

Titanium Tubing

Titanium Mechanical Advantage

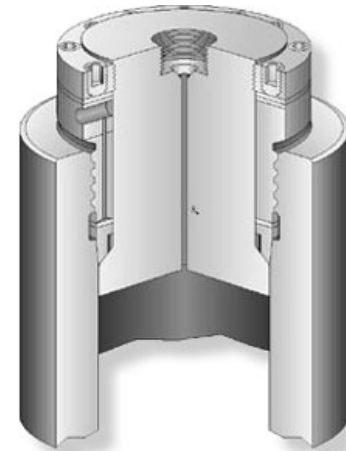
Proven production in 9-5/8" size for geothermal industry



Titanium Mechanical Advantage

Superior corrosion resistance

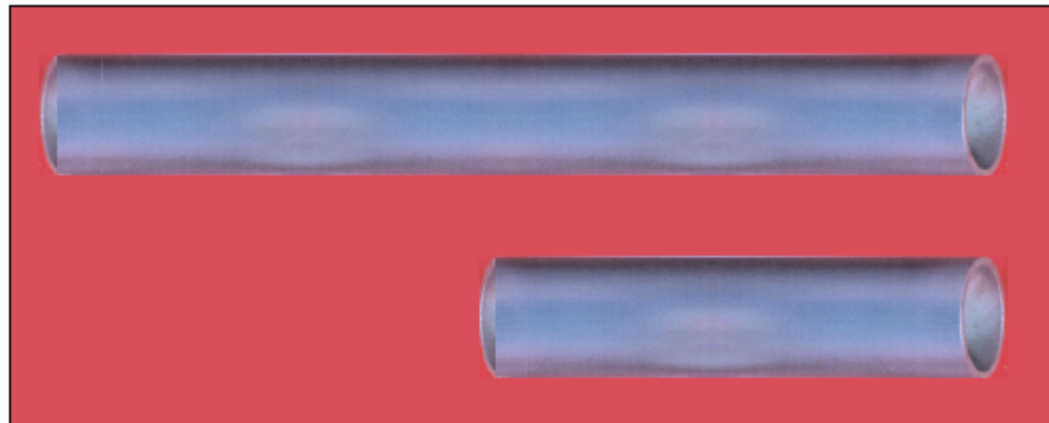
Current metallurgical testing for Chrome and Nickel alloys use titanium autoclaves and tubing for the apparatus.



Titanium Mechanical Advantage



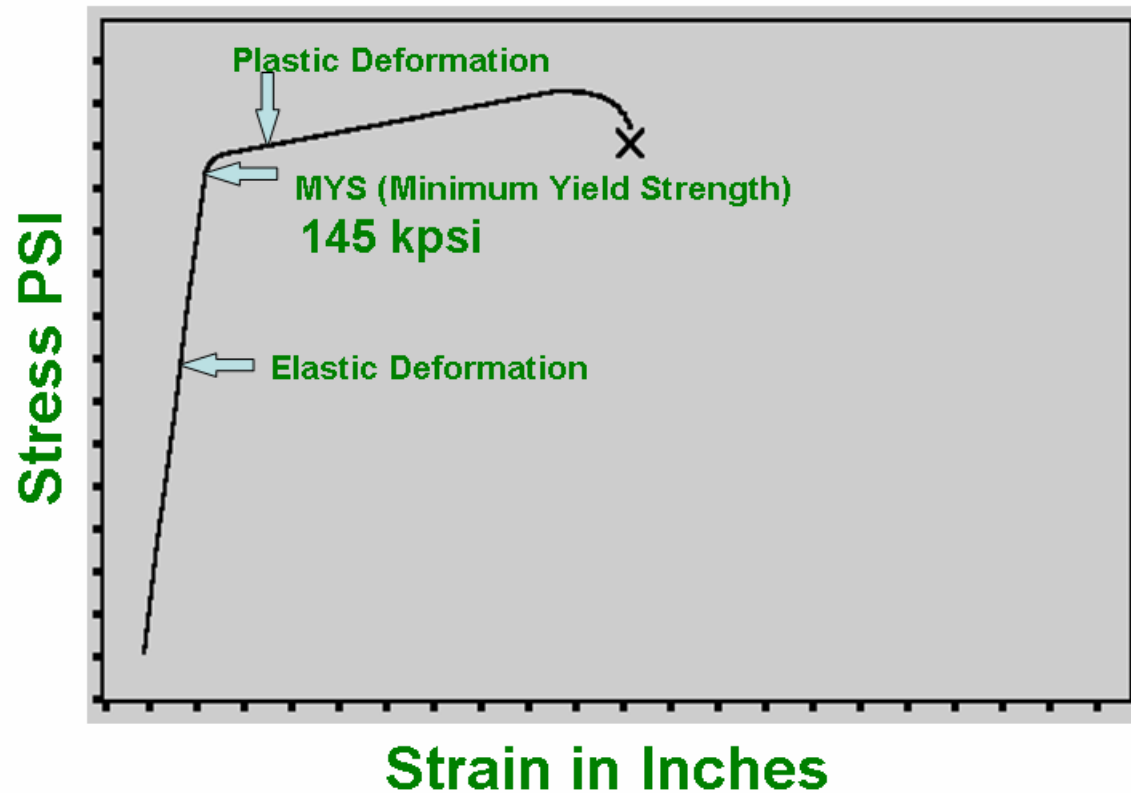
Joints with 40' length (versus 15'). That is 50% less connections and chance for leaking



Titanium Mechanical Advantage



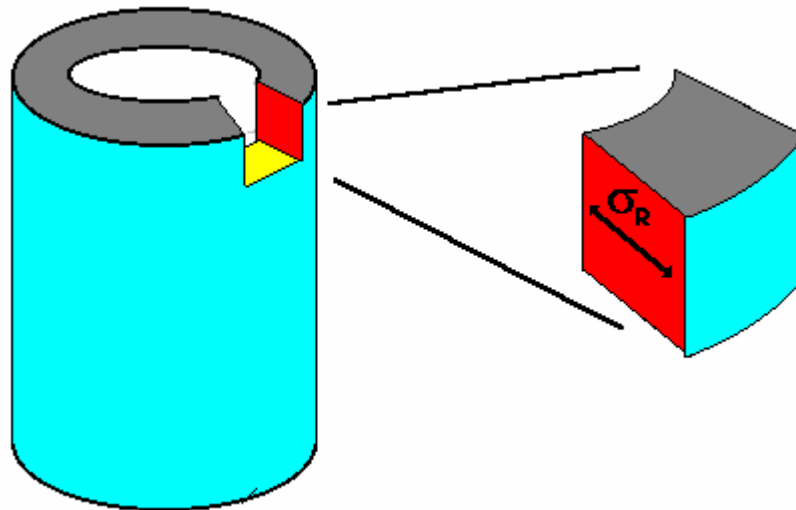
Much greater safety factors due to higher strength
(145 MYS)



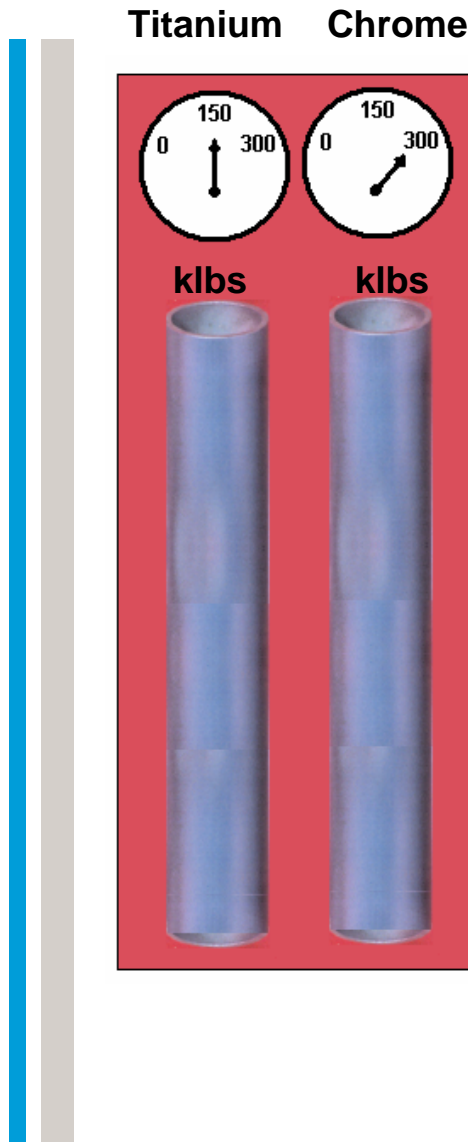
Titanium Mechanical Advantage



(Isotropic) Homogeneous strength of 145 MYS throughout heavy wall (coupling stock)

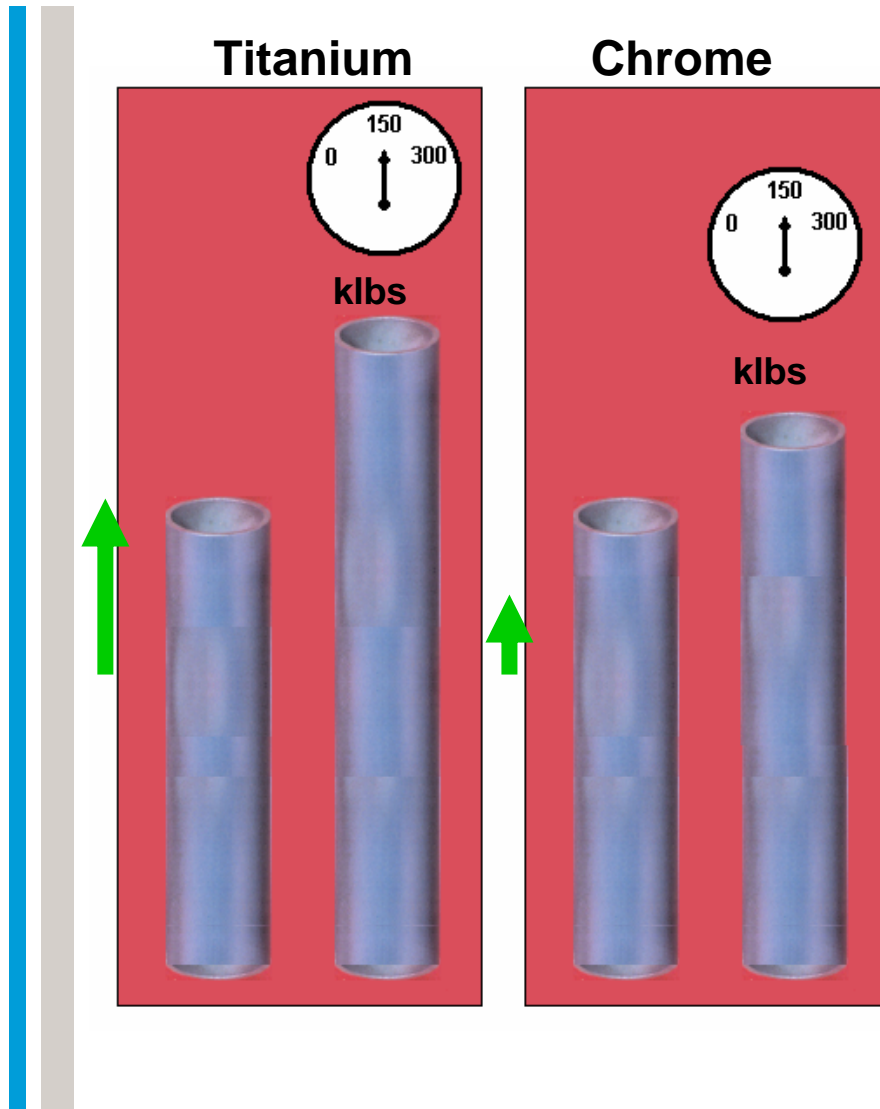


Titanium Mechanical Advantage



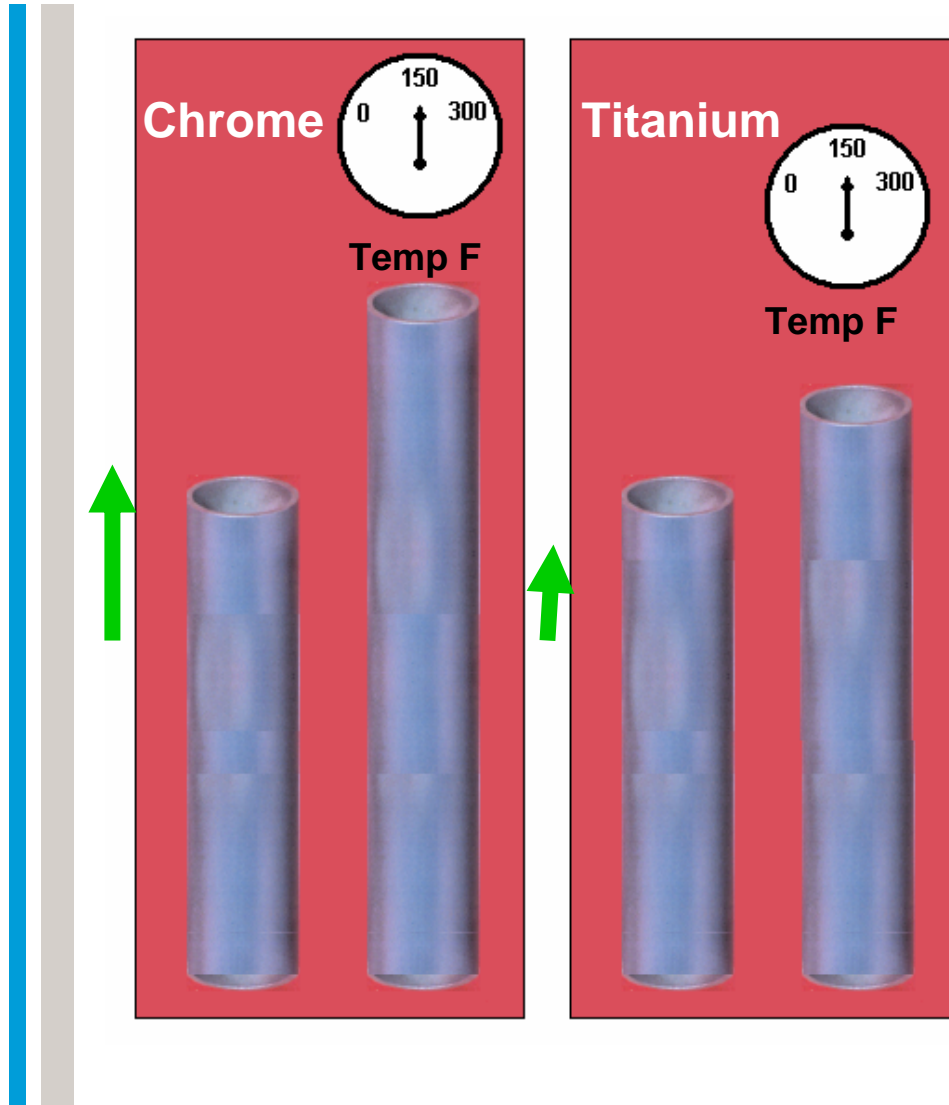
Much lower axial loading
due to 50% weight
reduction over Chrome for
the same tubing
dimensions

Titanium Mechanical Advantage



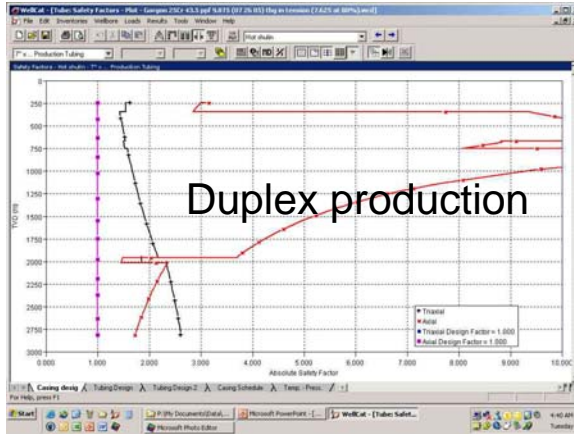
Half the Young's modulus. The pipe can stretch twice as long under the same load. It can be latched to packer and induce half the stress without using floating seals

Titanium Mechanical Advantage

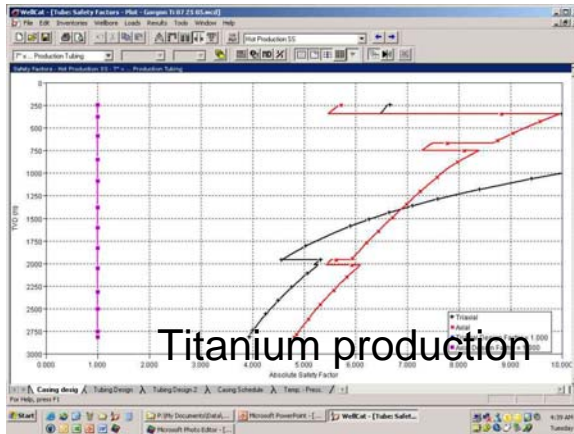


Much less expansion
due to temperature
means less axial stress
due to tubing movement

Tubing Design Safety Factors



Using 9-5/8", 0.545 Wall,
110 GD, 25 Duplex
Min Axial SF is 1.4



Using 9-5/8", 0.395 Wall,
145 GD, Ti-6246
Min Axial SF is 5.5

Other Titanium Advantages

- Very erosion resistant. High strength and quickly forming oxide film
- Greater ID for increased flow rate

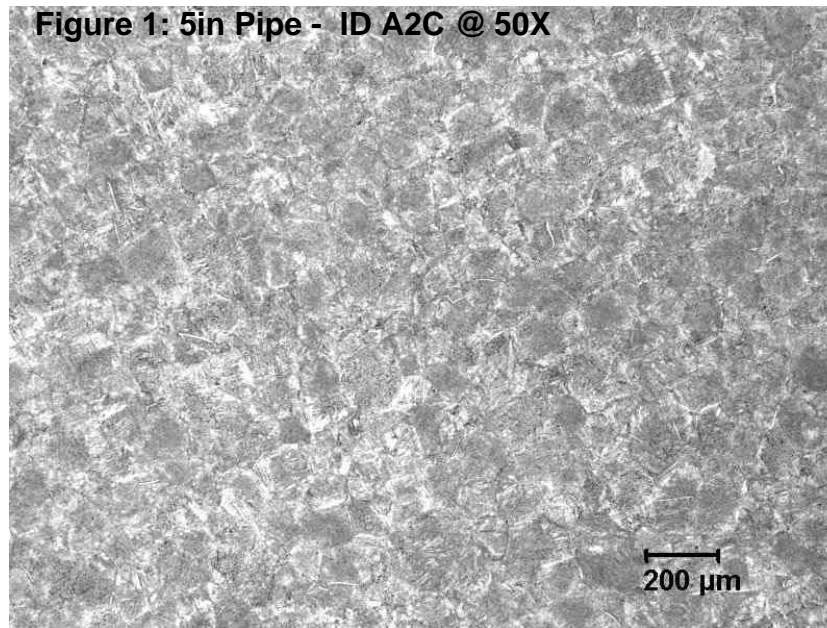
Titanium Cost Advantages

- Due to low density, a pound of titanium yields twice the amount of tubing (versus chromes)
- However since 2004, the price for chrome/nickel has increased to the point that the titanium alloy is now competitive with super duplex (+/- 20%)
- Titanium has current manufacturing capacity and reasonable delivery times 18 to 24 months for 60,000'

Titanium 6246

- Alloy was **qualified for NACE MR-0175** in the 80's (just in time for slowdown in industry)
- TIMETAL 6246 was developed in the 60's as a high strength high temperature alloy for jet engines.
- It's made of 82% Titanium, 6% Aluminum, 2% zinc, 4% zirconium, 6% moly
- Main product form is bar and billet, which is starting product for extrusion
- Oil companies starting using 6246 in late 70's and early 80's for downhole tooling

Alloy 6246 Pipe



Note – Hardness values range from 35-38Rc

Alloy may achieve uniform properties through entire thickness. This is critical for thicker-walled components which may be an issue with the super duplex ss.

Photos showing fine, equiaxed, beta transformed microstructure of the 5in OD extruded + annealed pipe

Titanium Use in Geothermal Wells

Geothermal Titanium Data

- Wells 5,000' deep with a BHT of 500-550F flowing at 500 psi
- Over 20 wells drilled and completed to date
- Wells have been on production since 1995 with no leaks
- Producing high chloride brine, with H₂S and CO₂

Titanium Pipe Going Into Geothermal Well



**Running in the well with 16”
Titanium casing
In geothermal well**

Titanium Pipe Going Into Geothermal Well



**Running in the well with 16" Titanium casing
In geothermal well**

Manufacturing Titanium

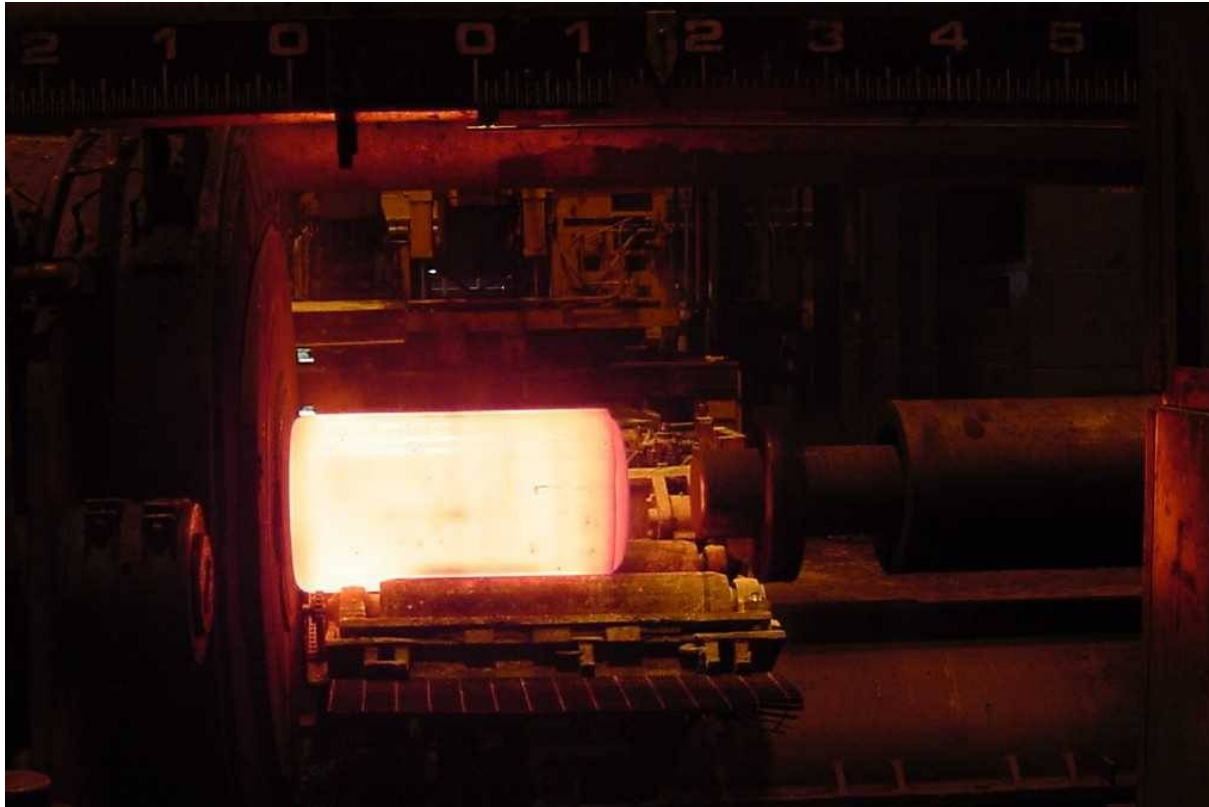
Titanium Billet Pierced



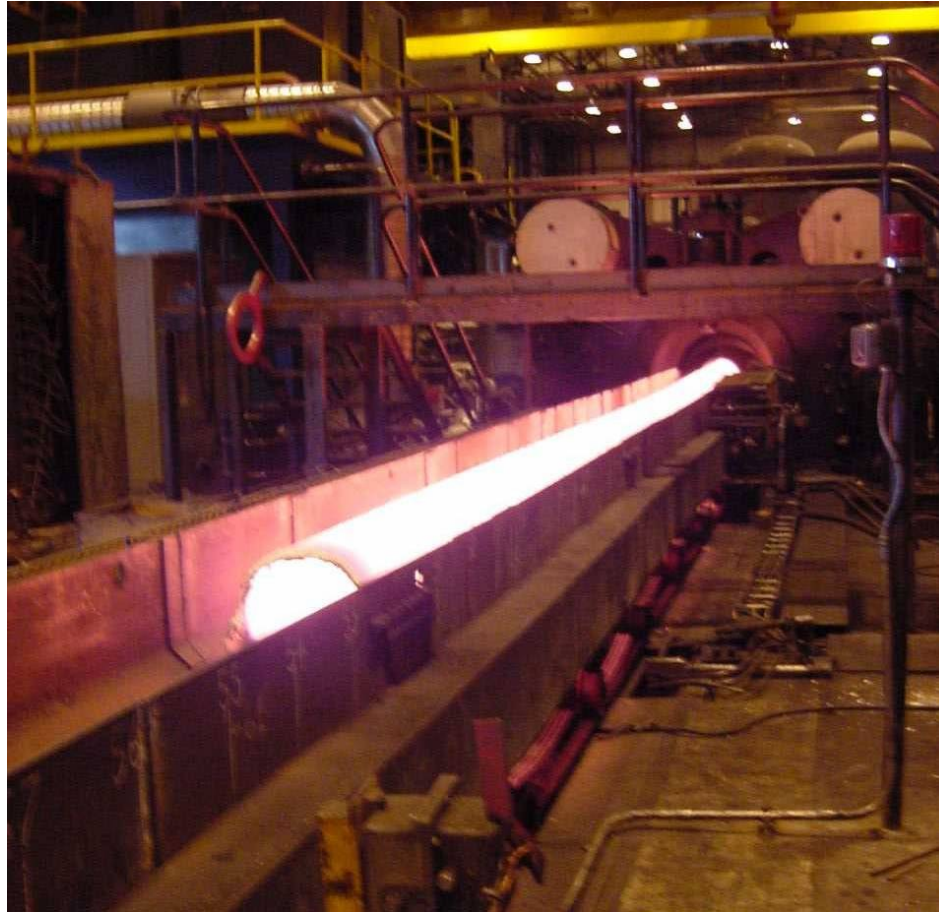
Billet coated with Glass Lubricant



Titanium Billet Heated and Ready For Extrusion



Titanium Tubing Extruded



Testing Programs

- **We have started an active metallurgical testing program on the Ti-6246 alloy through the use of funds from an internal Chevron project (scheduled to be completed 1st half of 2006).**
- **We propose to test the Hunting Apex connection for Titanium (currently used for titanium 9-5/8" tubing in geothermal wells) to qualify for our well's conditions.**
- **We propose to qualify all packer slips, tongs, and handling tools to ensure compatibility to the 145 grade Titanium tubing.**
- **Collapse testing has been performed on Titanium for Geothermal wells on 10-3/4" and 16" pipe with higher rating than API steel. We will also do collapse testing on our weight and grade.**

Testing Programs

Materials Test Qualification Program

- **Program will take one year.**
- **Objective will be evaluate corrosion and sand erosion for extreme environments that would include the high rate, sour, deep gas wells.**
- **Chances of success in passing the tests will be very high.**
- **Previous work by Chevron for Mobile Bay wells serve as a guideline for the program.**
- **We will also test the completions/packer fluid chemicals for compatibility with titanium**



Detailed Tasks for Materials Test Program

- **Production environment:** 500 F, 1,500 psi H₂S, 425 psi CO₂ & 150,000 ppm Chlorides (complete this year)- cracking and crevice corrosion tests
- **Packer fluids:** 500 F, two clear brines of choice (including chemical additives)
- **Sand erosion studies at Univ of Tulsa:** target tests to incorporate matl into SPPS model (may start this year)
- **Acid:** 15 % HCl for 12 hours at 340 F.
- **Methanol:** varying water contents at ambient temp to evaluate environmental cracking.
- **Liquid Mercury:** Slow strain rate tests to induce plastic strain at ambient temp to 400 F.

Two vertical bars, one blue and one grey, positioned on the left side of the slide.

Connection Testing Programs

Titanium Connection Testing

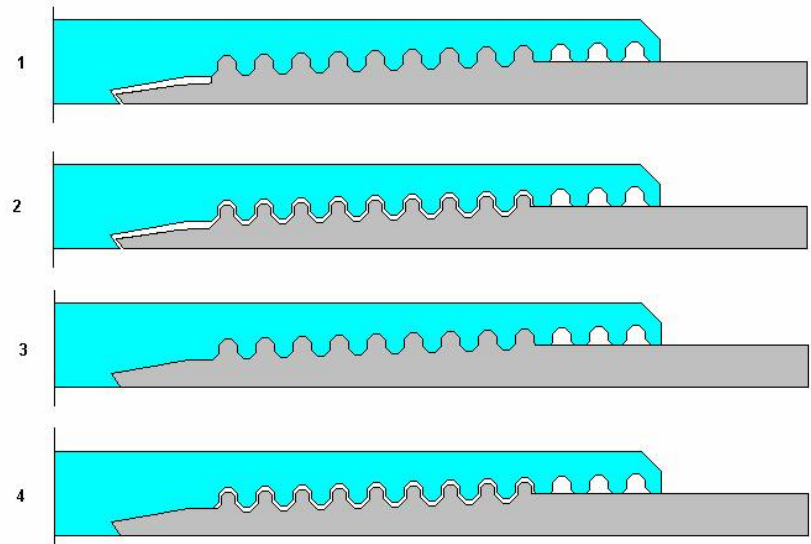
- We will test using a slightly modified Qualification-IV API-ISO 13679 connection test to 400F
- On the Qualification test we will use four samples

Sample 1 - (max thread interference with min seal interference)

Sample 2 - (min thread interference with min seal interference)

Sample 3 - (max thread interference with max seal interference)

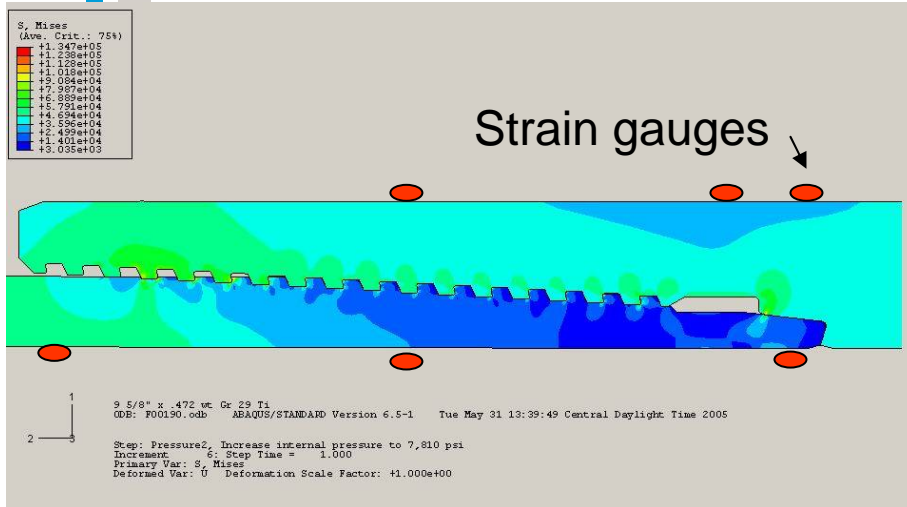
Sample 4 - (min thread interference with max seal interference)



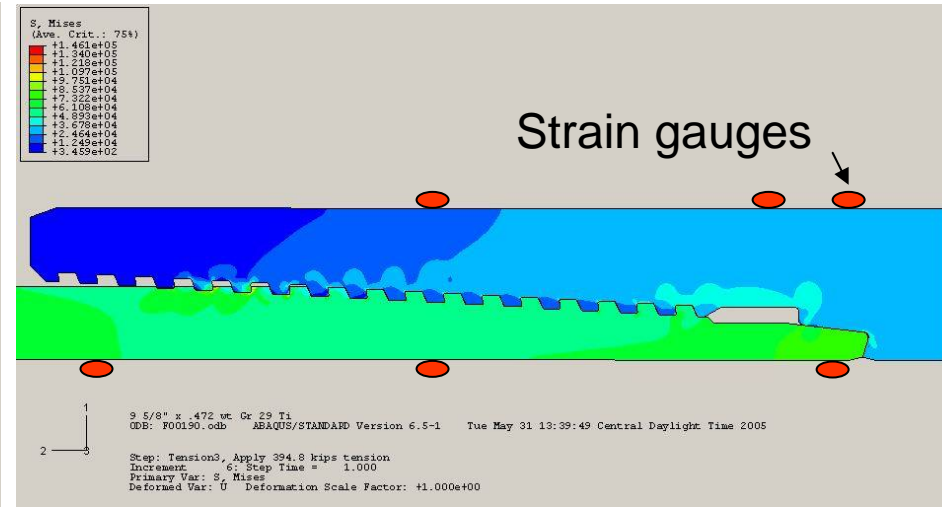
Titanium Connection Testing

We have performed an initial FEA analysis on the Apex connection with positive results. The analysis consist of titanium to titanium connections. The stress levels are very low compared to the minimum yield strength

Delta P of 7800 psi



395 Kips Tension

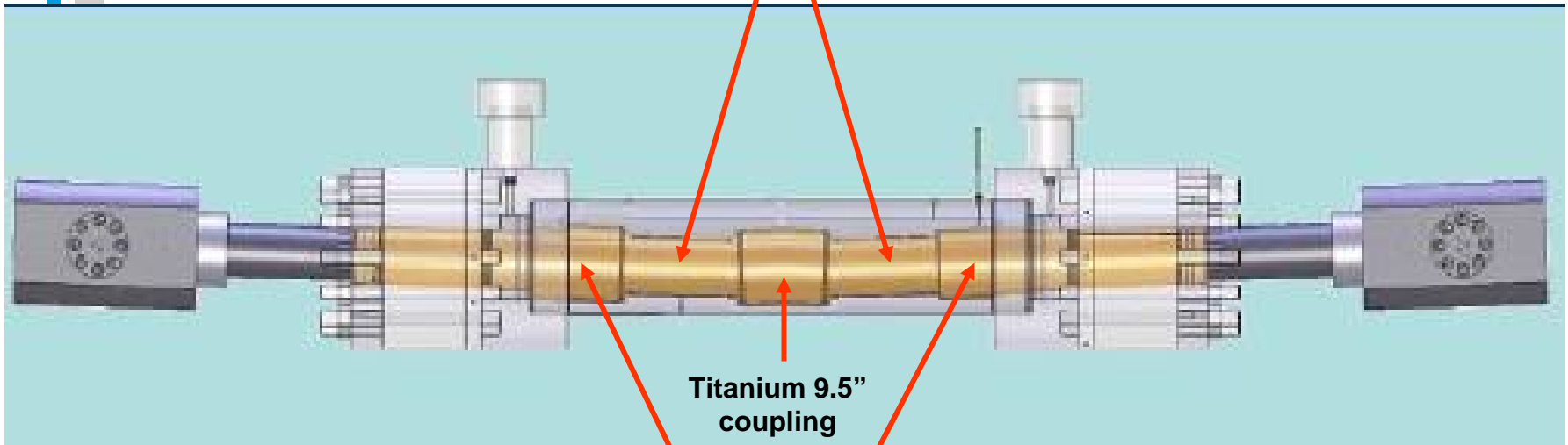


We will also analyze a titanium to 625 alloy connection

Test Chamber

Total length 105"

Titanium pin/pin 30" long



Titanium 9.5"
coupling

End fixture 10.750 OD, Inconel 625, Total length of 24"

Hunting Apex Connection



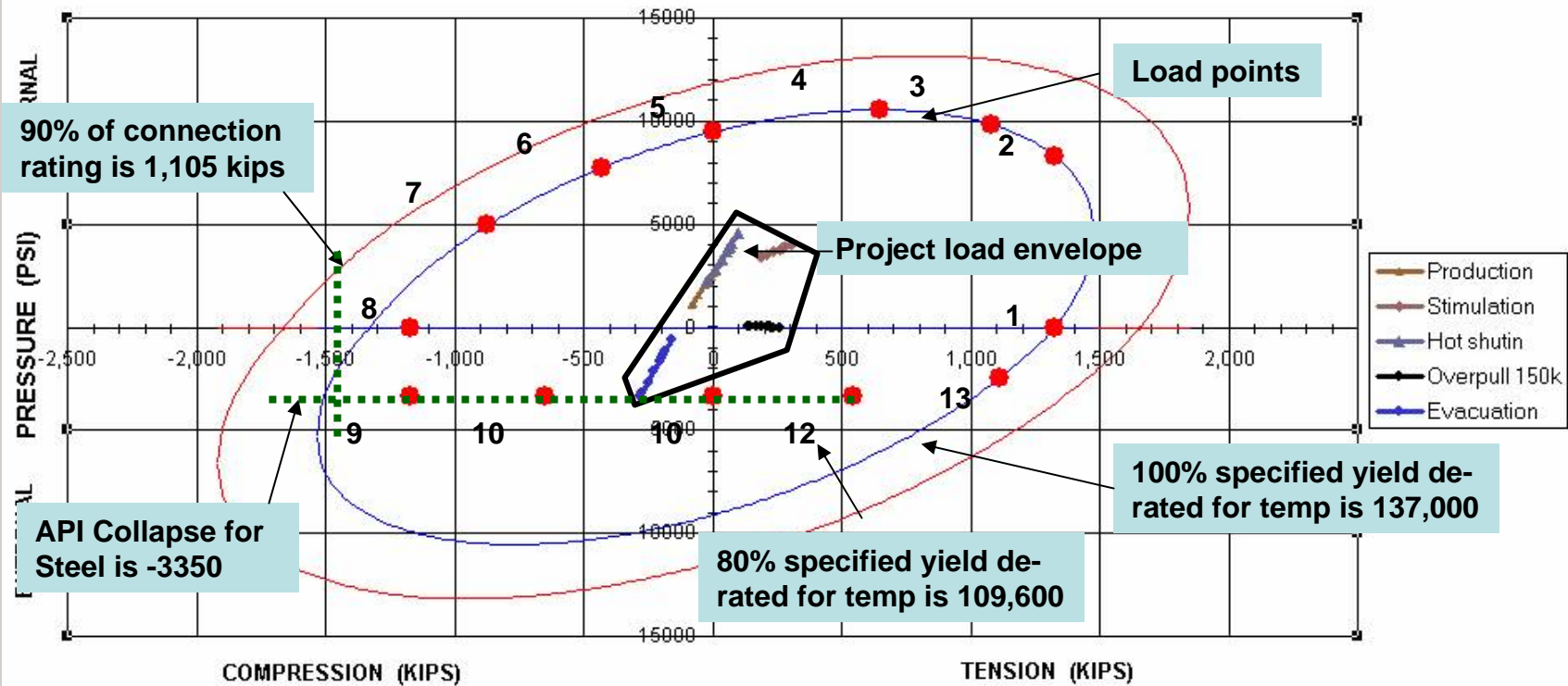
Hooked thread design



*Internal torque shoulder,
metal-to-metal seal and
lubricant relief groove*

Titanium Connection Testing

VME Tri-Axial Equivalent Yield Ellipse at ID of Pipe
 9 5/8" x .395" Wall Ti-6246 Gd 145 KSI SL APEX
 Load Points Based on Nom. Wall and Min. Yield at Ambient Temp.



Testing Handling Tools

Test the slips and elevators to ensure they will grip the hard 145 grade tubing. Also test the packer slips

