Bore Evacuator Corrosion on the M284 Cannon Tube

Presentation NDIA Joint Armaments Conference,
Exhibition & Firing Demonstration – Modeling & Simulation
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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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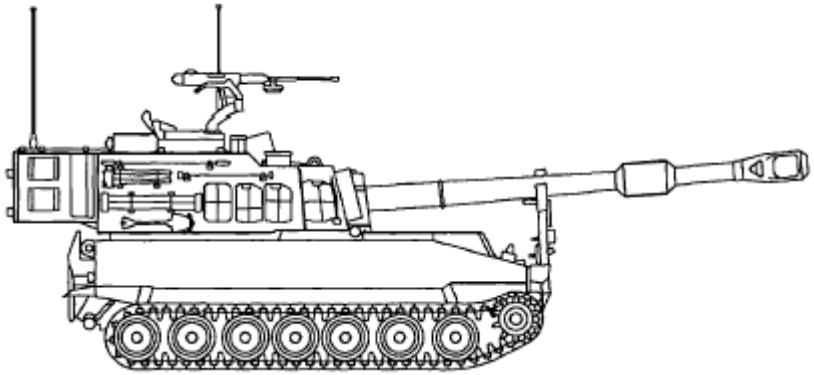
Agenda

- Benét Overview
- Background
  - Weapon
  - Future - PIM
  - Issues
- Criteria validation effort
- Results



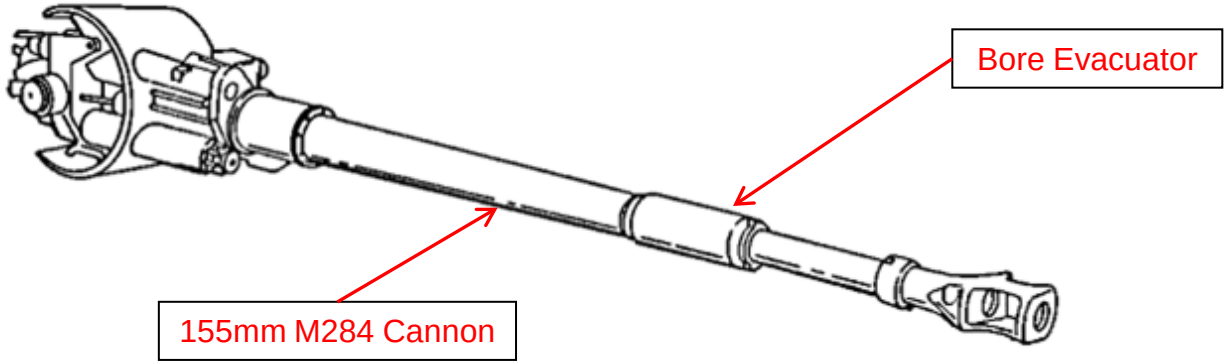
155mm M109A6

Benét Overview

- **Armament Designs**
  - Artillery, Tank, and Mortar Systems
  - Munitions Handling and Control Mechanisms
  - Turret/Cab Components, Mounts & Recoil Mechanisms
- **Advanced Prototyping**
  - Prototype processes from materials to tooling
  - RDA hardware generation via matrix with Watervliet Arsenal
- **Manufacturing Technologies**
  - Process, Material, and Producibility
- **Armament Technologies**
  - Fatigue and Fracture of Materials
  - Modeling & Simulation
  - Performance Coatings
  - Advanced Materials/Composites

Background

- 155mm M284 Cannon M109A6 Paladin Self-propelled Howitzer
- Paladin Integrated Management (PIM)
  - Modernization program for the vehicle platform
  - Utilizing the same armament as the M109A6
- Issues
  - Overhaul procedures uncovered numerous gun tubes with pitting in excess of condemnation criteria in the bore evacuator region.



Background

- Issues
  - Evacuator region configuration presented challenges to regular maintenance – not always performed
  - Storage practices have deviated from prescribed procedures resulting in excessive corrosion and pitting of the evacuator region

Bore Evacuator Region of Gun Tube

Heavily corroded Tube

Background

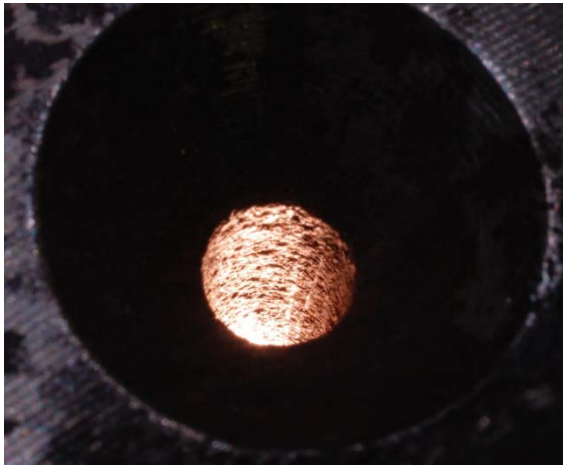
- Condemnation criteria
  - Pitting thresholds were published in associated technical manuals in 2006
    - Pitting or gouging thresholds are common for cannon tubes
  - Numerous tubes in queue for overhaul to support the PIM program displayed pitting in excess of criteria thresholds
  - An effort was launched to determine criteria validity

Current Condemnation Criteria 31 December 2006

Tube Area	Criteria	Method
Evacuator Holes	No pitting allowed	Visual
Evacuator Hole Chamfer	0.010 in. maximum pit depth	Reprorubber, NSN 9330-01-564-4432 See container for instructions
Tube Surfaces	0.100 in. maximum pit depth (bearing and non-bearing surface)	Reprorubber, NSN 9330-01-564-4432 See container for instructions

Criteria Validation Effort

- Objective – to determine if pitting in excess of criteria adversely effects fatigue life of the M284 cannon tube



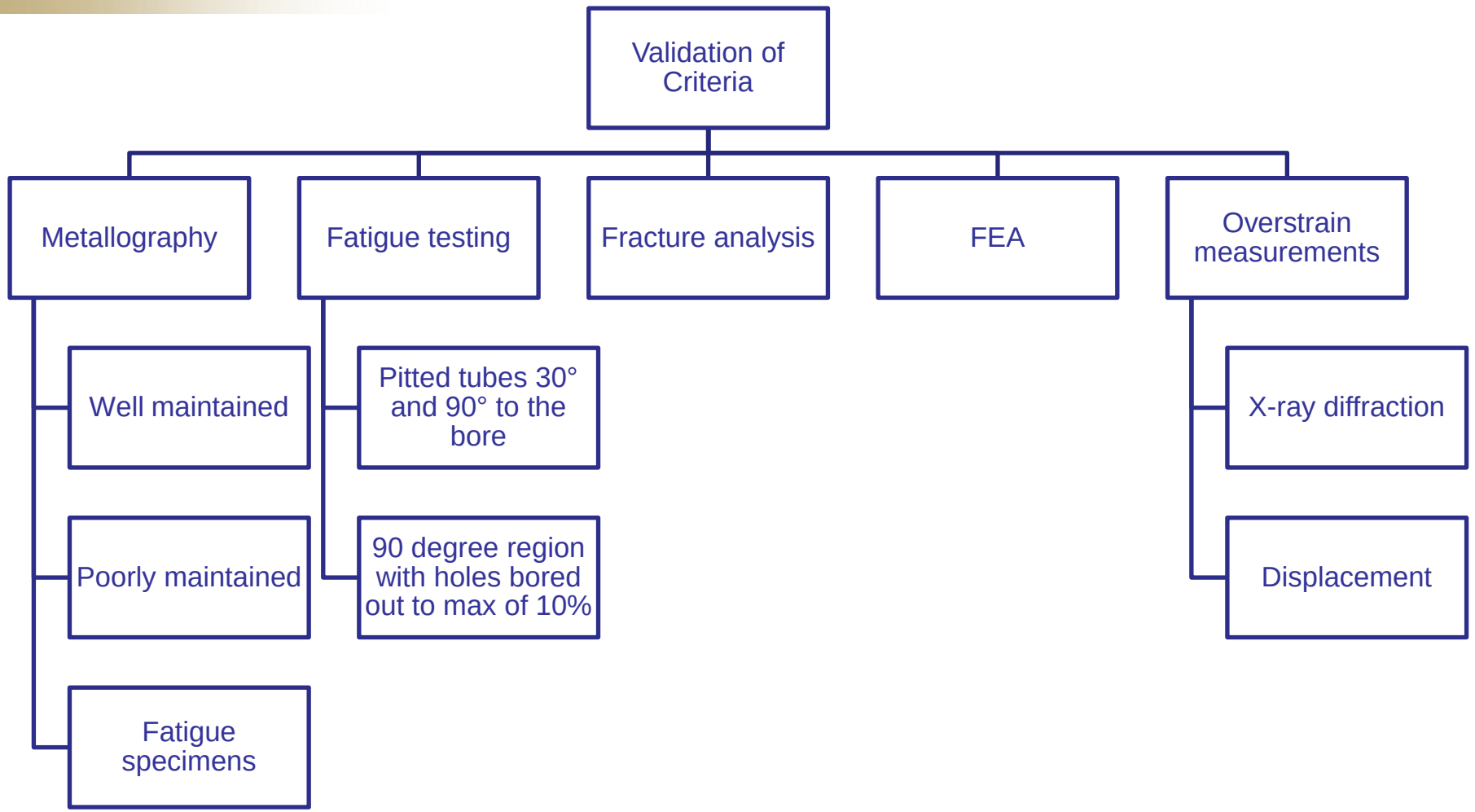
Method

- Field survey – determine condition of the fleet
- Fatigue test heavily corroded and pitted tubes to determine if fatigue life is affected
- Metallography to characterize the condition of well maintained and poorly maintained tubes
  - Pit depth
  - Environmental crack depth
- Fracture analysis to determine the critical region for fatigue crack propagation

Method

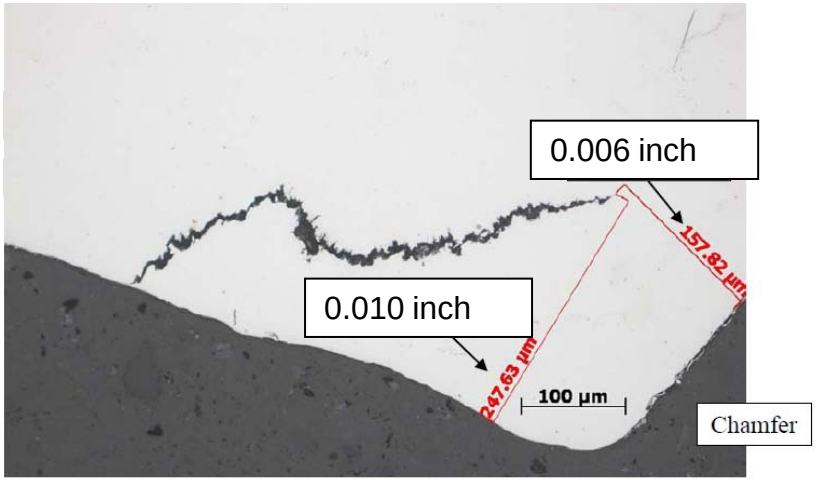
- Conduct finite element analysis to be validated with physical testing
  - Later used for reclamation feasibility analysis
- Fatigue life simulation to correlate with physical testing
  - Later used for reclamation configuration fatigue life estimates
- Overstrain measurements to determine residual stress gradients
  - To compare with FEA results

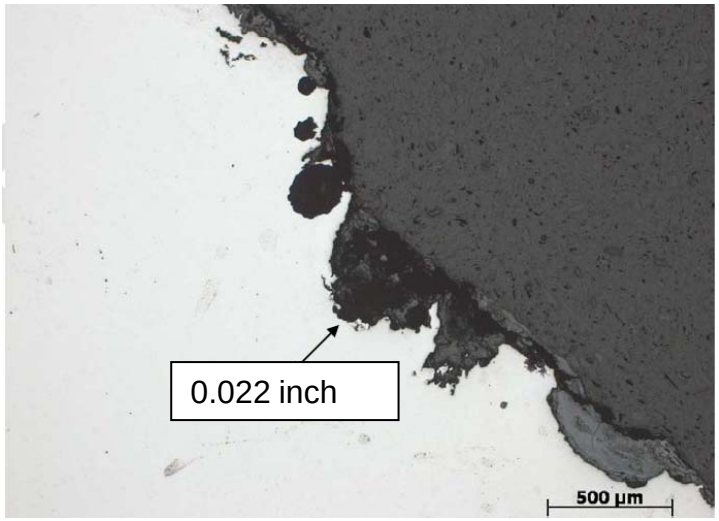
Snapshot of Benet Efforts

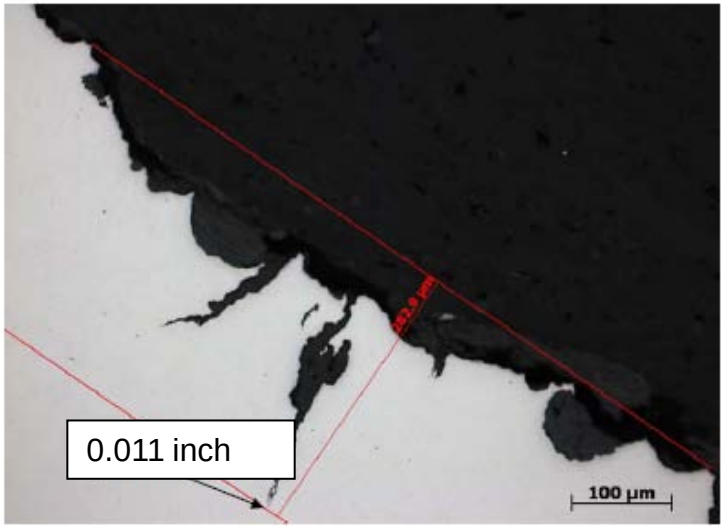


Metallography

Environmental cracking was found on the order of 0.030 inches primarily in the evacuator holes

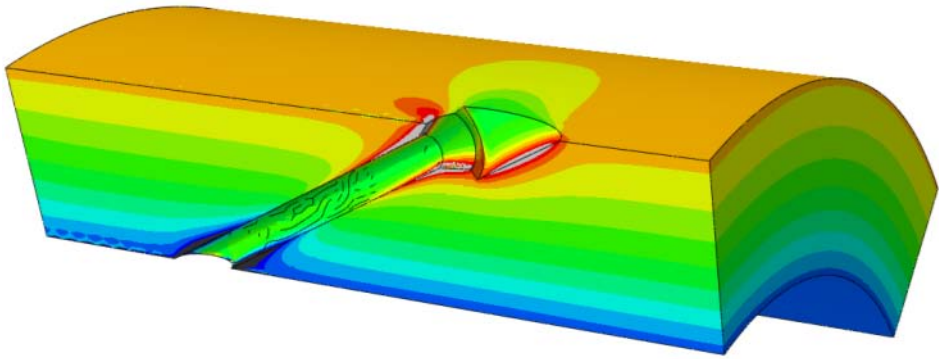


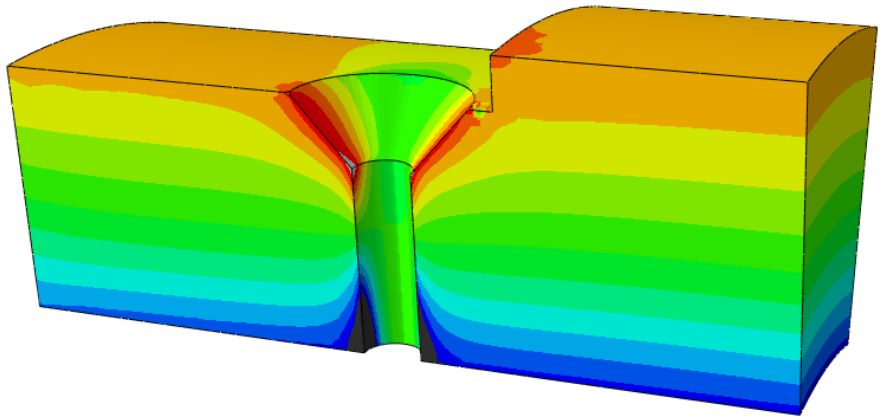




Finite Element Analysis

- Determination of critical region for propagation of fatigue cracks
  - FEA
  - Fracture analysis
- The critical region identified via FEA matched well with fatigue test specimen fracture surfaces



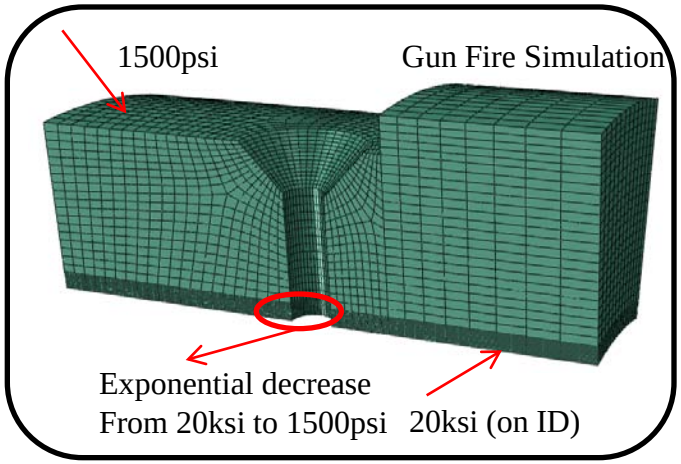


Finite Element analysis

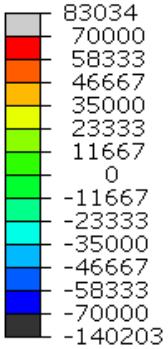
Material Properties:
E = 29.443e6 psi
ν = 0.28
σ_Y = 160 ksi
UTS = 185 ksi

OD Removal Study:

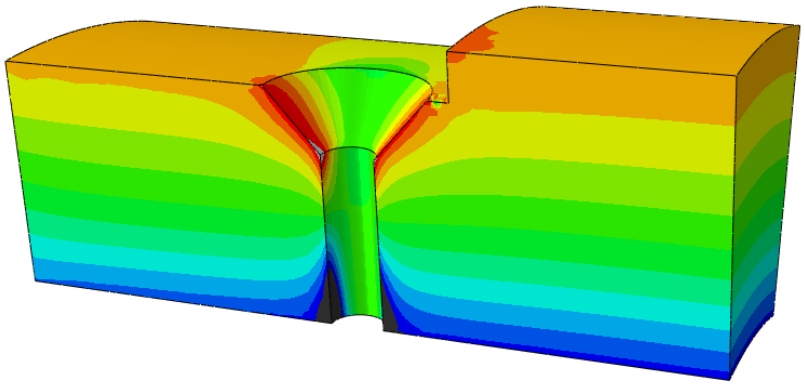
	ID
Base	ϕ = 6.20002”
0.05” shaved OD	ϕ = 6.20040”
0.1” shaved OD	ϕ = 6.20082”

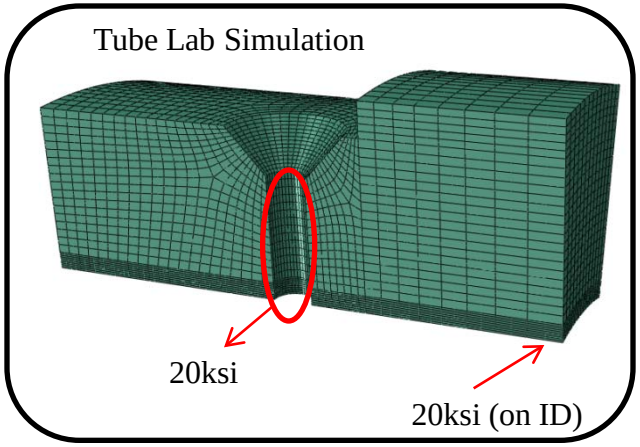


Hoop Stress



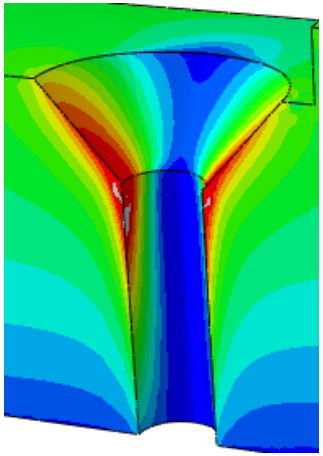
Residual Stress Profile

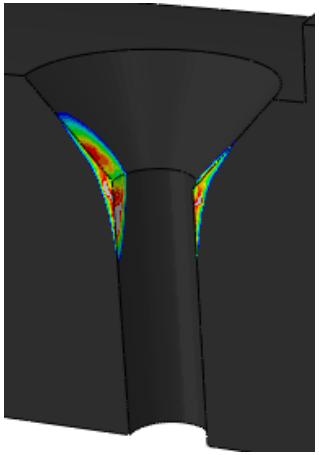


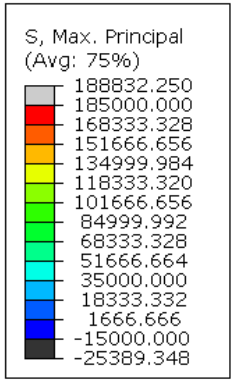


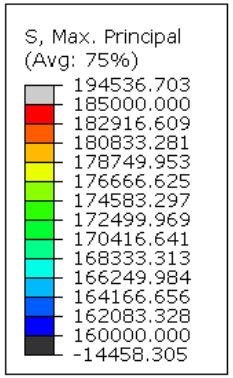
Finite Element analysis

Gun Fire Simulation

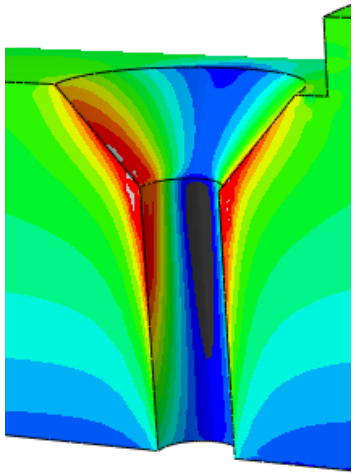


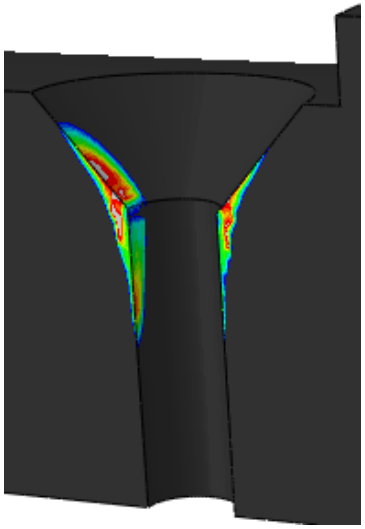






Tube Lab Simulation





Lower images show yield occurring in the colored areas

Validation of Condemnation Criteria

- Metallography
  - To determine pit characteristics
    - Depth
    - Shape
    - Surface density
  - Well maintained tubes – to determine if a significant difference of pit characteristics exist in comparison of typical corroded tubes
  - Fatigue specimens – metallography and failure analysis
    - To confirm failure mechanism of failed fatigue specimens
    - To determine initiation site of failure propagation

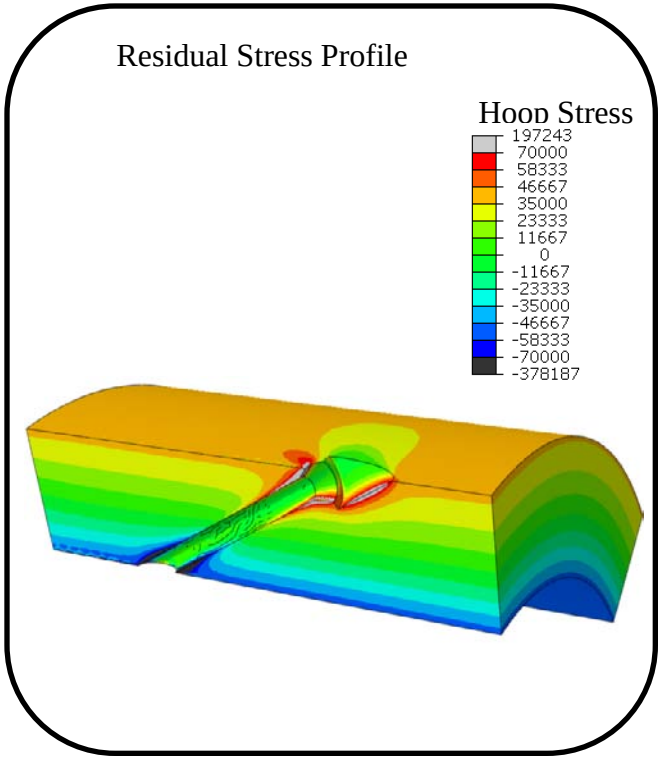
Fatigue Testing

- Goal
  - Fatigue test two severely pitted cannon tubes to determine if the current condition has an effect on Safe Service Life
- Purpose
  - Possible removal of hole pitting criteria

Fatigue Testing

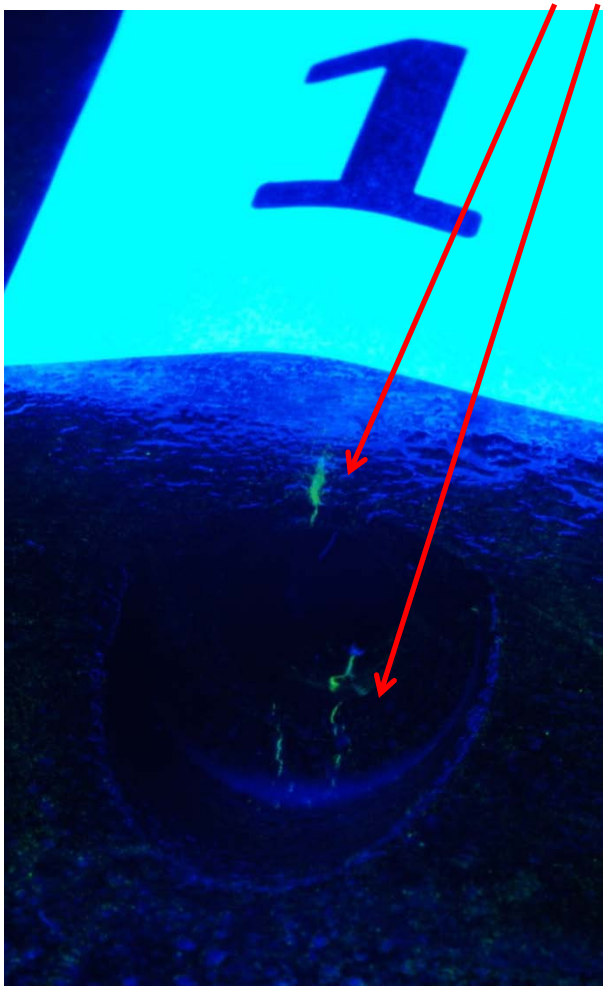
Fatigue Test Results

- Findings resulted in a Final Safe Life less than 50% of the original
- Results
  - Tube 1
    - Failure in 30° hole
    - Indications in all 30° holes
  - Tube 2
    - Failure in 30° hole
    - Indications in all 30° and 90° holes
      - 90° holes were not expected to fail (indicate cracking)

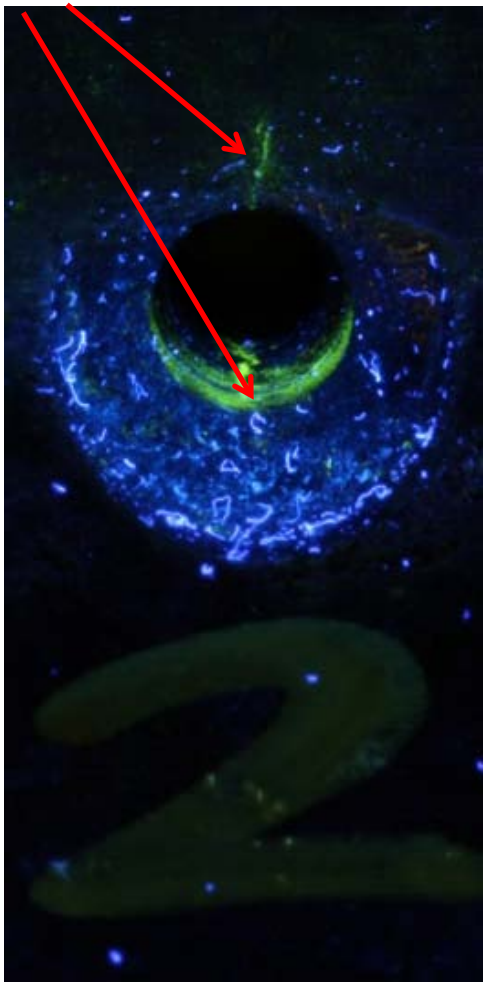


30° holes

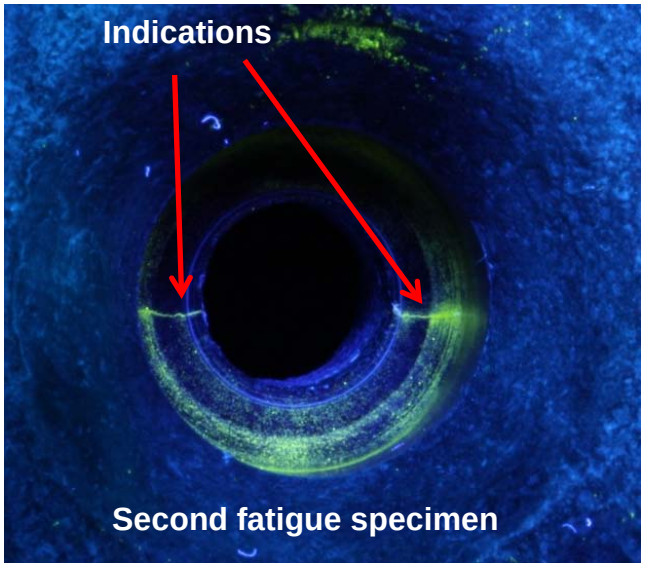
90° holes

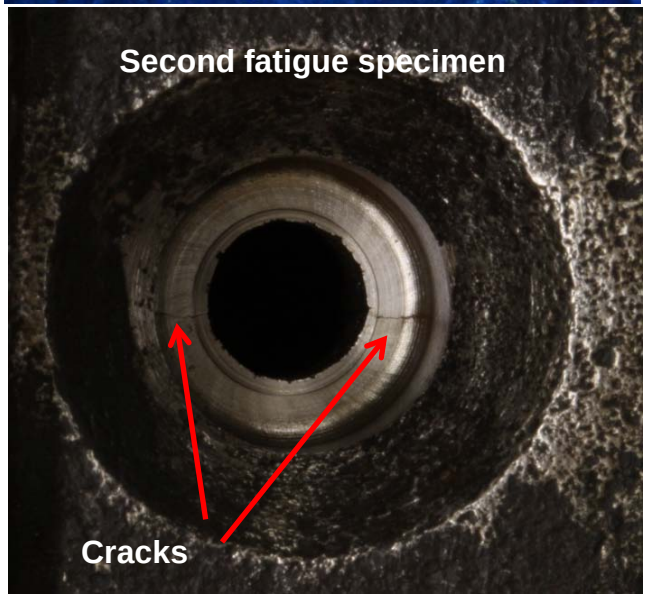


First fatigue specimen

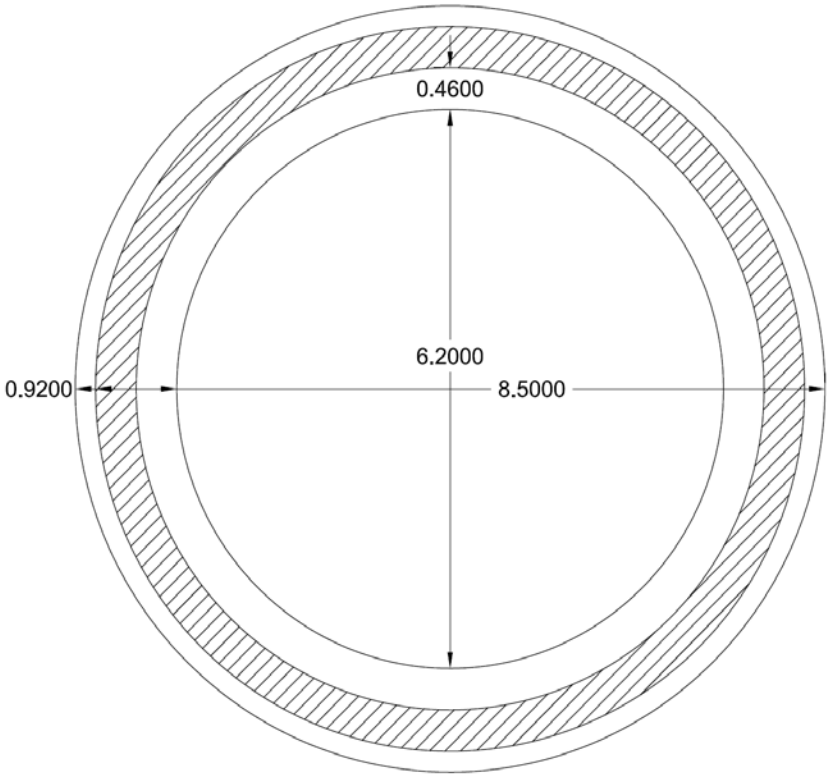


Second fatigue specimen



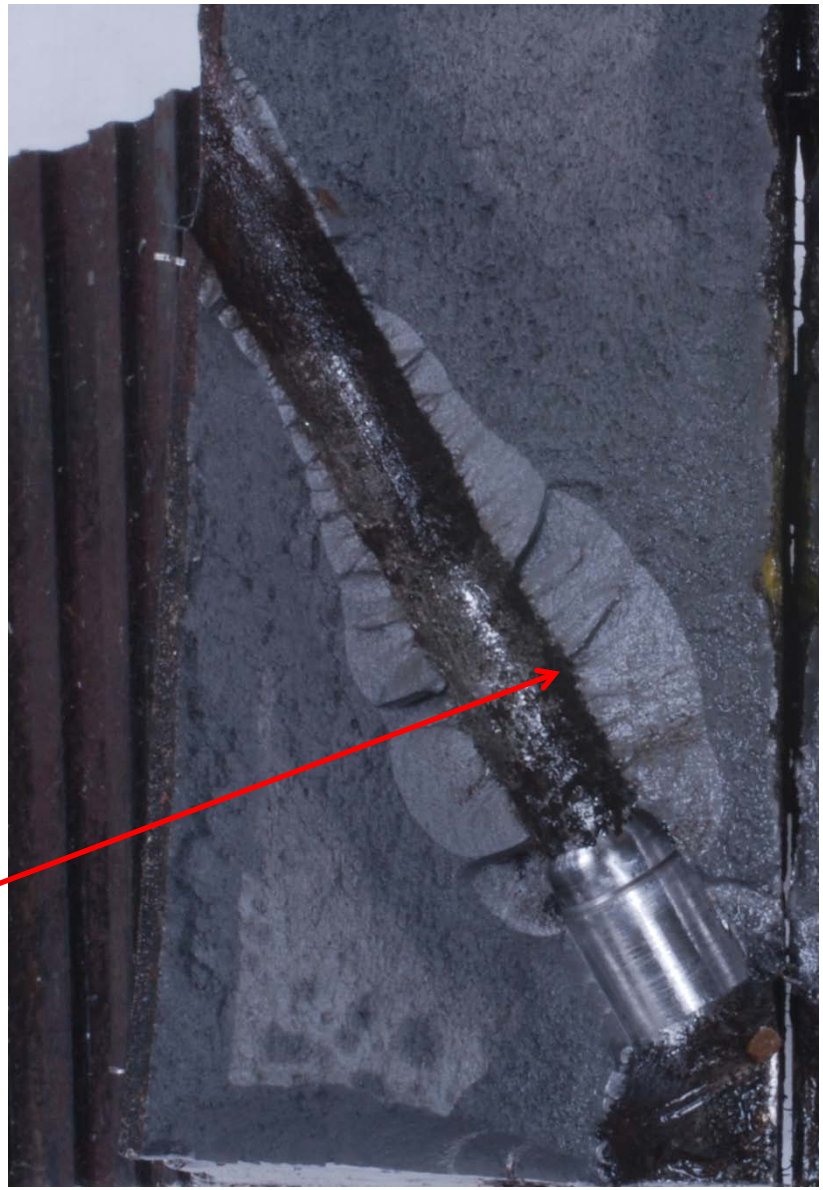


Fracture Analysis



Critical Region

Failure occurred within the predicted region at a corrosion pit with environmental cracking



Results

- Pitting in excess of current condemnation criteria concerning pitting in the evacuator region has been found to significantly effect fatigue life of the M284 cannon tube

QUESTIONS?

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