Subject: E-Chamber Top Plate and Flange Strength Analysis.

1. Summaries:
   a. The tightening torque (from MDC) for the 5/16-18 bolt is about 12 to 15 ft-lb. In this calculation 12 ft-lb (144 in-lb) was used in the model. This torque will induce 2304 lb tension in each bolt. The total clamping force for the whole flange is 27648 lb. In the model this force is simulated by thermal shrink in the bolt element. The contact surface between top plate and flange is modeled by contact element to simulate a compression only condition. The E-chamber assembly is shown in Fig. 1. The finite element model is shown in Fig. 2 and 3.

   b. The O-ring repelling force from the .01 inches compression is about 320 lb. In the model this force is simulated as pressure applied in the O-ring groove. The clamping force to resist 10 bar (150 psi) internal pressure is about 2385 lb.

   c. The ratio of total bolt tension to needed clamping force is about 10.

   d. The initial bolt tensional stress without internal pressure is $\sigma = 45,283$ psi (Fig. 4, 6). When internal pressure applied the tensional stress increased to 46,191 psi (Fig. 5, 7). The change in the bolt load is about 2%.

   e. The maximum contact pressure by the bolt tension is 7600 psi (Fig. 8). When the 10 bar internal pressure applied this pressure will be redistributed and the maximum pressure is 11000 psi (Fig. 9). The gap between the contact surfaces will be opened up about .00043 inches (Fig. 10, 11) in the inner edge of the contact surface. This is a small change compare to the .01 inches compression of the O-ring seal.

   f. When bolted without internal pressure, the maximum stress in the top plate is around the bolted area, $\sigma = 26,536$ psi (Fig. 12, 13). When pressure applied this stress reduced to 25,764 psi (Fig. 14, 15). This stress is a localized stress due to high local bolting force and the nature of finite element modeling. In the real world this stress will be reduced by washers and rounded corners. The stress in the center and edge of the feedthrough holes is about 13,206 psi (Fig. 14, 15).

2. Model:
   A three dimensional, quarter size, ANSYS model (Fig. 1, 2, 3) was built to simulate this structure. The flange contact interface was modeled by contact element to check if gap opening occurred when internal pressure applied. The bolt tension is simulated by thermal shrinkage applied in the bolt. The compression of O-ring was simulated by pressure in the O-ring groove.
3. Materials:
   a. Top plate:
      Size: 7.0” O.D, .375” thick.
      Material: 304 SST
      \[ E = 30 \times 10^6 \text{ psi} \]
      \[ \nu = .3 \]

   b. Chamber flange:
      Size: 4.5” ID, 7.0” OD, .5” thick,
      Material: 304L SST
      \[ E = 30 \times 10^6 \text{ psi} \]
      \[ \nu = .3 \]

   c. O-ring: No. 2-048
      Size: 4-7/8” (OD) x 4-1/4” (ID) x .07” (W)
      Material: Viton
      \[ E = 2000 \text{ psi} \]
      \[ \nu = .499 \]

   d. 5/16-18 Bolt:
      Size: Nominal dia. 5/16”
      Cross section area: .0524 in².
      Strength of Bolt:
      Grade 5: 85,000 psi (min).

3. Strength of SST 304:
   ASME Allowable stress: 15,700 psi
   Yield stress: 25,000 psi
   Ultimate stress: 70,000

4. Loading condition:
   a. Initial condition: Bolted without internal pressure
      Bolt tension: 27648 lb total from 12 bolts.
      O-ring compression load: 320 lb.

   b. Operation condition: Bolted with 10 bar (150 psi) internal pressure.
Fig. 1 E-Chamer Assembly
Fig. 2 Top Plate and Flange Model

Contact Element Between Top Plate and Flange

5/16-18 Bolts, Torque: 12-15 Ft-lb

Fig. 3 Top Plate and Flange Model

O-ring compression force is modeled by Pressure. P=429 psi
Fig. 4 Von Mises Stresses in the Assembly, Bolt Preload only

Fig. 5 Von Mises Stresses in the Assembly, with 150 psi Pressure
Fig. 6 Vertical Stresses in the Assembly, Bolt Preload only

Fig. 7 Vertical Stresses in the Assembly, with 150 psi Pressure
Fig. 8 Contact surface pressure, without Pressure

Max. P=7600 psi

Fig. 9 Contact surface pressure, with 150 psi Pressure

Max. P=11000 psi
Fig. 10 Contact surface Gap, without Pressure

Max. = .000065"
Relative Gap

Fig. 11 Contact surface Gap, with 150 psi Pressure

Max. = .0005"
Relative Gap
Δg = .000435
Fig. 12 Von Mises Stress in the Top Plate, Without Pressure

![Top View](image)

Max $\sigma = 26,536$ psi

In the bolted area, localized stress.

Fig. 13 Von Mises Stress in the Top Plate, Without Pressure

![Bottom View](image)

Max $\sigma = 26,536$ psi

In the bolted area, localized stress.
Fig. 14 Von Mises Stress in the Top Plate, With 150 psi Pressure

Top View

Max
\( \sigma = 25,764 \text{ psi} \)

In the bolted area, localized stress.

\( \sigma = 13206 \text{ psi} \)

\( \sigma = 10258 \text{ psi} \)

Fig. 15 Von Mises Stress in the Top Plate, With 150 psi Pressure

Bottom View

Max
\( \sigma = 25,764 \text{ psi} \)

In the bolted area, localized stress.

\( \sigma = 10285 \text{ psi} \)

\( \sigma = 10663 \text{ psi} \)