Design and Application of Composite Rifle Barrels

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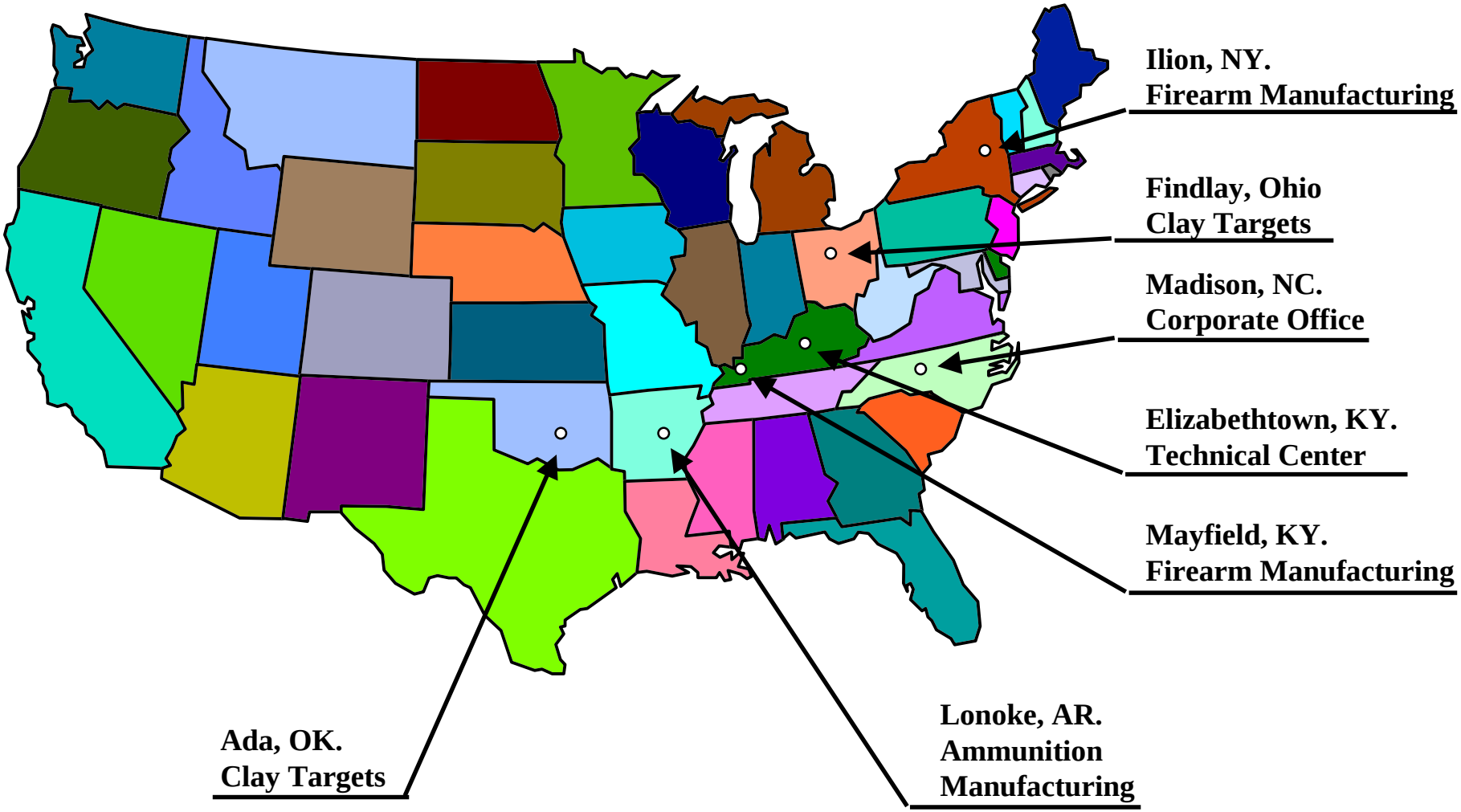

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The Technical Center

- **Established November 1994**
- **Dedicated to the Advancement of Sporting Firearms and Ammunition**

- **State-of-the-Art Facility**
  - Office Area
  - CAD Facilities
  - Laboratories
  - Short Range
  - Long Range
- **Diverse Expertise**
  - Mechanical
  - Electrical
  - Chemical
  - Computer Science
  - Material Science
  - Physics

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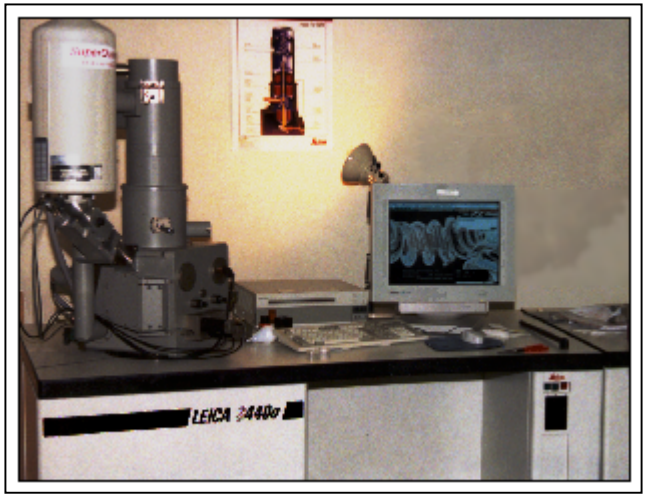
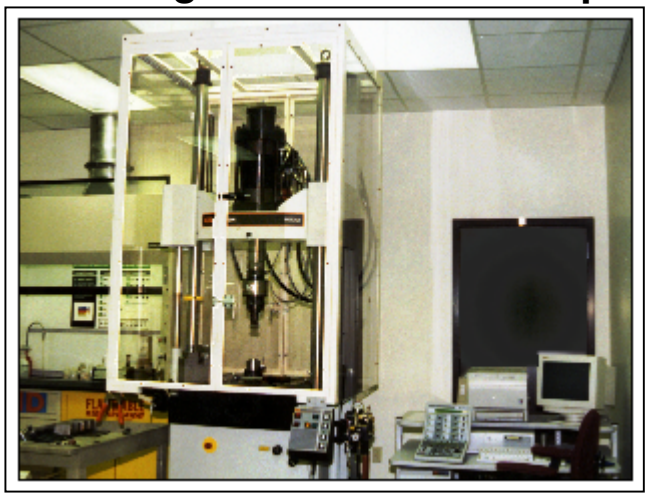
Technical Center Laboratories



Scanning Electron Microscope

Pressure / Velocity Short Range



Instron Tensile Fatigue Unit

Hand-loading Facility

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Technical Center Organization

Support & Research

- Direct Material Support
- CAD / FEA / Kinematic modeling
- Testing
- Applied Research
- Basic Research

Firearms Development

- Marketing / Product Engineering
- Design Acceptance Protocol
- Manufacturing Integration
- Manufacturing Support

Ammunition Development

- Marketing / Product Engineering
- Design Acceptance Protocol
- Manufacturing Integration
- Manufacturing Support

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RIFLE -- GENERAL TERMINOLOGY

- **Orientation Terminology**
  - Axial -- Parallel to the Major Axis of the Bore of the Barrel
  - Hoop -- Circumference around the Bore of the Barrel
  - Radial -- Radiating from the Centerline Perpendicular to the Outside Surface of the Barrel

- **6 Major Components -- Barrel >= 50% Total Firearm Weight**

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Traditional Rifle Enhancements

- **Reduced Weight**
  - Decreased Barrel Length
  - Decrease Barrel Diameter
- **Increased Accuracy**
  - Increase Barrel Length
  - Increase Barrel Diameter

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REMINGTON COMPOSITE BARREL HISTORY

- **1985 -- Plans to Prototype Composite Barrels**
  - Liner - Invar Material
  - Graphite Hand-Laid Composite Material
  - .22 LR Barrels (Biathlon Rifles)
  - Cost Prohibitive

- **1987 -- Center-fire Cartridge Prototype Composite Barrel**
  - Hand Laid-Up Graphite Fiber / Epoxy Composite Material
  - Exact Composite Material Unknown
    - Hercules Magnamite Material
      - AS1, AS4, AS6, IM6, HMS4, or HMU Type Fibers
  - Liner Design Unknown
  - Barrel “Exploded” on Firing 1 Proof Round
    - Metal and Graphite Fiber Fragments

- **End of Remington Involvement with Composite Rifle Barrels**

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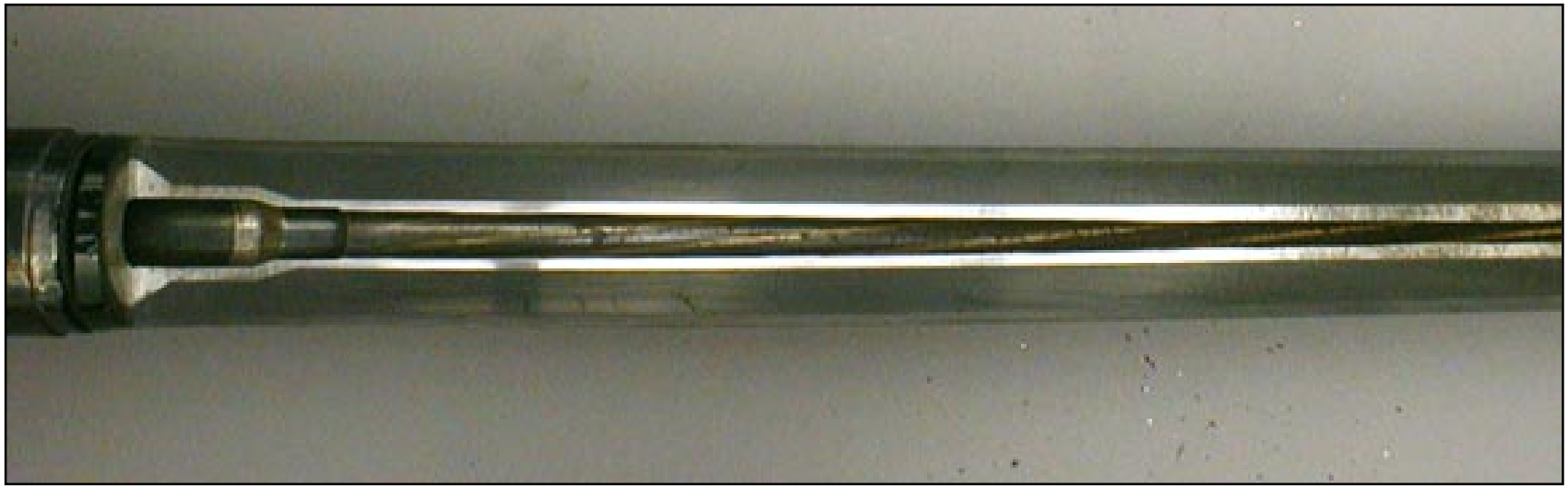
PHASE I OVERVIEW

- **Material System**
  - Composite Material
    - Fiber: IM7
    - Resin: 977-2
  - Liner Material
    - AISI 416 Stainless Steel
- **Concept**
  - Steel Liner
    - Maintain the chamber, rifling, crown
  - Composite Material
    - Provide HOOP (Bursting) strength
    - Provide Barrel Stiffness



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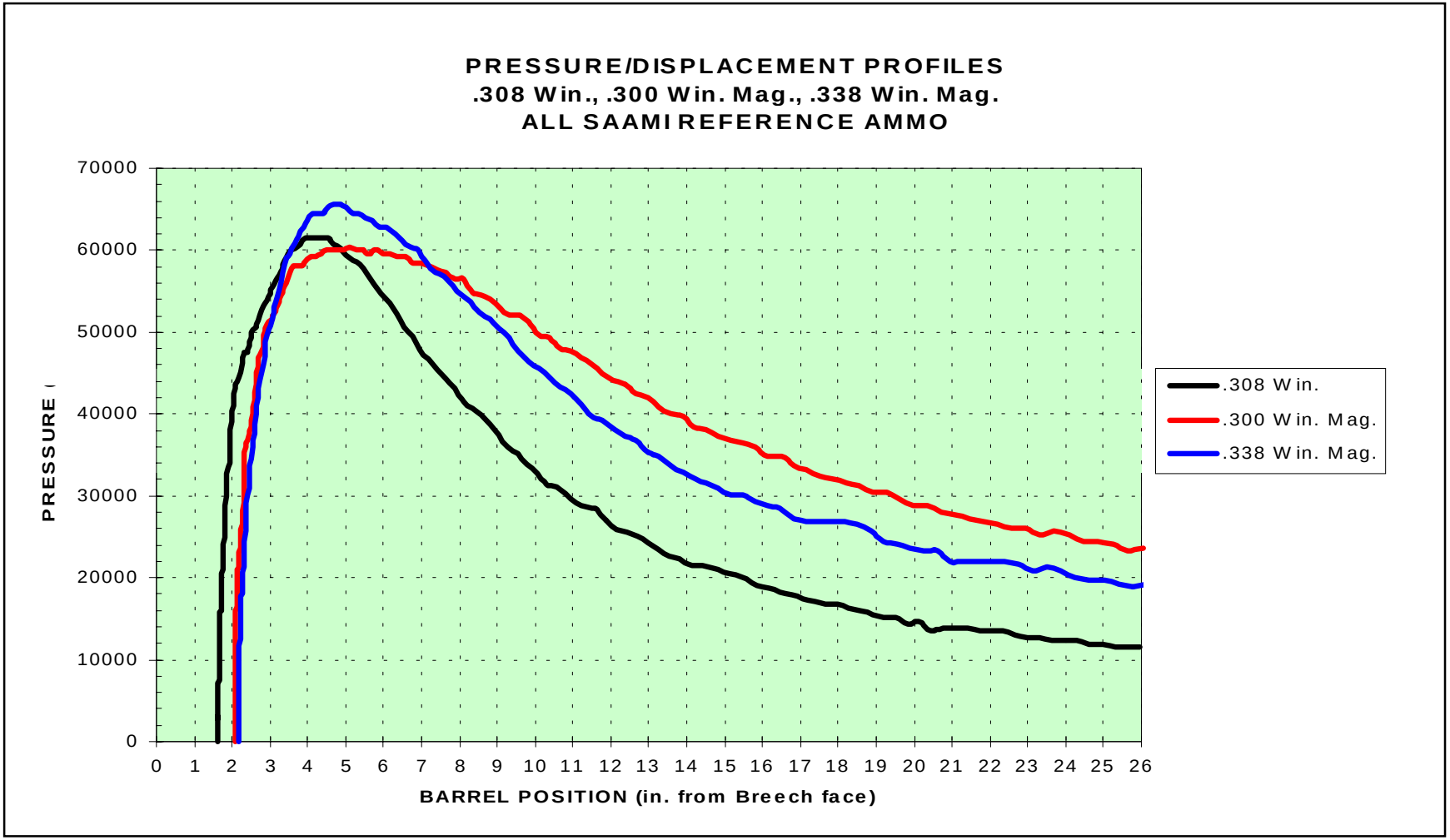
PHASE I
PRESSURE PROFILES



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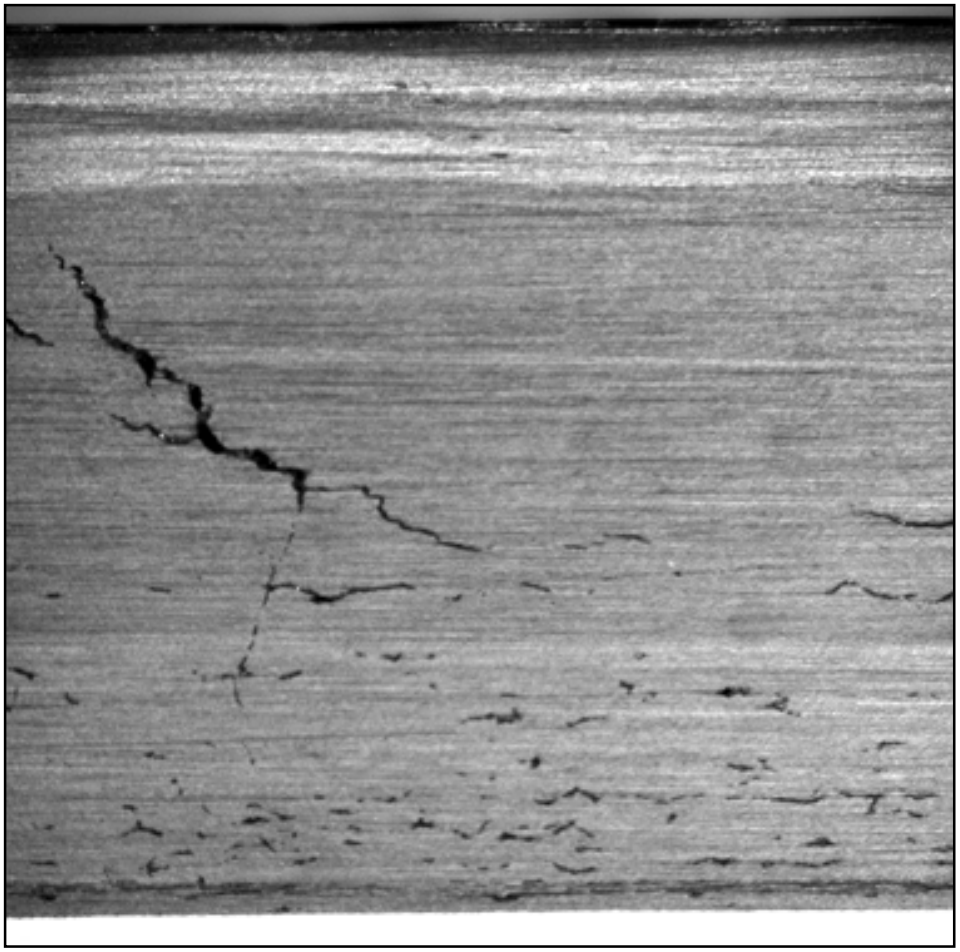
PHASE I



- **Objectives**
  - Maintain / Increase the Margin of Safety of the Composite Gun Barrel when Compared to the Steel Design
  - Maintain or Improve Bending Stiffness Down the Length of the Barrel
  - Reduce Overall Barrel Weight
- **Three Layers**
  - Steel Liner
  - Hoop Oriented Composite Layer
  - Axial Oriented Composite Layer

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PHASE I RESULTS

- **Manufacturability Issues**
  - Manufacturability of the steel liner
  - Wrapping and curing the composite onto the liner
  - Machining / finishing of the muzzle and composite material
  - Integration into the firearms manufacturing plant

- **Crack Propagation and Growth in the Composite Material**
  - 3 Layer Approach Provides Excellent Environment for Crack Growth
  - Absence of Crack Arrest Mophology

- **Fatigue of the liner**
  - Radial Stiffness - Fatigue Life Degradation
  - Excessive Head Space Growth
  - Chamber Expansion

- **Dis-Bonding of the Liner and Composite Material**
  - Composite Over-wrap “Walking” Off of the Barrel Liner

- **Barrel performance characteristics**
  - Accuracy Results Favorable

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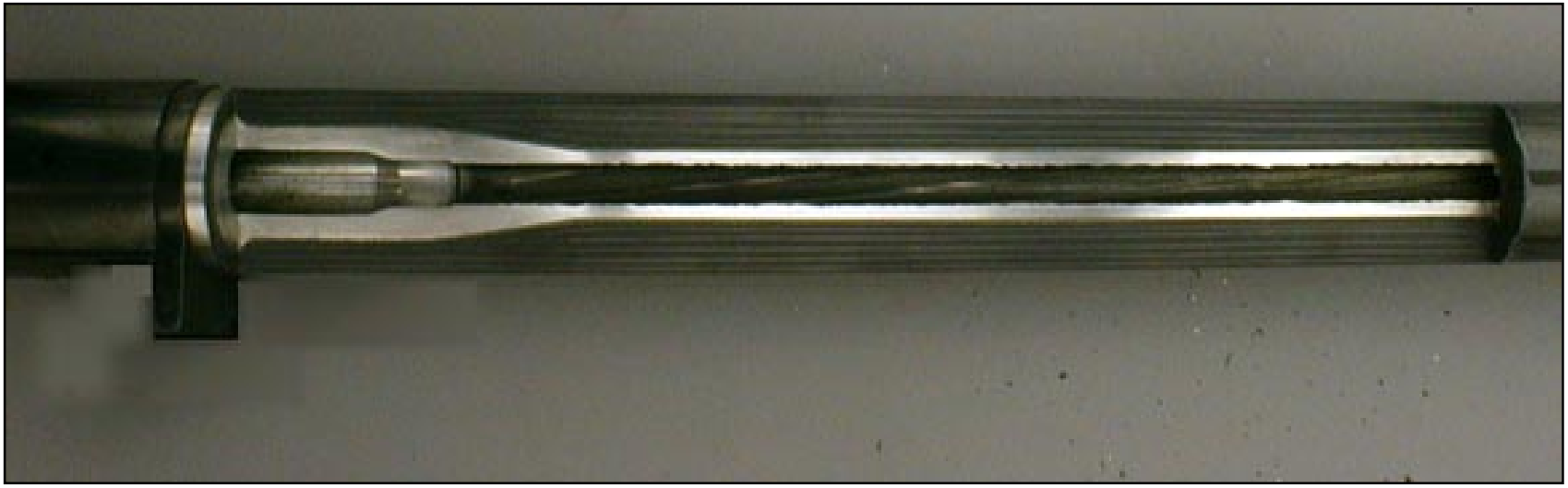
PHASE II OVERVIEW

- **Solve Problems Areas Identified in Phase I Testing**

- **Address Marketing Concerns**
  - Barrel / Receiver Interface

- **Complete DAT (Design Acceptance Testing) Protocol for all Proposed Caliber's**
  - Non-Magnum Design
  - Magnum Design



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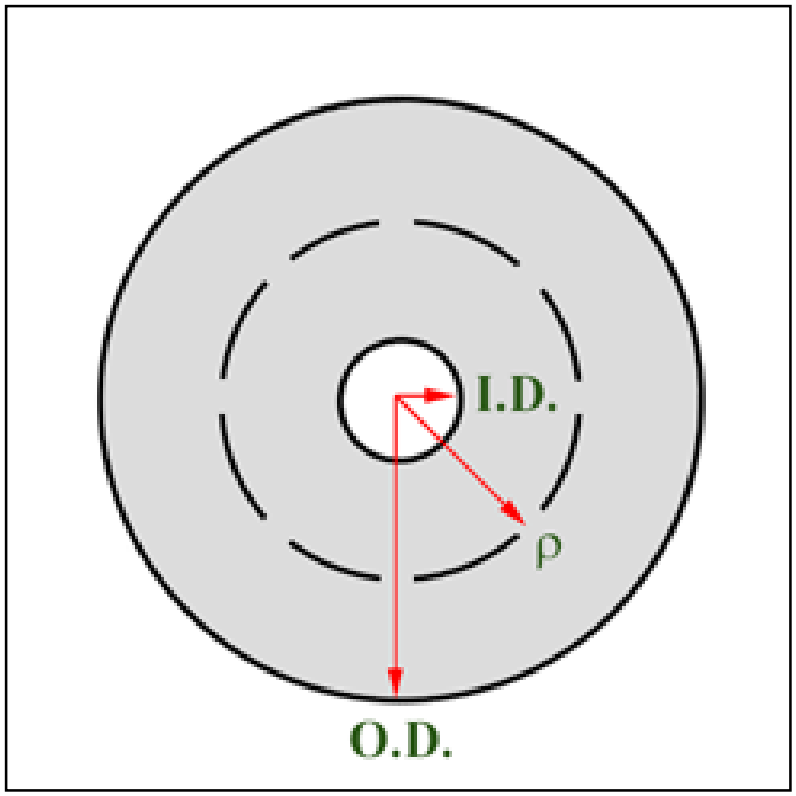
AUTOFRETTAGE

- **Autofrettage translates to "Self-Hooping"**

- **Napoleonic Age**
  - Steel technology not yet mature
  - Canon Barrels Hooped to operate at higher pressures
  - Similar to wooden barrels

- **Current Century**
  - "Built-Up" barrels
  - Sleeves of steel shrink-fit over the bore cylinder
  - Navy 16" guns

- **Modern Times**
  - Swage, Hydraulic, Explosive
  - Plastically deform the steel at/near bore surface
  - Drive plastic/elastic interface into the bulk material



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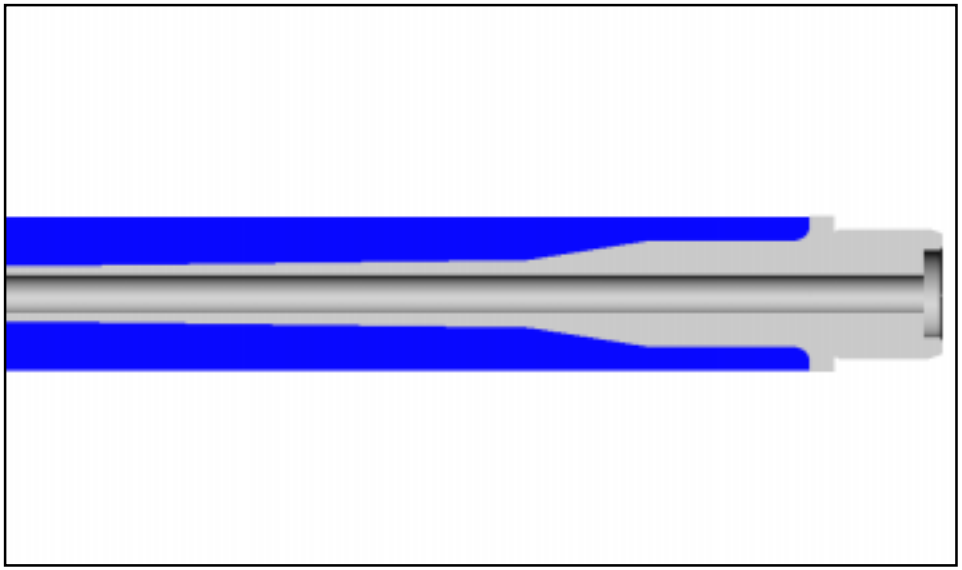
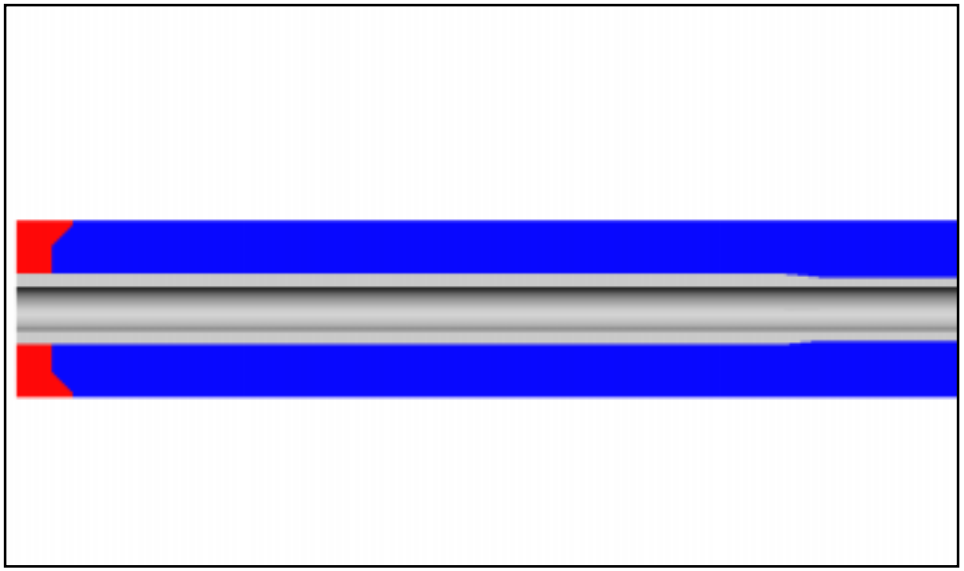
PHASE II LINER DESIGN

- **Liner Material**
  - AISI 416 Stainless Steel



- **Double Taper Liner**
  - Increase Radial Stiffness at Breech Area
  - Eliminate Head Space Growth
  - Decrease Stress Loads Distributed to the Composite Material



- **Reverse Taper Liner**
  - Mechanically Lock Composite to the Liner
  - Provide Surface to “Hold” the Barrel in Tension upon Curing the Composite

- **Muzzle Cap**
  - Protect Exposed Composite Material
  - Provides Platform for Muzzle Device Attachments

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PHASE II COMPOSITE DESIGN

- **Composite Material**
  - IM7 / 8552 System

- **Alternating Layer of Hoop (0°) and Axial (90°) Layers**
  - Hoop Layers -- Filament Wound
  - Axial Layers -- Unidirectional Prepreg Sheet

- **Layer Thickness / Dispersion**
  - Control Radial Crack Propagation and Growth
  - Control Crack Size by Fiber Orientation

- **Hold Liner in Tension / Composite in Compression upon Curing**
  - Expanded Liner at Cure Temperature
  - Composite Constrains Liner when Cooled to Room Temperature

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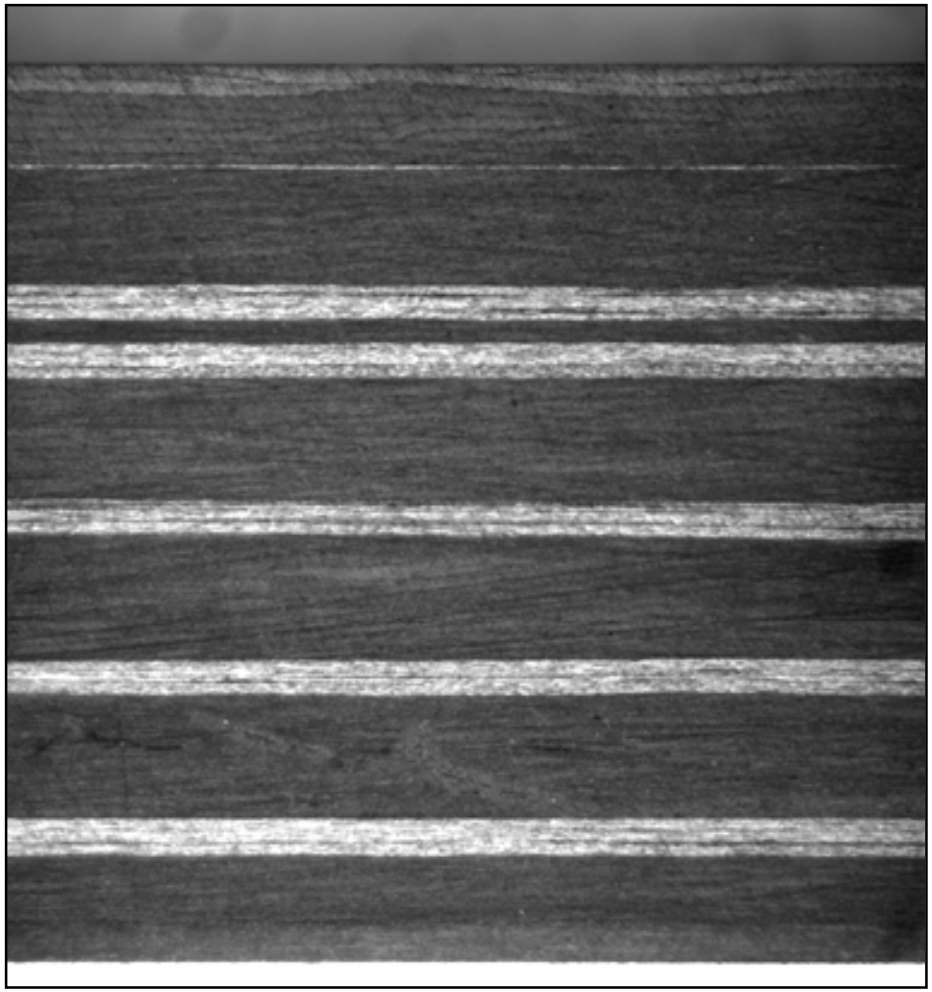
PHASE II



- **Minimize Cracks Created by Residual Stresses from the Curing Cycle**
  - Trade Secret Curing Cycle Process
- **Alternating Hoop and Axial Layers to Mitigate Crack Growth**
- **Exterior "Aesthetic" Layer**
  - 45° Filament Wound Exterior Composite Layer
- **Composite Machined and End Cap Assembled and Epoxied in Place**
- **Barrel Final Grind and Clear Coated**

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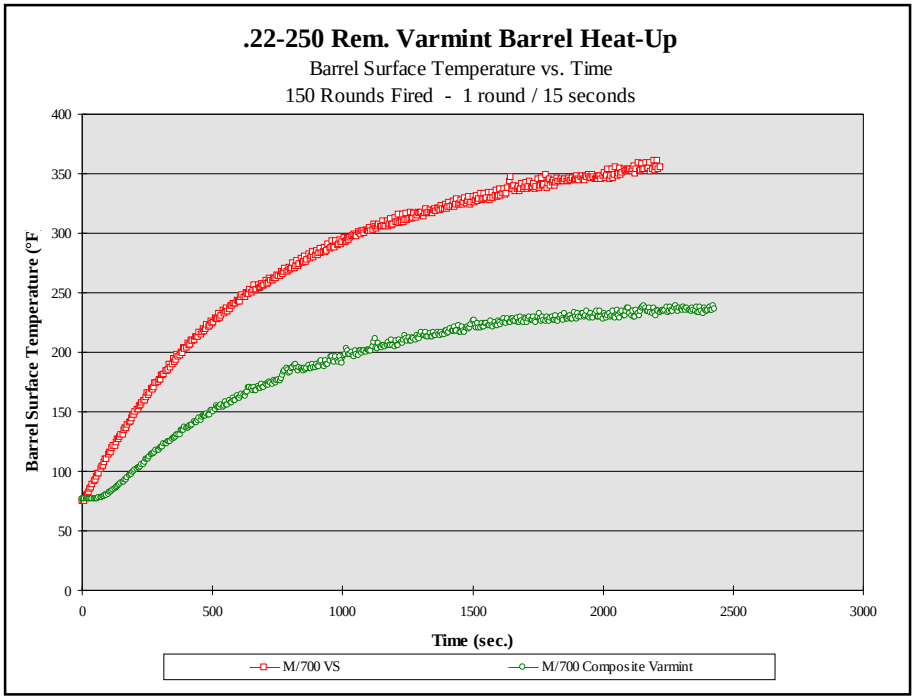
PHASE II RESULTS

- **Accuracy Characteristics Favorable**
  - All Average Group Sizes Less Than 0.8” @ 100 Meters, Standard Factory GFM Barrels, Current Standard Production Quality Liner.
  - Accuracy Held in Excess of 2,000 rounds (Compared to 1,500 Rounds for Standard Varmint Barrels)

- **Improved Heat Transfer Properties**
  - Increased Heat Transmission through the Composite Material
  - Larger Surface Area at the Exterior of the Barrel
    - Greater Heat Convection

- **Decreased Barrel Surface Temperature**
  - Cooler Barrel System



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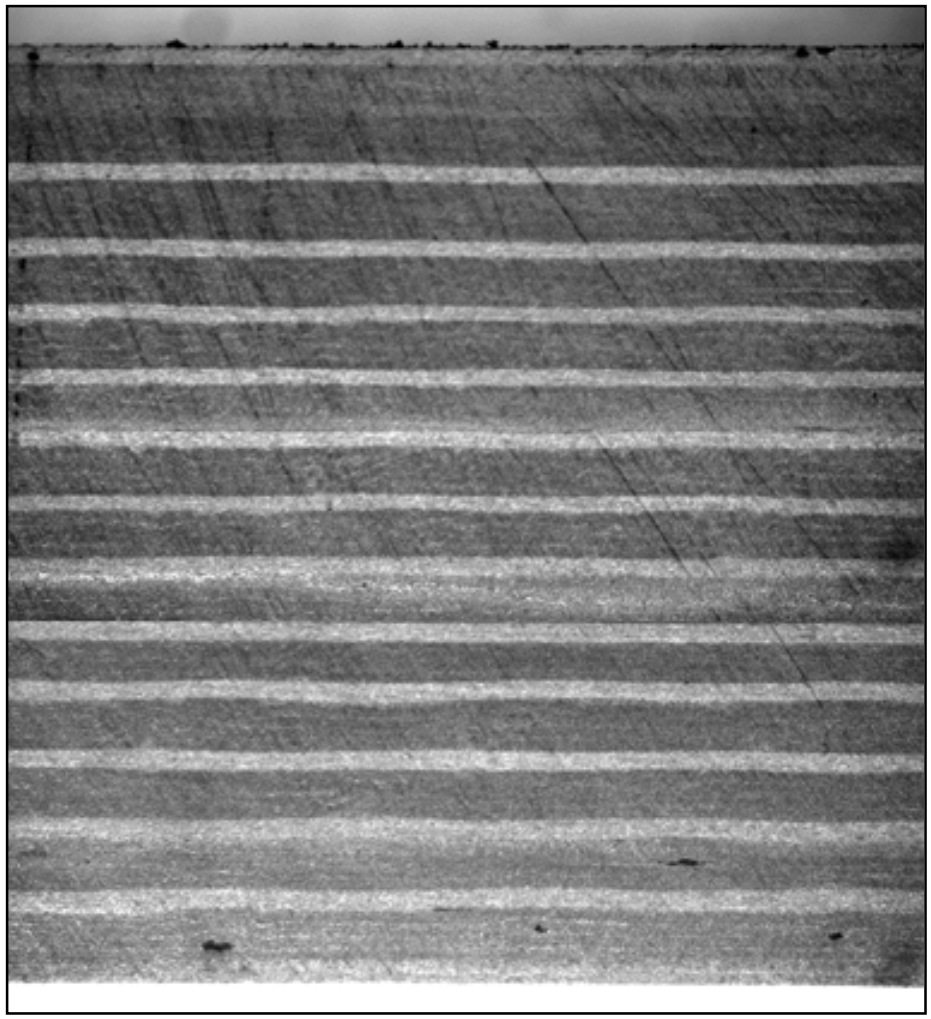
FINAL PRODUCT



- **Increased Volume Provide Better Grasp of Manufacturing Costs**
  - Increase the Number of Alternating Layers without Effecting Cost
- **CNC Cutting of Uni-directional Prepreg**
- **Multi-Spindle Winding Machine: High Volume Production**

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FINAL PRODUCT

◎ **M/700 VS COMPOSITE**

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