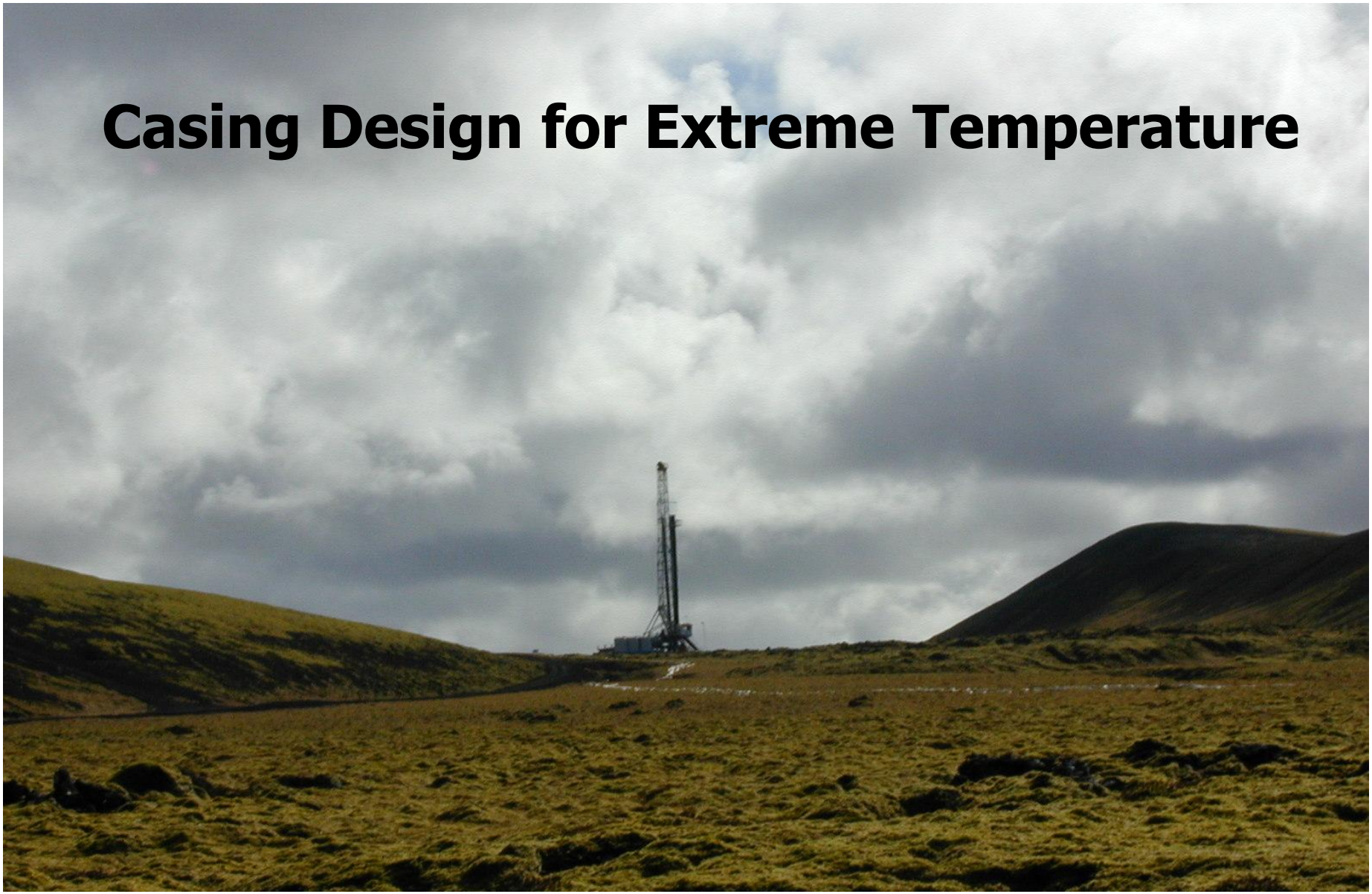
Casing Design for Extreme Temperature



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Basic assumptions

- The hole will be cased off down to the critical point
- Bottom Hole Temperature max 550 C
- Bottom Hole Pressure max 26,7 MPa
- ASME and ASA codes or standards has to be "intertwine" into API standards
- The well shall be "safe" in flowing and closed conditions

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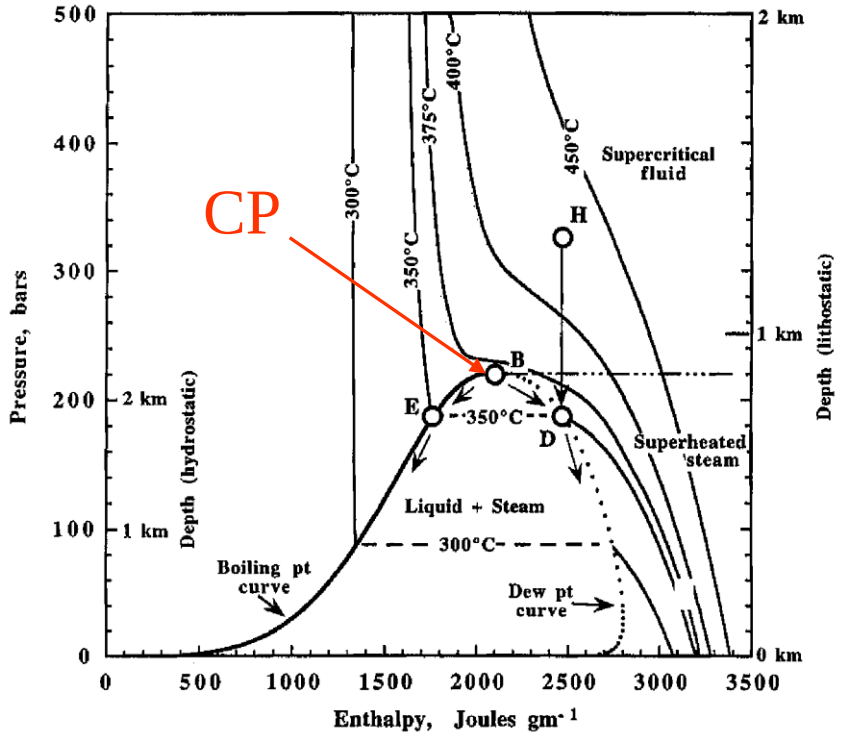
Critical Point (CP)

CP represents the highest temperature and pressure at which the substance can exist as a vapour and liquid in equilibrium.

CP for water:

T_C = 374 °C

P_C = 22,1 MPa



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Temperature and pressure assumptions above CP

- Boiling point curve to CP (3400 – 3500 m)
- Hydrostatic conditions to CP

  below CP
- Temperature will increase by 100 °C/km

  or
- Constant density with depth (Icochor)

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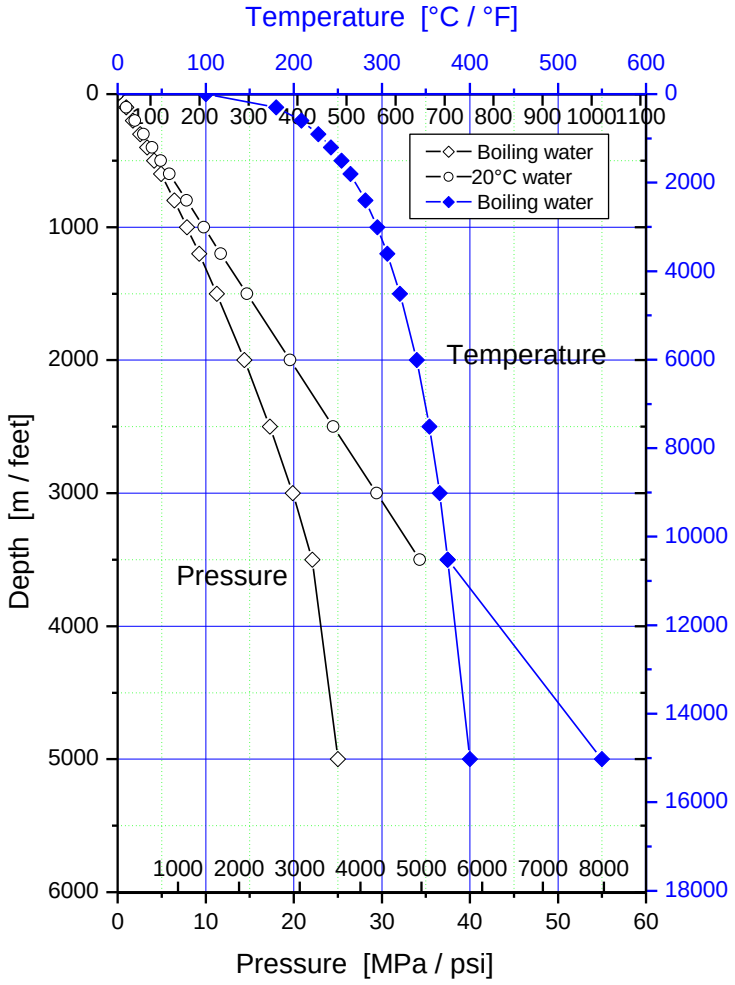
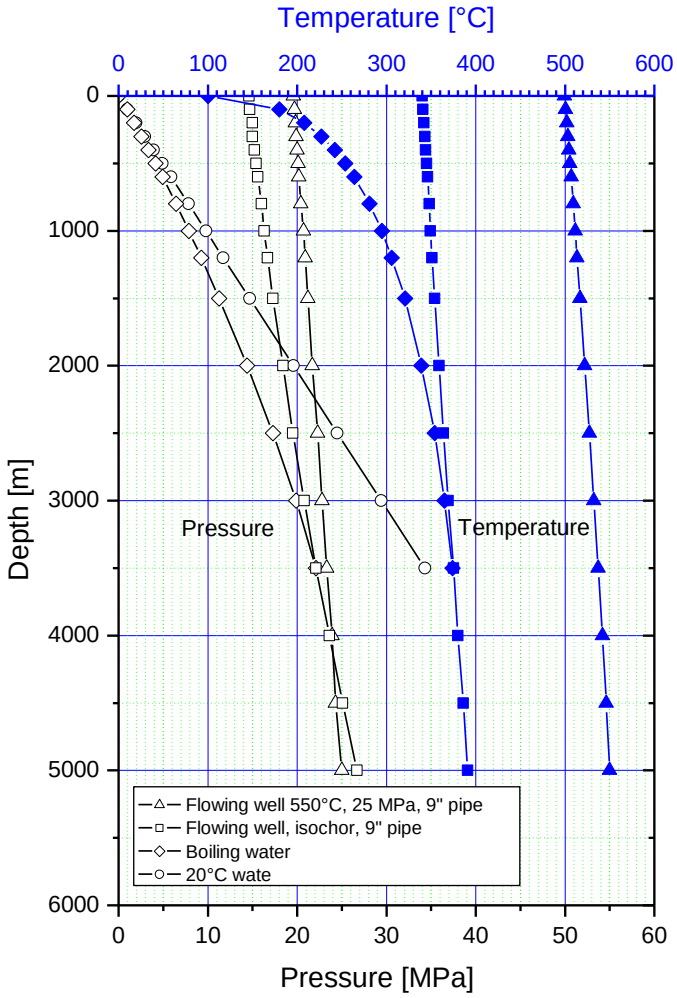
Reservoir temperature and pressure Static and Flowing





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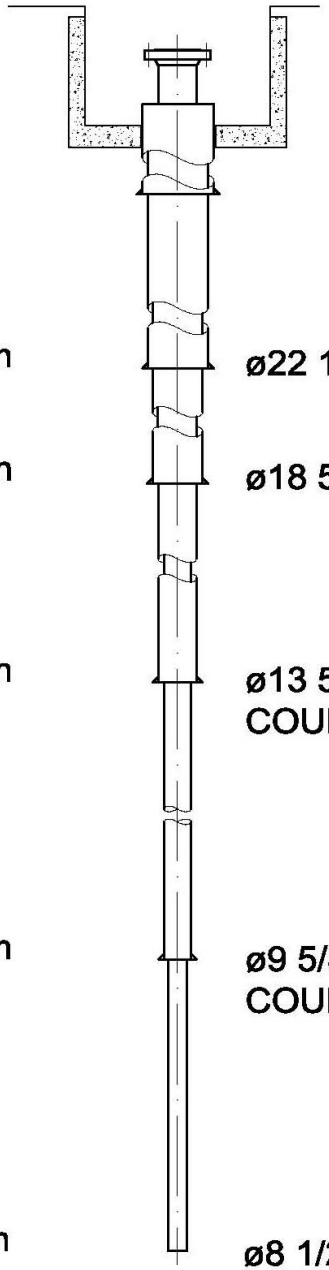
Design conditions

- Basic parameters at wellhead
  - Flowing well:
    - T= 500°C and P= 19,5 MPa (Linear)
    - T= 340°C and P= 14,5 MPa (Isochor)
  - Closed well:
    - T= 400°C and P= 22 MPa
    - T= 20°C and P= 26.7 MPa

Well Design



300 m — ø22 1/2" INTERM. CASING I, X56

800 m — ø18 5/8" INTERM. CASING II, X56

2400 m — ø13 5/8" ANCHOR CASING, T95 and K55
COUPLING HYDRIL 563 m

3500 m — ø9 5/8" PRODUCTION CASING, K55
COUPLING HYDRIL 563

5000 m — ø8 1/2" OPEN HOLE

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Conclusions

Diameter:

- ø13 5/8”, 88,2 lbs/ft for top 300 m of anchor casing
- ø13 3/8”, 72,0 lbs/ft for 300 to 2400 m of anchor casing
- Ø9 5/8”, 53,5 lbs/ft production casing

Casing materials:

- T-95 type 1 and K-55 for anchor casing
- K-55 for production casing

Casing connections:

- Hydril 563 (coupling and thread)

Wellhead flange:

- ø10” ANSI, Class 2500 (material group 1.9, ANSI B16.5)

Wellhead master vale:

- ø10” ANSI, Class 2500 (material group 1.9, ANSI B16.34)

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Stress Calculations

axially σ_z; tangentially σ_t; radially σ_r

$$\sigma_z = \frac{P_m A_p}{A_r}, \qquad \sigma_t = \frac{P_m D_i}{2t}, \qquad \sigma_r = -\frac{P_m}{2},$$

Internal overpressure P_m (MPa)
Internal pipe area A_p, (mm^2)
Cross-sectional area of pipe wall A_r (mm^2)
Internal pipe diameter D_i (mm)
Pipe wall thickness t (mm).

Stress Intensity

Permissible stress levels:

$S_1 = |\sigma_z - \sigma_t|$; $S_2 = |\sigma_t - \sigma_r|$; $S_3 = |\sigma_r - \sigma_z|$

stress intensity S

$S = \max(S_1, S_2, S_3)$

Allowable Stress

$$S_m = \min\left[\frac{2}{3}S_Y, \frac{2}{3}S_Y R_Y, \frac{1}{3}S_T, \frac{1{,}1}{3}S_T R_T\right]$$

SY = minimum yield strength at room temperature

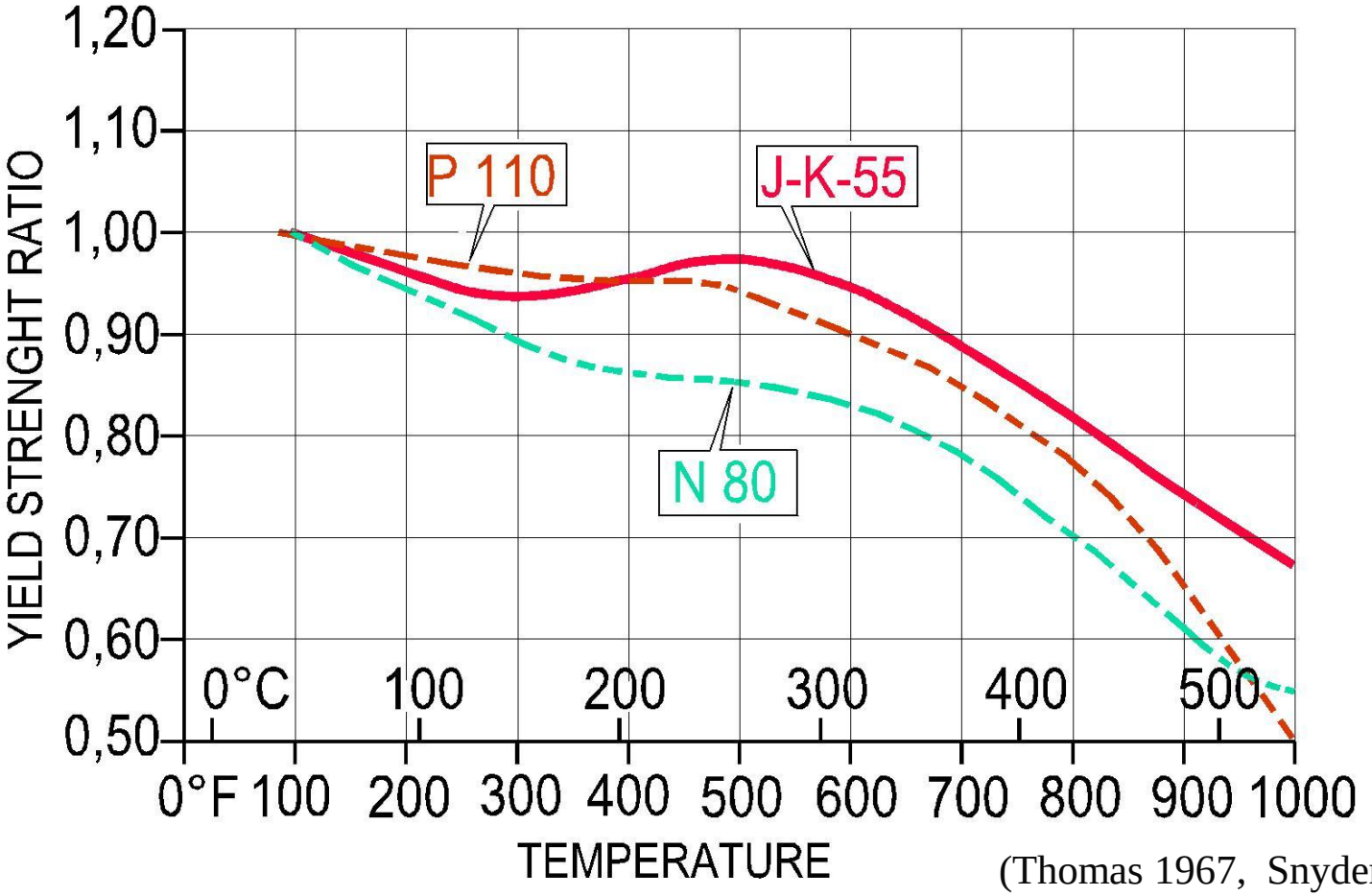
ST = minimum tensile strength at room temperature

RY and RT are the ratios of minimum yield strength and minimum tensile strength at working temperature to room temperature respectively.

Stress Intensity < Allowable Stress

$$S < S_m$$

Casing material at elevated temperature



(Thomas 1967, Snyder 1979)

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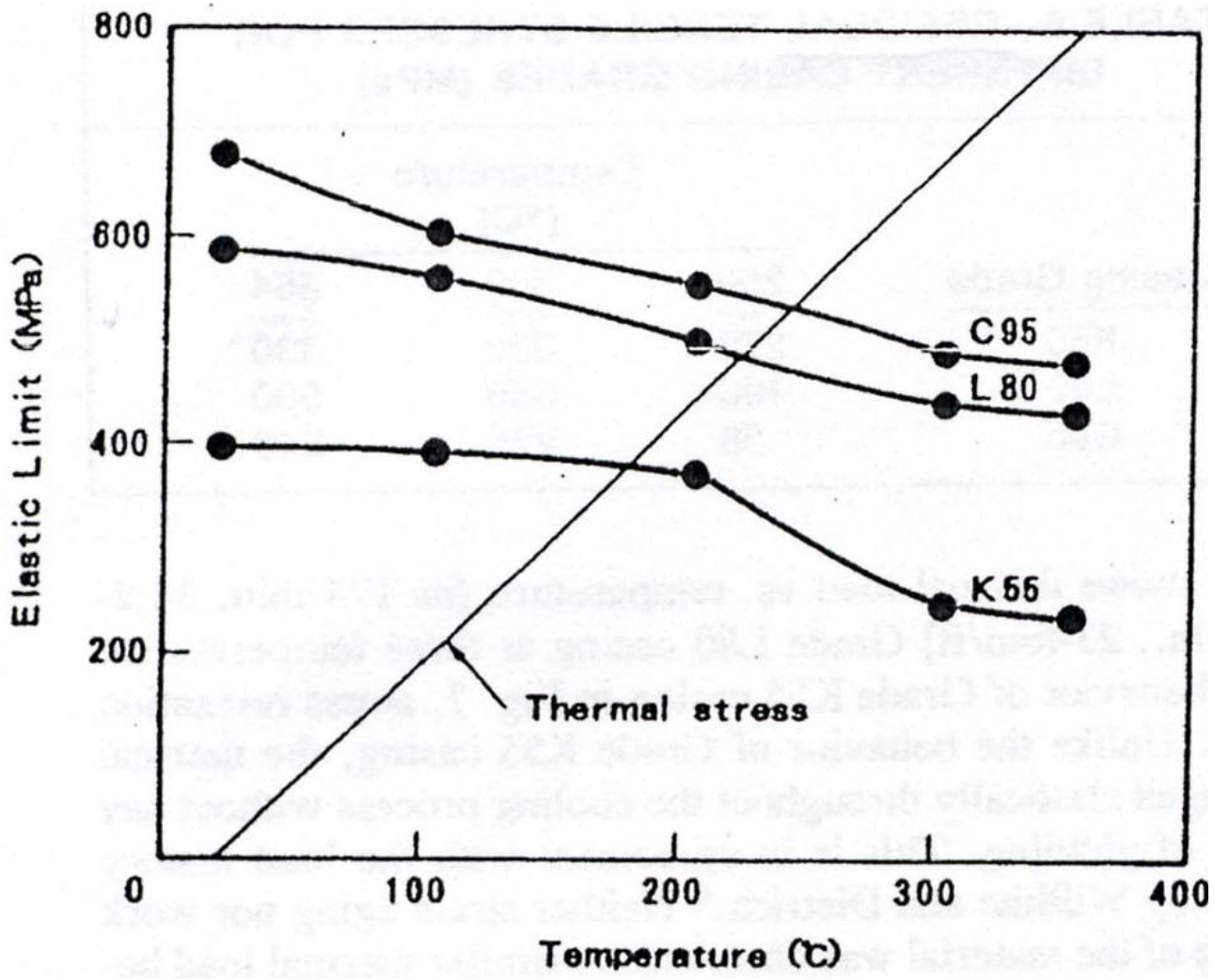
Elastic limit vs. temperature



(Maruyama 1990)

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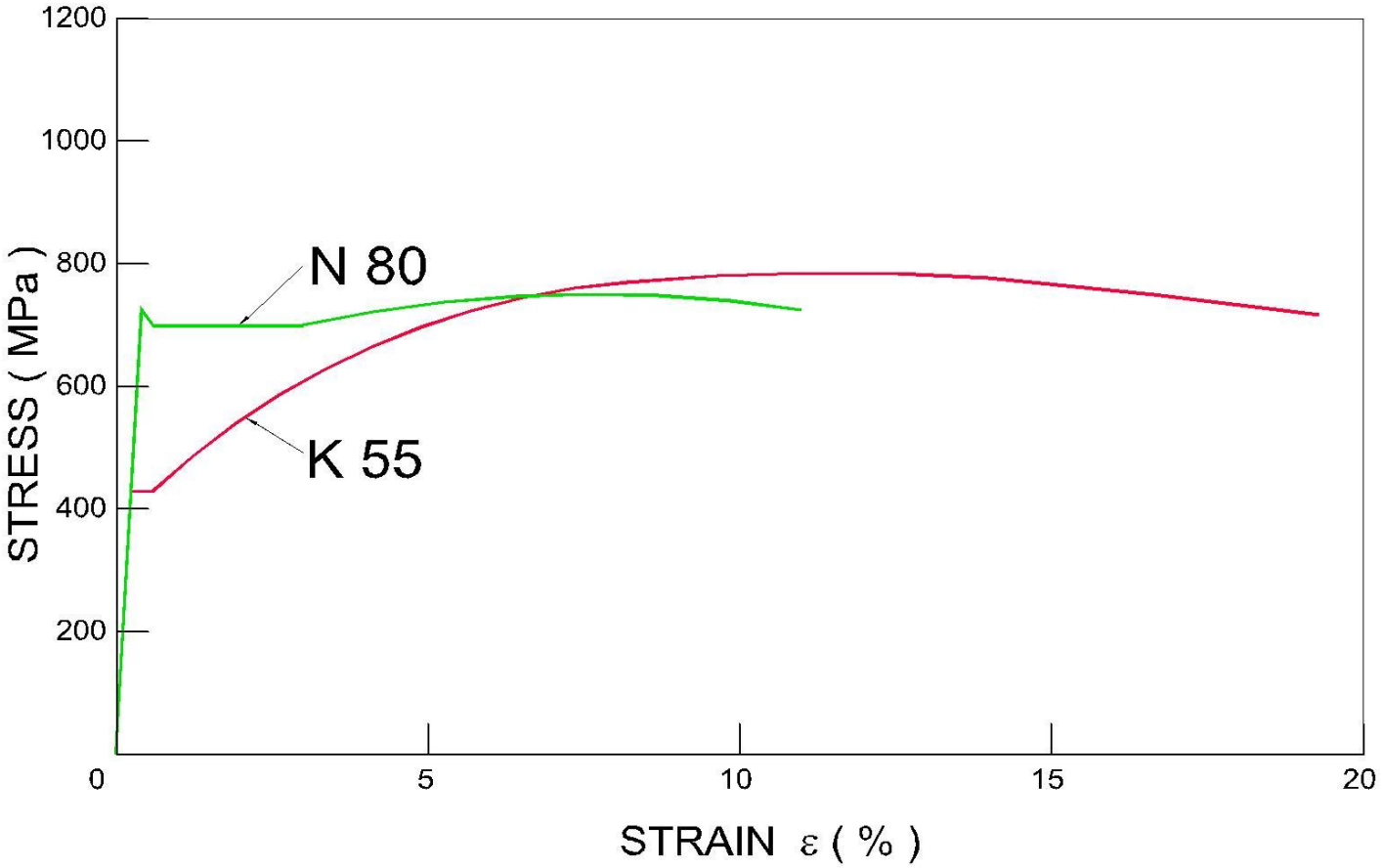
Tensile stress/strain curves



(Maruyama 1990)

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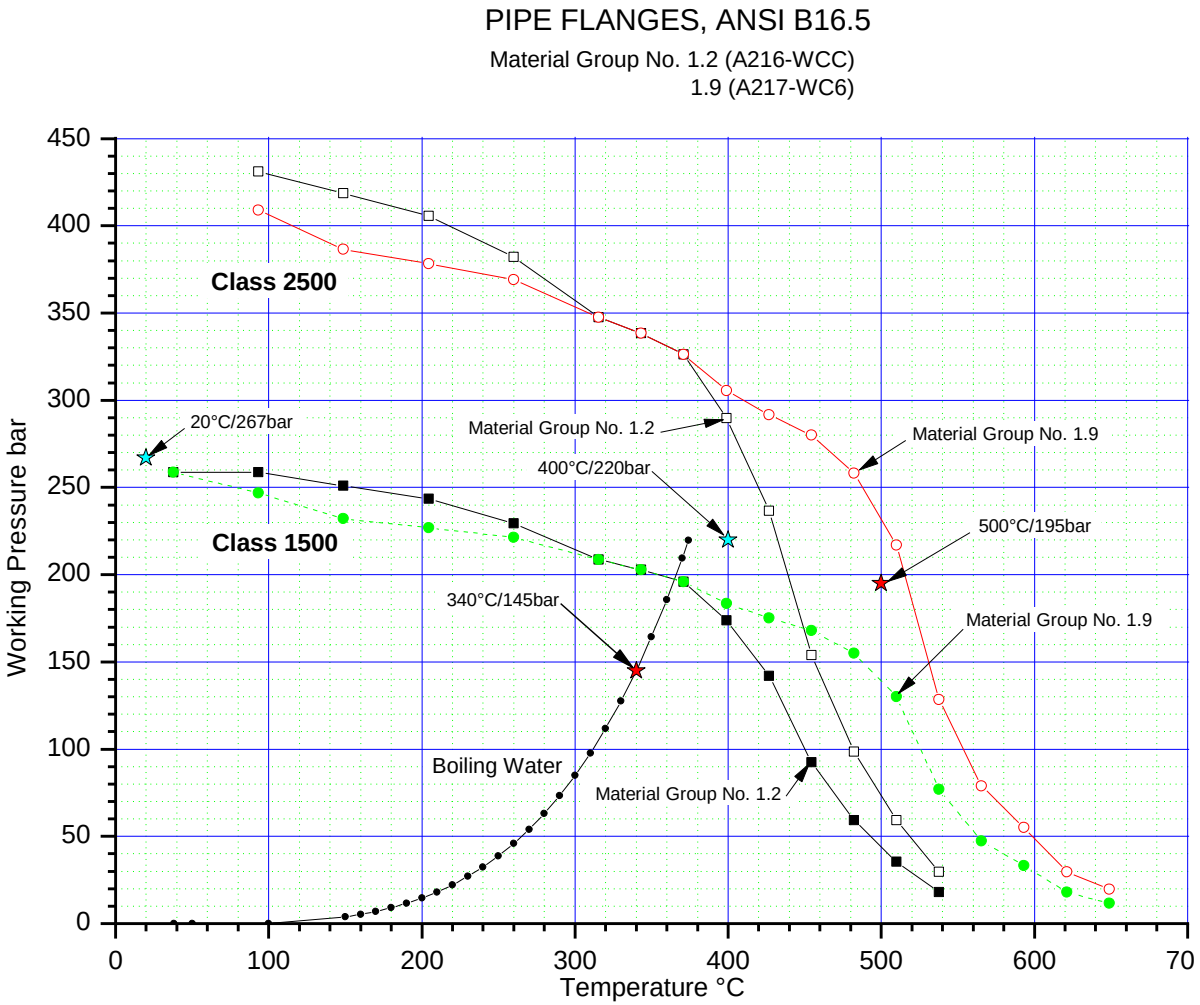
ANSI B16.34
Wellhead master valve selection criteria



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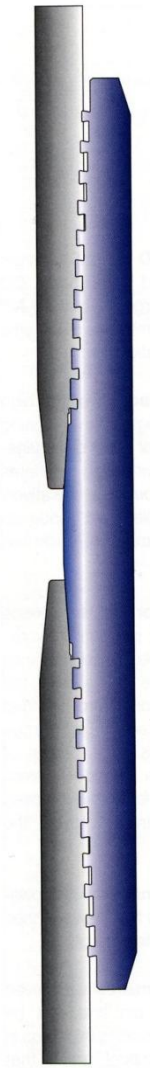
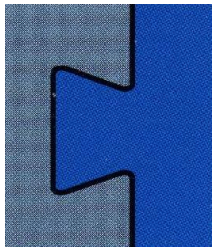
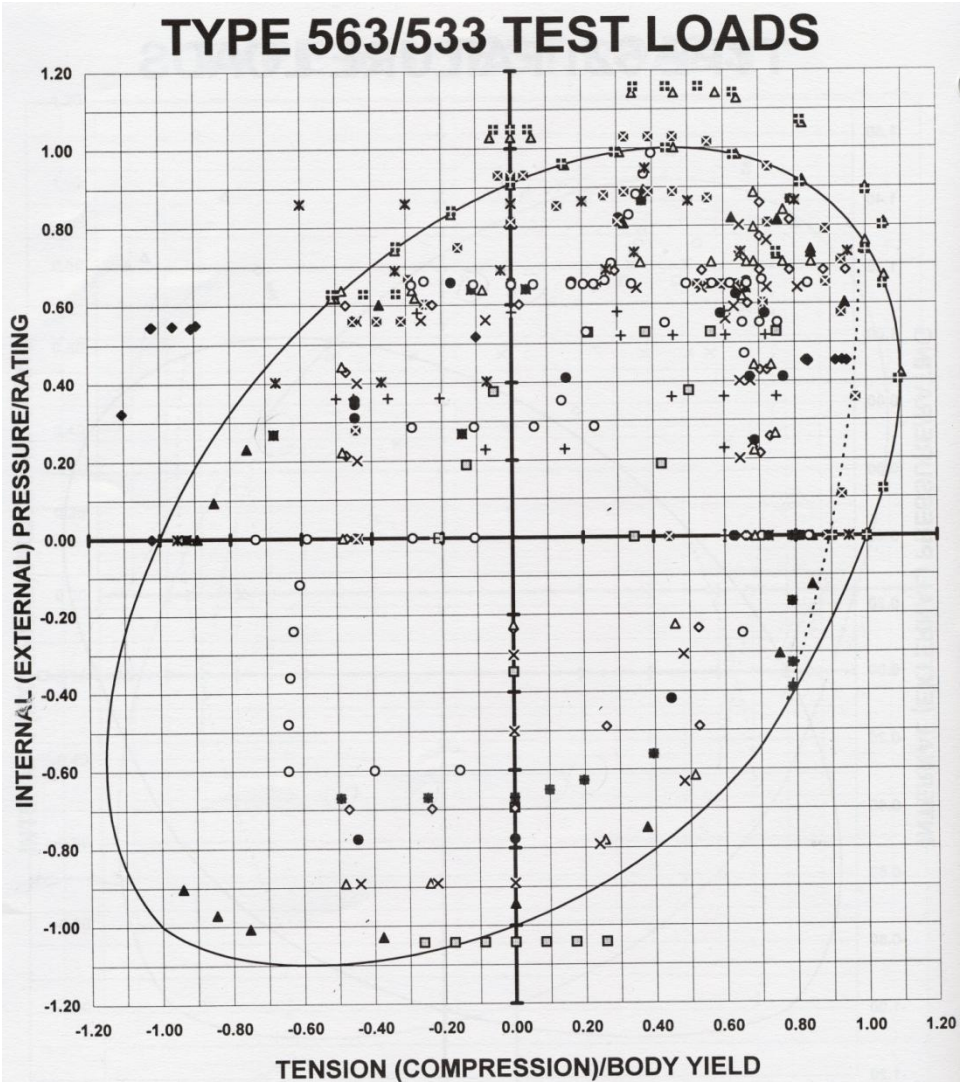
HYDRIL connections, type 563







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Final Points

- Information on casing material at temperature higher than 350 C are scarce
- K55 appears to be the best suitable material
- Creep resistant material is needed for top part of anchor casing API T95
- Premium connection are essential HYDRIL 563
- Stress relaxation for K55 and L80 can be expected for temperature as low as 250 C
- Thermal cycling should be kept to minimum

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