Hot Thermodynamics for Freezing Soils

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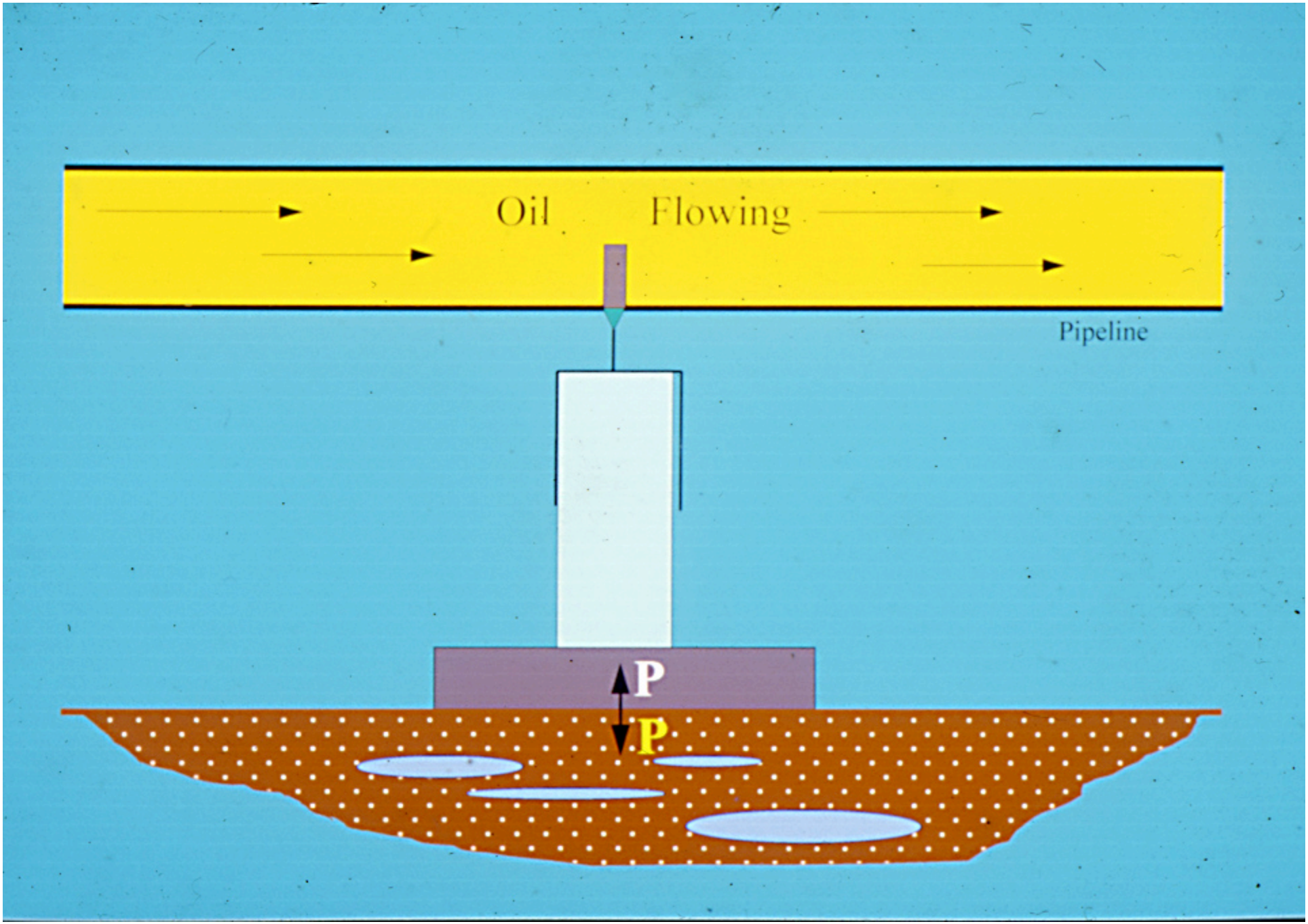
FROST
HEAVES


Oil Flowing
Pipeline
P
P

CRREL: Segregation Potential (SP)

$$SP \equiv v / (Grad\, T_{ff})$$

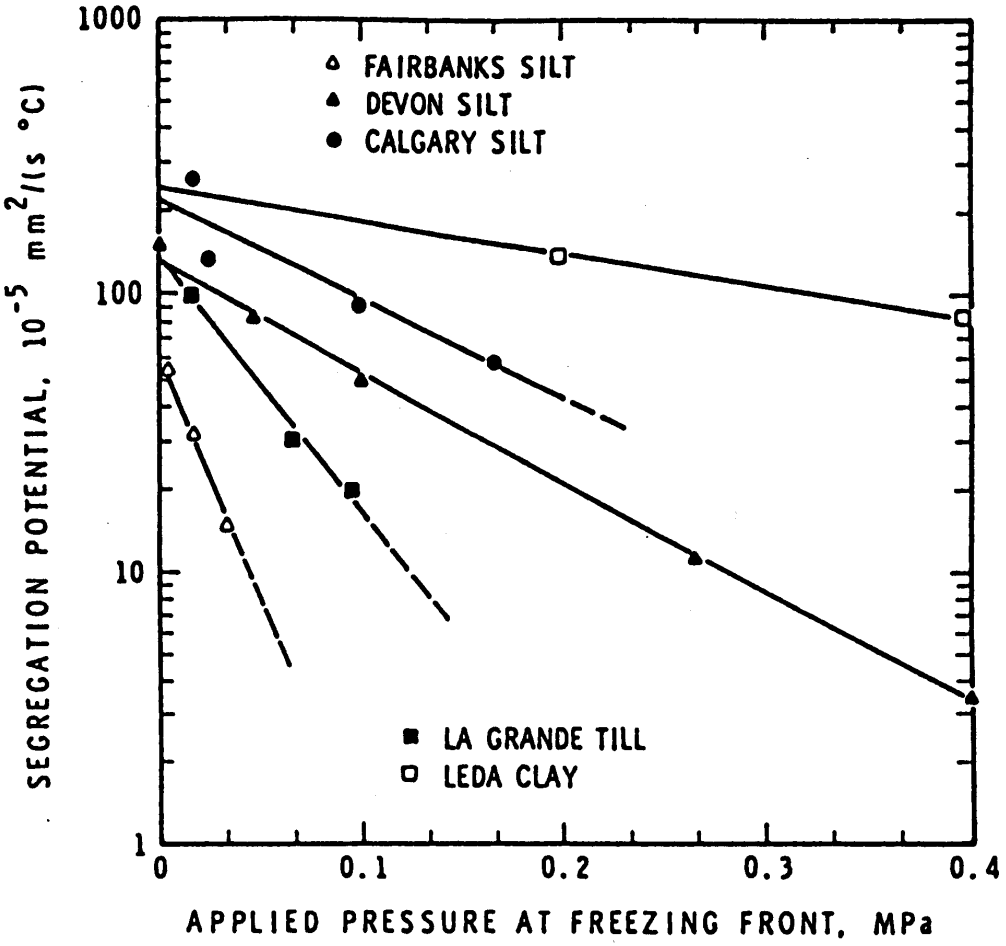


FIGURE 74.4. Summary of data for SP parameter.

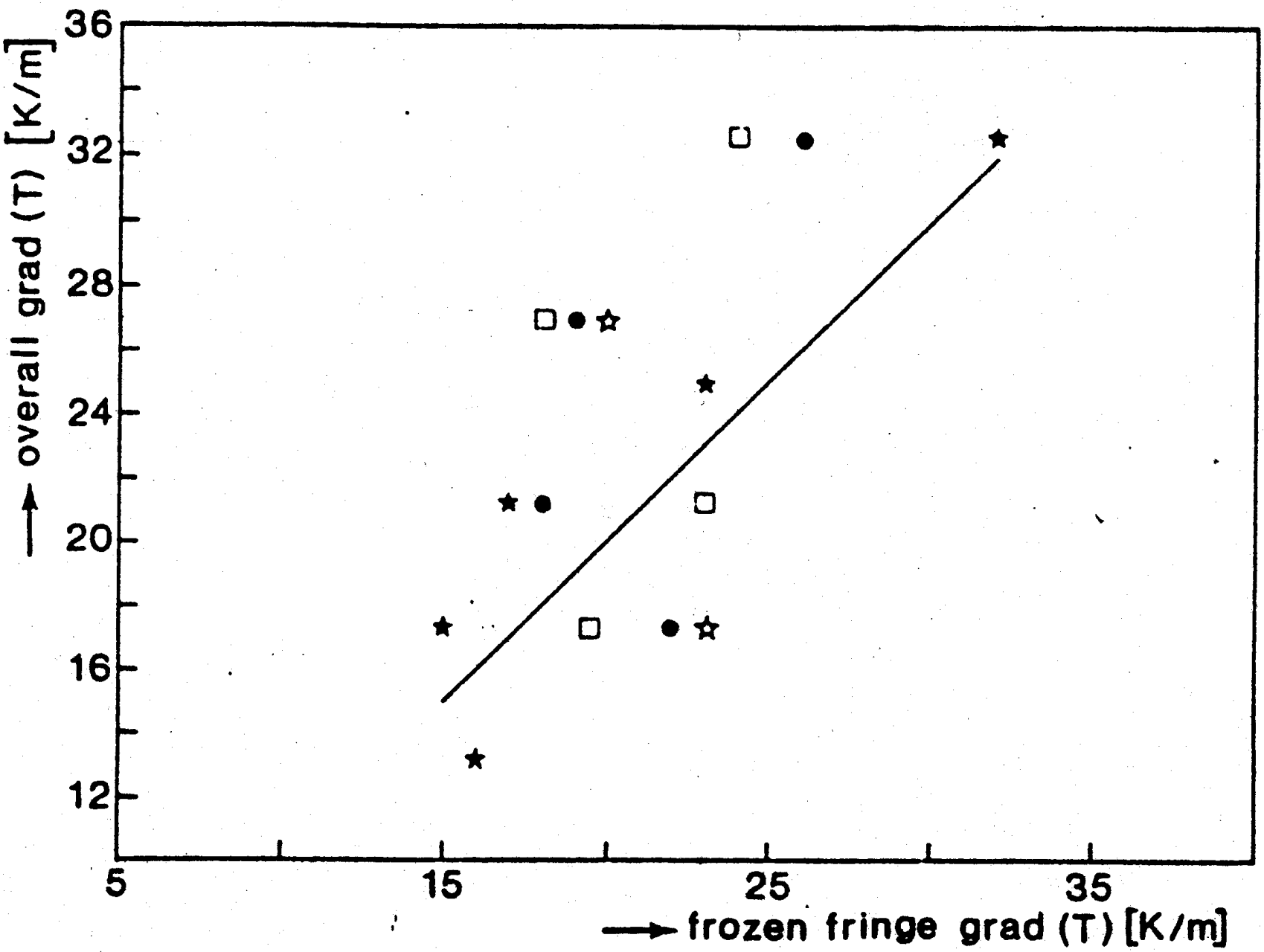
CORNELL: Heave Rate

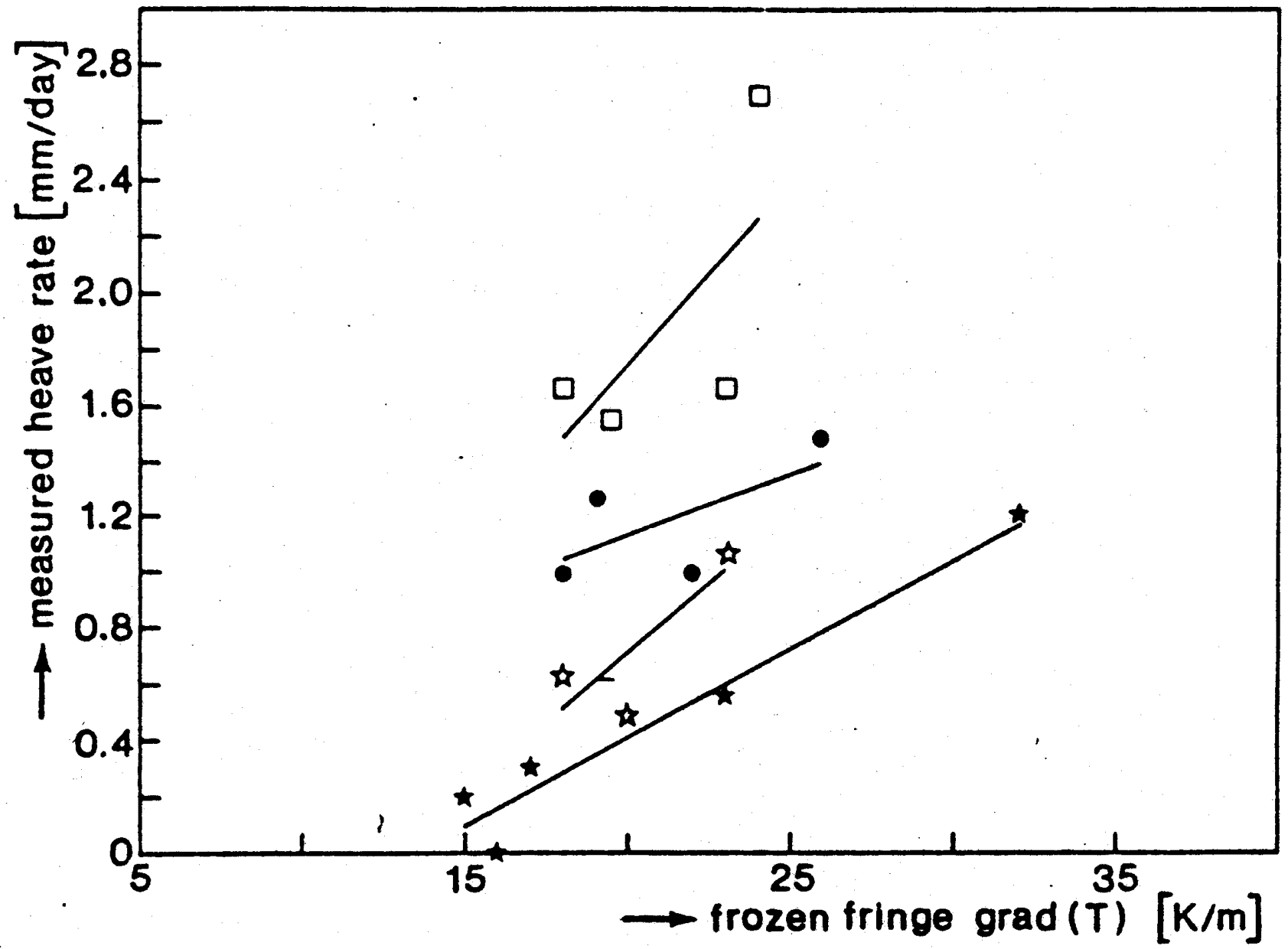
$$dh_{sec}/dt = A - B \times (\partial T/\partial z)_{ff}$$

where dh_{sec}/dt is the heave rate

and

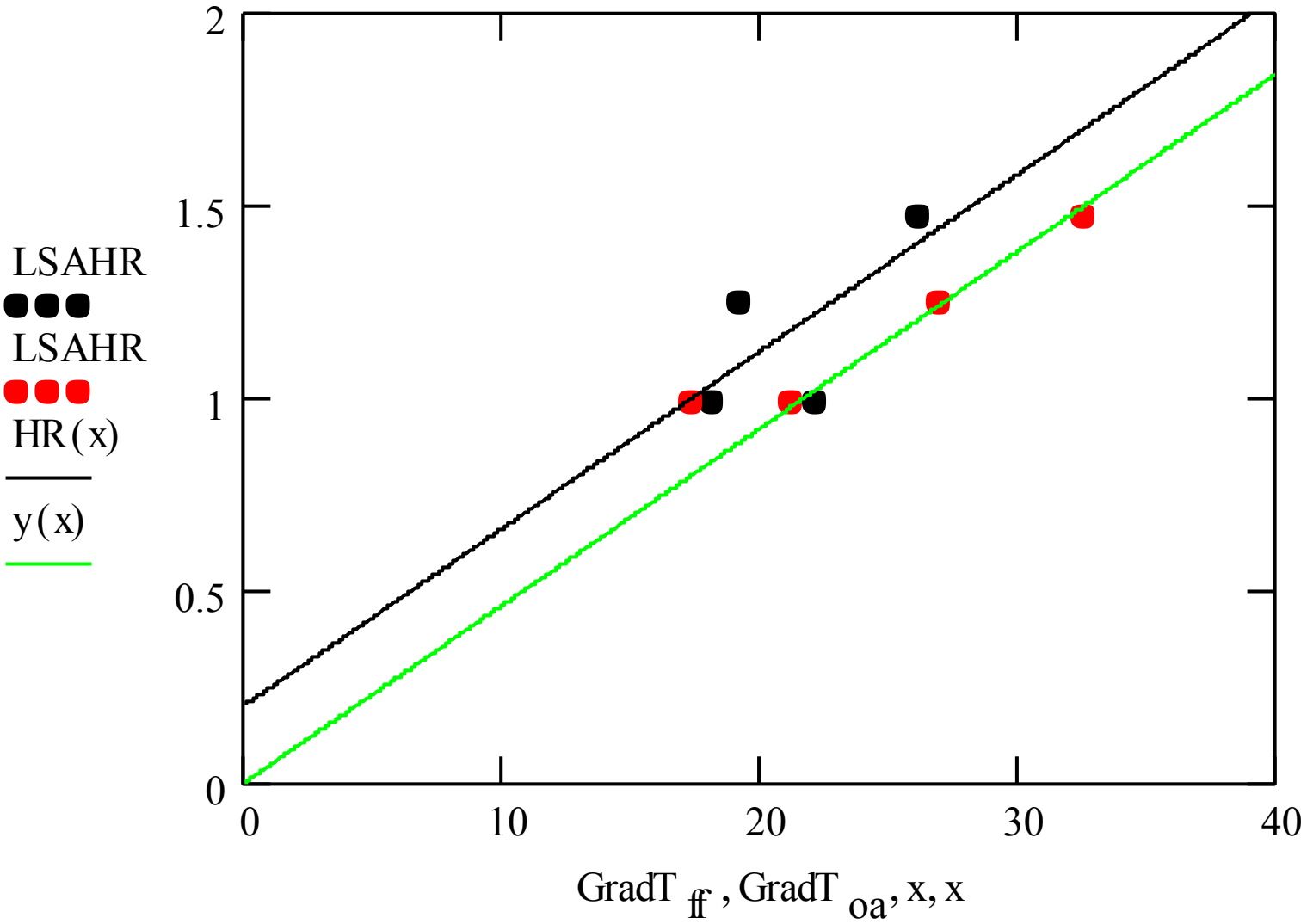
$B = SP \times (\rho_w / \rho_i)$


36
32
28
24
20
16
12
overall grad (T) [K/m]
5
15
25
35
frozen fringe grad (T) [K/m]


measured heave rate [mm/day]
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
5
15
25
35
frozen fringe grad (T) [K/m]

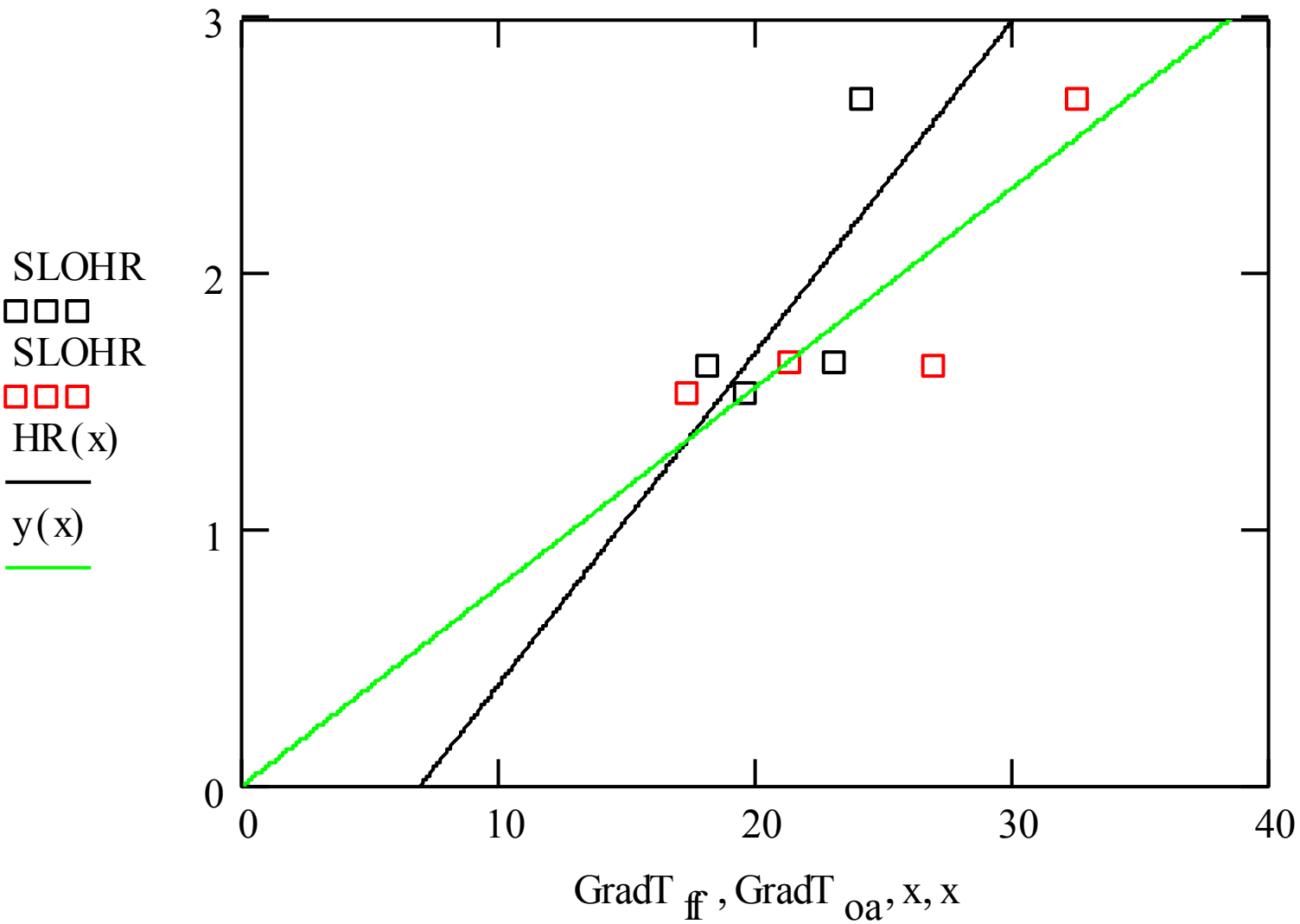
$A := 0.2$ $B := 0.046$ $b := 0.046$

$HR(x) := A + B \cdot x$ $y(x) := b \cdot x$



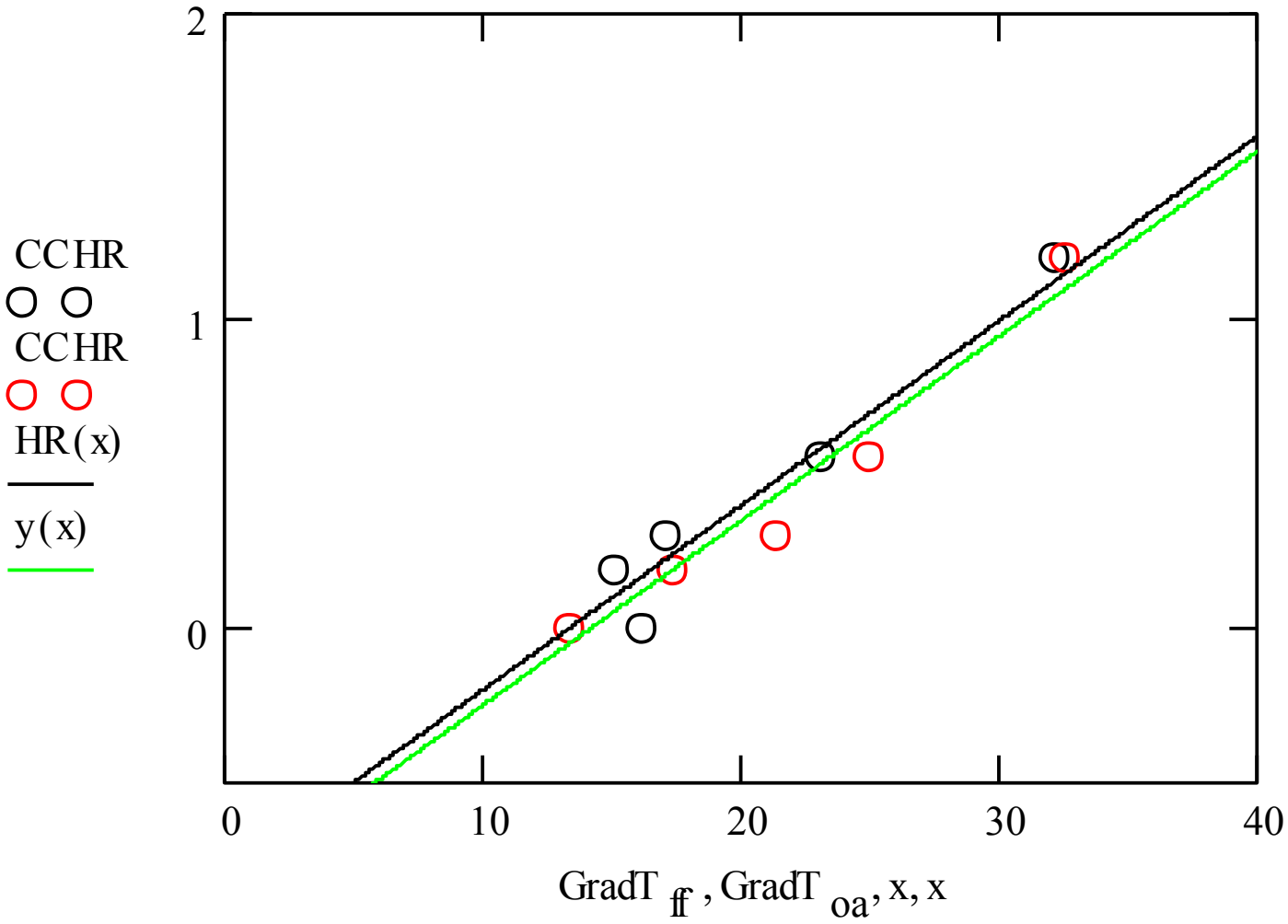
$A := -0.9 \qquad B := 0.13 \qquad b := 0.078$

$HR(x) := A + B \cdot x \qquad y(x) := b \cdot x$



$A := -0.8 \quad B := 0.06 \qquad a := -0.85 \quad b := 0.06$

$HR(x) := A + B \cdot x \qquad y(x) := b \cdot x + a$



Clapeyron

$$\bar{V}_i \, dp_i - \bar{V}_i \, dp_i = H_f \, T^{-1} \, dT$$

$$\bar{V}_i \, Grad \; p - \bar{V}_i Grad \; p_i = H_f \, T^{-1} \, Grad \, T$$

Darcy

$$v = -K(\theta_l, \vartheta_i) \; Grad \; p$$

$$HI \equiv v\,Grad^{-1}(-T) \qquad [m^2\ s^{-1}\ K^{-1}]$$

Grad(-T) is the overall temperature gradient
From the soil surface to the frost front

*(**not** the temperature gradient in the frozen fringe)*

$$HI = \frac{K}{\overline{\overline{V}}_l} \left\{ \overline{V}_i \frac{Grad\ p_i}{Grad\, T} + \frac{H_f}{T} \right\}$$

$$HI = \frac{K}{\overline{\overline{V}}_l} \left\{ \frac{H_f}{T} \right\} \qquad [m^2\, s^{-1}\, K^{-1}]$$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