Barrel Armor
more Firepower on target

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
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
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
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

Load lb.

Tension
Compression

Time, min.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
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Tailorable Explosive Formulation

- Variable energy input for:
- Different metals & thicknesses

Early Interphase

New waveform

Old waveform

Control waveform and interphase alloy creation
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Other Phase II Developments
- Thin-wall Cladding
- Bi-metallic Clads
- Implosive Cladding - Penetrator Rods

.040" Cu clad onto .063" stainless steel thinwall tubing.

Bi-metallic Clads
Tantalum on Copper on Steel

3-Point Bend Test
Failure Close-up

Interface Waveform
Note material separation at bond interface
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
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
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

Standard Bushmaster

Barrel Truncated
Rifling Removed

Barrel Cladded
Honing and Rifling

1 meter

Completed Test Barrel

Not Possible Utilizing Existing Barrels
Test Barrel Design

- Rifling Honed Out to \( \approx 27.15\text{mm} \) (1.069”)
- Tantalum Clad Approximate 1.02mm (0.040”)
- Smoothbore Design: Tantalum Honed Down to Wall Thickness of 0.8mm (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
Rifled Design Test Results

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

- Nominal 0 Rnds
- Ta Clad 300 Rnds
- Ta Clad 600 Rnds
- Std Bush 229 Rnds
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 Fluorescence
  - 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”, important in view of Exec. Order 13148.
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.
Future Efforts

- Technical Challenges
  - Alternative Liner Materials
  - Autofrettage
  - Partial Clads
  - Rifling Design
  - Gun Tube Fabrication
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.
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 the 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?
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.
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.
Rifling Design

Liner material over “substrate” rifling would provide the greatest strength for the lands.
Prototype Gun Tube Producibility

This task will examine the necessary requirements for expl. bonding in manufacturing cycle.

Task important for future manufacturing design and for accurate cost estimations for production.
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Std. 25 mm Bushmaster Barrel
Fired to Destruction
375 Rounds M919 APFSDS-T

TPL Inc. Ta Clad Bushmaster Test Barrel
Mid-Point of Testing: 300 Rounds
M919 APFSDS-T (Same Lot No.)
After 600 Rounds - Barrel Still Serviceable