ABS Plastic Coupling Cracking

Dirk Duffner
Duffner Engineering
dduffner@duffnerengineering.com

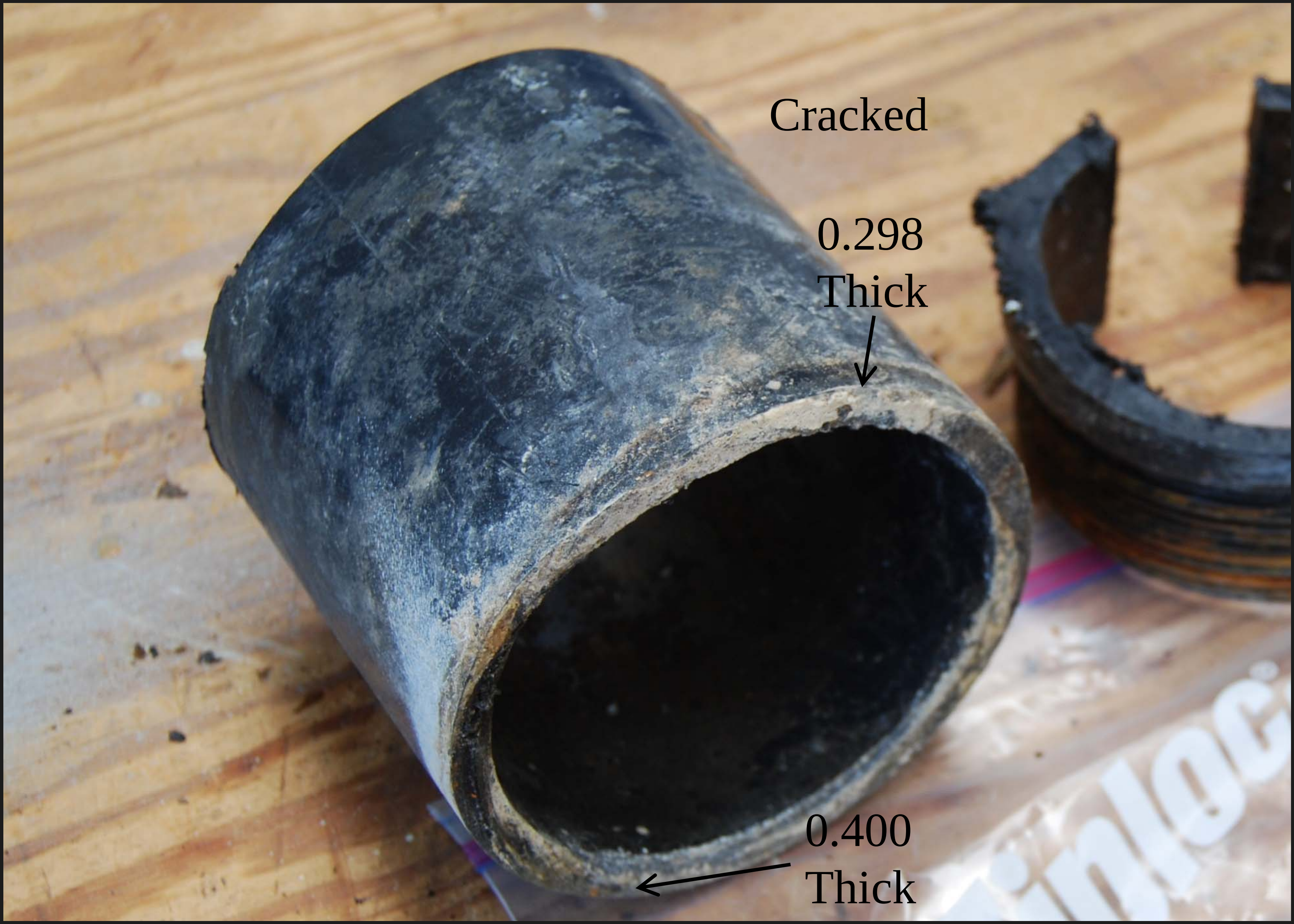
Summary

- Acrylonitrile Butadiene Styrene (ABS) plastic couplings installed as part of a water closet carrier system were found to be leaking in many of the rooms of a local hotel. The installer was blamed for his alleged use of certain thread sealing compounds that were incompatible with ABS. Our examination found that the leaks resulted from cracks through the coupling walls that exhibited features common to creep rupture or environmental stress cracking (ESC).
- We conducted a lifetime prediction analysis including mechanical testing, residual stress measurements, strength and strain to failure measurements, and finite element analysis, and determined that the failures could not have occurred as a result of the incompatible material alone.
- Manufacturing and design defects existed in the ABS couplings that made them particularly sensitive to installation tolerances as well as relatively low applied stresses.

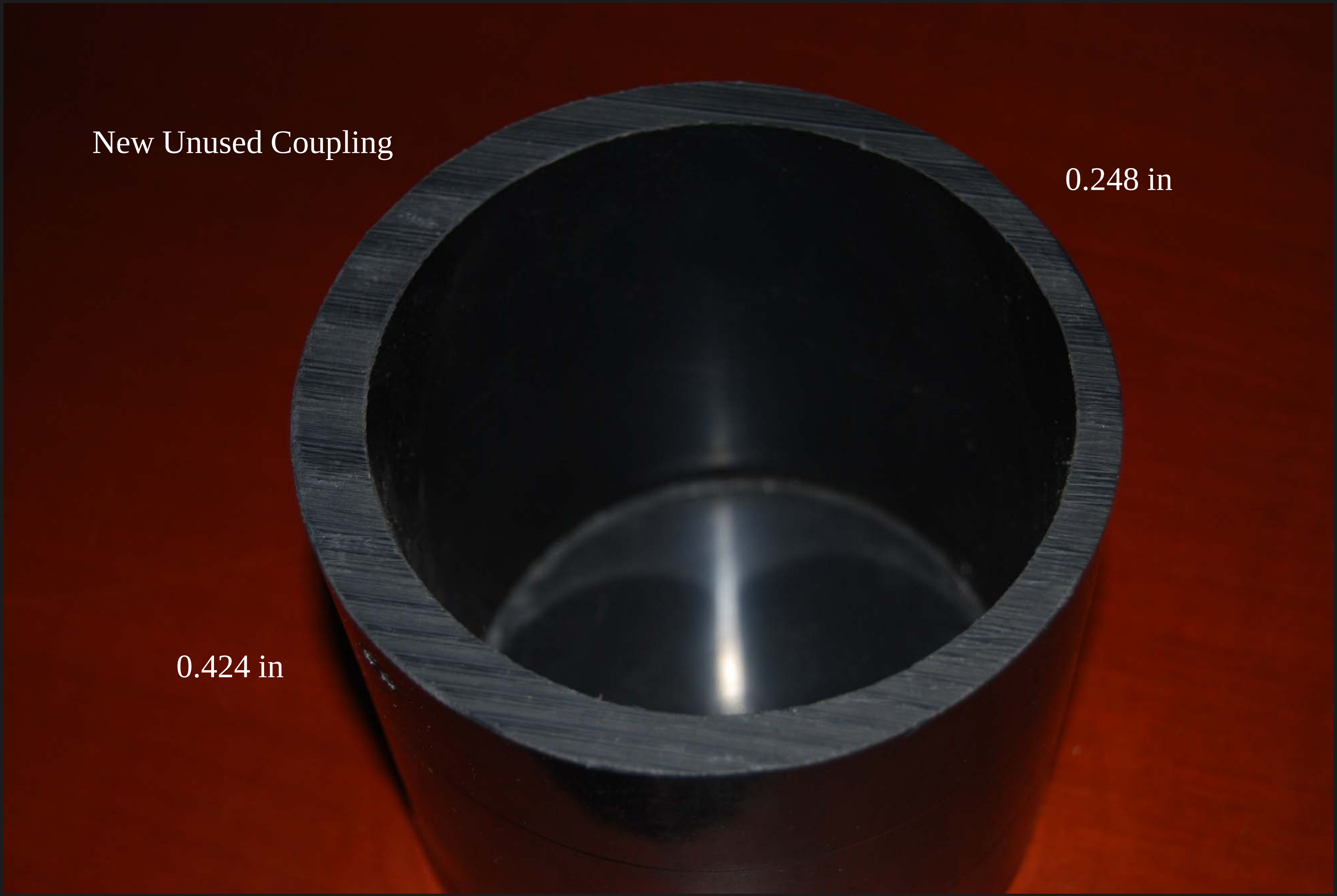
Lifetime Prediction Analysis

- Environmental Stress Cracking
- Environments Selected for Analysis
  - Air
  - Thread Sealing Compound (diacetone alcohol)
- Stress
  - Residual
    - Manufacturing
  - Applied
    - Concentricity
      - Contact force at tip of coupling during installation

Subject ABS Plastic Coupling



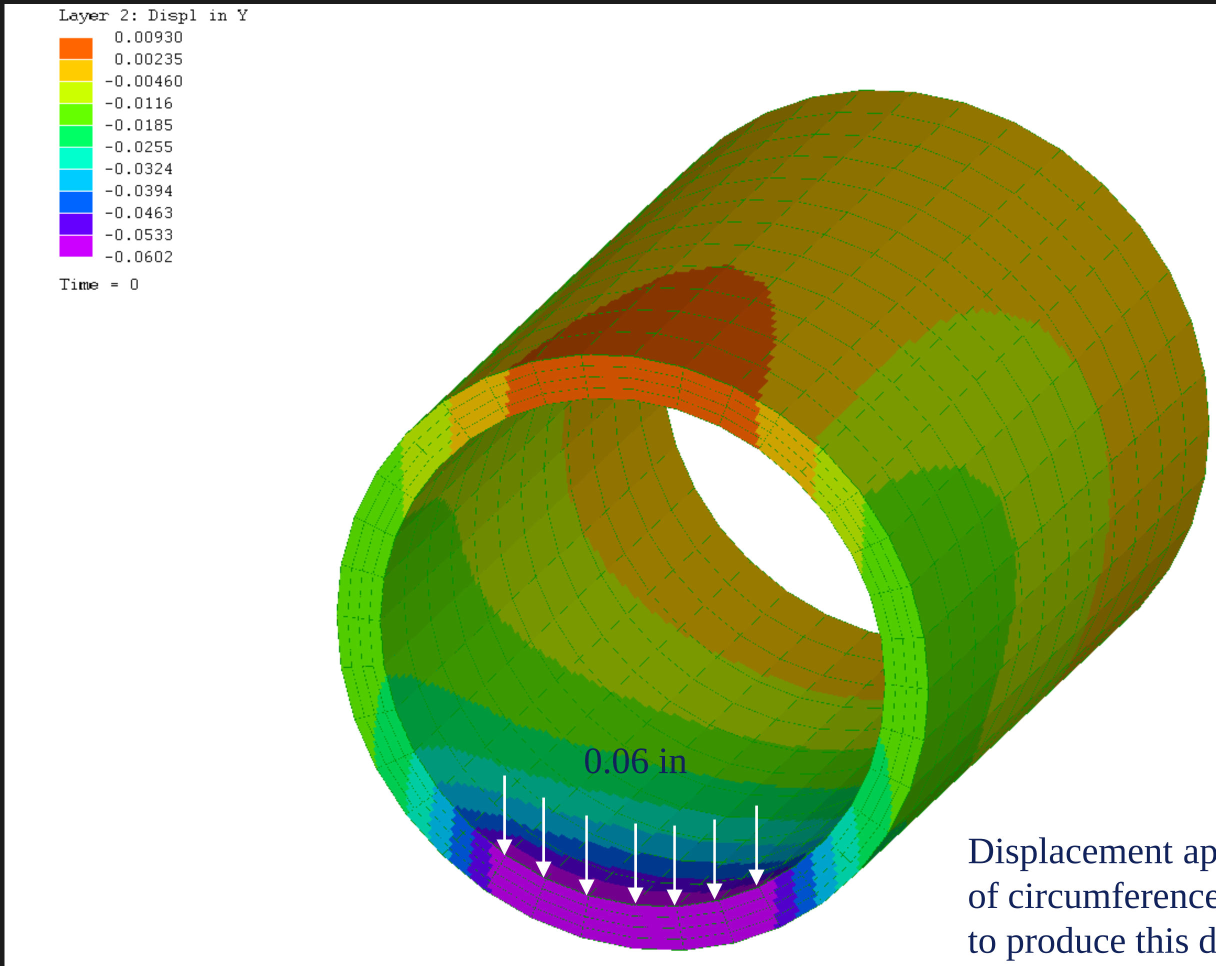
OD and ID Not Concentric



Coupling Data for Finite Element Model

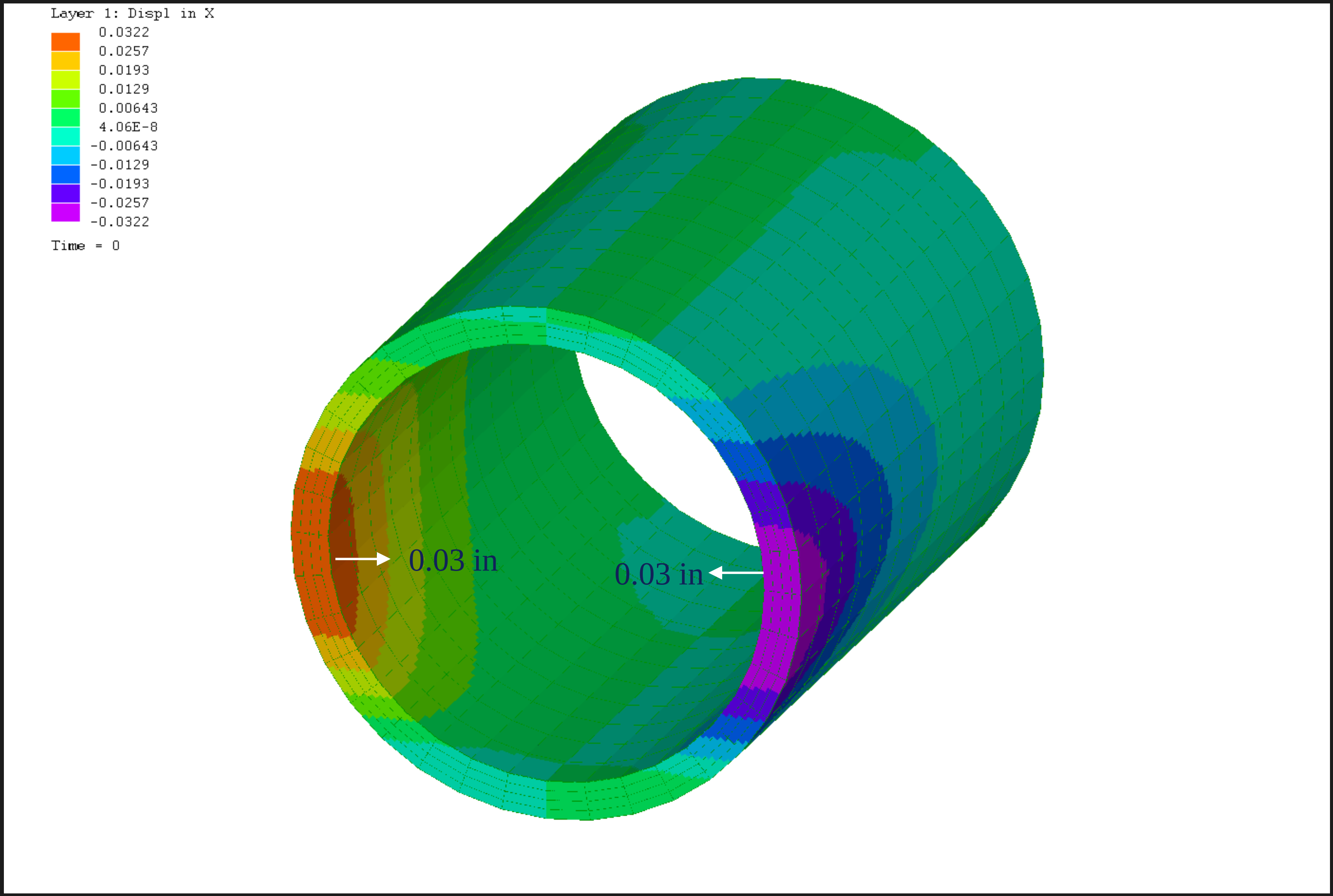
- OD = 4.607 in
- ID = 3.933 in
- T = 0.340 in
- L = 6 in from tip to end of threads
- ID not concentric with OD
  - Thinnest section = 0.298 in
  - Thickest section = 0.400 in
  - Offset from average = 0.06 in
    - Causes contact force at tip of coupling
- E = 289,000 psi

Downward Interference Load

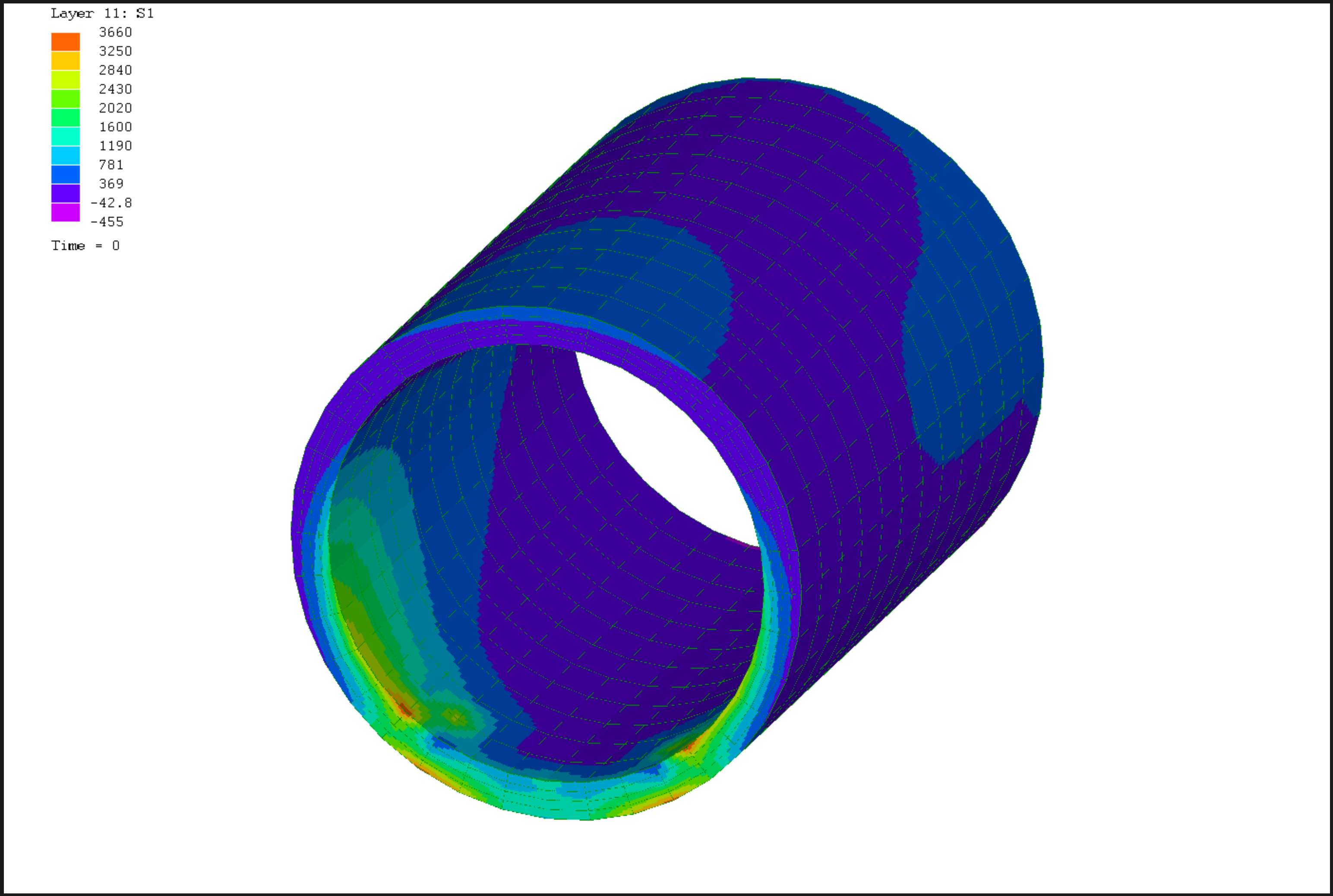


Displacement applied over 2.4 in of circumference; necessary load to produce this displacement at bottom is 280 lb (117 lb/in)

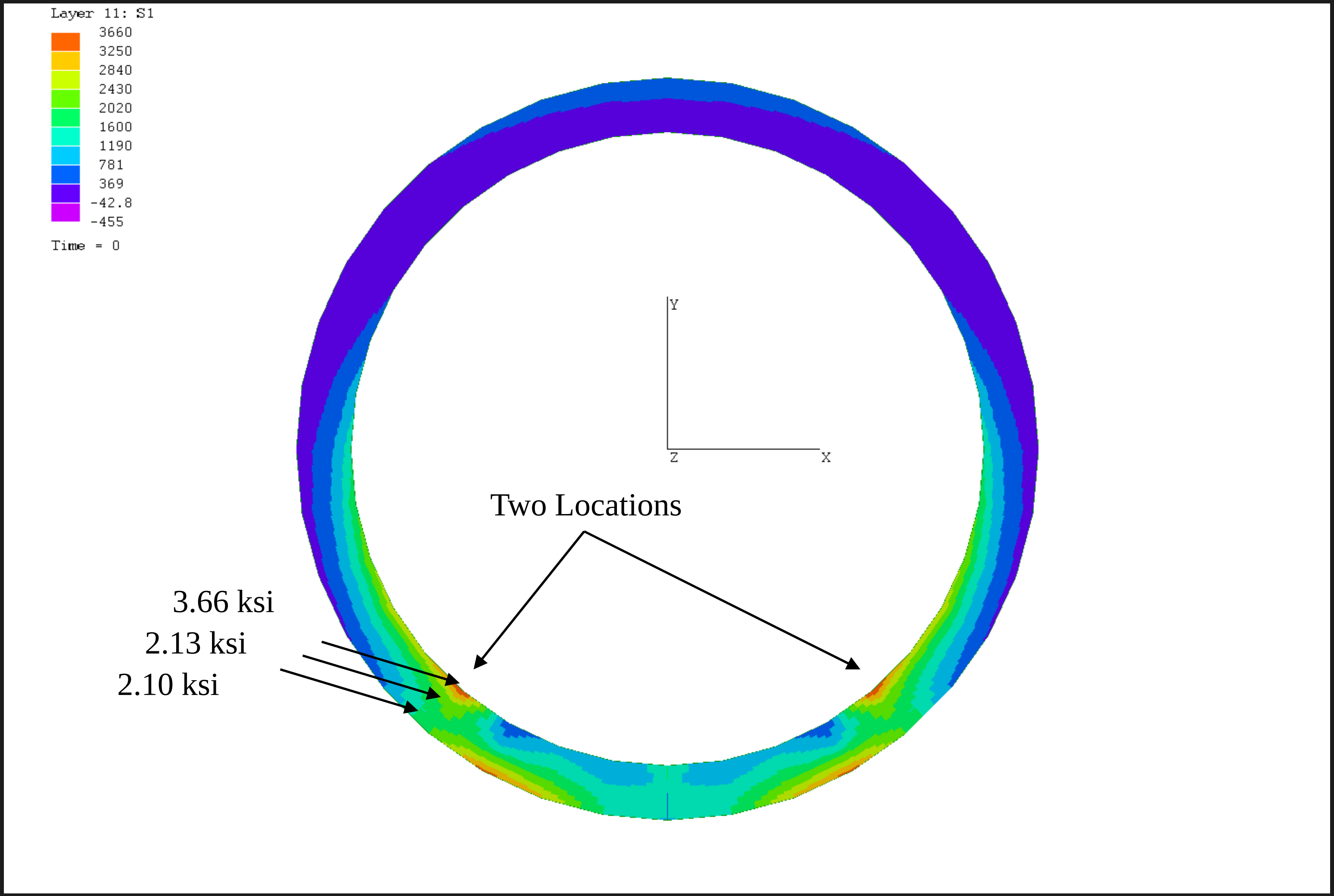
Resulting Lateral Displacement



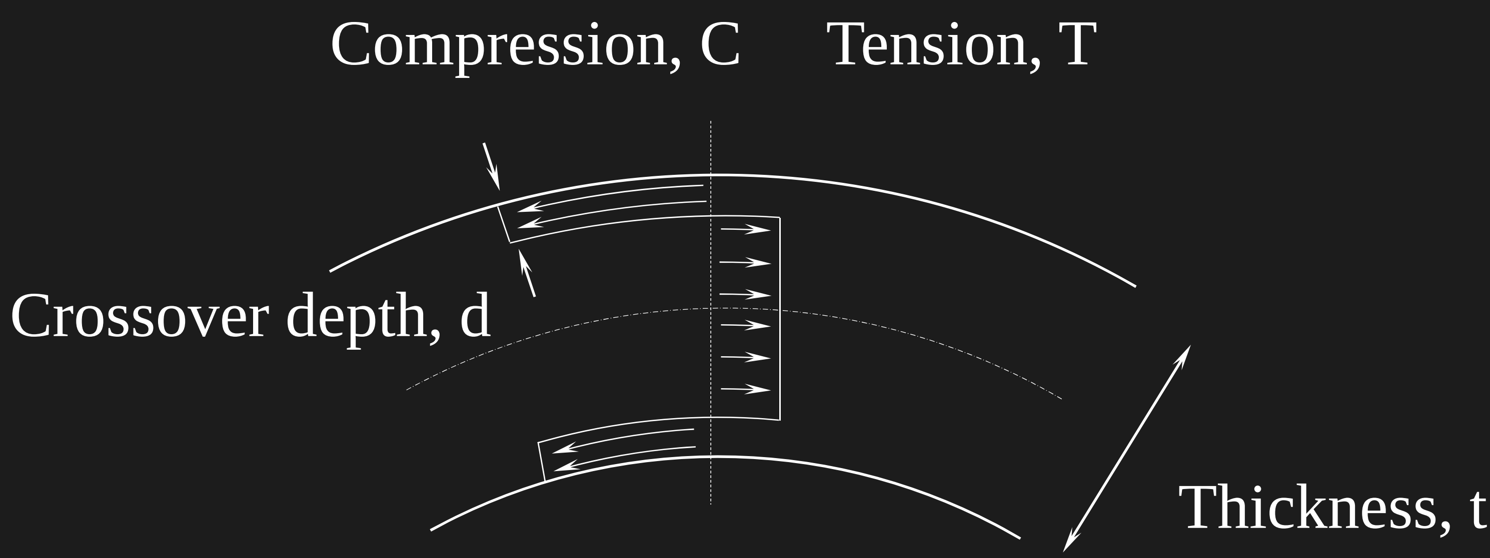
Resulting Max Stress = 3.66 ksi



Resulting Applied Stress Distribution



Residual Stress Distribution



Force Balance Through Cross Section

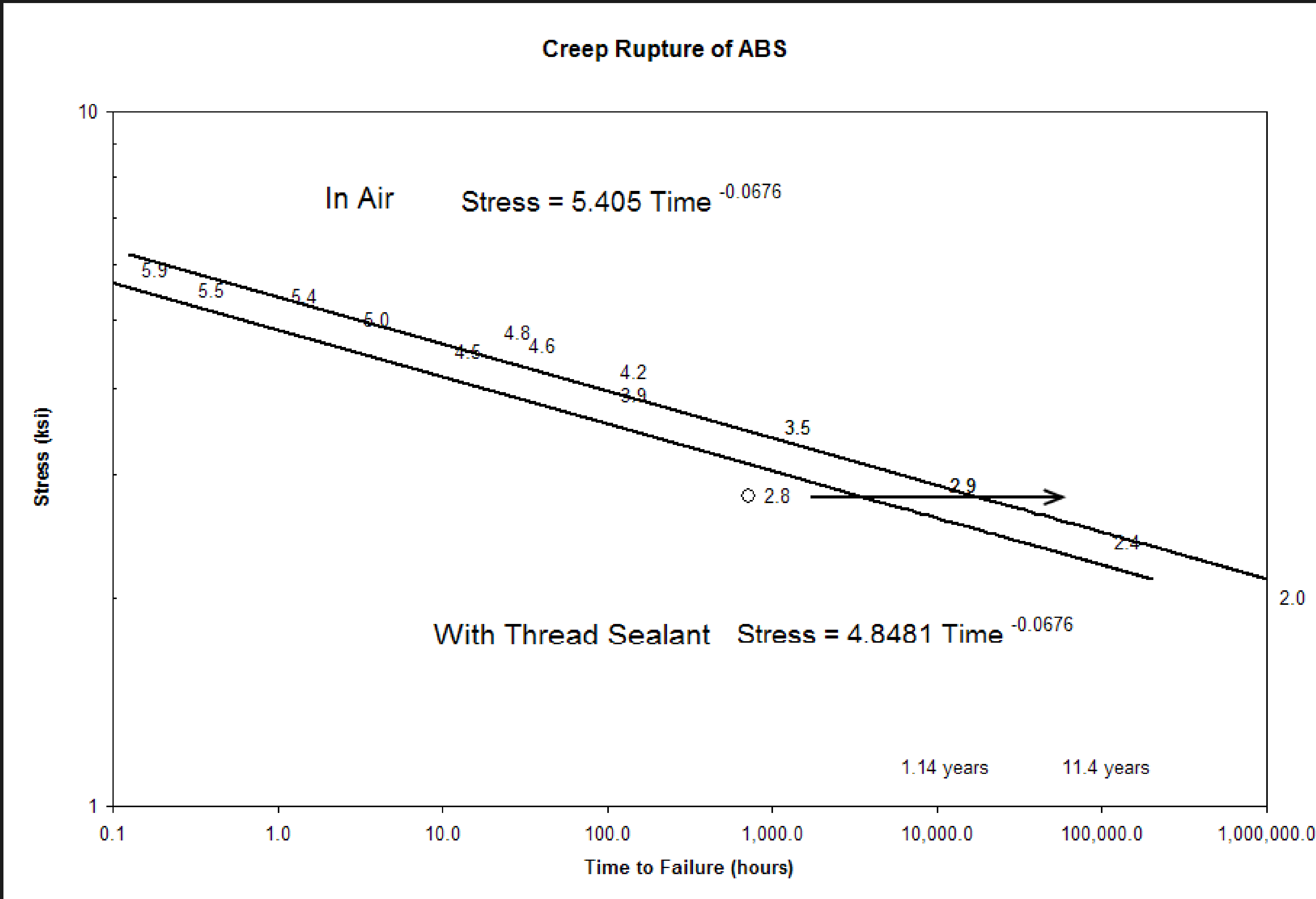
$$C\,d = T\,(t/2 - d)$$

$$T = (C\,d) / (t/2 - d)$$

Average Residual Stress

- Average measured compressive stress to crossover depth
  - Cracked Specimens -5.6 ksi
  - Uncracked Specimens -3.3 ksi
- Crossover depth 0.01 to 0.02 in
- Average d = 0.014 in
- Average t = .338 in
- Average Tensile Residual Stress
  - Cracked Specimens 0.51 ksi
  - Uncracked Specimens 0.30 ksi

Material Strength Curves



Life Prediction

- In Air
  - Cracked 2.13+0.51=2.64 ksi – 4.6 yr
  - Uncracked 2.13+0.30=2.43 ksi – 15.6 yr
- In Thread Sealing Compound
  - Cracked 2.13+0.51=2.64 ksi – 0.9 yr
  - Uncracked 2.13+0.30=2.43 ksi – 3.1 yr

Results

- Effect of Environment
  - Shortens life from avg of 10.1 yr to 2.0 yr
- Effect of Residual Stress
  - Shortens life from avg of 9.4 yr to 2.8 yr
- Effect of Applied Stress
  - Shortens life from >100 yr to average of 6.1 yr depending on residual stress and environment
  - Proper design stress of 1.24 ksi achieved if Y displacement reduced from 0.060 in down to 0.035 in