



# Titanium Production Tubing for HPHT Oil & Gas Wells

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# Overview

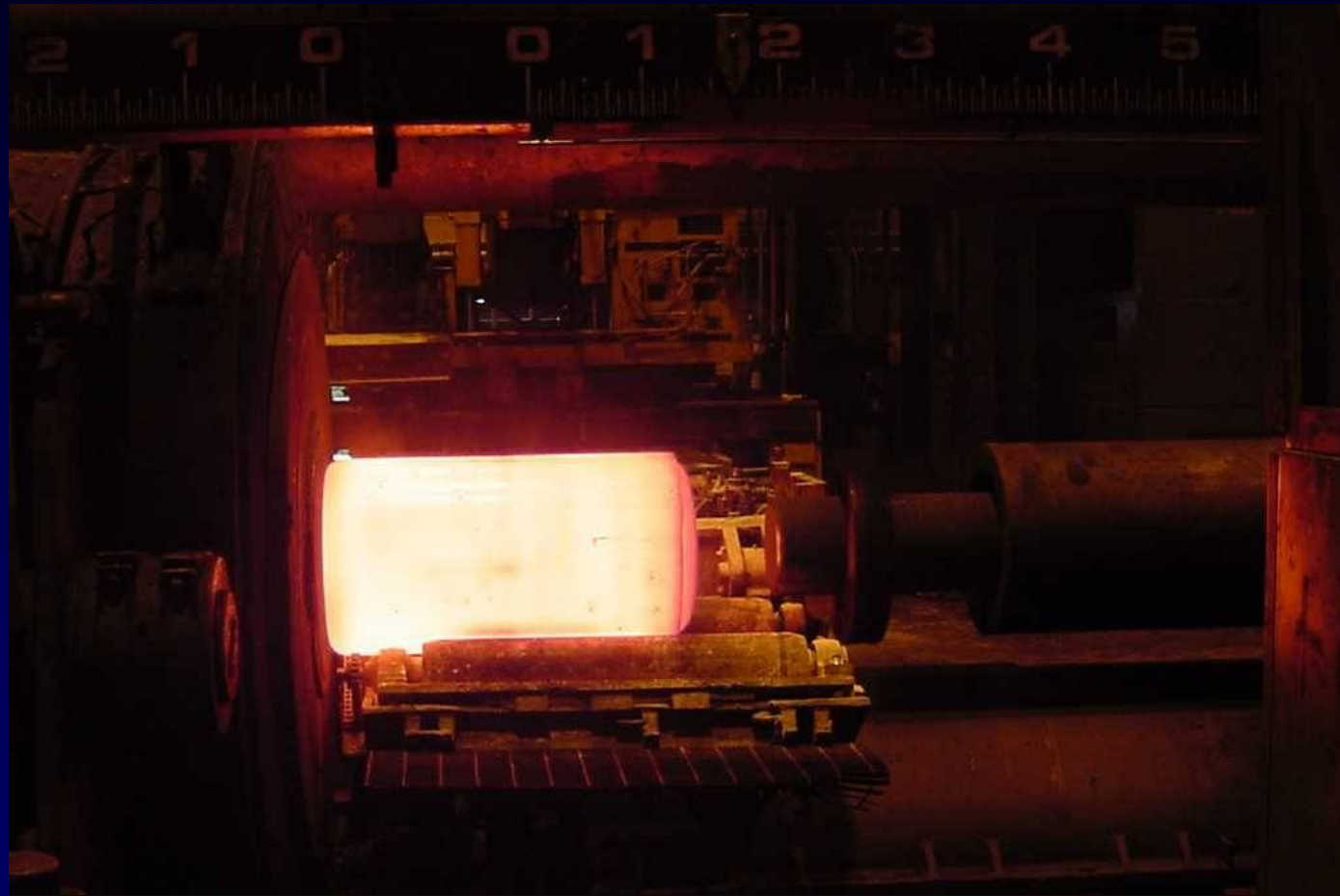
- Titanium alloy seamless pipe manufacturing & application
- Titanium advantages over high chrome/nickel alloys
- Current test program for TIMETAL 6246 extruded pipe qualification
- Summary



# Titanium Extrusion Hollow Coated with Lubricant



# Heated Titanium Hollow Being Loaded Into Extrusion Press



# Titanium Tubing Being Extruded



*ITA Conference San Diego, CA October 2, 2006*



# Proven Capability in Geothermal Well Casing Applications



16in titanium alloy casing being installed



Approx. 20 wells installed with titanium alloy pipe since about 1995 with excellent results





# TIMETAL 6246

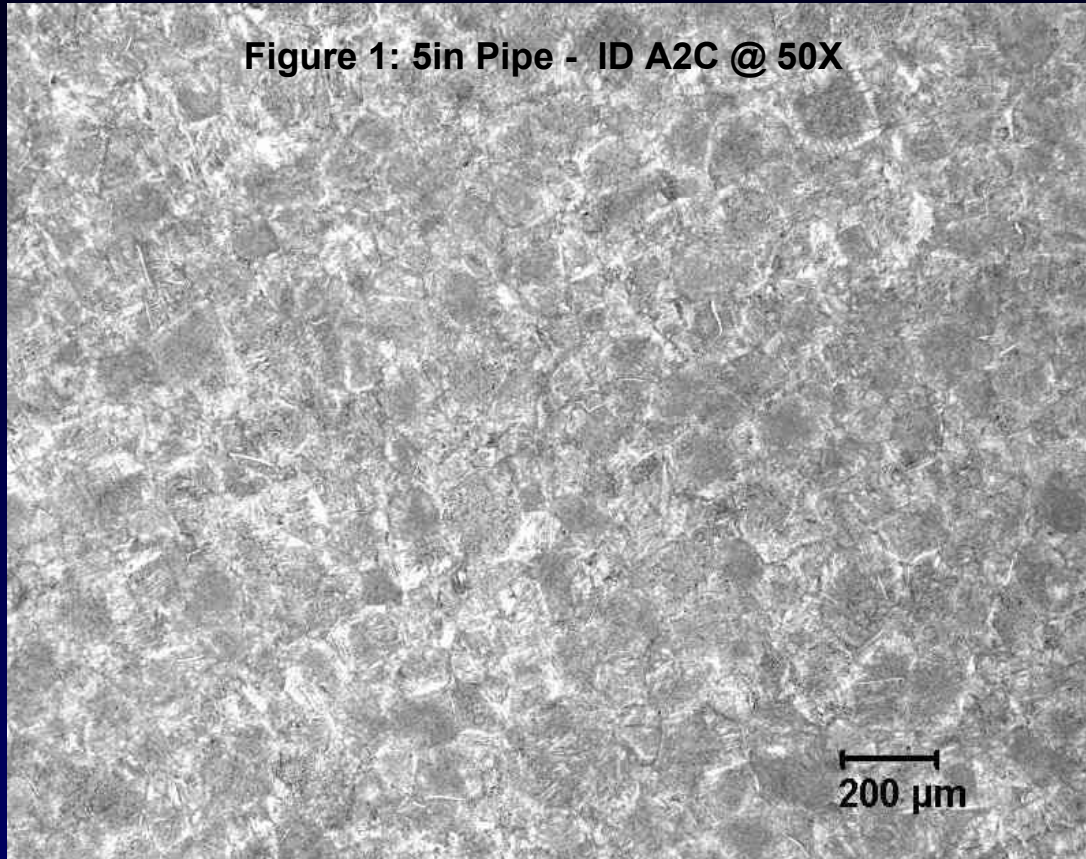
- Alloy was **qualified for NACE MR-0175** in the 80's (just in time for slowdown in the Oil & Gas industry)
- TIMETAL 6246 was developed in the 60's as a high strength high temperature alloy for jet engines
- The high Mo content imparts excellent corrosion resistance for deep sour wells
- Main product form is bar and billet, which is starting product for seamless tubular extrusion
- Oil companies started using 6246 in late 70's and early 80's for downhole tooling



# TIMETAL 6246 Extruded Pipe



Figure 1: 5in Pipe - ID A2C @ 50X



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.

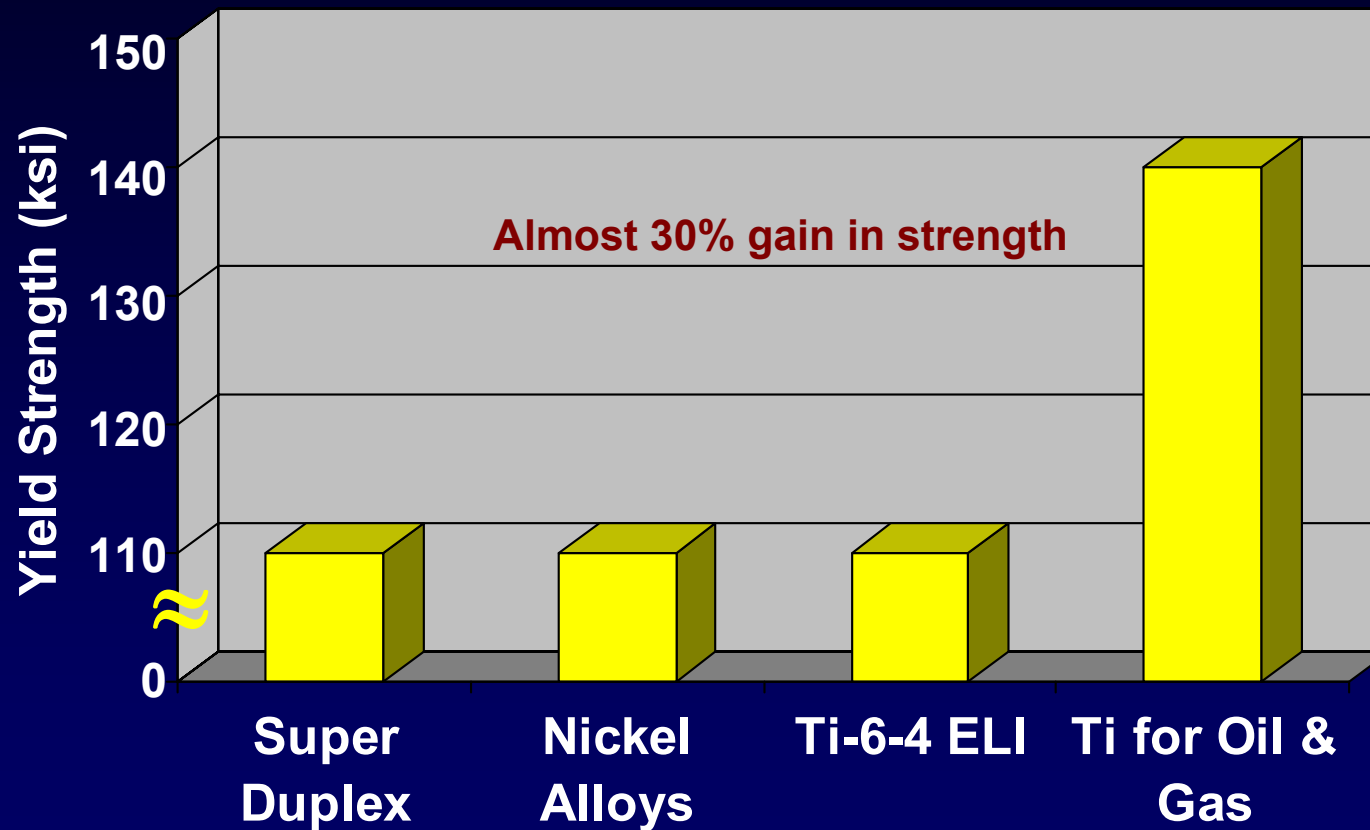
Photo showing fine, equiaxed, beta transformed microstructure of a 5in OD extruded + annealed pipe

Note – Hardness values range from 35-38Rc

# Titanium Mechanical Advantage



Much greater safety factors due to higher strength (140 MYS)

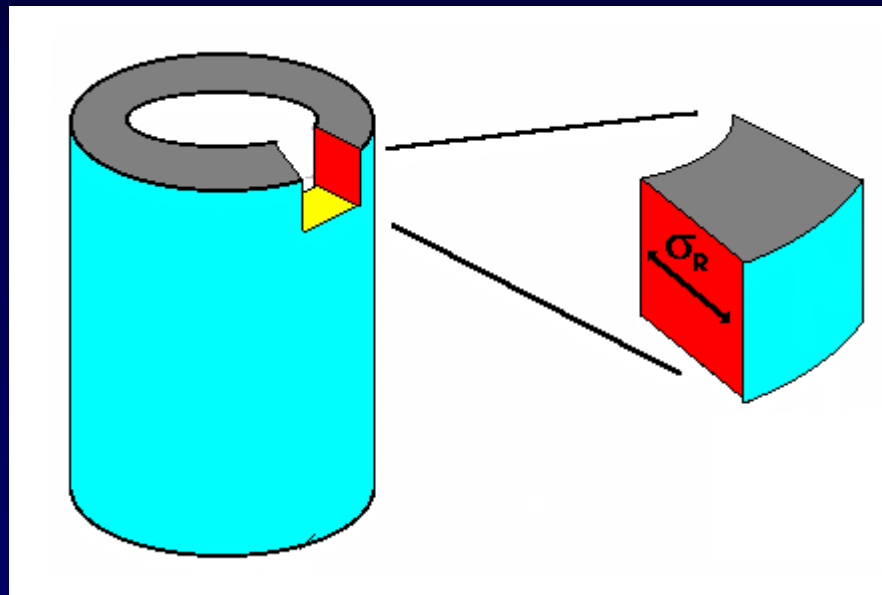


# Titanium Mechanical Advantage



(Isotropic) Homogeneous strength of 140 MYS throughout heavy wall (coupling stock)

Cold working of nickel alloys produces significant anisotropy



$$\sigma_L \approx \sigma_R \approx \sigma_C$$



# Titanium Advantage

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

Titanium



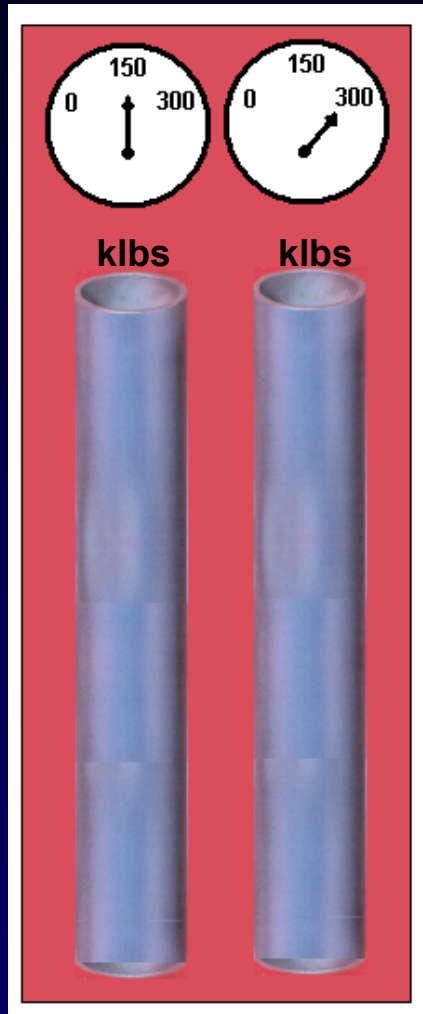
Chrome





# Titanium Advantage

Titanium    Chrome

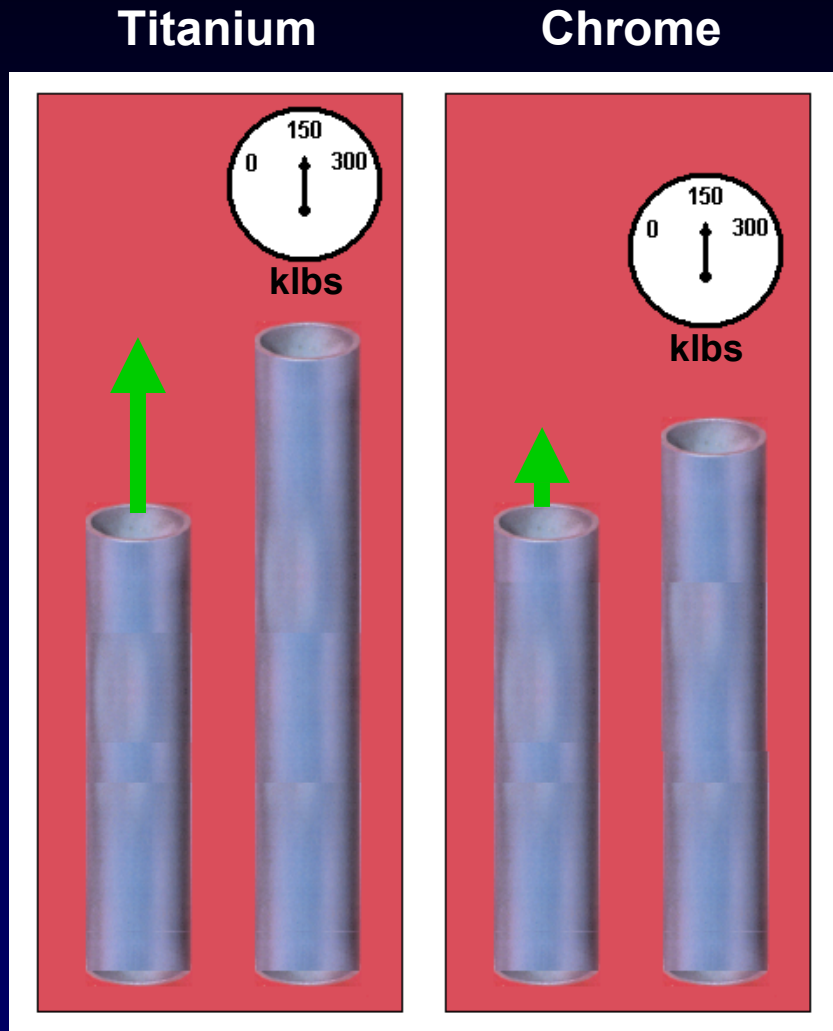


Much lower axial loading due to 50% weight reduction over Chrome or Nickel Alloys for the same tubing dimensions





# Titanium Advantage

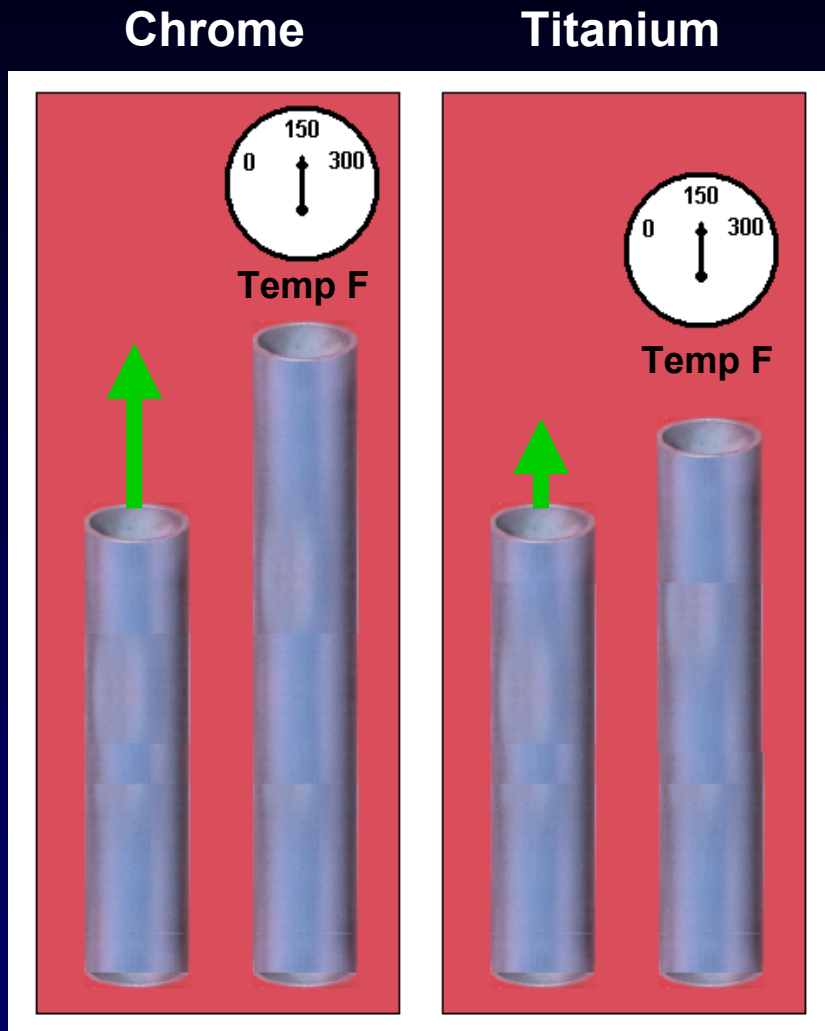


Half the Young's modulus. The pipe can stretch twice as long under the same load. It can be latched to packer and induce half the stress without using floating seals





# Titanium Advantage



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





# Titanium Cost Advantages

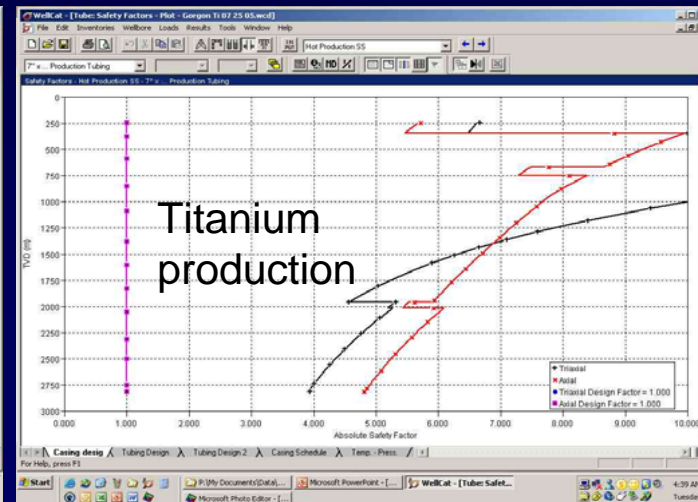
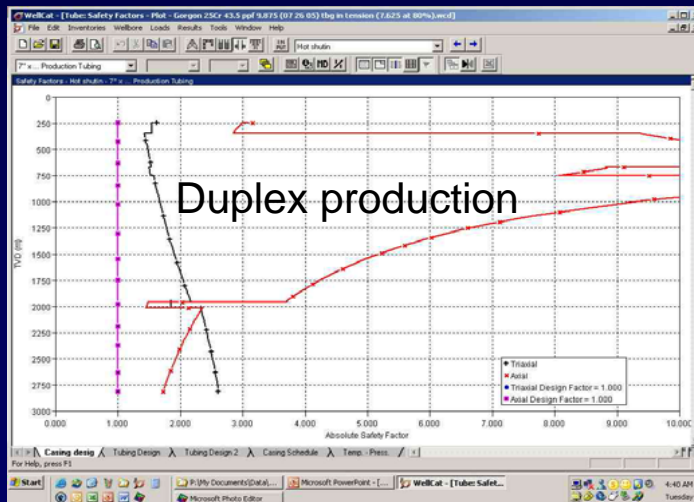
- Due to low density, a pound of titanium yields twice the amount of tubing (versus chrome/nickel)
- The price for chrome/nickel has increased to the point that the titanium alloy is now competitive with super duplex (+/- 20%)
- Industry has current manufacturing capabilities and reasonable delivery times for 60,000ft orders





# Other Titanium Advantages

- Very erosion resistant. High strength and quickly forming oxide film
- Greater ID for increased flow rate
- Safety factor for titanium >3.5X that for chrome/nickel (even with a 25% wall reduction)





# Testing Programs





# Overview of Test Programs

- Chevron has started an active metallurgical testing program on TIMETAL 6246 through the use of funds from an internal Chevron project (scheduled to be completed 1<sup>st</sup> qtr of 2007).
- Initial testing of the Hunting Apex connection for Titanium is underway (currently used for titanium 9-5/8" tubing in geothermal wells) to qualify for Chevron's Oil & Gas well conditions.
- Chevron will also qualify all packer slips, tongs, and handling tools to ensure compatibility to the 140 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. Chevron will also do collapse testing on our weight and grade.



# Detailed Tasks for Materials Test Program



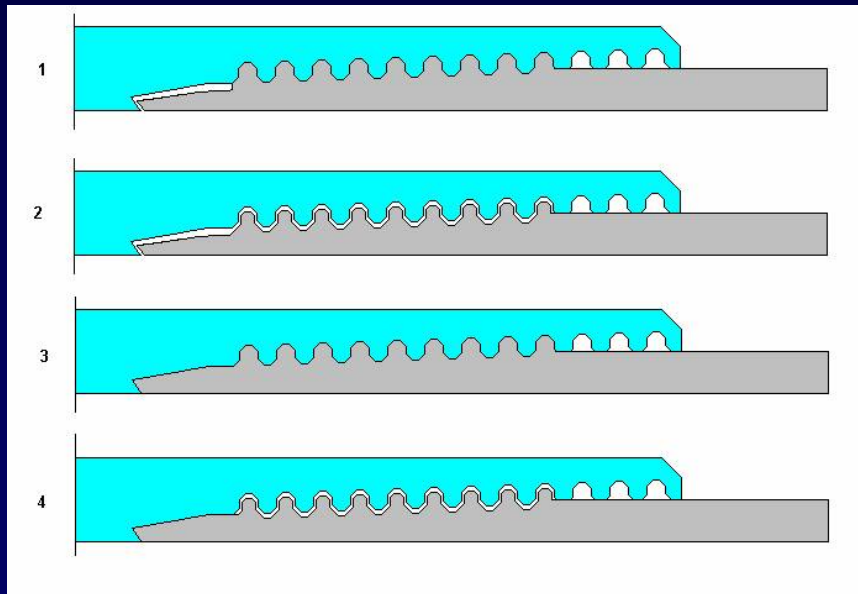
- **Production environment:** 500 F, 1,500 psi H<sub>2</sub>S, 425 psi CO<sub>2</sub> & 150,000 ppm Chlorides cracking and crevice corrosion tests (complete )
- **Packer fluids:** 500 F, two clear brines of choice (including chemical additives)
- **Sand erosion studies at Univ of Tulsa:** target tests to incorporate matl into SPPS model (started this year)
- **Acid:** 15 % HCl for 2 days 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 350 F.
- **Total expenditure >\$300K for test programs**





# TIMETAL 6246 Connection Testing

- FEA analysis revealed that the Ti connection will have very low stresses due to its high yield strength
- 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



Four conditions will test min and max seal and thread interference

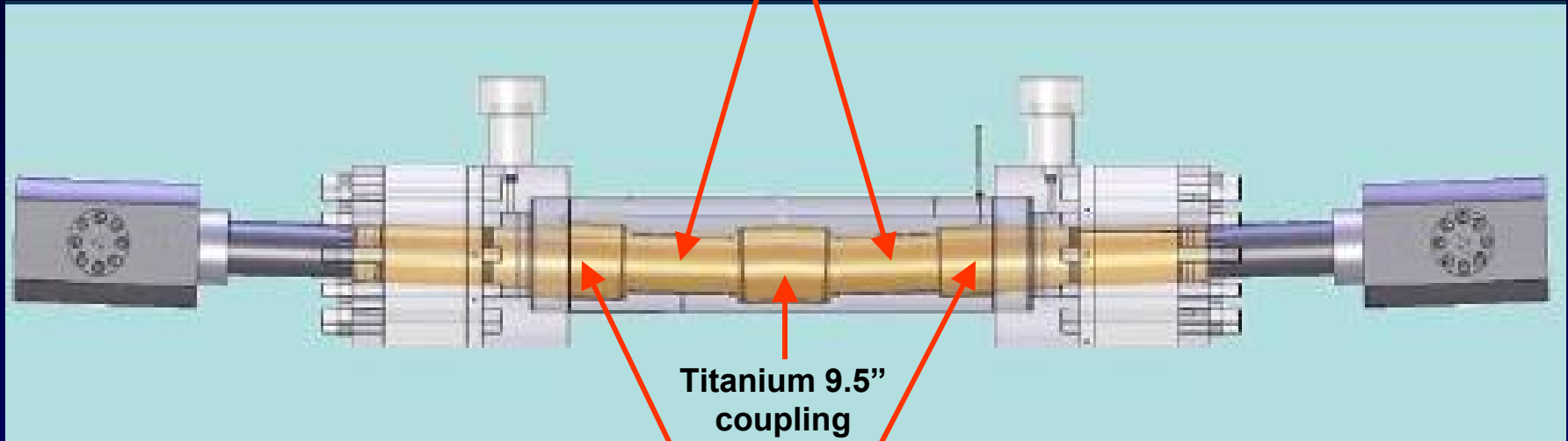




# Test Chamber

Total length 105"

Titanium pin/pin 30" long



Titanium 9.5"  
coupling

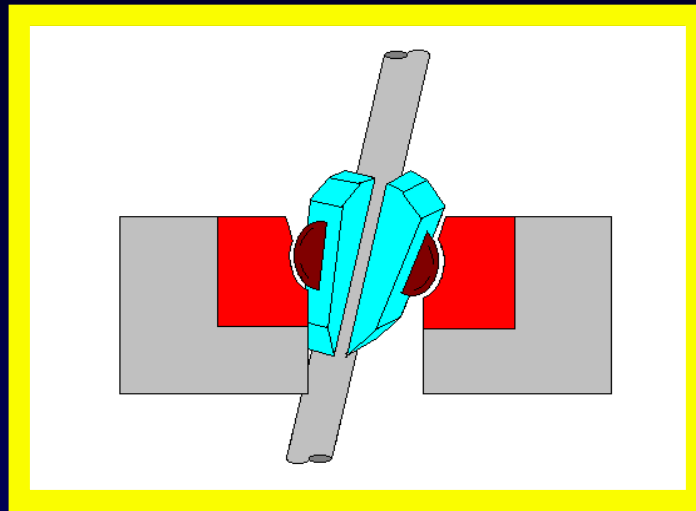
End fixture 10.750 OD, Inconel 625





# Testing of Handling Tools

Testing of the slips and elevators to ensure they will grip the hard 140 grade tubing. Also testing of the packer slips



- Precision slips will ensure that the entire slip surface is in contact with the pipe before the weight/load is applied .
- Testing will be performed on a modified Precision slip/elevator for the TIMETAL 6246 9-5/8" OD pipe





# Summary

- Titanium offers an attractive solution to HPHT material issues
- Current pricing & delivery issues with chrome/nickel alloys may push titanium into a more general material replacement scenario
- Chevron, Hunting, and TIMET are currently involved in an active qualification program for TIMETAL 6246
- The potential for titanium in downhole Oil & Gas production tubing is very large – Chevron has 2 fields where the interest in titanium is immediate

