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37th Annual NDIA - Gun & Ammunition Symposium

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SBIR Phase II Grant

"Gun Tube Liner Erosion and Wear Protection"

- **Robert F. Lowey - Prin. Investigator, TPL Inc.**
- **Sponsored by Drs. R. Reeber and D. Stepp, ARO**

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Phase I SBIR

"Advanced Method for Manufacturing Erosion Resistant Gun Barrels"

- **Funded by the Army Research Office and Sponsored by Dr. Robert Reeber, ARO**
- **Tom Schilling, Prin. Investigator - TPL**

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Phase I SBIR results:

- **Developed a Unique Explosive**
- **Demonstrated Ta Cladding in 120 MM Smoothbore Tubes**

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Phase II SBIR Objectives

- **Transfer 120 mm cladding technology to 25 mm gun barrels and...**
- **Demonstrate feasibility of refractory metal clads in gun barrels by fabricating and field testing to failure a 25 mm gun barrel**

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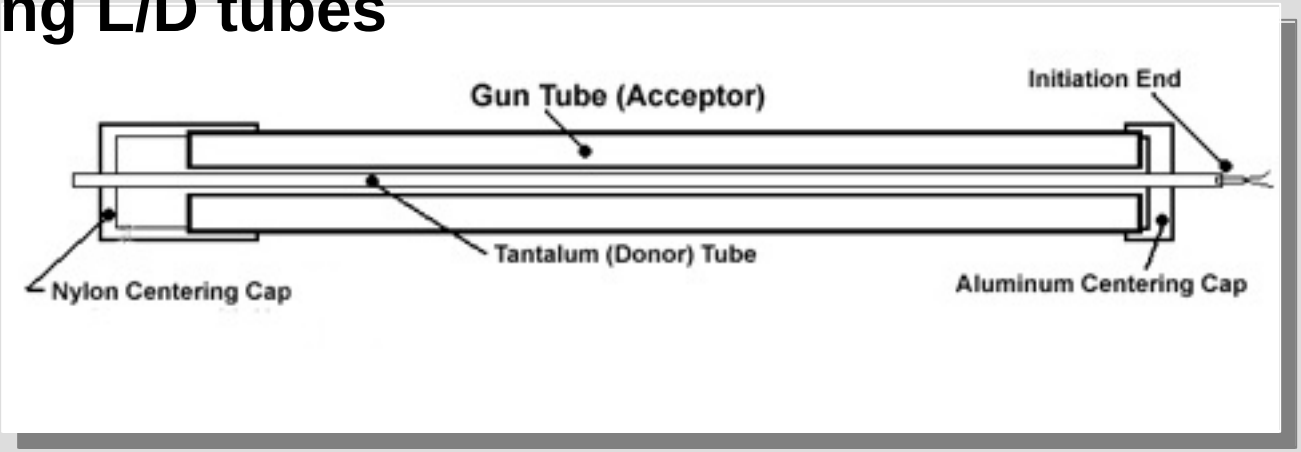
Phase II

- **Development of explosive formulation for small diameter bores**
- **Development of method for cladding long L/D tubes**



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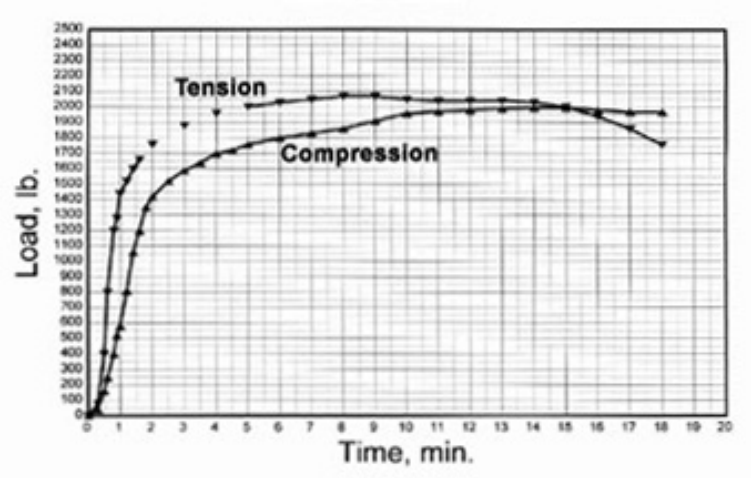
Excellent Bond Strength

- **3 - point bend tests**
- **Pull out test**

Guided Bend Tests



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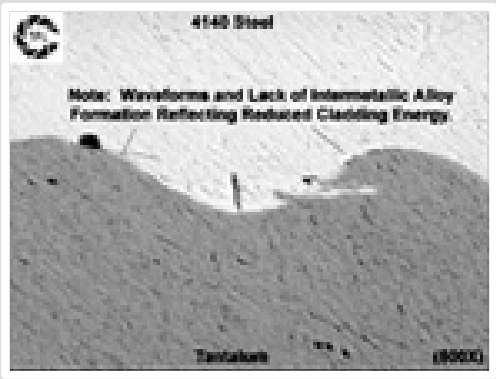
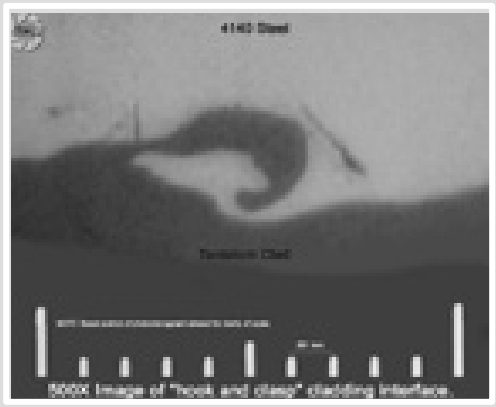
Tailorable Explosive Formulation

- **Variable energy input for:**
- **Different metals & thicknesses**

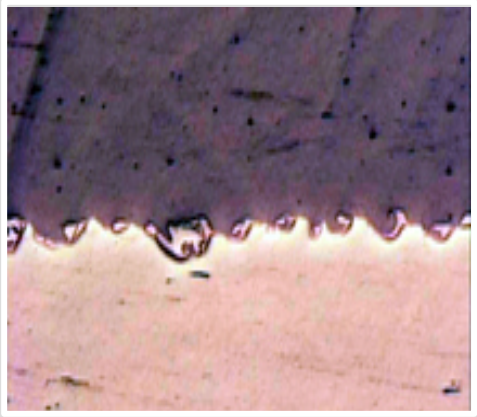


New waveform



Old waveform

Early Interphase



- **Control waveform and interphase alloy creation**

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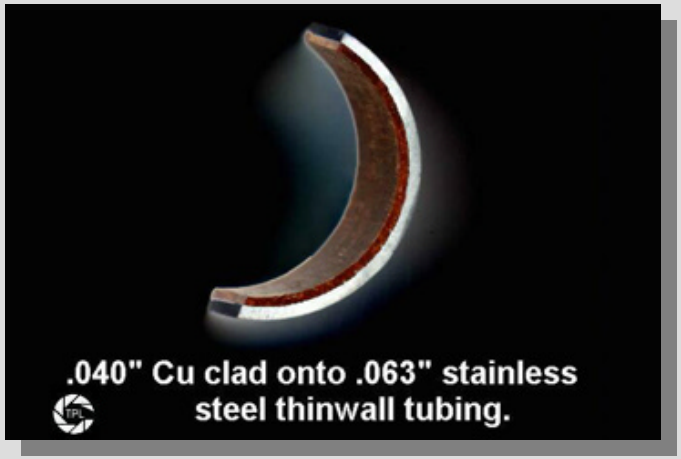
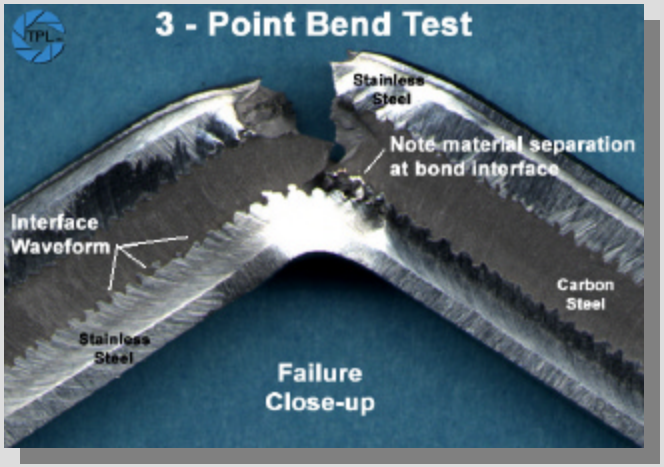
Other Phase II *Developments*

- **Thin-wall Cladding**



- **Bi-metallic Clads**



- **Implosive Cladding - Penetrator Rods**

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Late Program Re-Direction

- **Original Partner had IRAD Funding Shortfall that Would Not Allow for Testing as Planned**
- **Alternative Plan Developed with ARL/NSWC**
  - **Utilize Scrap Bushmaster Barrels**
    - Drs. Reeber & Stepp
  - **NSWC will Fund Testing at ATC**
    - Roger Ellis
  - **ARL will Provide M919 Ammunition**
    - Dr. Jonathan Montgomery

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Test Objectives

- **To Test the Erosion Resistance of Tantalum with the Most Erosive Ammunition Available**

- **Demonstrate the Bond Strength of Explosively Clad Bore Liners by Firing to Destruction**

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Test Barrel Design

- **Smoothbore Design Selected to Keep Focus on Test Objectives: Erosion Resistance and Bond Strength**
- **No-Twist Rifled Design Added to Assure Proper Sabot Confinement for Functionality of M919 ammunition**
- **Design Criteria from Dr. J. Montgomery - ARL**

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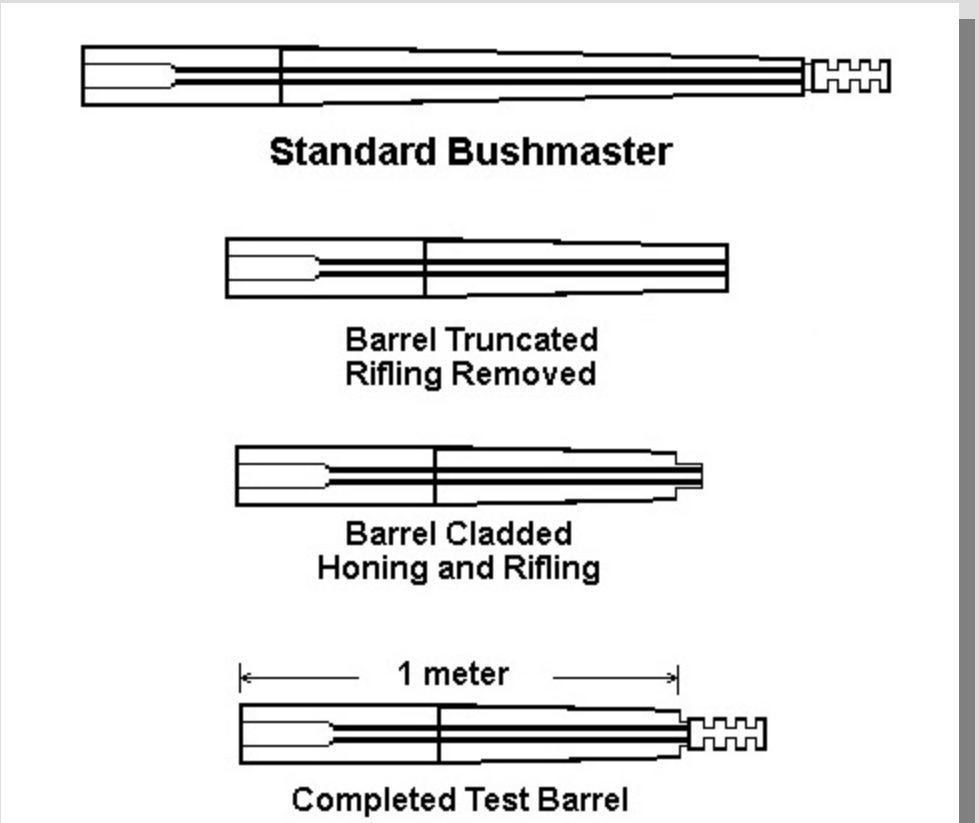
Test Barrel Design



Not Possible Utilizing Existing Barrels

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Test Barrel Design

- **Rifling Honed Out to ~ 27.15mm (1.069”)**
- **Tantalum Clad Approximate 1.02mm (0.040”)**
- **Smoothbore Design: Tantalum Honed Down to Wall Thickness of .8mm (0.031”)**
- **Rifled Design: Double Clad**
  - **Groove - Ta Thickness: 0.54mm (0.021”)**
  - **Land - Ta Thickness: 1.06mm (0.042”)**

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Endurance Test Ammunition

- **M919 (APFSDS-T)**
  Lot No. ADJ91D365-002
- **HES9053 Propellant**
  Flame Temp of 3692 K
- **ATC Obtained 1,985 Rounds from Primex for Tests**

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Endurance Firing Sequence

- **Cycle B Firing Schedule, 150 rounds/Cycle IAW TECOM 1-WE-100-BUS-050**

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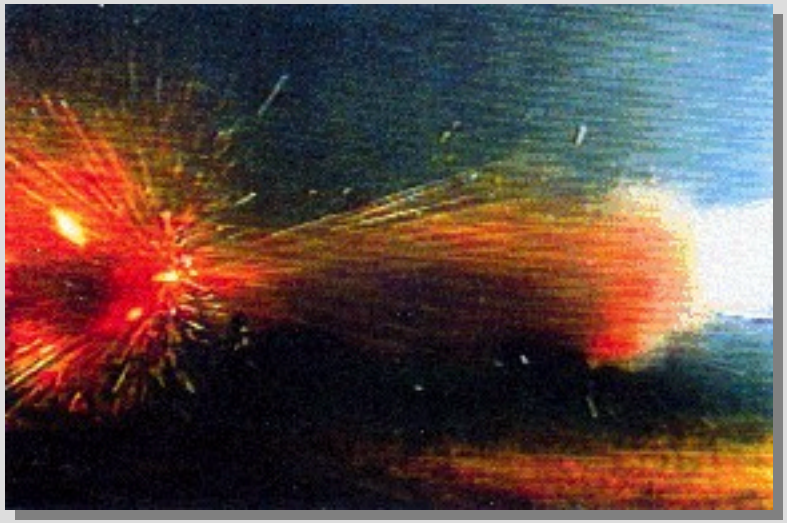
Endurance Testing - 1991

- **Std. Nitrided M242 Subjected to Identical Test Regimen**
- **Barrel Condemned after 229 rnds - M919**
  Barrel Shot to Destruction after 375 rnds



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Tantalum Clad 25mm Barrels

Tested March 26-31, 2001

at

ATC, Aberdeen Proving Grounds

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Test Results

- **Smoothbore Design:**
  - **Fired 1,385 Rounds**
  - **No Significant Increase in Dispersion**
  - **Barrel Still Considered Field Serviceable**

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Test Results

- **Rifled Design:**
  - Fired 600 Rounds
  - No Significant Increase in Dispersion
  - Barrel Still Considered Serviceable
  - Passed BG10 Barrel Bore Gage

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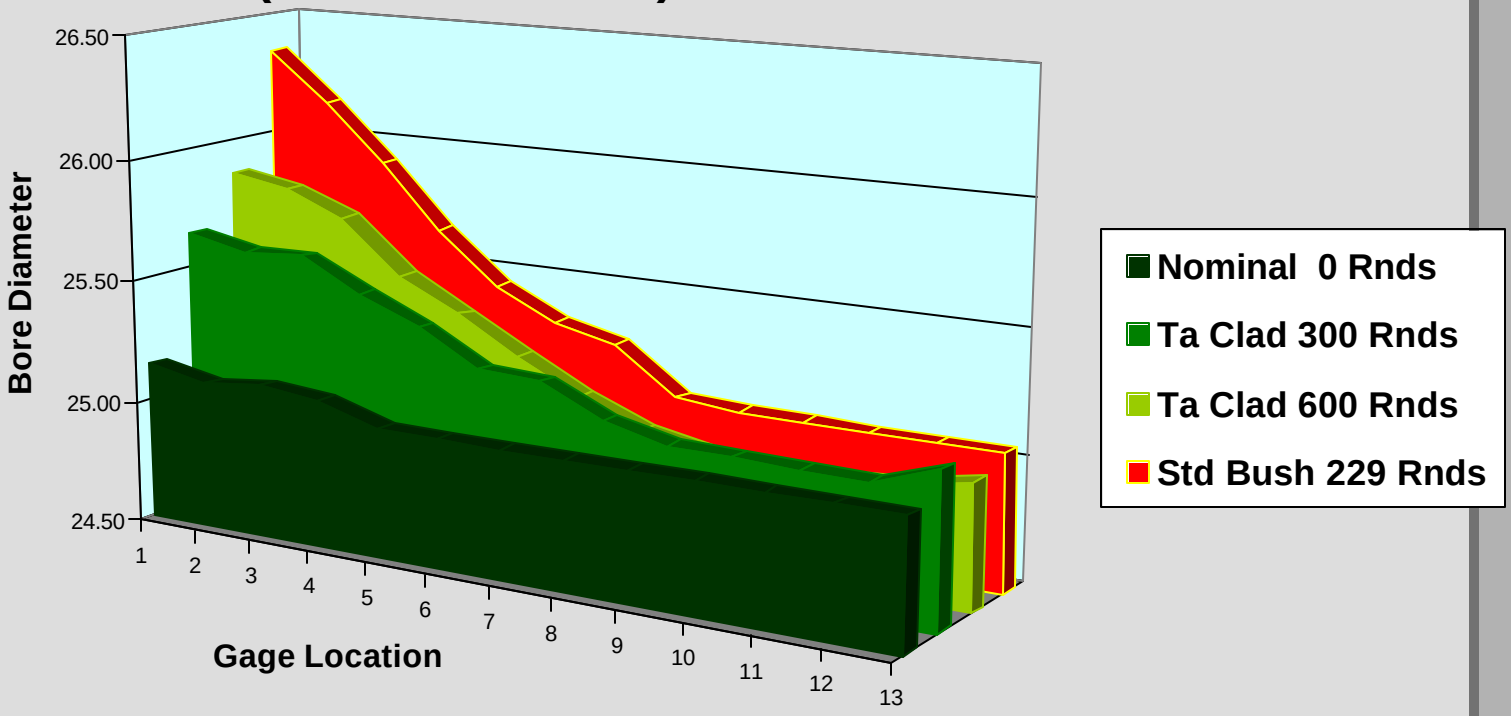
Rifled Design Test Results

Bore Wear/Erosion Diameters. Comparison: Ta Clad (No.C) vs. Std. Nitrided Bushmaster (Tube No.H12373) with M919 Ammunition



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Post Firing Analysis

- **Conducted by Benet Labs and Dr. J. Montgomery**
- **Forensic characterizations included:**
  - **Microstructural Analysis and microhardness**
  - **Adhesion Testing**
  - **SEM and EDS**
  - **Hydrogen Analysis**
  - **X-Ray Flourescence**
  - **Pulsed Laser Heating**

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Benet Labs - Recommendations

- **TPL's explosive bonding selected as"back-up risk mitigating technology behind (Benet's) CMS"**
- **TPL's explosive bonding recommended as primary candidate for medium caliber gun tubes**
- **Recommended TPL's sub-caliber test set-up as method for further alternative materials testing**
- **Explosive bonding is environmentally "friendly", <u>important</u> in view of Exec. Order 13148.**

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Current Efforts

- **Discussions with NSWC & UDLP for program With 5”62 Cal and AGS gun systems**
- **Phase I SBIR with ARL for a lightweight Mortar Tube**
- **Developing Phase II “plus up” with UDLP for Autofrattage Study**
- **IRAD for Cladding Over Rifling: 5” 62 Cal.**

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Future Efforts

- **Technical Challenges**

  - **Alternative Liner Materials**
  - **Autofrettage**
  - **Partial Clads**
  - **Rifling Design**
  - **Gun Tube Fabrication**

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Alternative Liner Materials

- **Goal is to obtain a balance between material costs and the anticipated service life of the barrel.**
- **Seeking alternative metals with reduced costs but that still offers significant improvement in barrel life and performance.**

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Alternative Liner Materials

- **Literature Search for Alt. Materials:**
  - **Physical Properties**
  - **Cost**
  - **Availability**
  - **Workability**
- **Laboratory Testing:**
  - **Strength of Bond Tests**
  - **Vented Combustion Tests**
- **Live Fire Testing:**
  - **Compare results with Ta Tests**

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Autofrettage

- **A series of test claddings will be conducted to answer the following questions:**
  - What is extent of dynamic and residual stresses created by the EB process?
  - Are the residual stresses additive?
  - Does it make a difference if the gun tube is autofrettaged before or after EB?
  - What are the effects of a partial clad in a gun tube?

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Partial Clad Design

Objective is to reduce costs with a liner clad only onto that portion of the gun tube bore which requires the most wear and erosion protection.

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Rifling Design

- **This task requires completion of Alternative Liner Materials study first.**
- **In conjunction with Navy gun tube designers, design steel “substrate”rifling that will support liner material in resisting the forces incurred projectile launch.**
- **Rifling design can be live fire tested in a 25mm configuration at ATC.**

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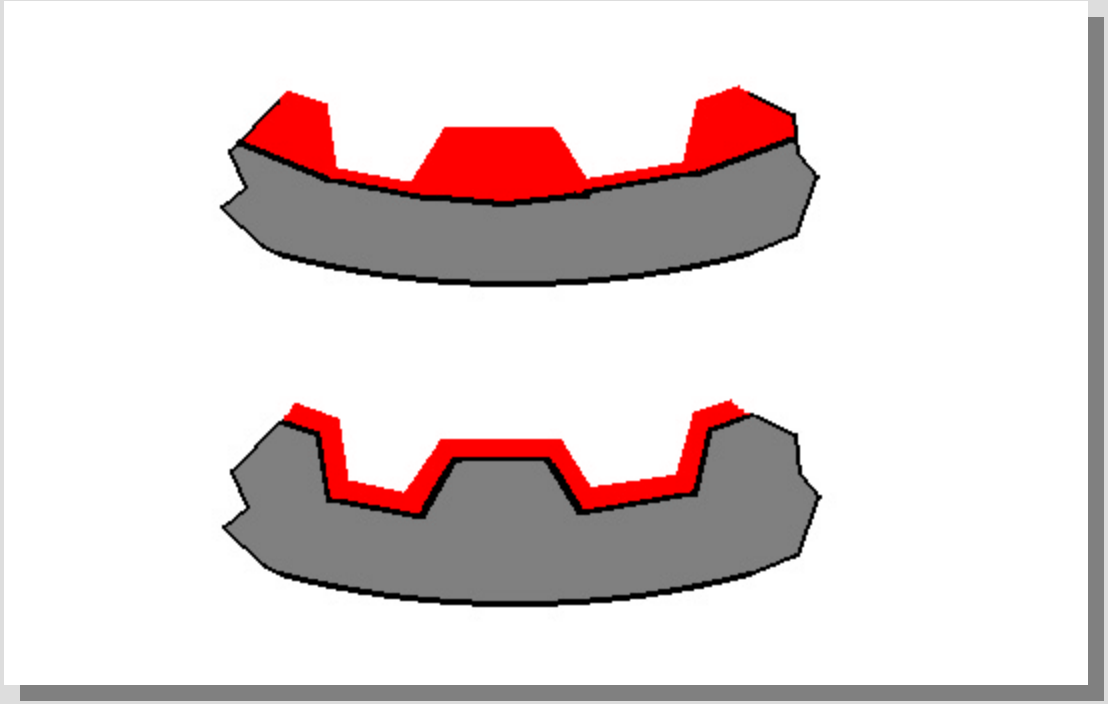
Rifling Design

Liner material over “substrate” rifling would provide the greatest strength for the lands.



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Prototype Gun Tube Producibility

- **This task will examine the necessary require-ments for expl. bonding in manufacturing cycle.**
- **Task important for future manufacturing design and for accurate cost estimations for production.**

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