APPENDIX B

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DEVELOPMENT OF HYDRAULIC HEAD EQUATION

1. Notation.

H= hydraulic head (meters),

h_m= reading on scale of mercury in manometer tube (cm),

h_r= reading on scale of free surface of mercury in reservoir (cm),

E_m= elevation of top of manometer board above arbitrary reference plane (meters),

E_p= elevation of top of piezometer/tensiometer tube above arbitrary reference plane (meters),

L= length of piezometer/tensiometer (meters),

p= water pressure (dynes/meter^2),

ρ= density of water (gm/cm^3),

ρ_m= density of mercury (gm/cm^3),

g= gravitational constant (9.81 dynes/gram),

C= capillary depression of mercury-water interface in manometer tube (cm). (c = 0.9 cm)

2. Development of equation.

P_A= gage pressure (atmospheric) = 0

P_B= $-0.01\ \rho_m\ (h_m + C - h_r) = P_B$,

(Note: The conversion factor, 0.01, is used since h_m, h_r, and C are in centimeters and H is in meters).

Now $P_p = -0.01\ \rho_m g\ (h_m - h_r + C) + \rho g\ (E_m - E_p - 1 + 0.01\ h_m + L + C)$

or $$\frac{P_p}{\rho g} = -0.01\frac{\rho m}{\rho}\ (h_m - h_r + C) + E_m - E_p - 1 + 0.01\ h_m + L + 0.01C \qquad (1)$$

The hydraulic head at P is

$$H = \frac{P_p}{\rho g} + Z$$

where $Z = E_p - L$

Therefore

$$H = -0.01 \frac{\rho m}{\rho} (h_m - h_r + C) + 0.01 h_m + 0.01C - 1 + E_m - E_p + L + E_p - L$$

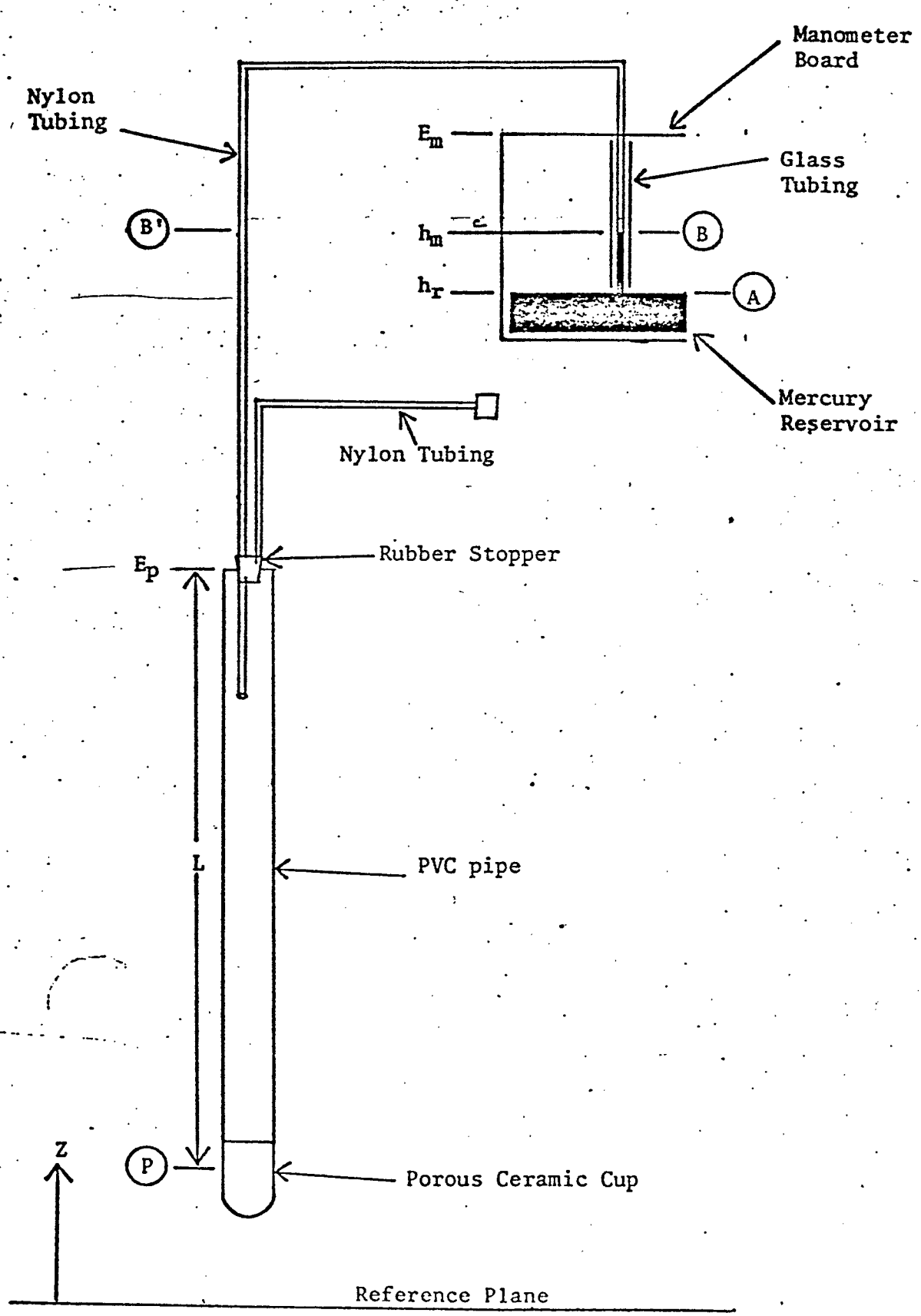
or $$H = -0.01 \left(1 - \frac{\rho m}{\rho}\right) h_m + 0.01 \frac{\rho m}{\rho} hr - 0.01 \left(1 - \frac{\rho m}{\rho}\right) C - 1 + E_m$$

If $\rho = 1.0$ and $\rho_m = 13.55$, then

$$H = -0.1255\, h_m + 0.1355\, h_r - 0.1255\, C - 1 + E_m \qquad (2)$$

The water pressure head at P (meters) can be calculated from equation (1) or

$$\frac{P_p}{\rho g} = -0.1255\, h_m + 0.1355\, h_r - 0.1255\, C - 1 + E_m - E_p + L \qquad (3)$$


Manometer Board
Nylon Tubing
E_m
Glass Tubing
B'
h_m
B
h_r
A
Mercury Reservoir
Nylon Tubing
Rubber Stopper
E_p
L
PVC pipe
Z
P
Porous Ceramic Cup
Reference Plane