DRG Conference

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Collapse of production casing
An oilfield perspective

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Agenda

- API/ISO thick wall collapse equation
- Lubinski neutral axial stress
- Theory and load case
- Discussion and conclusions

Two thick wall collapse models

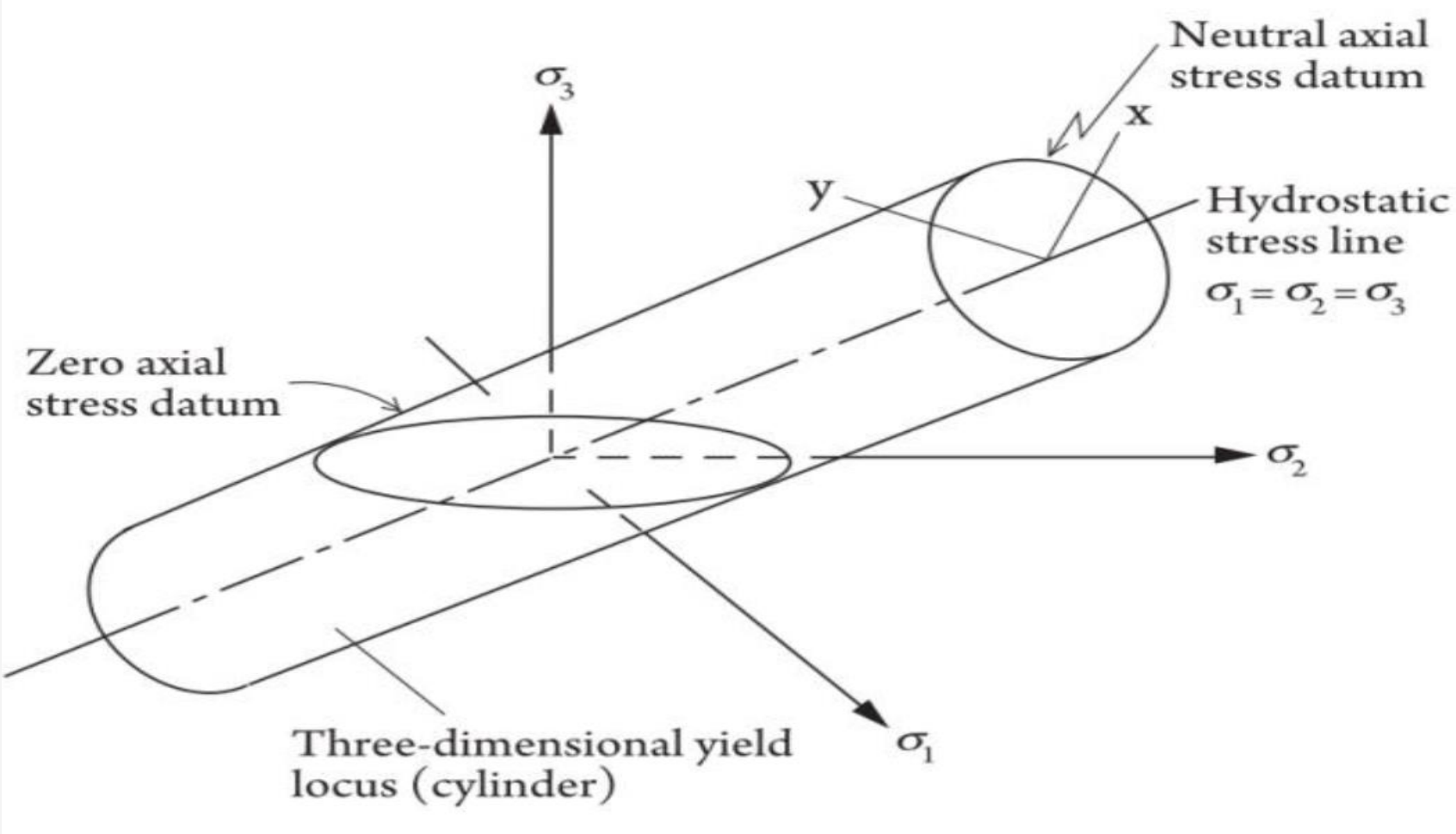
Å API/ISO (2007) collapse equation
- Ellipse of plasticity (2D) introduced in the 1930s
- Zero axial stress nominal collapse

$$P_a = \frac{\sqrt{3}}{3}\frac{A_s}{A_o}\sigma_y$$

Å Lubinski (1975) collapse equation
- Circle of plasticity
- Good match with experimental data
- Neutral axial stress nominal collapse

$$P_n = \frac{1}{2}\frac{A_s}{A_o}\sigma_y$$

Axial stress datum



Neutral axial stress (tension is positive)

$$\sigma_n(x) = \frac{A_i p_i(x) - A_o p_o(x)}{A_s}$$

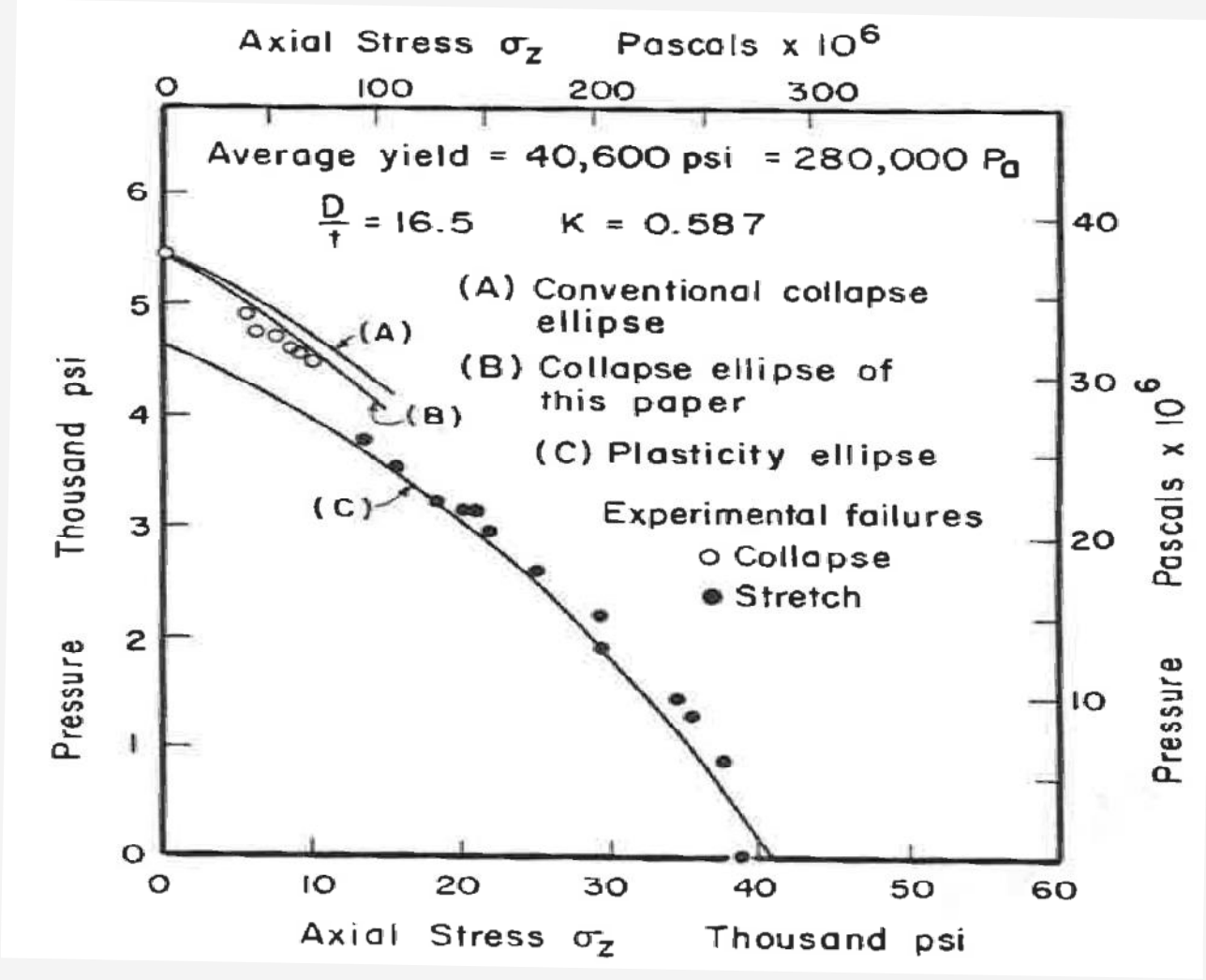
$$\text{Hydrostatic datum}: \ \sigma_n(x) = -p(x)$$

$$\text{Buckling datum}: \ \Delta\sigma(x) = \sigma(x) - \sigma_n(x)$$

$$\text{Collapse datum}: \ \Delta\sigma(x) = \sigma(x) - \sigma_n(x)$$

THE SAME

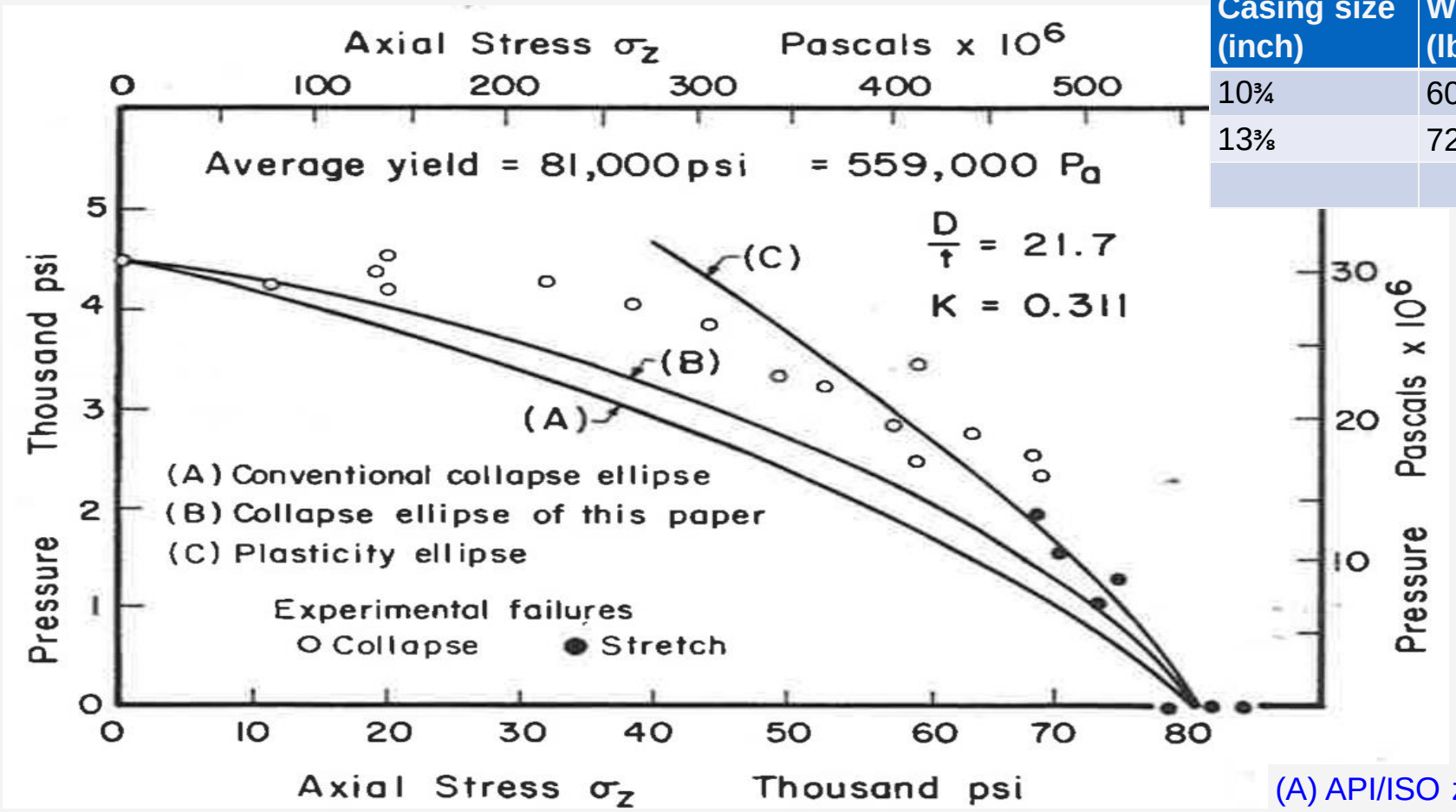
Edward and Miller data (group 6)



Casing size (inch)	Weight (lbs/ft)	D/t
7	32	15.5
9⅝	53.5	17.7

(A) API/ISO zero axial stress datum
(B) Lubinski neutral axial stress datum

Edward and Miller data (group 7)



Casing size (inch)	Weight (lbs/ft)	D/t
10¾	60.7	19.7
13⅜	72	26

(A) API/ISO zero axial stress datum
(B) Lubinski neutral axial stress datum

Four general load cases - burst and thick wall collapse

Bending stress	Inside pipe wall	Outside pipe wall
Positive (tension)	$A_s\sigma_z = A_s\sigma_a + F_E\frac{r_o r_i}{2I} + \kappa E A_s r_i$	$A_s\sigma_z = A_s\sigma_a + F_E\frac{r_o^2}{2I} + \kappa E A_s r_o$
Negative (compression)	$A_s\sigma_z = A_s\sigma_a - F_E\frac{r_o r_i}{2I} - \kappa E A_s r_i$	$A_s\sigma_z = A_s\sigma_a - F_E\frac{r_o^2}{2I} - \kappa E A_s r_o$

$$\sigma_{vM_i}^2 = \left(\frac{F_E}{A_s} \pm \frac{F_E r_o r_i}{2I} \pm \kappa E r_i\right)^2 + 3\left(\frac{A_o(p_i - p_o)}{A_s}\right)^2$$

$$\sigma_{vM_o}^2 = \left(\frac{F_E}{A_s} \pm \frac{F_E r_o^2}{2I} \pm \kappa E r_o\right)^2 + 3\left(\frac{A_i(p_i - p_o)}{A_s}\right)^2$$

Example load case

$$x^2 + y^2 = \left(\frac{\sigma_{vM}}{\sigma_y} \right)^2$$

$$x_i = \frac{F_E}{A_s \sigma_y}, \quad y_i = \frac{\sqrt{3} A_o (p_i - p_o)}{A_s \sigma_y}$$

- Collapse of 9ę " 53.5# production casing
- Hot production load case
- Surface $\Delta T(0) = 200$ °C
- Bottom $\Delta T(L) = 100$ °C
- Well cement prevents helical buckling
- Neglect casing bending from well curvature
- Yielding starts at inside casing wall
- Use effective force (circle of plasticity)
- Assume that casing stress remains below yield

$$F_E(x) = A_s \sigma(x) - A_i p_i(x) + A_o p_o(x)$$

$$\frac{F_E(x)}{A_s} = \sigma(x) - \sigma_n(x)$$

Incipient yield thick wall collapse equation

$$p_o(x) = p_i(x) + \frac{\sqrt{3}A_s}{3A_o}\sqrt{\sigma_{vM}^2 - \frac{F_E^2(x)}{A_s^2}}$$

$$\frac{F_E(x)}{A_s} = \sigma(x) - \sigma_n(x)$$

$$\sigma(x) = \sigma_0(x) + \sigma_1(x)$$

$$\sigma_n(x) = \frac{A_i p_i(x) - A_o p_o(x)}{A_s}$$

Initial axial stress in casing

- Initial condition is the moment the cement cures

$$\sigma_0(x) = \frac{w_s(L-x)}{A_s} + \frac{A_i}{A_s} p_i(L) - \frac{A_o}{A_s} p_o(L)$$

Thermal stress in casing

- Heat a fully restrained cemented casing

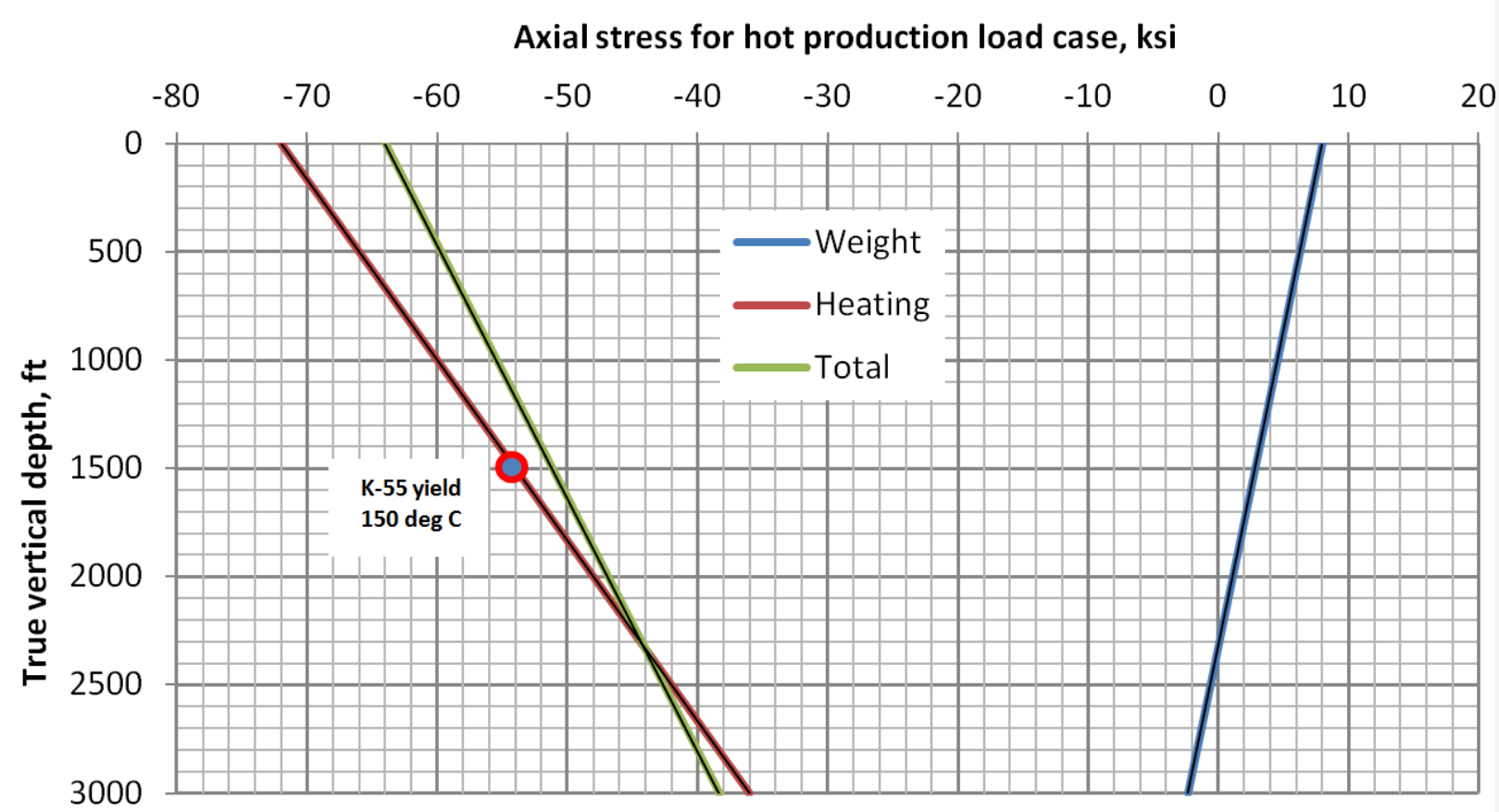
$$u'' = \alpha \Delta T' \,,\; u(0) = u(L) = 0$$

$$\sigma_1(x) = E\left(u' - \alpha \Delta T(x)\right) = -E\alpha \Delta T(x)$$

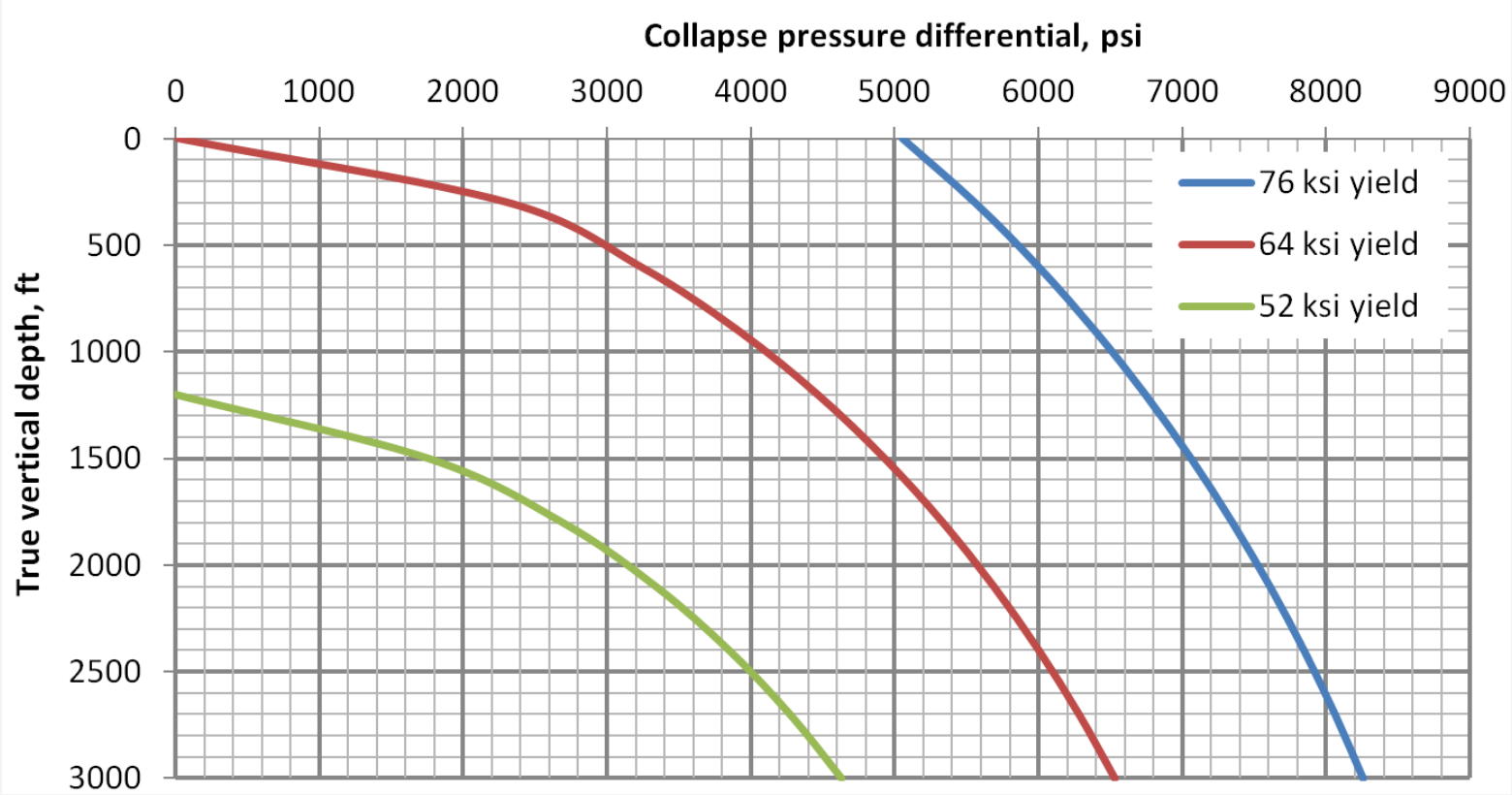
- Linear example case

$$\Delta T(x) = \Delta T_0 + (\Delta T_1 - \Delta T_0)\frac{x}{L}$$

Calculated axial stress



Example collapse pressure differential



Discussion and conclusions

- Two thick wall collapse models
  - Zero axial stress gives a skewed ellipse
  - Neutral axial stress gives a circle
  - For burst, both models are applicable and give identical values
- Experimental collapse data correlate well with neutral axis stress datum
- Neutral axis collapse stress datum is the same as helical buckling datum
- Additional pressure dependence for ellipse of plasticity
  - Ellipse: Appears in both *x* and y coordinates
  - Circle: Appears in *y* coordinate only
- Thick wall collapse equation is presented
- Hot production load case is exemplified

References

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