

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

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### M831A1 CARTRIDGE, 12944397



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### 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



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- 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** Æ,

Forging and Heat Treat Processes can Potentially **Induce Unacceptable Flaws** 

#### **Magnetic Particle Inspection** (MT)

100% TDP Requirement from onset of Program

#### **Magnetic Particle Concerns** Ó

- 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





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- Ist Tank Ammo Production UT of Non-Uniform Cross Section
- Ist 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

Depth (mm)Lengths (mm)Width (mm)0.286.1, 8.64, 12.490.18

### Longitudinal EDM Notch Standards







#### **Government TDP Required**

#### **ATK Supplement**

### Circumferential EDM Notch Standards





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#### **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 Ó
- 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<sup>+</sup>% 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





### ATK Engineering and UT Expertise at Work (continued)



- 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 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</p>
  - Demonstrates High Reliability for "Critical Characteristic"

# System Validation / Qualif



- ATK Performs a 51Consecutive 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%

### UT Inspection System









### 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

### System Data File



CALIBRATION REPORT		Top Probes								
Date and Time Heat Lot	02/19/02 05:01:31 PM Validation	===== Flaw #	Test	= Gate	Lin-Pos (mm)	Ang-Pos (deg)	Size (deg)	Min-Amp (%)	Max-Amp (%)	
Component Type	Base Case	$\lambda$	1	λ	5.6	103	9	44.5	125.0	
Component Ref	9280442 G1	2 /	1	1	6.8	105	10	40.5	125.0	
Scan File UT/File	Scan2001.PRG Final_Internal.st3	3	1	1	7.9	109	5	45.0	73.0	
Flaws Matched	33 of 33	4	/3 /	$\frac{1}{1}$	20.3	139	.6	48.0	71.4	
Extra Flaws	0//////////////////////////////////////	5	3	$\frac{1}{1}$	21.5	141	8	44.0	116.6	
Status	PASS	6	3	1 /	22.6	144	8	49.5	103.6	
		7	3	1	23.7	147	2	48.5	48.5	
		8			26.0	195	5	50.6	70.1	
		9			27.1	/198	6	62.1	95.6	
		10			28.2	201	/5 /	64.1	/83.1	
		11			29.4	204	3	43.6	48.1	
		/12			41.3	210	8	59.4	92.4	
		$\frac{13}{13}$			122	/212/	7	181	62/9	

### 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 Specif



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</li>

### System Main Screen

DeW Systems Ultrasonic Inspection System Since Last Calibration 高能用刀 Manual (F2) Start Cycle (F3) Results File 2 Oct 2002 tot Heat Lot 2 Oct 2002 Parl Type, Bare Cate SceniFile: Scien2001 PRG Accepted 10 Dew Operator: Gary Accepted 0 Access LevelA UT File Final Internal st3 Flawed 1 Flawnet 0 Setup (F4) Calbrate (F5) Log Off (F6) Top Scanning Probes - Raw Data - Side Scanning Probes - Raw Data 100-100-Test 1 TeitE Test 7 80-Ted 2 89-Telt 3 Test B 60-60-Test 4 Test-9 40-40-Text 5 Test 10 29-20-Gale Gale 1111122 1 1 2 2 10 10-225 45 -90 135 190 270 315 793 Position (mm) Position (runi) 225 270 315 45 135 180 10 04 90 14.69 3255 15 20 25 30 35 48 店山 45 45 40 10 18 15 35 ŝ 20 26 30 Scan 1 Scan 1 15 System State Stationary Probes - Raw Data No Pat 100-Accepted Accept/Stamp Test 11 Untexted Accepted & Stamped Test 12 88-🔁 lineng Tested 🍊 Flawed Suspect Calibration Component Test 13 Unknown 68-3 Test 14 Inspect. 341 Samples/Chari 40-Test 15 1 13 Side Ekch Immi Test 16 Scana 20-1.13 Top Pitch imm) 43 Stamp Gale 49 min scans 3 2 0.00 Gate dB. Col Passed 20 - 25 10 语 -30 40 Sean Latched Alams - Gate 1 Latched Alamit - Gale 2 11 12 13 14 15 16 7 8 3 10 11 12 13 14 15 2 3 4 5 **a** 9 10 3 4 5 1 System Status Automatic Mode - Elick 'Start Cycle' to begin inspection

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### Ultrasonic Instrument





### **Calibration Data**



#### 🔁 View Calibration Data X Scan Offset Calibration Master Last Calibration 0-1 Scan 30 Scan 30 Part ÷ 4 2-Gate: . 4-Part Type: Base Case + 6-8-Lin Repeatability: 2 10-12-Maximum Extras: 1 Scan 39 Scan 39 14-16-Master Defects: 44 18-Defects Matched: 44 20-Extra Defects: 0 22-24-Decision: PASS 26-Close (Esc) Scan 49 Scan 49 29-8 9 10 11 12 13 14 15 16 8 2 3 56 12 3 5 9 10 11 12 13 14 15 16 4 7 4 6 Test Test





<b>= 5</b> Syste	em Error	×
0	EMERGENCY STOP	
•	Release 'Emergency Stop' and press 'Control On', then click	ΟK
	Cancel	

	System Calibration Required
System Logged Off	System Calibration Required.
To operate this system choose Log On. To close the software choose Exit. For both options a valid password is required.	Please place the calibration components in the inlet chute in this order. 9280442 G1 9280442 G2 9280443 G1 9280443 G2
Log On (F1) Exit (Esc)	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