

RELIABILITY PHYSICS

N86-29362

WATER PERMEATION AND DIELECTRIC BREAKDOWN

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**WATER PERMEABILITY**

**in**

**PUB**

**TEDLAR**

**PUB / TEDLAR**

**AS**

**A**

**FUNCTION**

**OF**

**TEMPERATURE**

**AND**

**HUMIDITY**

# THEORY

## ASSUMPTIONS:

(1) FICK'S LAW

$$J = P dp/dx$$

(2) IDEAL GAS BEHAVIOR

(3) IMMISCIBILITY

(4) SPONGE STRUCTURED

(5) DIFFUSION THROUGH  
WATER FILLED VOID  
SPACE

(6) CLAUSIUS-CLAPEYRON

# PVB AND TEDLAR

## TEMPERATURE DEPENDENCE

$$P = \frac{P_0 \exp(-Q_u / RT)}{T}$$

$Q_u$  IS ACTIVATION ENERGY FOR  
WATER SELF DIFFUSION

$$J = \frac{J_0 \exp(-[Q_u + \Delta H_v] / RT)}{T^{6.57}}$$

$\Delta H_v$  IS ENTHALPY OF WATER EVAPORATION

## HUMIDITY DEPENDENCE

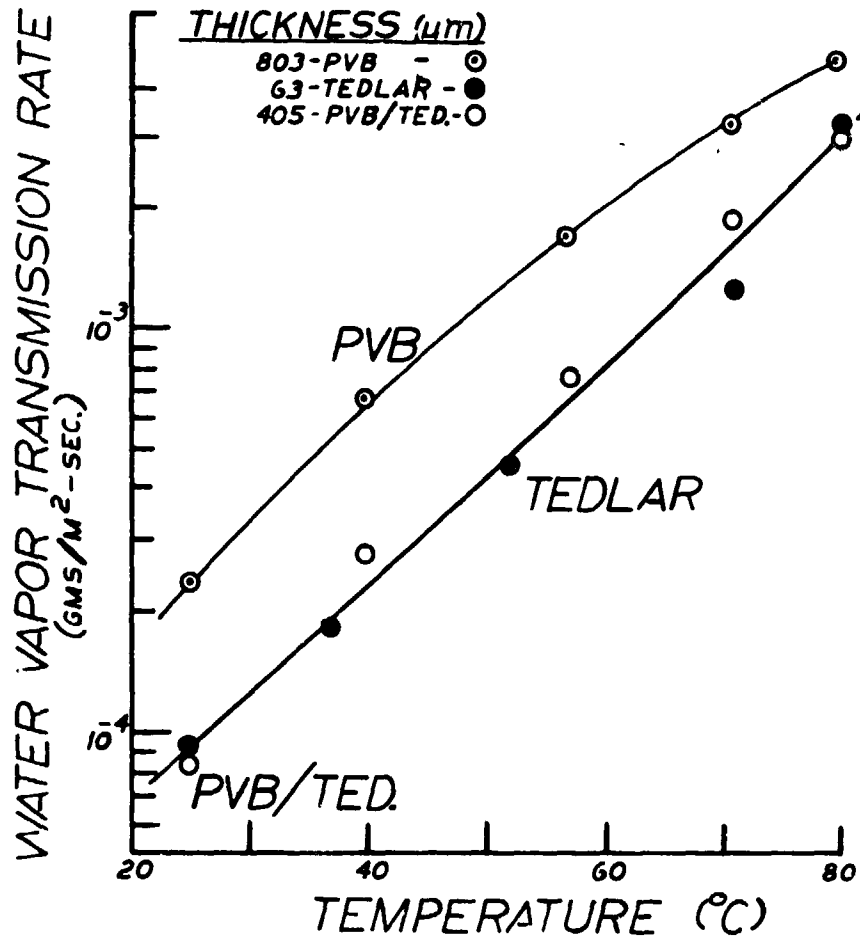
$$J = K [R.H.]$$

# PUB/TEDLAR COMPOSITE

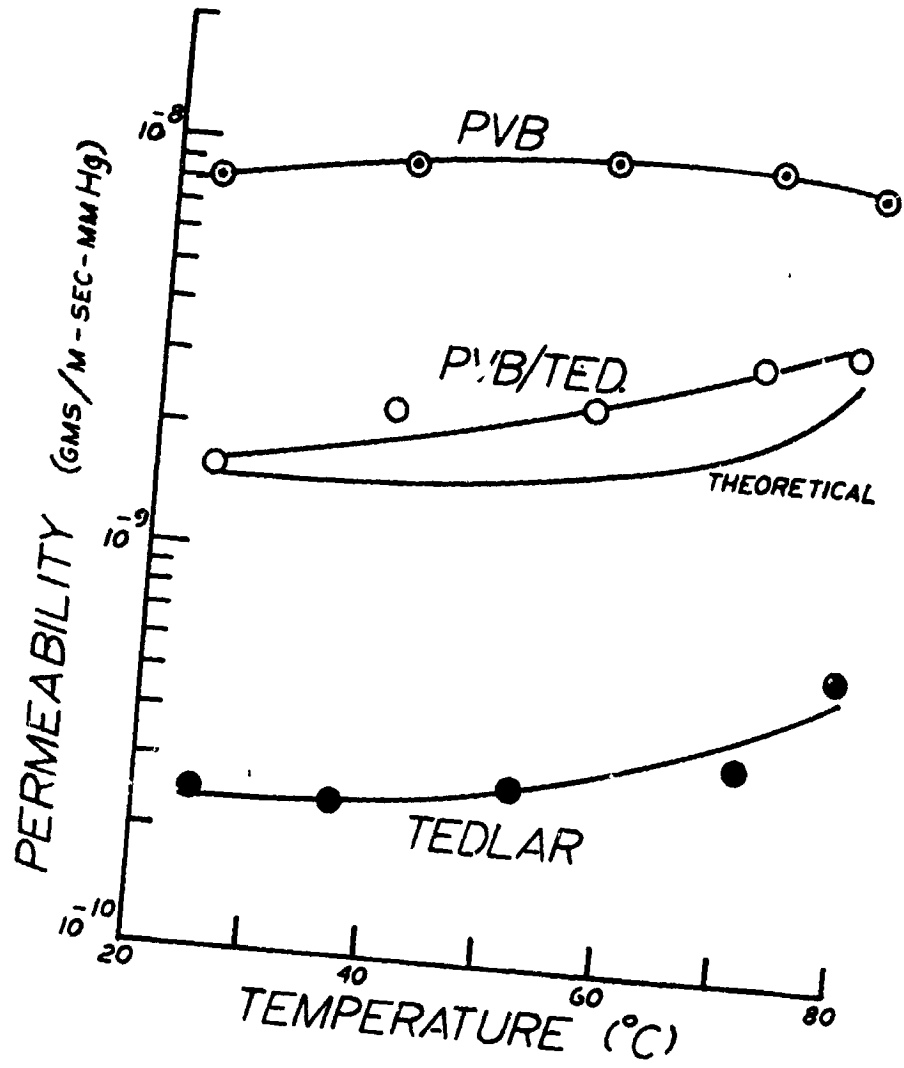
$$\frac{1}{P_{\text{PUB/T}}} = \left[ \frac{t_{\text{PUB}}}{P_{\text{PUB}}} + \frac{t_{\text{T}}}{P_{\text{T}}} \right] \left[ \frac{1}{t_{\text{PUB}} + t_{\text{T}}} \right]$$

$$J_{\text{PUB/T}} \begin{cases} = J_{\text{PUB}} & (\text{if } J_{\text{PUB}} < J_{\text{T}}) \\ \text{or} \\ = J_{\text{T}} & (\text{if } J_{\text{T}} < J_{\text{PUB}}) \end{cases}$$

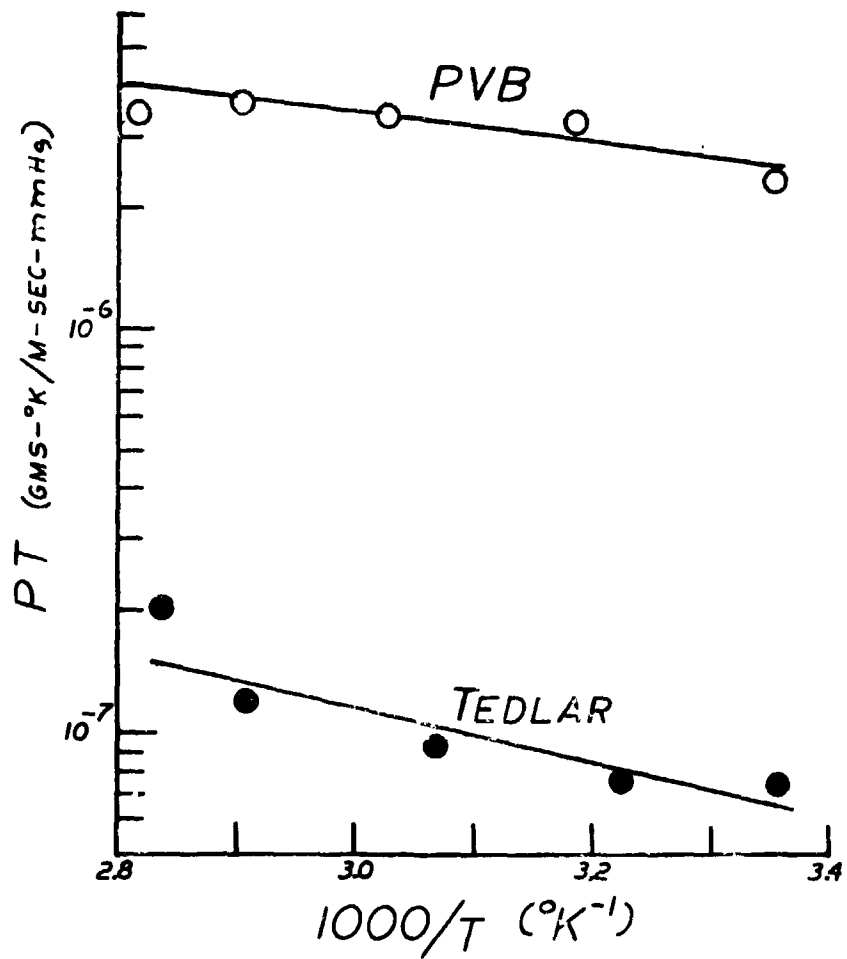
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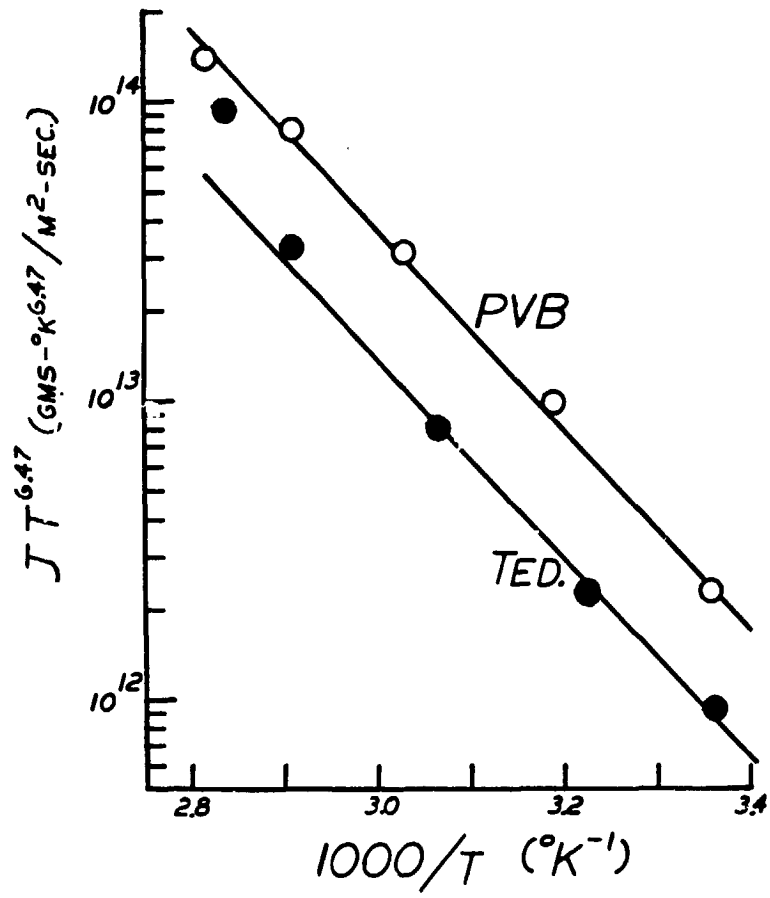
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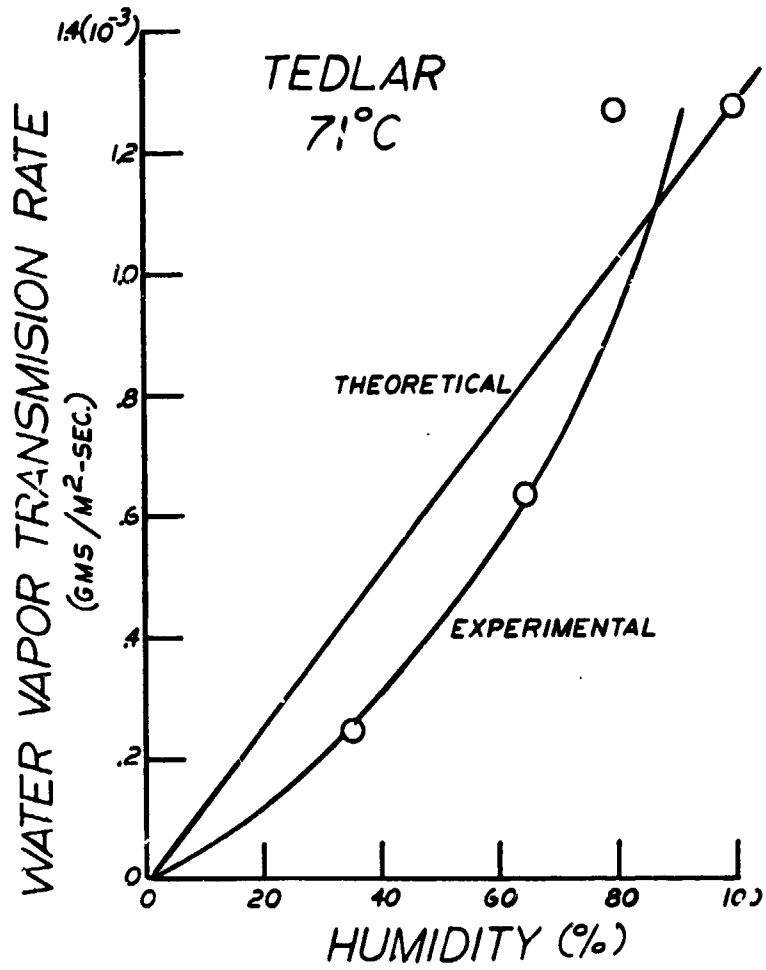
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**RESULTS & CONCLUSIONS**

$$(1) \frac{P_{PUB}}{P_T} \equiv 100$$

$$(2) \frac{J_{PUB}}{J_T} \equiv 3 \begin{pmatrix} t_{PUB} = 803 \mu m \\ t_T = 63 \mu m \end{pmatrix}$$

(3) **THEORY=EXPT** for J(T) & P(T)  
**EXPT**

$$Q_u + \Delta H_u = 15 \text{ Kcal/mole}$$

**LITERATURE:**

$$Q_u = 4.6 \text{ Kcal / mole}$$

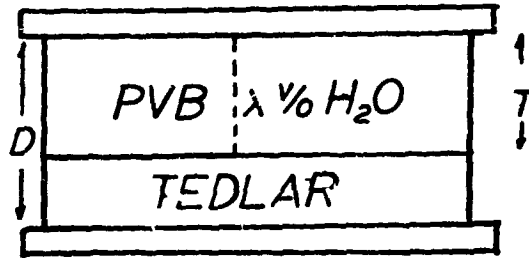
$$\Delta H_u = 9.8 \text{ Kcal / mole}$$

$$Q_u + \Delta H_u = 14.4 \text{ Kcal / mole}$$

(4) **NEED THERMODYNAMIC INFORM**

RELIABILITY PHYSICS

- RESISTANCE
- CAPACITANCE
- BREAKDOWN VOLTAGE



DIELECTRIC CONSTANT:

$$K = \left[ \frac{K_T [X][K_W - K_P] + K_P}{TK_T + [D-T][X][K_W - K_P] + K_P} \right] \left[ \frac{l}{D} \right]$$

RESISTIVITY:

$$\rho = \rho_T \left[ \frac{D-T}{D} \right] + \left[ \frac{T}{D} \right] \left[ \frac{\rho_W \rho_P}{\rho_W + [\rho_P - \rho_W][X]} \right]$$

# DIELECTRIC BREAKDOWN

AT

25 °C

IN

PVB

TEDLAR

PVB/TEDLAR

} 0%  
R.H.

AND

PVB

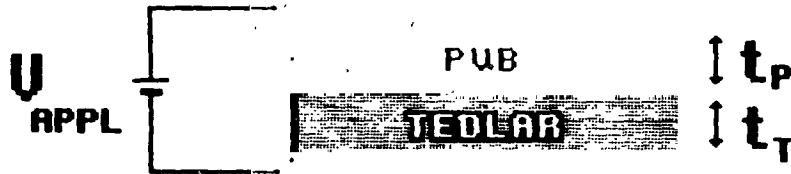
TEDLAR

PVB/TEDLAR

} 100%  
R.H.

# THEORY

## GAUSSES' LAW:



## VOLTAGE DIVISION

$$U_P = \left[ \frac{t_P / K_P}{t_P / K_P + t_T / K_T} \right] U_{APPL}$$

$$U_T = \left[ \frac{t_T / K_T}{t_P / K_P + t_T / K_T} \right] U_{APPL}$$

**BREAKDOWN VOLTAGE (0% R.H.)**

LARGER OF:

$$U_{BR} = E_{BR_T} K_T \left[ \frac{t_P}{k_P} + \frac{t_T}{k_T} \right]$$

OR

$$U_{BR} = E_{BR_P} K_P \left[ \frac{t_P}{k_P} + \frac{t_T}{k_T} \right]$$

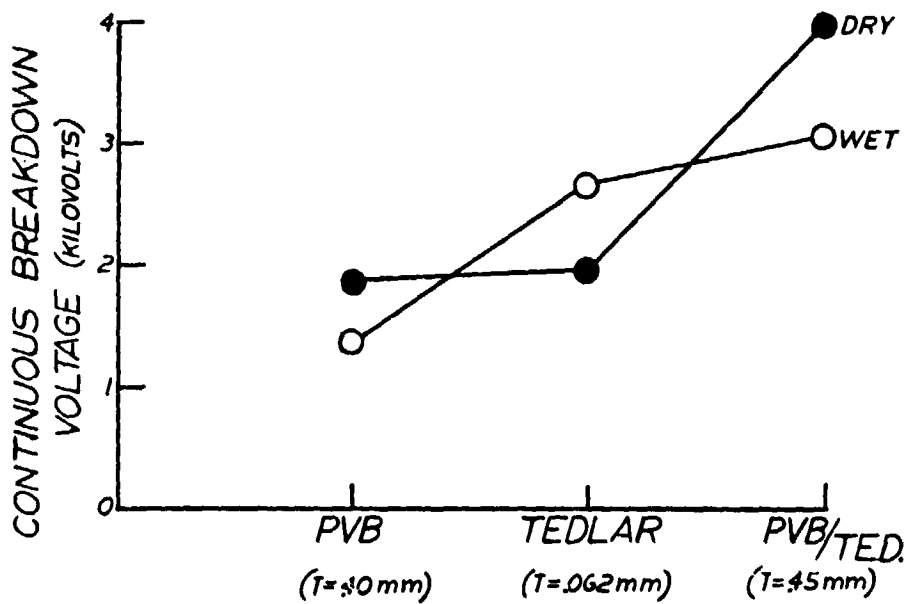
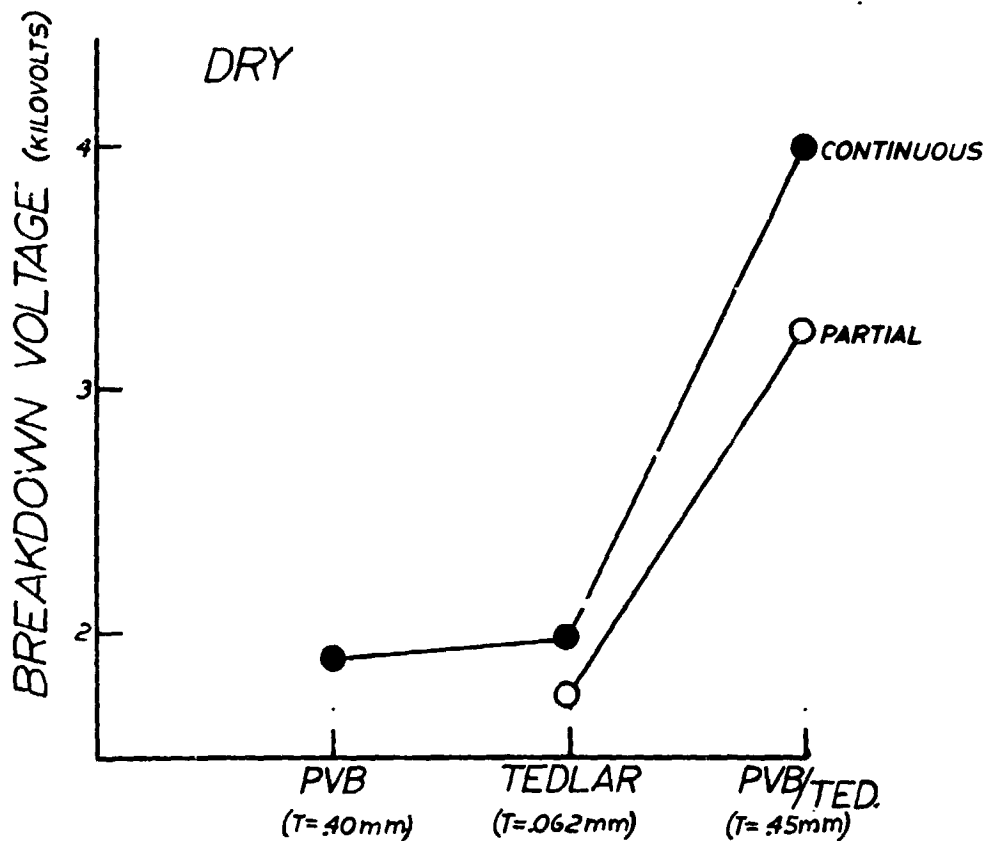
WHERE

$$E_{BR_P} = U_{BR_P} / t_P$$

$$E_{BR_T} = U_{BR_T} / t_T$$



RELIABILITY PHYSICS



ELECTRIC FIELDS AT BREAKDOWN

	<u><math>E_{BR}</math> (KV/cm.)</u>
PVB	25
TEDLAR	280
AIR	30

PVB/TEDLAR  
BREAKDOWN VOLTAGE

	<u><math>V_{BR}</math> (KV)</u>	<u><math>K_{PVB}</math></u>	
EXPT.	3.2	-	
THEORY	{	10.1	42
		6.1	61
		5.3	10.0



CONCLUSIONS

BREAKDOWN VOLTAGES

THEORY  $\neq$  EXPT. (PVB/T)

DRY > WET (PVB & PVB/T)

WET > DRY (TEDLAR)

PARTIAL  $\approx$  .8 CONTINUOUS

DESTRUCTIVE (TEDLAR)

NON-DESTRUCTIVE (PVB & PVB/T)

CRITICAL ELECTRIC FIELD

TEDLAR > PVB  $\approx$  AIR