Explosive Energy Qualification and Equivalency Comparison in Impulsively Loaded Pressure Vessel

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EDS System Overview

EDS is a trailer-mounted chemical munition treatment system with a rotating explosive containment vessel.

Phase 2 System
40-foot single drop trailer
11 foot shipping height
8.5 feet wide
55,000 pounds total
EDS vessel description

• Cylindrical cup
• Flat door
• 316 stainless steel
• Grayloc™ metal gasket
• 4140 steel clamps
• Vessel volume is 620 liters
• Previously rated for 500 uses at 4.8 pounds TNT equivalent
Today’s Discussion

• Loading insight from modeling and simulation

• V26 explosive qualification testing for use at 9lbs TNT equivalent

• C-4 and TNT equivalency test results
Analysis procedure

- Used Eularian shock code, CTH, to simulate detonation and calculate pressure history
- Used pressure histories to calculate vessel response with LS-Dyna
- Simulated 1, 2, 3, 4, 6, and 10 pound charges for P1 size vessel

![Graph showing pressure at vessel waist with 3 pound charge](image.png)
Peak strain is at the vessel waist

Peak strain from 3 pound charge

Peak strain from 10 pound charge
Test Objectives

• Assess common net explosive weighting conversion for C-4 to TNT.

• Conduct explosive certification testing for the V26 vessel to receive a rating continued use at 9 lbs of TNT equivalent via 1.25X over test.
Test Schedule

- All tests completed in July-August 2013 at Albuquerque, New Mexico
- Test 1
  - 9 lbs Composition C-4 (estimated 11.25 lbs TNT-equivalent)
  - Bare charge
- Test 2
  - 7.2 lbs Composition C-4 (estimated 9 lbs TNT-equivalent)
  - Bare charge
- Test 3
  - 9 lbs TNT
  - Bare charge
- Test 4
  - 3 lbs TNT-equivalent
  - Distributed 6-pack, no burster detonation
- Test 5
  - 7.2 lbs TNT-equivalent
  - Distributed 6-pack with all high order bursters
Test Explosive Configuration

- Single bare charge
- Located along the center axis at midpoint of vessel
- Length-to-diameter aspect ratio 1.5-2
- Same configuration for 9# C-4, 9# TNT, 7.2# C-4
Bulk Motion Data Reflects Dynamic Strain Results

Vessel body hoop with aft and door hoop

Internal pressure (psi)

External pressure (psi)

Aft hoop

Vessel center hoop

Door hoop

Microstrain

Internal pressure (psi)

External pressure (psi)
Strain Data for 11.2# TNT Qualification

- More energy is absorbed closer to the vessel center for single bare charge

- 9# of C-4 has a consistent strain response increase from 7.2# C-4
Qualification Test
Consistency Verification

• Strain rate and magnitude increase of 9# C-4 load over 7.2# appears proportional

• Center and end loading agree

• Total strain of 0.19% is within design limit
C-4 and TNT Comparison

- Conversion factor estimate of 1.25lbs TNT per 1lb C-4 is supported

- Several directions agree tightly with conversion factor
C-4 and TNT Comparison

- Strain response of door seal appears equivalent

- Vessel response is consistent for 9# TNT and 7.2# C-4
## Summary Data

<table>
<thead>
<tr>
<th>Test</th>
<th>Gauge</th>
<th>Permanent Strain(με)</th>
<th>Estimated Error(με)</th>
<th>Average Δε (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9# C4</td>
<td>center-hoop</td>
<td>600</td>
<td>+/- 100</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>1/3 from aft - hoop</td>
<td>330</td>
<td>+/- 50</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>2/3 from aft - axial</td>
<td>-290</td>
<td>+/- 70</td>
<td>-0.011</td>
</tr>
<tr>
<td></td>
<td>aft end average</td>
<td>44</td>
<td>+/- 50</td>
<td>0.002</td>
</tr>
<tr>
<td>7.2# C4</td>
<td>center-hoop</td>
<td>100</td>
<td>+/- 100</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>1/3 from aft - hoop</td>
<td>130</td>
<td>+/- 50</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>2/3 from aft - axial</td>
<td>-10</td>
<td>+/- 70</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>aft end average</td>
<td>10</td>
<td>+/- 50</td>
<td>0.000</td>
</tr>
<tr>
<td>9# TNT</td>
<td>center-hoop</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>1/3 from aft - hoop</td>
<td>120</td>
<td>+/- 50</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>2/3 from aft - axial</td>
<td>-50</td>
<td>+/- 70</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>aft end average</td>
<td>20</td>
<td>+/- 50</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Conclusions

- V26 explosive qualification testing demonstrates strain totals within the ASME Code Case design limit for 9lbs TNT equivalent
- Comparative explosions between C-4 and expected TNT equivalent reinforce the static conversion factor of 1.25lb TNT per 1lb C-4
- Vessel response data can be used to improve explosive loading prediction codes
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