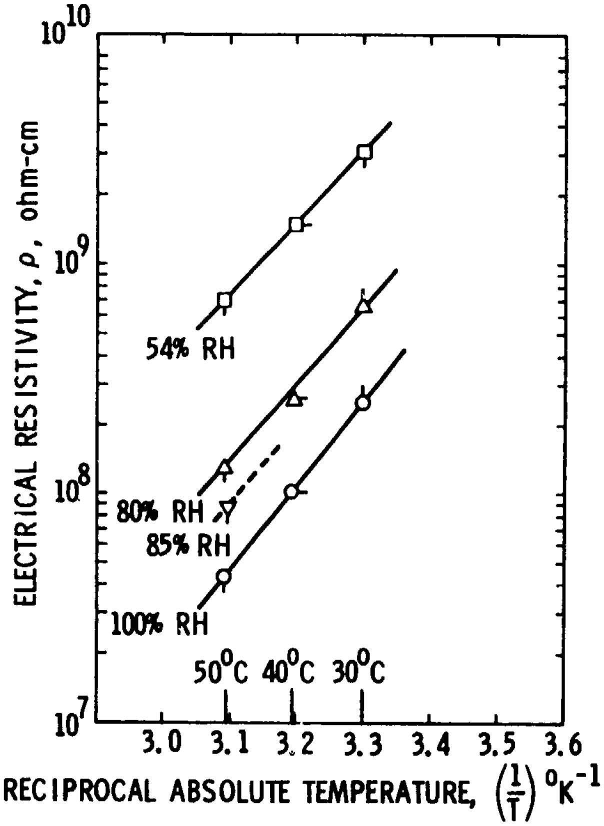
Electrical Resistivity of PVB



EQUATION

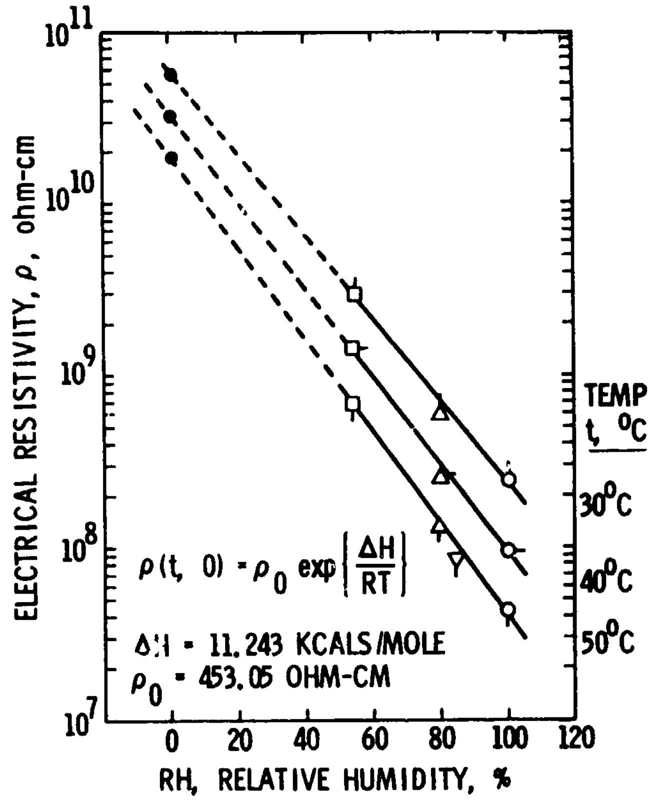
$$\rho(t, RH) = \rho_0(RH) \exp\left\{\frac{\Delta H}{RT}\right\}$$

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

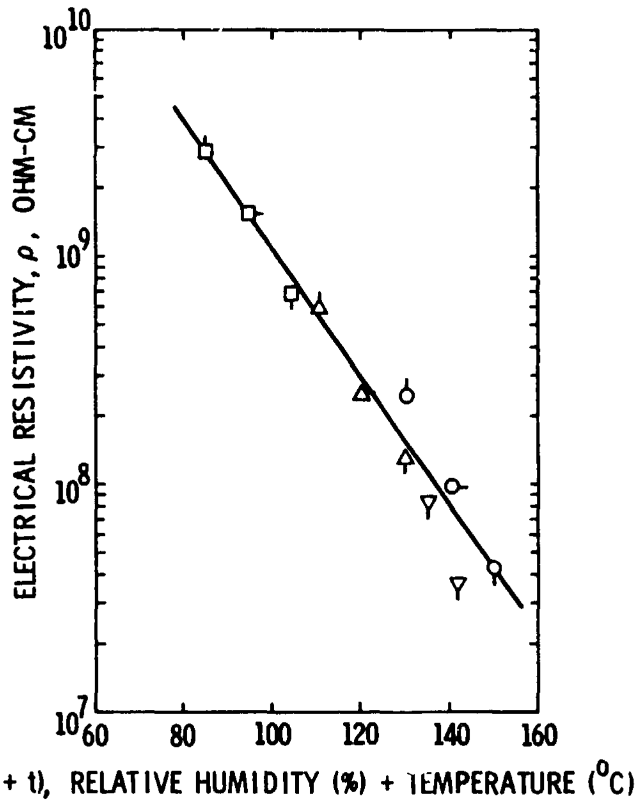
Electrical Resistivity of PVB as a Function of Relative Humidity

ρ AT 0% RH
(FROM LINEAR EXTRAPOLATION)

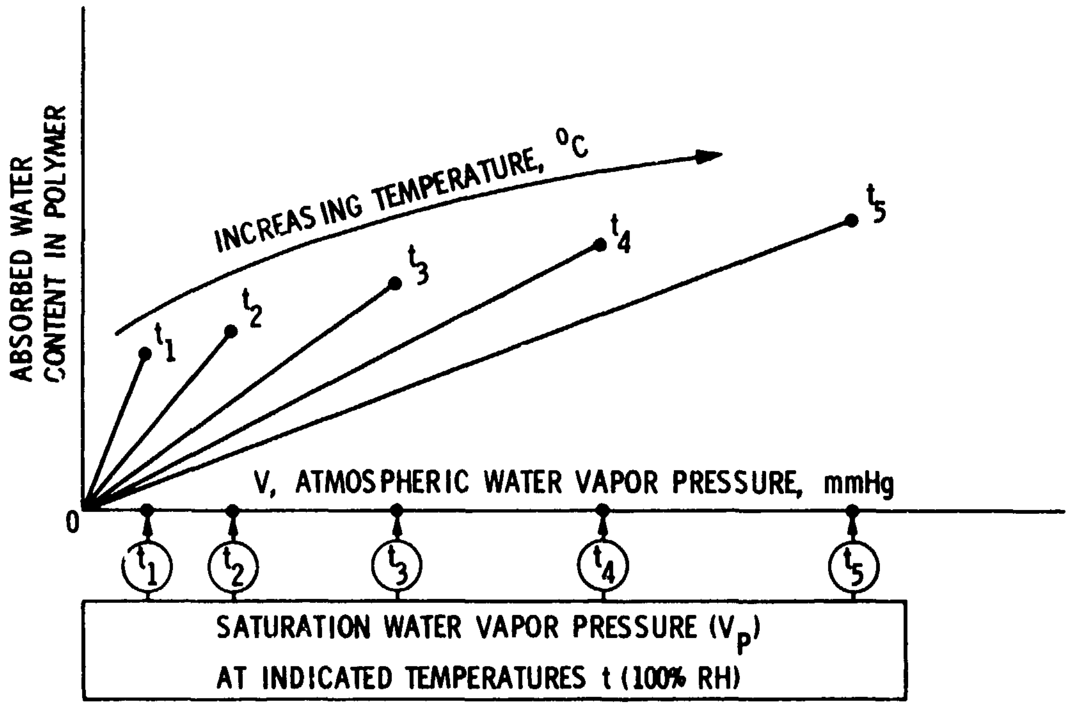
TEMP. ^{0}C	ρ, ohms-cm
30	$5.8 \cdot 10^{10}$
40	$3.3 \cdot 10^{10}$
50	$1.8 \cdot 10^{10}$



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

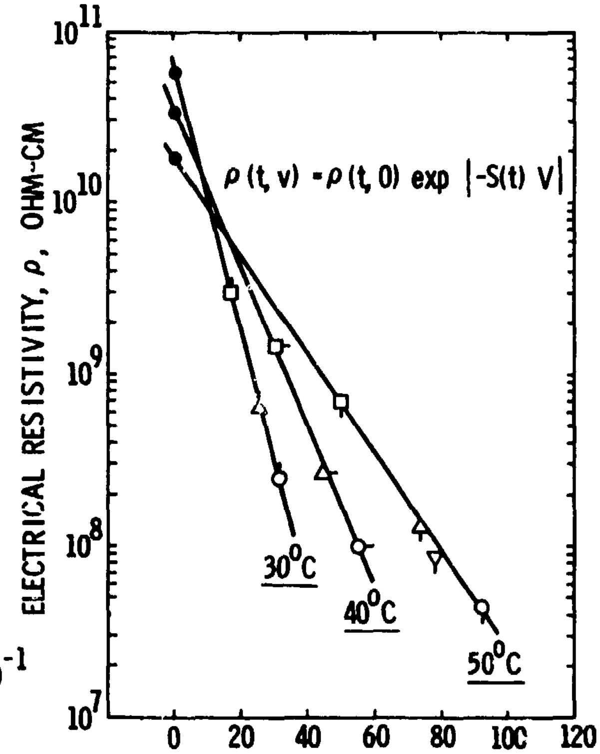


Generalized Hygroscopic Behavior of Polymeric Materials



RELATIVE HUMIDITY AT TEMP. $t = V/V_p(t)$

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



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

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

$E_1 = 9.23$ KCALS/MOLE

SLOPES*, S(t), OF THESE DATA LINES

TEMP. °C	S(t)
30	$1.70 \cdot 10^{-1}$
40	$1.08 \cdot 10^{-1}$
50	$6.62 \cdot 10^{-2}$

*NATURAL LOG

The Basic Equations

SLOPES OF ρ VERSUS V

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

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

$E_1 = 9.23$ KCALS/MOLE

SATURATION VAPOR PRESSURE

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

$V_0 = 1.031 \cdot 10^9$ mmHg

$E_2 = 10.41$ 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

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

$\rho_0 = 453.05$ OHM-CM

$\Delta H = 11.243$ kcals/mole

(R = 1.987 CAL/DEG-MOLE)

Derivation of the "(RH + t)" Variable

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

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

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

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

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

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

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

a) TAYLOR'S EXPANSION

b) $T_0 = 273 : T\,(^0K) = 273 + t\,(^0C)$

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

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

DEFINE

$$A = \mathrm{Ln}\,\rho_0 + \Delta H/RT_0$$

$$k_1 = \Delta H/RT_0^{\,2}$$

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

6) $$\mathrm{Ln}\,\rho(t, RH) = A - k_1 t - k_2 (RH)$$

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

→

k_2	TEMP. °C
0.0548	30
0.0584	40
0.0619	50

7) $$\mathrm{Ln}\,\rho(t, RH) = A - k(t + RH)$$

Least Squares Analysis

- $\ln \rho(t, RH) = A - k_1 t - k_2 (RH)$
    - $A = 25.9468$
    - $k_1 = 0.08033$
    - $k_2 = 0.0568$
- $k_1 = \Delta H / R T_0^2$
    - $\Delta H = 11.89$ 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)