Performance of a Lightweight 81-mm Mortar Barrel

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June 22, 1999

International Infantry & Small Arms Section
Symposium, Exhibition & Firing Demonstration

Program Goals

- 81-mm Mortar Barrel, 30% lighter than the M253 cannon that weighs approximately 35 lb
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- Design capable of firing top zone of existing charges
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- Maintain rate-of-fire requirements of M253 barrel
  - 30 rd/min for first 2 minutes
  - 15 rd/min sustained

Approach

- Maintain steel bore liner to minimize wear & erosion concerns
  - Coatings not considered
  -
- Investigate lightweight materials as sheaths to produce weight savings
  - Aluminum Alloy
  - Titanium Alloy
  - Graphite/Epoxy (GREP) Composite
  -
- Fabricate Blast Attenuation Device from same material chosen for barrel sheath

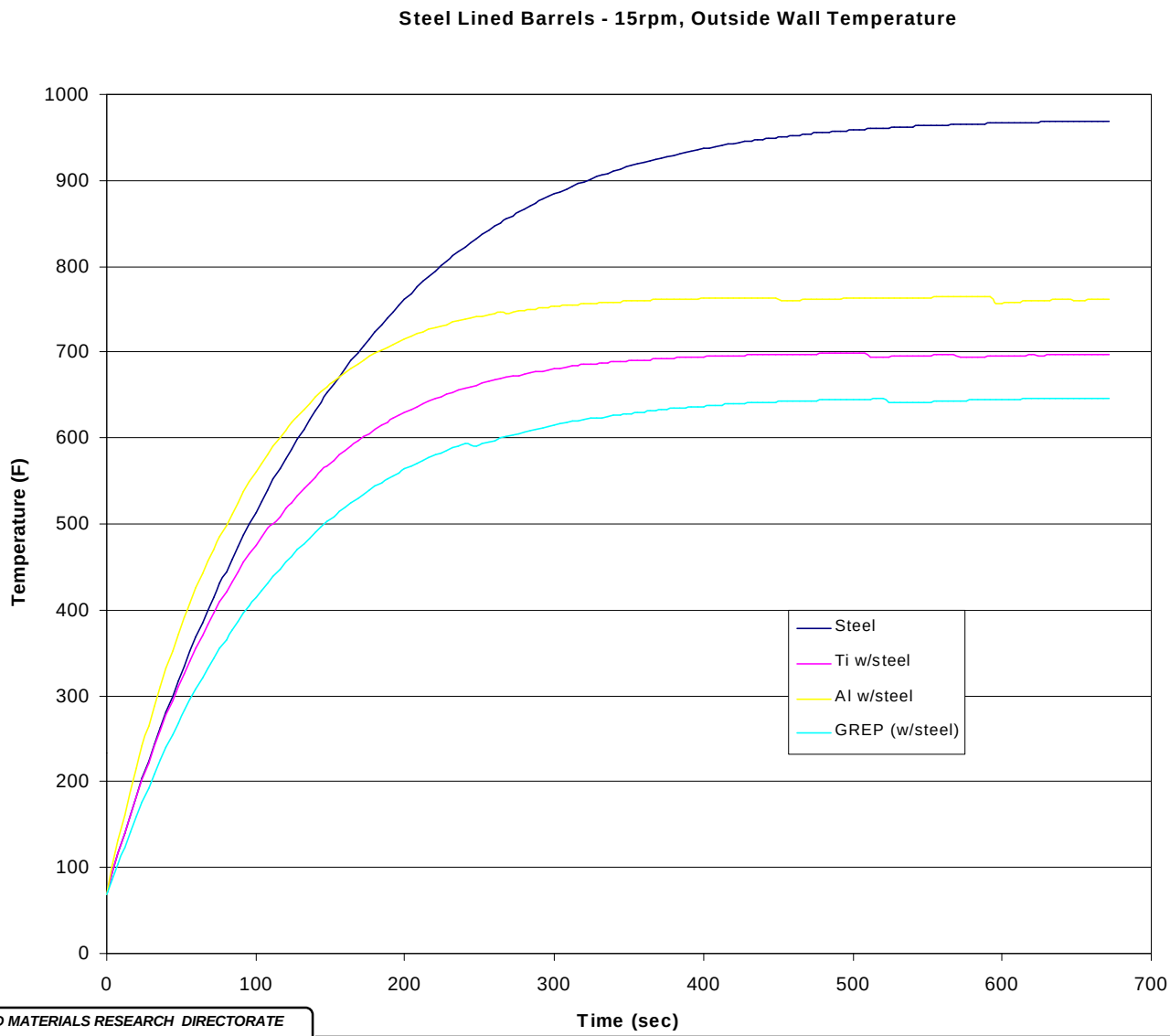
Thermal Considerations

- Interior ballistic model of the M821A1 projectile, zone 4
-
- IB results provide heat input to bore wall in ARL barrel heating code
-
- Barrel modeled with:
  - 0.040” thick steel liner
  - lightweight material sheath
  - fin augmentation factor

M253 Barrel

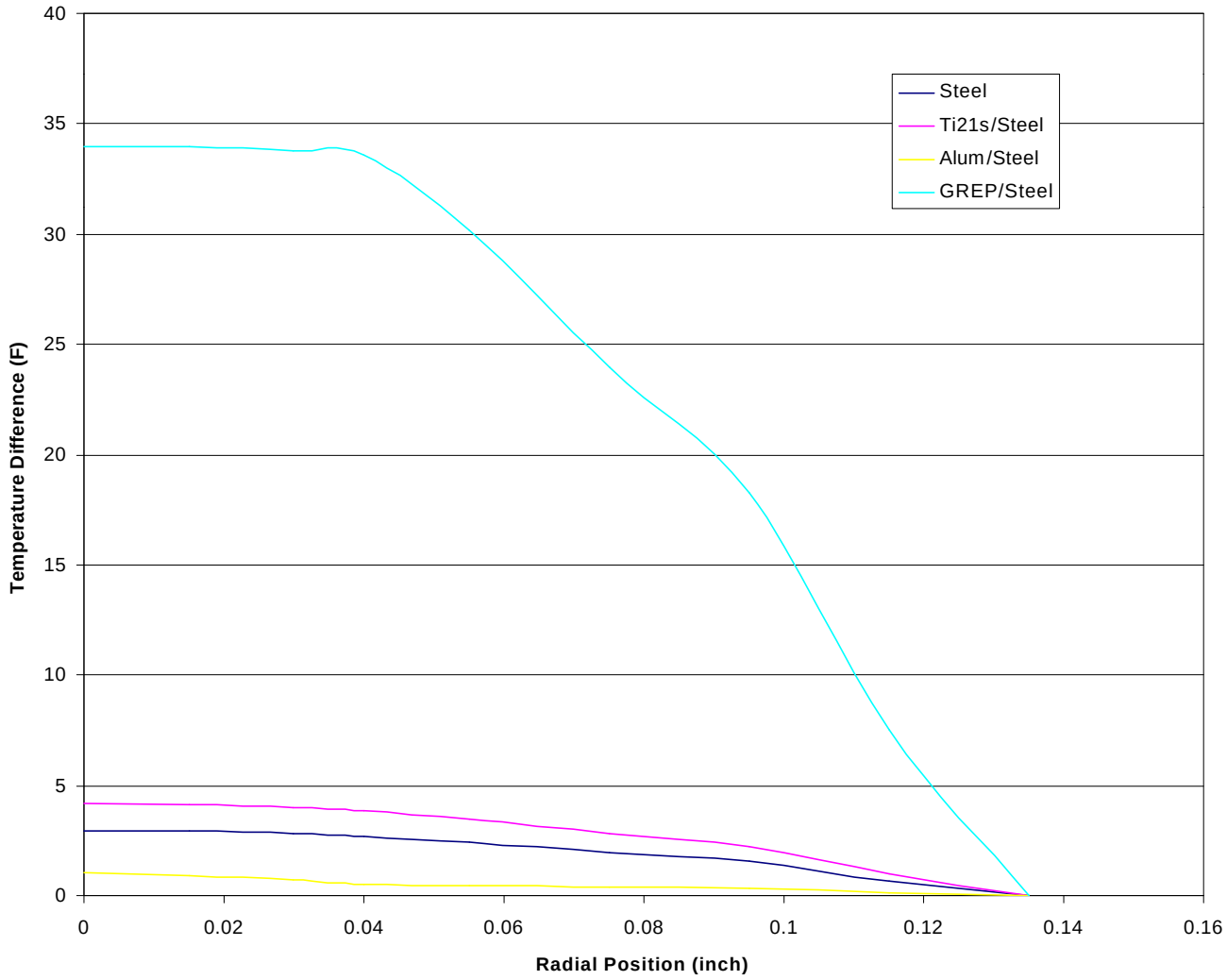
Breech end cooling fins

Barrel Temperature Calculations

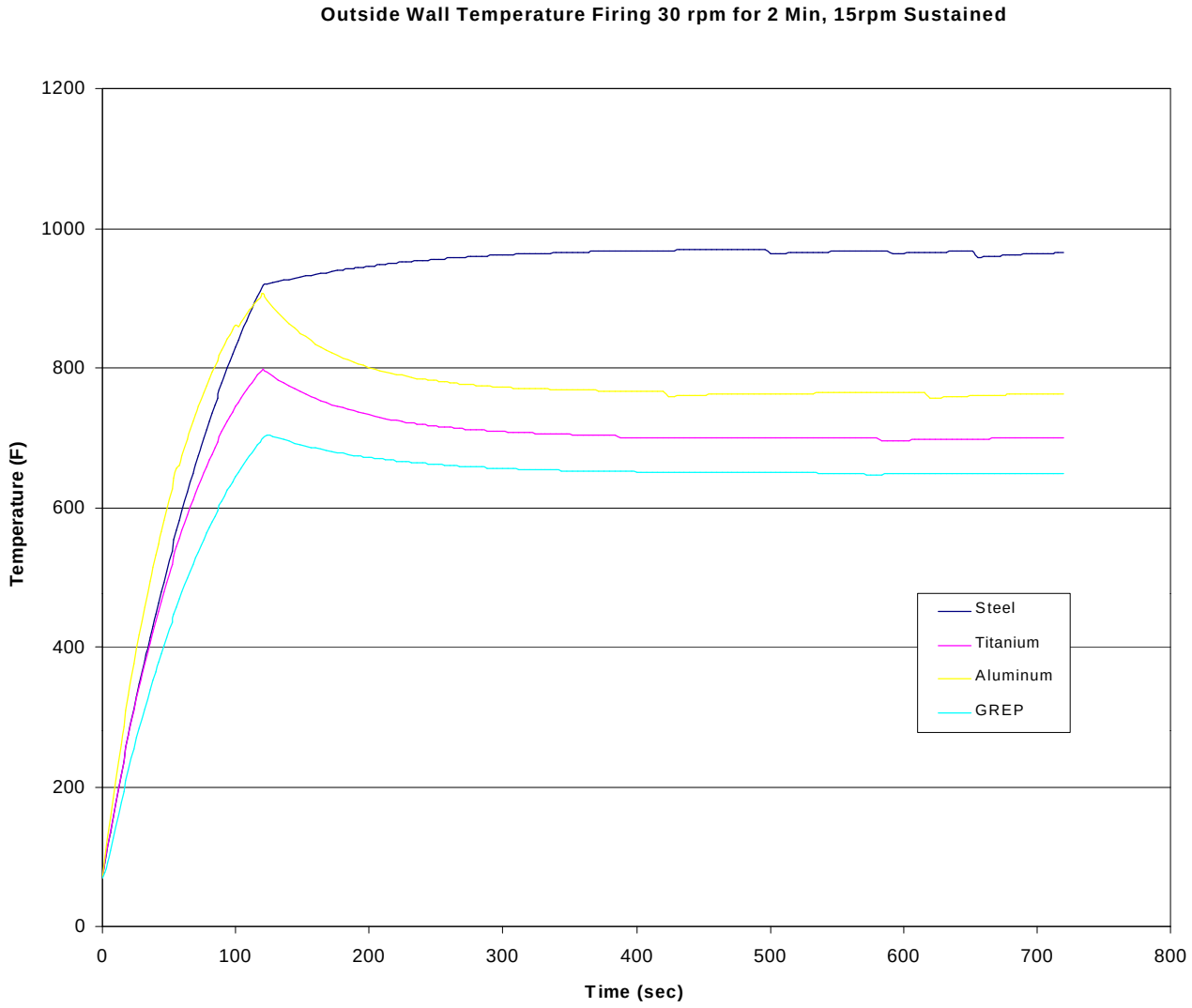


Through-the-Thickness Temperature

Data from 15 rd/min Firing Rate



Temperature Response under Maximum Firing Rate



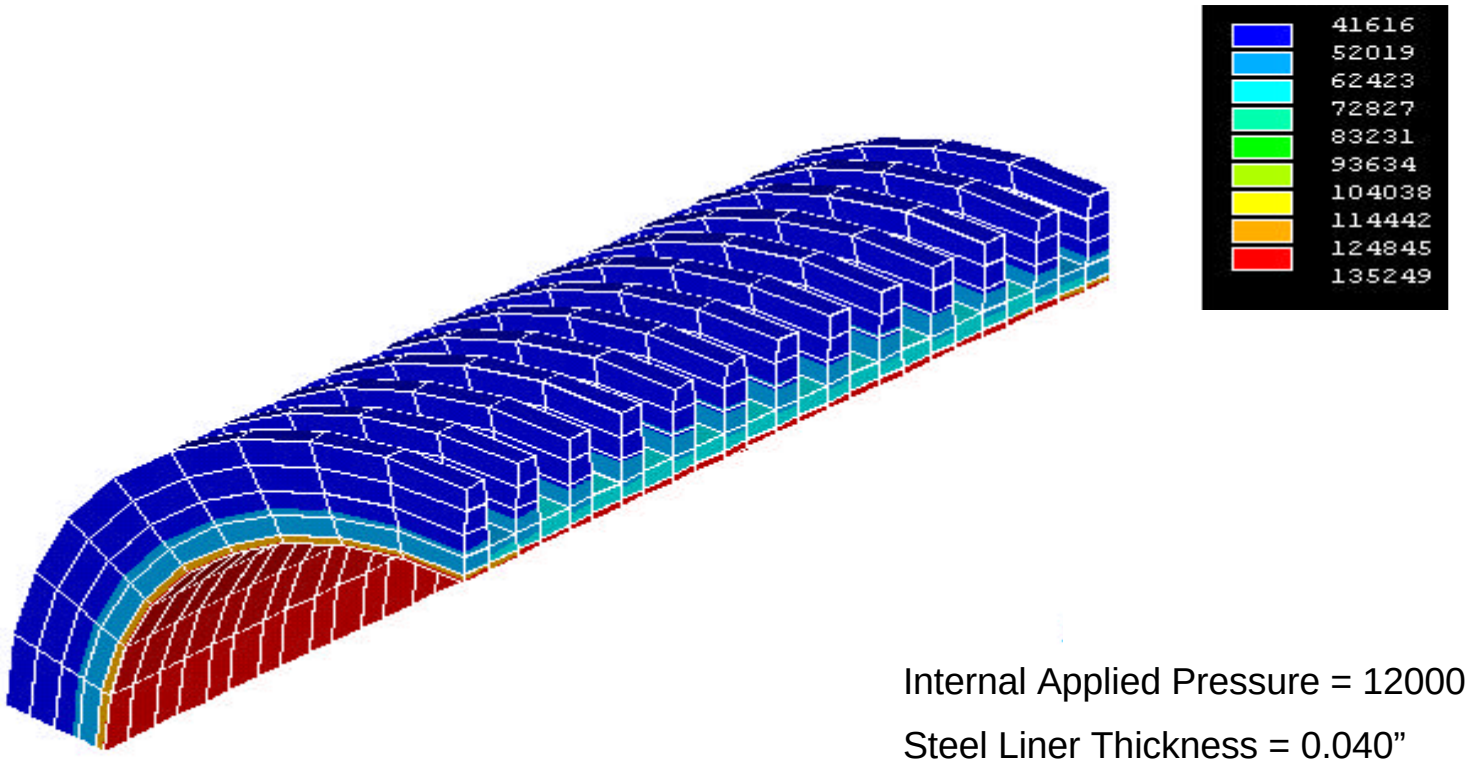
Lightweight Material Thermal Requirements

- Aluminum Alloy capable of withstanding 900 F
- Graphite/Epoxy composite with resin integrity to 750 F
- Titanium Alloy subjected to 800 F

TIMETAL®21S Alloy

- 0.2% yield strength ~ 195 kpsi @ ambient
-
- 0.2% yield strength ~ 140 kpsi @ 800 F
-
- 0.2% yield strength ~ 100 kpsi @ 1000 F
-
- Density 44% less than steel
-
- Coefficient of Thermal Expansion < COTE of steel

FEA of Steel-lined Titanium Barrel

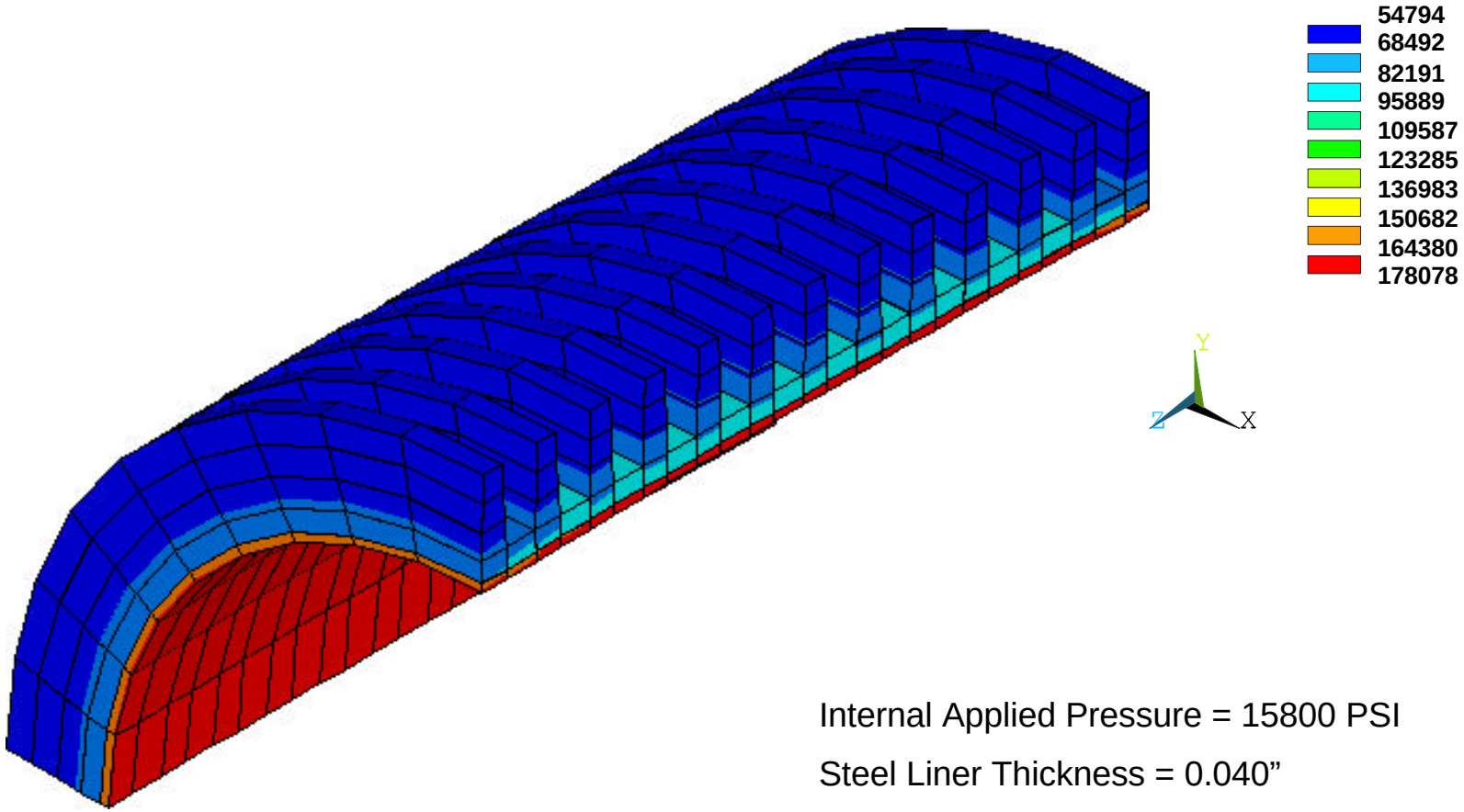


Internal Applied Pressure = 12000 PSI

Steel Liner Thickness = 0.040”

Interference Fit Not Modeled

FEA Results



Internal Applied Pressure = 15800 PSI

Steel Liner Thickness = 0.040”

Interference Fit Not Modeled

Interference Residual Stress Calculations

Residual Stress in Steel Liner

Interference (in)	Contact Pressure (psi)	Hoop Stress at ID (psi)	Hoop Stress at OD (psi)
0.002	487	-20226	-19739
0.003	731	-30359	-29628
0.004	974	-40451	-39477
0.005	1218	-50585	-49367
0.006	1462	-60718	-59256
0.007	1705	-70811	-69106

$(\sigma_\theta)_{ri} = -P_c\,(2b^2)/(b^2-a^2)$ $(\sigma_\theta)_{ro} = -P_c\,(b^2+a^2)/(b^2-a^2)$ where a = Bore Radius and b = Interface Radius

Residual Stress in Titanium Sheath

Interference (in)	Contact Pressure (psi)	Hoop Stress at ID (psi)	Hoop Stress at OD (psi)
0.002	487	8890	8403
0.003	731	13344	12613
0.004	974	17780	16806
0.005	1218	22234	21016
0.006	1462	26688	25226
0.007	1705	31124	29419

$(\sigma_\theta)_{ri} = -P_c\,(b^2+a^2)/(b^2-a^2)$ $(\sigma_\theta)_{ro} = -P_c\,(2a^2)/(b^2-a^2)$ where a = Interface Radius and b = Outer Wall Radius

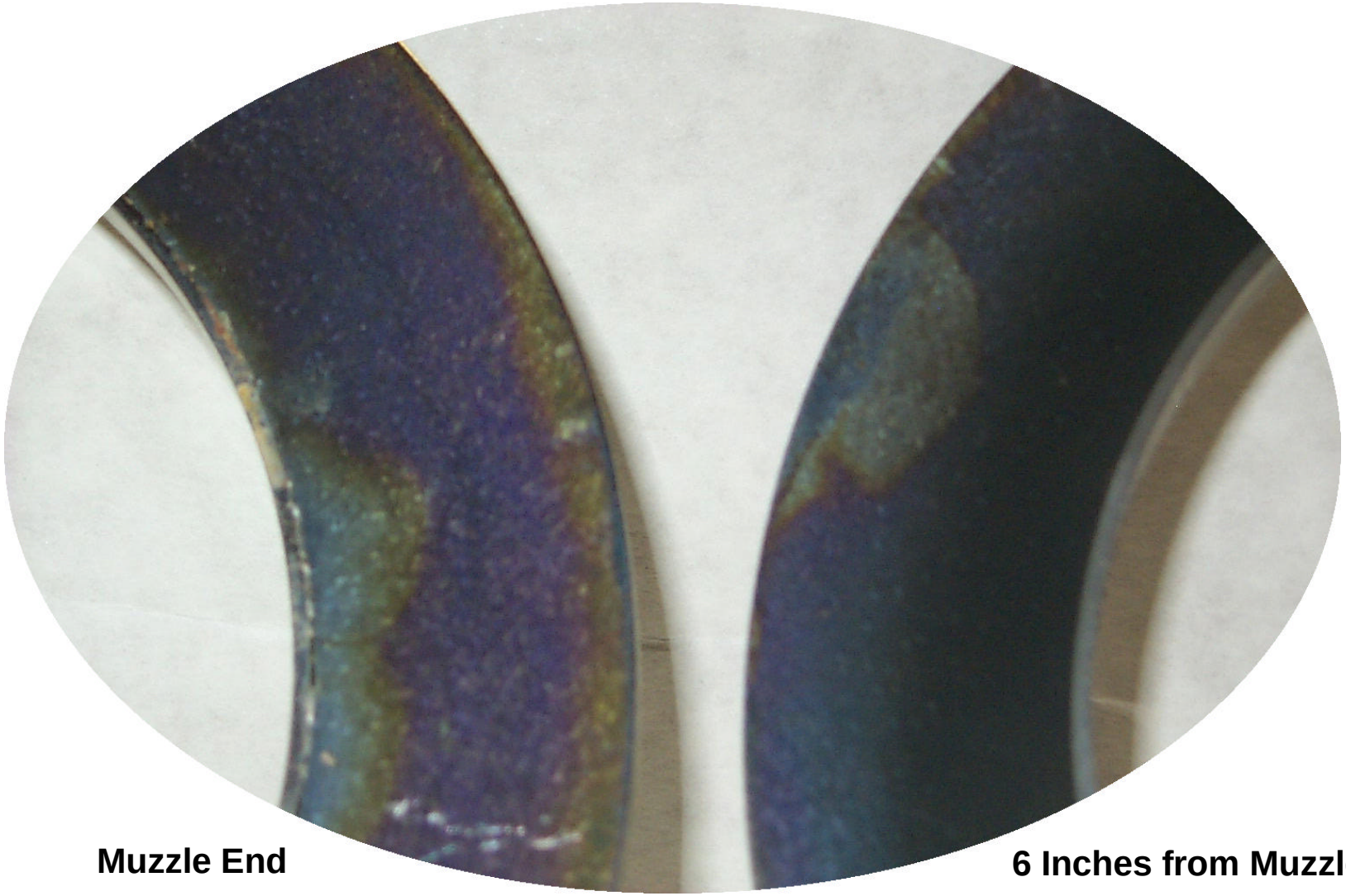
Shrink Fit Assembly

Assembly Ring Sections

Muzzle End

6 Inches from Muzzle

Liner/Sheath Interface

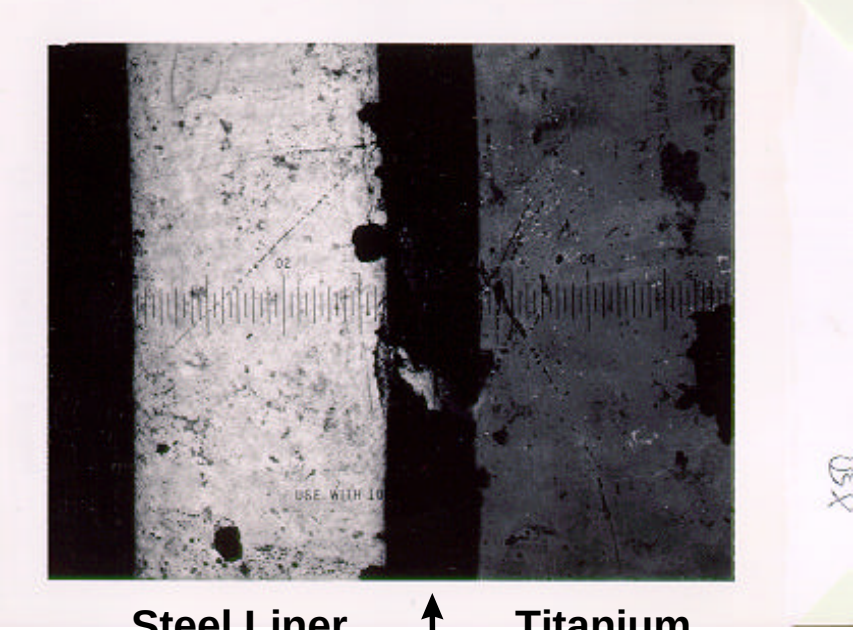


Muzzle End

6 Inches from Muzzle

Magnified View of Liner/Sheath Interface

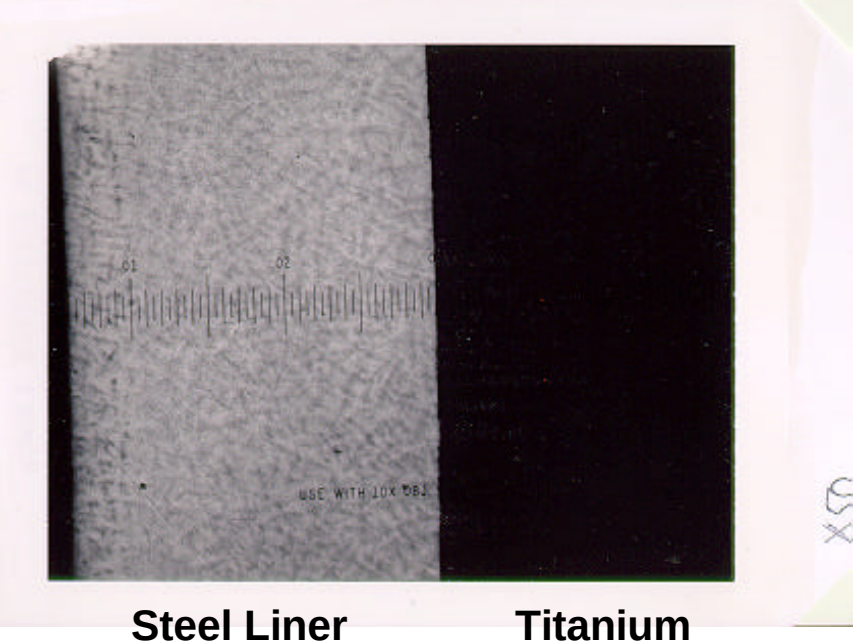
Muzzle End Section



Steel Liner **Titanium**

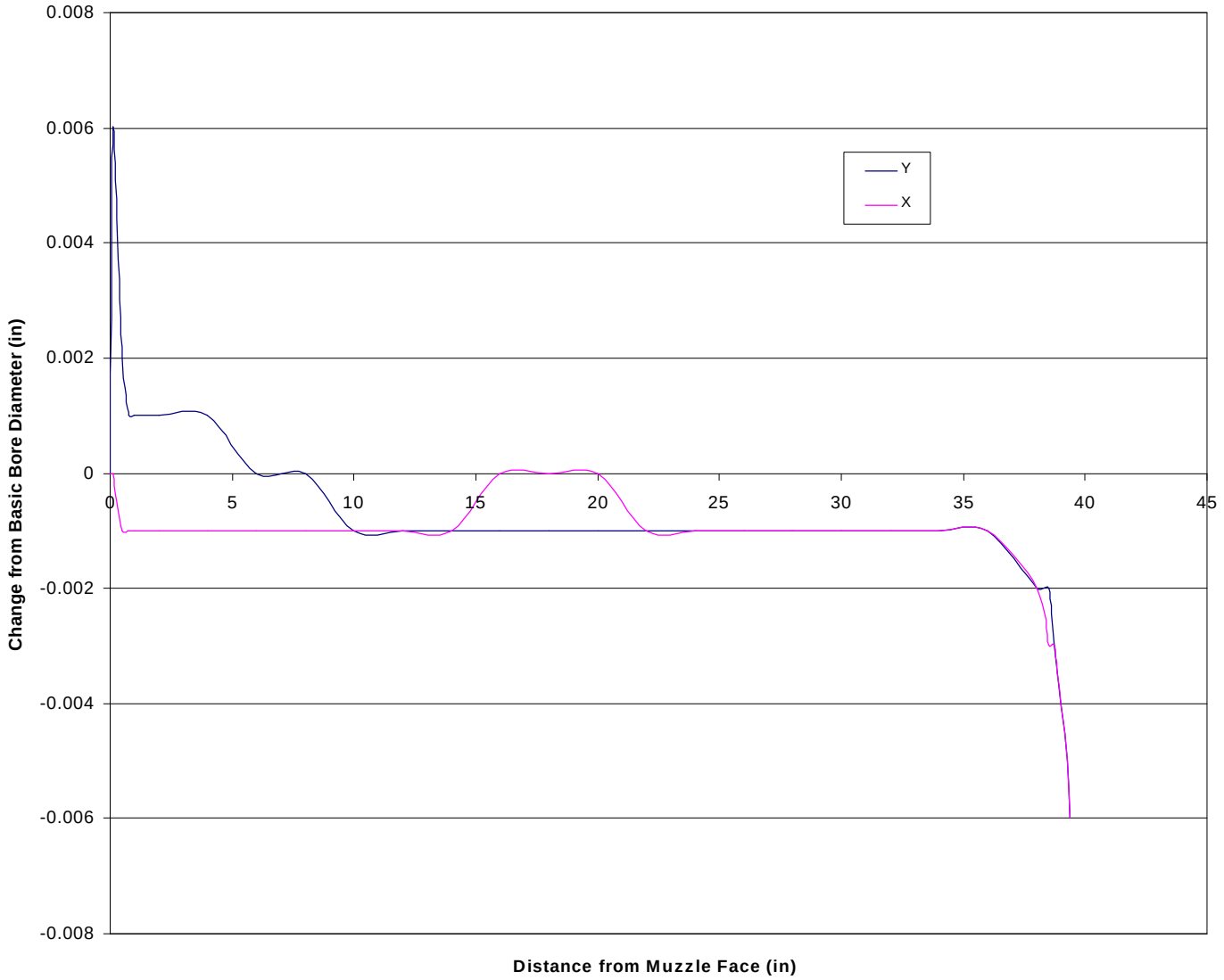
Gap

6 inches Rear of Muzzle



Steel Liner **Titanium**

Star Gauge Measurement of Assembly



Status

- Barrel fabrication & assembly at Watervliet
  - Maraging steel liner machined
  - Rough Machining of Ti sheath completed
  - Delivery expected August 12
- BAD fabricated in-house
  - Ti-6Al-4V (locking ring, nut, and collet)
  - Ti-6Al-6V-2Sn (cone)
- Maximum operating temperature test scheduled for completion in FY99