

NAMES: Solution

A pressure vessel and head is of the type shown in the figure below. The inner radius of the vessel is 30 inches, the thickness of the vessel wall is 1.25 inch and the thickness of the vessel flange is 1.50 inch. The thickness of the vessel head is 1.50 inch. The vessel is made of ASTM A517 grade 55 steel with a yield strength of 45-ksi, and ultimate strength of 82.5-ksi and an ASME design strength of 30-ksi. The bolts are made of B4FB5-class C steel, forged material. The ultimate strength of the bolt material is 125-ksi, the yield strength 85-ksi, endurance limit of 20-ksi, and a proof strength equal to 65% of the ultimate strength. The design will operate at a temperature of 650F, with material properties as given above at operating temperature. The design is to have a bolt circle diameter 67 inches. The pressure in the vessel will vary from 0 psi to 250 psi. The design engineer specified 100, 1"-8 bolts for this design to assure the flange is clamped at all points. The design uses a 12-point nut and bolt whose head diameter is 1.88 times the bolt major diameter. Do you agree with the design engineer's design? Show all calculations and diagrams to justify your decision. The endurance limit has been obtained using actual samples and contains all stress concentration effects.

$$\sigma_p = .65 \sigma_{\text{net}} \\ = (.65 \times 125)$$

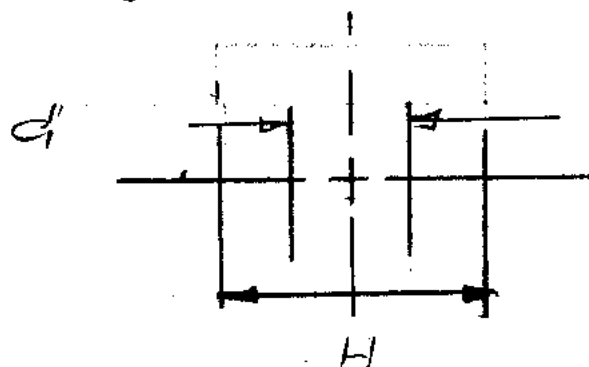
$$\sigma_p = S_p = 81 \text{ Ksi}$$

$$\sigma_{\text{net}} = 125 \text{ Ksi}$$

$$\sigma_{yp} = 85 \text{ Ksi}$$

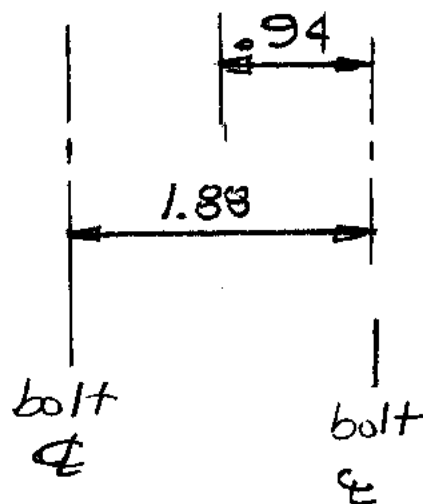
$$K_m = 8 K_b \text{ - same } \text{type} \text{ mat'l} \\ E = 30 \times 10^6 \text{ psi}$$

Bolt spacing, assuming 1"-8 bolts



$$H = 1.88 d$$

For 1" bolt, $H = 1.88$ inch



Space bolts so
just touch.

$$S_{bc} = \frac{D_{bc}}{2} \times 2\pi \\ = 218.49 \text{ in}$$

$$N = \frac{S_{bc}}{1.88}$$

$$N = 172 \text{ bolts}$$

$$\text{use } N = 100 \text{ bolts}$$

WIK 99
Bolt
Pg 2 of 3

$$P_{total} = \left(\frac{\phi_s + \phi_{pc}}{2} \right)^2 \left(\frac{\pi}{4} \right) P$$
$$= \left(\frac{67+60}{2} \right)^2 (.785)(250)$$

$$P_{total} = 791,330 \text{ lb}$$

$$P_{ext} = \frac{P_{total}}{N}$$

$$P_{ext} = 7,920 \text{ lb}$$

$$P_b = \frac{P_{ext}}{9}$$

$$P_b = 880 \text{ lb}$$
$$P_m = 7040 \text{ lb}$$

Because of temperature, use F_u, max

$$F_u, max = F_u = .95 p A_t$$

$$F_u = (.9)(81)(.606) \left(\frac{1b}{in^2} \right) (in^2)(1000)$$

$$F_u = 44,180 \text{ lb}$$

$$F_{b, min} = P_{b, min} + F_u$$
$$= 0 + 44,180 \text{ lb}$$

$$F_{b, min} = 44,180 \text{ lb} > 0$$

WIN 99
Bolt
Pg 3 of 3

$$\sigma_u = \sigma_{min} = \frac{44,180}{.606}$$

$$\sigma_u = 72.9 \text{ ksi}$$

$$\sigma_u < \sigma_p$$

$$F_m, max = 7040 - 44,180$$

$$F_m < 0$$

~ criteria satisfied

$$\begin{aligned}\sigma_{b, max} &= \sigma_{max} = \frac{F_{b, max}}{A_t} \\ &= \frac{(880) + 44,180}{.606}\end{aligned}$$

$$\sigma_{b, max} = 74.4 \text{ ksi} < \sigma_p$$

Fatigue

$$N_s = \frac{S_e (\sigma_{uet} - \sigma_u)}{S_e (\sigma_m - \sigma_u) + \sigma_{uet} \sigma_a}$$

$$\sigma_m = \frac{P_m + F_u}{A_t} \quad P_m = 440 \text{ lb}$$

$$\sigma_m = 73.6 \text{ ksi}$$

$$\sigma_a = \frac{P_a}{A_t} \quad P_a = 440 \text{ lb}$$

$$\sigma_a = 0.7 \text{ ksi}$$

$$N_s = \frac{(20)(125 - 72.9)}{20(73.6 - 72.9) + (125)(.7)}$$

$$N_s = 10.3 \quad - \text{Fatigue}$$

$$N_{yield} = \frac{\sigma_{yp}}{F_{max}} = \frac{85}{74.4} = 1.14 = N_{yield}$$