Development of Battery Automation Equipment

Lithium Reserve Battery for the M234/235 Self-Destruct Fuze

Alex Hughes
Director of Manufacturing Services
Development of Battery Automation Equipment

Program History

- **Phase I**
  - Initial Concept of the Process
  - Selection of Qualified Vendors

- **Phase II**
  - Conducted Risk Review of the Piece Parts and the Equipment
  - Conducted Preliminary Design Review of the Equipment
  - Conducted Critical Design Review of the Equipment

- **Phase III**
  - Final Proveout of the Machines

- **Current Status**
Development of Battery Automation Equipment
Development of Battery Automation Equipment

Program History

- The Automated Battery Line is part of a complete fuze assembly line contracted under the High Rate Equipment (HRE) contract, capable of delivering 190,000 fuzes/month on 1-8-5 shift basis.

- In 2000 an IPT Team was formed between KDI, ARDEC, and ARL to review the process and design requirements for the Self-Destruct Lithium Reserve Battery.
Development of Battery Automation Equipment

Phase I

- Initial Concept of the Machines
- Developed a Process Flow of the Assembly Equipment with Specific Quality Checks (SOW)
Development of Battery Automation Equipment

Phase I

• Selection of Qualified Vendors
  • Vendor Selection Rating Matrix
    • Technical
    • Facilities/Personnel
    • Schedule
    • Financials
    • Intangibles
  • Four Companies were reviewed
• RD Systems was the IPT’s Final Selection
Phase II

• Conduct Risk Review of Piece Parts and Equipment
  • Risk Assessment Metrics
    • Probability of Occurrence
    • Severity of Impact
    • Risk Leveling of Scoring Matrix
  • Management Board Approval
Risk Assessment Metrics

- **Probability of Occurrence**
  - **High** (a 70% or Greater Chance That This Risk Will Occur)
  - **Medium** (a 30-69% Chance That This Risk Will Occur)
  - **Low** (a 10-29% Chance That This Risk Will Occur)
  - **Very Low** (a Less Than 10% Chance That This Risk Will Occur)
## Risk Assessment Metrics

### Severity of Impact

<table>
<thead>
<tr>
<th>COST</th>
<th>RISK TYPES</th>
<th>PERFORMANCE</th>
<th>SEVERITY OF IMPACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase of $500K or greater</td>
<td>Increase of 6 Months or greater</td>
<td>Customer-critical requirement will not be achieved; all margin has been exceeded</td>
<td><strong>High (Critical):</strong> Will likely cause program failure and/or would not be able to meet primary requirements</td>
</tr>
<tr>
<td>Increase of at least $200K but less than $500K</td>
<td>Increase of at least 3 Months but less than 6 Months</td>
<td>Decrease in customer-critical performance eliminates all margin</td>
<td><strong>Medium (Serious):</strong> Will cause major deviation from program plan and harm credibility with customer</td>
</tr>
<tr>
<td>Increase of at least $20K but less than $200K</td>
<td>Increase of at least 1 Months but less than 3</td>
<td>Customer-critical requirement will be achieved but all margin has been eliminated</td>
<td><strong>Low:</strong> Will cause moderate deviation from program plan, but all key program requirements will be met</td>
</tr>
<tr>
<td>Increase of less than $20K</td>
<td>Increase of less than 1 Months</td>
<td>Customer requirements will be met with adequate margins</td>
<td><strong>Very Low:</strong> Will cause only a small deviation from plan and all requirements will be met</td>
</tr>
</tbody>
</table>
## Risk Assessment Metrics

### Risk Level of Scoring Matrix

<table>
<thead>
<tr>
<th>Probability of Occurrence</th>
<th>Very Low (1)</th>
<th>Low (2)</th>
<th>Medium (3)</th>
<th>High (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (4)</td>
<td>Medium (5)*</td>
<td>Medium (6)*</td>
<td>High (7)*</td>
<td>High (8)*</td>
</tr>
<tr>
<td>Medium (3)</td>
<td>Low (4)*</td>
<td>Medium (5)*</td>
<td>Medium (6)*</td>
<td>High (7)*</td>
</tr>
<tr>
<td>Low (2)</td>
<td>Low (3)*</td>
<td>Low (4)*</td>
<td>Medium (5)*</td>
<td>Medium (6)*</td>
</tr>
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</table>

* Indicates a decommissioned risk.
## Risk Assessment Metrics

### Risk Level of Scoring Matrix

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<tr>
<th>Impact</th>
<th>Probability of Occurrence</th>
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<tbody>
<tr>
<td>Very Low (1)</td>
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</tbody>
</table>
Development of Battery Automation Equipment

- **Manufacturing Risk: (H8)**
  - Wicking of Electrolyte/Salt Build Up on Needle
  - Low / Over Fill of Ampule
  - Tight Tolerance (Needle to Hole)
  - Meeting rate / cycle time of Fill and Seal
  - Corrosion of Fill and Seal Equipment
  - Proper placement of Ball onto the Cover
  - Breaking of Ampule glass during the Ball press Operation
  - Obtain proper seal after the Ball is pressed into Cover

- **Manufacturing Risk: (H7)**
  - Cleaning and Etching of Terminal Pin
  - Lithium Punch Tool Build Up
Development of Battery Automation Equipment

• Manufacturing Risk: (M5)
  • Perpendicularity of Terminal Pin
  • Terminal Pin Tinning coverage (RD Prototyped a Process Developed by Ardec)
  • Solderability of Terminal Pins
  • Time between cleaning & tinning
  • Maintain Case flatness
  • Control the Welding Burrs on Case
  • Proper seating of Terminal Plate
  • Improper Terminal Plate Weld
  • Electrical Failure not detected
  • Gross Battery Leak not detected
  • Fine Battery Leak not detected
Development of Battery Automation Equipment

- **Manufacturing Risk:** Wicking of Electrolyte/Salt Build Up
- **Manufacturing Operation:** Electrolyte Fill
- **Probability of Occurrence:** High (Inherent properties of electrolyte to wick)
- **Severity of Impact:**
  - Cost: High (may have to go to hand line $20-$60/battery)
  - Schedule: High (2 years to get new battery line)
  - Performance: Medium (heat soak/inspection will pick up low/over fills but chance of latent defect getting through)
- **Risk Level:** High (8)
- **Risk Manager:** Alex Hughes / Ben Lagasca
- **SAVIT Producibility Study (parts completed - testing in progress)**
  - No hole cover & projection weld
  - No hole slip fit cover & laser weld
Development of Battery Automation Equipment

- KDI Fill & Seal Investigation (Data Gathering)
  - Use of Inert Atmosphere
  - Pull vacuum then fill
  - Effects on electrolyte temperature
  - Needle size/material effects
  - Pump size/stroke/speed/suck back features
  - Fill with cover and no cover
  - Pelletize salt then fill
- RD Systems Fill & Seal Prototype (Chill electrolyte/parts, Fill open reservoir then laser weld cover)
- HIBAR Fill & Seal Prototype (Pull vacuum, Fill through hole, Inert gas purge, press ball)
- MANTECH Fill & Seal prototype (process yet to be defined)
Development of Battery Automation Equipment

- Utilize phased approach to build/design equipment
  - Build prototype and down select prior to final design of battery equipment
- Utilize Thales expertise/support
  - Hand build batteries - data gathering
  - Support production facility setup
  - Provide technical expertise
- Revised Probability of Occurrence: Low (several approaches but nothing proven yet)
- Revised Severity of Impact:
  - Cost: Medium
  - Schedule: Medium
  - Performance: Low
Development of Battery Automation Equipment

- **Fill and Seal Results**
  - Reduced Salting to a Manageable Level
  - Fill Volume (20-28 micro liters)*
    - Stdev 0.70
    - Average 23.33
    - Max 25.73
    - Min 21.36
    - + 3 Sig 25.45
    - -3 Sig 21.21

* Samples taken over a 4 hour run
Development of Battery Automation Equipment

Phase II

- Lithium Laminate Assembly
  - Cutting the Lithium and Adhering the Lithium to the Nickel to Form the Anode
Development of Battery Automation Equipment

Phase II

- Conducted Preliminary Design Review (PDR)
  - Reviewed the Initial Concept of the Machines at RD Systems

- Conducted Critical Design Review (CDR)
  - Reviewed the Detailed Drawings of the Assembly Equipment
  - Reviewed Exit Criteria for IPT’s Technical Approval
    - All the Manufacturing Risk Points were resolved
Development of Battery Automation Equipment

Phase III

– Final Proveout of the Machines
  – Preliminary Production Review of Individual Machines
  – IPT Concurrence of Acceptance Test Plan (ATP)
    – Verify all Inspection Stations
    – Capability Studies of Each machine
    – Verify Throughput, First Pass Yield, and Uptime
– Proveout of Assembly Line
  – Initial Proveout will be conducted at RD Systems
  – Final Proveout will be conducted at KDI
Development of Battery Automation Equipment

- **Current Status**
- KDI’s SD Fuze High Rate Equipment Complete
- Battery Automation Equipment
  - Phase I & II Complete
  - Phase III
    - PDR’s & CDR’s Complete
    - Began Proveout of individual work cells 2/18/03
    - Proveout RD Systems June 03
    - Proveout KDI July 03
    - First Article Battery Testing September 03
    - First Article Fuze Testing November 03