CALCULATION OF HEATER TUBE THICKNESS IN PETROLEUM REFINERIES

API 530

Scope

- API 530 covers design procedures of process fired heater tubes (direct fired, heat absorbing tubes within enclosures)
- Furnace tubes and waste heat exchangers tubes are designed on API 530
- Design of external piping is not covered in this standard

LIMITATIONS

- Apply to thin tubes with thickness to dia ratio less than 0.15
- Apply to seamless tubes. When applied to welded tubes multiply allowable stress with joint efficiency
- No consideration for graphitization, carburization, or hydrogen attack

DESIGN

- Heater tubes are designed in two different design conditions:
  - Elastic Design (lower temperature)
  - Rupture Design (higher temperature)
- Creep rupture occurs in steel at high operating temperature even at stress levels well below the yield strength
- Creep rupture is permanent deformation, a failure mode other than elastic/plastic deformation

DESIGN

- When tube temperature will be high enough for creep to be significant, tube will fail from creep rupture
- For steels operating at lower temperature, the effects of creep will be negligible (elastic)
- Experience indicates that in elastic case tube will last indefinitely unless a corrosion or oxidation mechanism is active

DESIGN

- Elastic design
  - Based on preventing bursting
  - Design in elastic range at lower temperature
  - Allowable stresses based on yield strength

$$t_s = \frac{P_e D_o}{2S_e + P_e} \qquad t_m = t_s + CA$$

where,

$P_e = design\ pressure$

$S_e = allowable\ stress\ in\ elastic\ range$

$D_o = outer\ diameter\ of\ tube$

$t_s = stress\ thickness$

$t_m = minimum\ thickness$

$CA = corrosion\ allowance$

Design

- Rupture design
  - Based on preventing creep rupture
  - Design in creep range at higher temperature
  - Allowable stresses based on rupture strength

$$t_s = \frac{P_r D_o}{2S_r + P_r} \qquad t_m = t_s + fCA$$

where,

$P_r = rupture\ design\ pressure$

$S_r = allowable\ rupture\ strength$

$f = corrosion\ fraction\ function\ of\ B\ and\ n$

$B = CA/ts$

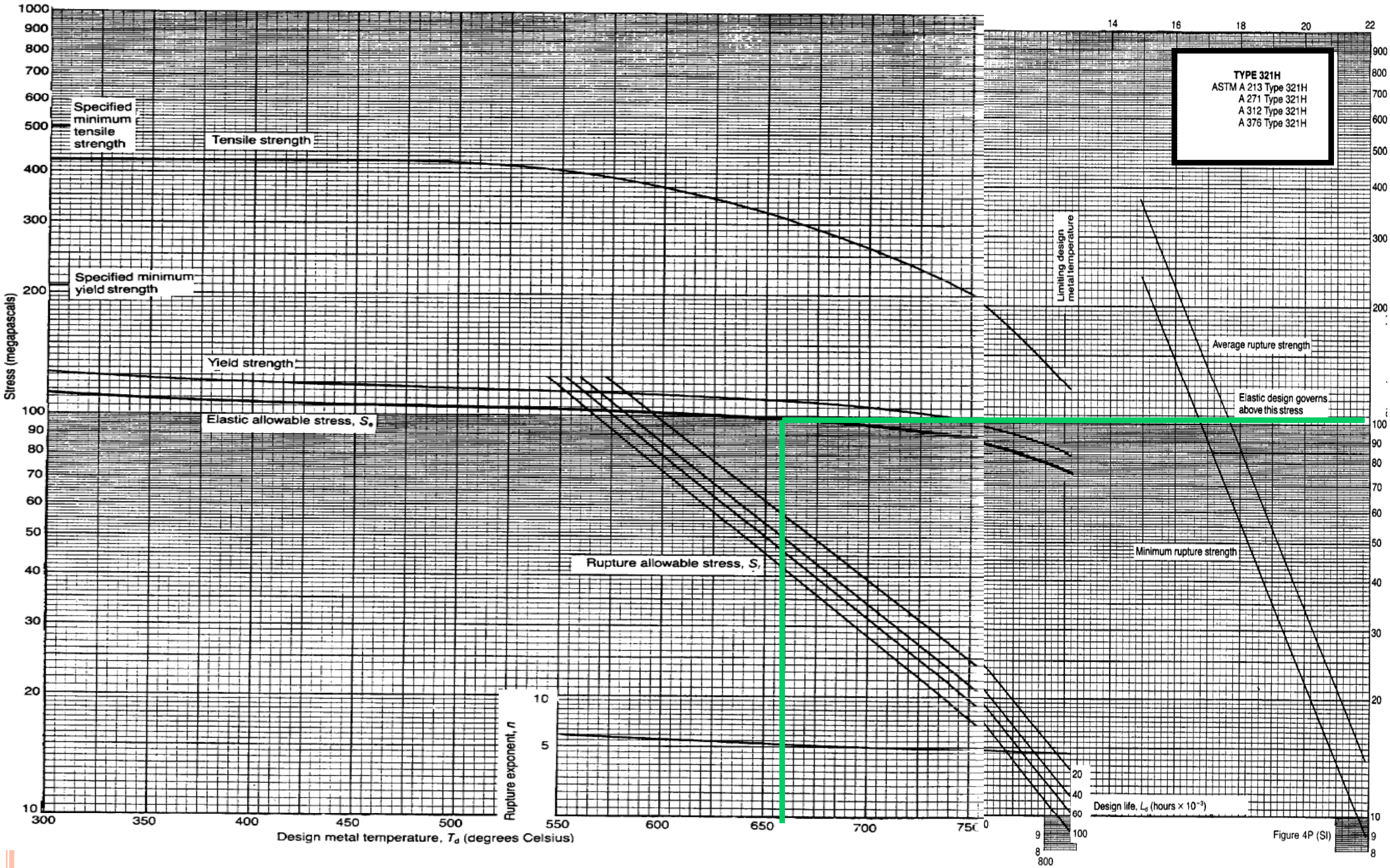
$n = rupture\ exponent\ at\ design\ metal\ temperature$

Design

- Known values will be design pressure, design metal temperature and outside diameter of tubes
- Determination of design criteria (elastic or rupture) will be done with the help of graph given in API 530
- The same graph will provide the value of allowable elastic or rupture strength
- Here, we will go through both of designs

DESIGN

- We take the example of a coil
  - Design pressure = 38 kg/cm^2
  - Design temperature = 660 °C
  - Material of coil – A-312 TP 321 H
- Graph will define the type of design to be followed



TYPE 321H
ASTM A 213 Type 321H
A 271 Type 321H
A 312 Type 321H
A 376 Type 321H
Specified minimum tensile strength
Tensile strength
Specified minimum yield strength
Yield strength
Elastic allowable stress, S_e
Rupture allowable stress, S_r
Rupture exponent, n
Stress (megapascals)
Design metal temperature, T_d (degrees Celsius)
Limiting design metal temperature
Average rupture strength
Elastic design governs above this stress
Minimum rupture strength
Design life, L_d (hours × 10^{-3})
Figure 4P (SI)

DESIGN

- **Rupture design governs as allowable stress is less than elastic marginal stress**
- **More data is required to get the value of allowable rupture strength like design life of tube (to be decided by the designer) and rupture pressure which is less than elastic design pressure**
- **See the graph on the next page for clarity**

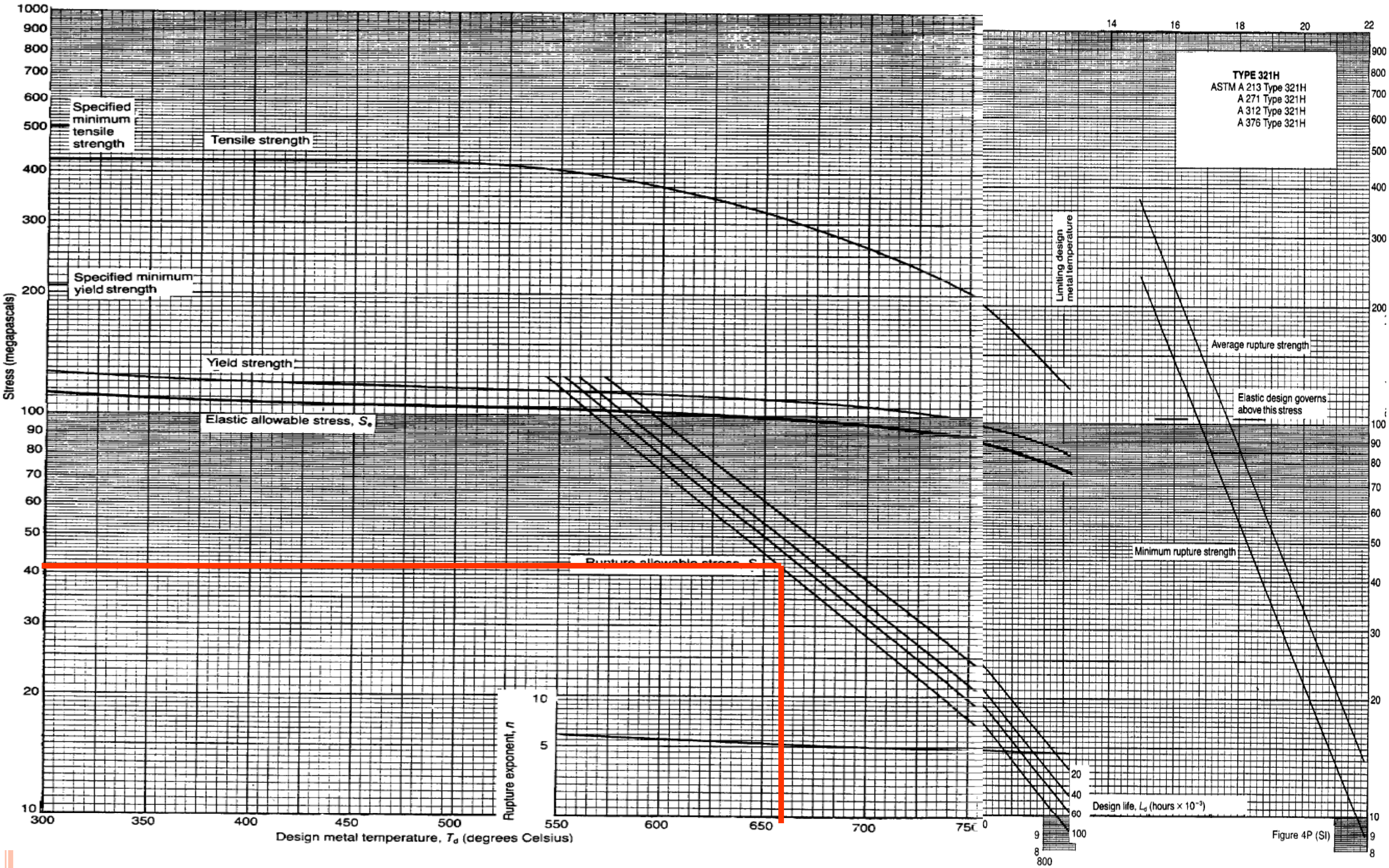

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Figure 4P (SI)

Design

- So allowable rupture strength comes out close to 41 MPa considering design life of 100,000 hrs
- Likewise, we can evaluate the thickness by using the formulas given above if rupture pressure is defined
- Elastic design is simple to practice design procedures

Thank You

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