Development of an Ultrasonic Inspection System for the 120MM Case Base

Presented At

The National Defense Industrial Association
38th Annual Gun, Ammunition, and Missiles Symposium & Exhibition
25 March 2003

Art Skeates III
Alliant Techsystems
120mm M831A1 Cartridge Lead Engineer
M831A1 CARTRIDGE, 12944397

- CONTAINER, PROPELLANT
  - 12953553
- PROPELLANT, M14
  - 12956320
- RING, RETAINING
  - MS16624-3177
- SPRING, DISC
  - 12526678
- CASING, CARTRIDGE
  - 12944287
- CASE BASE AND SEAL ASSY
  - 12524833
- PACKING PREFORMED O-RING
  - MS9068-121
- ELECTRIC PRIMER
  - 12525143
- PROJECTILE HEAD
  - 12944394
- SEAL
  - 12944394
- RING
  - 12526248
- CAP CASE
  - 12526280
- STABILIZER
  - 12526954
- DISC
  - 12944392
- CUP AND TRACER ASSY
  - 12944424
- CLOSURE SCREW ASSY
  - 12524920

Public Release of this document is only authorized for this NDIA Presentation
Case Base

Manuf

- Forged from High Quality, High Strength Steel
- Heat Treated
- CNC Machined
- Dimensional Inspection
- **NDT Inspection (Critical II Characteristic)**
- Protective Finish / Inspected
- Injection Mold Rubber Seal Assembly
- Final Inspection
- Ship to LAP Facility
Case Base Perf
Requirements

- Requirements
  - Fit Gun Chamber
  - Obturation
    - Provide seal for pressures in excess of 100,000 PSI
      - Failure results in injury or death of Tank Crew
  - Soundness
    - No splits or cracks after firing
  - Extract from Gun After Firing
NDT History & Concerns

- **Steel Fabrication**
  - Forging and Heat Treat Processes can Potentially Induce Unacceptable Flaws

- **Magnetic Particle Inspection (MT)**
  - 100% TDP Requirement from onset of Program

- **Magnetic Particle Concerns**
  - Operator Dependent
    - Reliability, Visual, Fatigue, Certification
  - Numerous parameters to control and verify
    - Magnetism, Particle Concentration, Contamination, Black Light Intensity, White Light Intensity, Carrier Fluorescence
NDT History & Concerns (Continued)

- **Current Tank Ammo Contract**
  - Revised the NDT Requirements
  - 200% MT Required When Critical Flaw Rate > 1 in 40,000
  - Ultrasonic Inspection Required When The Critical Flaw Rate > 1 in 16,000
- ATK Decides to Procure An Automated UT Inspection System For Use As Its Primary Case Base NDT Inspection System
Primary Technical Challenge
- The Case Base Cross Section

- 1st Tank Ammo Production UT of Non-Uniform Cross Section
- 1st Tank Ammo Production UT of a Finish Machined Part
Key Decision
- ATK’s Supplemental Standards

- ATK Designed and Implemented the Use of Additional EDM Notch Standards to Maximize the Systems Inspection Coverage Area
  - Also Maximized the Reliability of Flaw Detection

- Typical Gov’t TDP & ATK Standards Notch Sizes

<table>
<thead>
<tr>
<th>Depth (mm)</th>
<th>Lengths (mm)</th>
<th>Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.28</td>
<td>6.1, 8.64, 12.49</td>
<td>0.18</td>
</tr>
</tbody>
</table>
Longitudinal EDM Notch Standards

Government TDP Required

9280443-G1

ATK Supplement

9280443-G2
Circumferential EDM Notch Standards

Government TDP Required  ATK Supplement
Automated UT System Development

- Selected a Supplier to Develop and Manufacture an Acceptable System
- Extensive support and coordination with supplier
- Two Weeks After Witnessing a Pre-ship Validation, Supplier Went into Voluntary Insolvency
  - Pre-ship Validation Identified Some Minor Issues but Performed Well, System Appeared to be 95+% Complete
- ATK Took Possession of the System and Proceeded on Its Own to Complete the Systems’ Development and Qualification
ATK Engineering and UT Expertise at Work

- **Time of Discovery**
  - Installed System in Factory, Discovered that Despite the Apparently Successful Pre-ship Validation, the System has Some Shortcomings that Require Significant Design Changes

- **Major Redesign of the Part Rotation System**
  - Consistent Rotation Speed Vital
  - Upgraded from 1 Drive Roller to 4 Drive Rollers
  - Optimized Roller Material and Configuration
  - Upgraded Base Plate Design to Reduce Rotational Friction

- **Redesign Resulted in Significant Improvement in the UT Inspection Performance**
ATK Engineering and UT Expertise at Work

- ATK’s Engineering Challenge
  - Numerous Additional Issues Discovered
    - Motion Control Code Errors
    - LabVIEW Data Acquisition Code Errors
    - Counter/Timer Circuit Fails (provides trigger pulse for UT instrument)
  - Inspection Coverage Area and Ultrasonic Transducers Inadequate
Case Base in Drive System
Redesigned Base Plate
Revised the Majority of the Ultrasonics
- Transducer Type, Location, and Orientation
- Redesigned the Transducer Scanning Heads and the Fixed Transducer Locating Brackets
- Revised and Optimized the Transducer Inspection Parameters
- Used ATK Designed EDM Notch “Coverage Standards” to Insure Proper System Performance
ATK Engineering and UT Expertise at Work
(continued)

- Replaced Light Duty Vertical and Horizontal Motion Tables with Heavier Duty Versions
- Upgraded and Revised the Motion Control Software to Eliminate Errors
- Upgraded Rotational Motor to Increase Available Torque Output
System As-Received
System Af Upgrade
ATK Pre-Validation

- ATK Performed a 27 Consecutive Hour Pre-Validation Test Run
  - 2 Gov’t & 2 ATK Standards Each Inspected 234 Times (7,488 Notches Detected at 100% Reliability)
  - 2 “Good Parts” Each Inspected 234 Times
    - < 1% False Rejects
  - Demonstrates High Reliability for “Critical Characteristic”
ATK Performs a 51 Consecutive Hour Government Witnessed System Validation / Qualification

- System Qualified!!!
- 2 Gov’t TDP & 2 ATK Standards Each Inspected 462 Times (14,784 Notches Detected at 100% Reliability)
- 2 “Good Parts” Each Inspected 462 Times
  - 4 False Rejects, 0.43%
System Design Features

- Fail-Safe System Design
  - Any Problems/Issues System Defaults to Reject Status
- Fully Automatic, Semi-Automatic and Manual Operation Modes
- PC Keyboard & Mouse used to Set-Up & Control the System
  - Full Access for System Level Administrator
  - Limited Access for Production Operator
- Automatic Second Scan When Defects are Detected
- Detailed Data Files (Calibration Standards & Flaws)
- Robust Design and Ease of Operation / Maintenance
- Periodic System Verification Utilizing Standards
### CALIBRATION REPORT

<table>
<thead>
<tr>
<th>Date and Time</th>
<th>02/19/02 05:01:31 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Lot</td>
<td>Validation</td>
</tr>
<tr>
<td>Component Type</td>
<td>Base Case</td>
</tr>
<tr>
<td>Component Ref</td>
<td>9280442 G1</td>
</tr>
<tr>
<td>Scan File</td>
<td>Scan2001.PRG</td>
</tr>
<tr>
<td>UT File</td>
<td>Final_Internal.st3</td>
</tr>
<tr>
<td>Flaws Matched</td>
<td>33 of 33</td>
</tr>
<tr>
<td>Extra Flaws</td>
<td>0</td>
</tr>
<tr>
<td>Status</td>
<td>PASS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Top Probes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flaw #</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
</tbody>
</table>
System Design Features (Continued)

- Self Feed Input Chute & Accept Chute
- Locked Reject Chute (Limited Access to Rejected Parts)
- Automated In-line “U” Acceptance Stamping
- Temperature Controlled Electronics & Coupling Media
- Filtering in Both the Upper and Lower Tanks
- Per Channel Instantaneous and Latched Visual Alarms
- Permanent Storage of Inspection History
- Extensive Use of Non-Metallic Pads/Guides/Etc. to Prevent Parts Damage
UT Inspection Specifics

- Horizontal Scanning of the Case Base Aft Face
  - 5 Transducers, 6 Tests
- Vertical Scanning of the Case Base Sidewall
  - 4 Transducers, 5 Tests
- Fixed Transducers to Inspect Specific Locations
  - 5 Transducers, 1 Receiver, 5 Tests
- Inspection Cycle < 1 Minute/Part
System Main Screen
Ultraeonic Instrument
System Alerts

**System Error**

EMERGENCY STOP
Release 'Emergency Stop' and press 'Control On', then click OK.

**System Logged Off**

To operate this system choose Log On.
To close the software choose Exit.
For both options, a valid password is required.

**System Calibration Required**

System Calibration Required.
Please place the calibration components in the inlet chute in this order:

9280442 G1
9280442 G2
9280443 G1
9280443 G2

Make sure no other components are in the inlet chute.
Click OK when ready.
Conclusion & Recognition

- ATK’s Determination and Resolve Has Resulted in a Significant Advancement in the State-of-the-Art NDT Inspection Method for the 120mm Case Base
- Special Thanks & Appreciation Go To:
  - Tom Rockne, Former ATK Tank Ammo Program Director
  - Gary Lamecker, ATK Level III for UT