An Evaluation of the Effectiveness of Common Door Blast Shields

Adrian Pierorazio, J. Kelly Thomas, & Jihui Geng

Baker Engineering and Risk Consultants, Inc.

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- Sponsored development of methodologies by BakerRisk for explosion blast load and structural response predictive methodologies
- Cooperative’s support gratefully acknowledged
Outline

- Main Objective & Background
- Project Approach
- Experimental Results
- Numerical Benchmarks
- Numerical Results
- Conclusions
Main Objective and Background

Main Objective

- Evaluate performance of “L-Shaped” door blast shield design (other designs also evaluated)

Background

- Blast doors can be expensive, pose operational issues (difficultly in opening and closing doors) and require regular maintenance
- Effective blast shield allows use of conventional doors
- “L-Shaped” shield design utilized at variety of sites
Door Blast Shield Arrangement

explosion
Project Approach

- Test door blast shield in shock tube
  - Range of pressures & impulses
- Benchmark numerical tool (BWTI CFD code) against experimental data
- Utilize BWTI to examine alternative blast loadings
Experimental Task - Overview

- Conduct small scale model tests in BakerRisk’s large shock tube facility
  - Provide benchmark data for computational task
  - Develop understanding of shield performance

- Shock tube:
  - Compressed gas driver (3’ diameter and up to 21’ length)
  - Expands to 8’x8’ target over 21’ expansion section
  - Open ended 16’ extension section
  - Can produce up to 40 psig reflected load

- Test rig:
  - Building model, 8’(W) x 3’(H) x 1’(D)
  - Shield model, 18”(W) x 18”(H) x 9”(D), roof plate
Shock Tube Photograph
Shield Configuration Schematic

Shock Tube

Extension Section

Shield

Shock Tube

Extension Section
# Shock Tube Test Matrix

<table>
<thead>
<tr>
<th>Door Shield Orientation</th>
<th>Driver Length (feet)</th>
<th>Side-On Pressure (psig)</th>
<th>Baseline Tests Without Building</th>
<th>Baseline Tests With Building</th>
<th>Tests with Door Blast Shield</th>
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</thead>
<tbody>
<tr>
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<td>4</td>
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</tbody>
</table>
No Building (4 psig, 5 foot driver)
Building Only
(4 psig, 20 foot driver)
Normal Orientation (4 psig, 5 foot)\n($P_s/P_u = 1.6$, $i_s/i_u = 1.1$)

4 psig with 5 foot driver length

- Expansion Section End
- Door Location
- Edge of Shield
- Building Wall

Pressure (psig) vs. Time (ms) graph.
45 degree Orientation (4 psig, 5 foot) 
($(P_s/P_u=1.2$, $i_s/i_u=1.0)$

- Expansion Section End
- Door Location
- Edge of Shield
- Building Wall

Pressure (psig) vs. Time (ms) graph
# Shock Tube Test Results

<table>
<thead>
<tr>
<th>Door Shield Orientation</th>
<th>Driver Length (feet)</th>
<th>Side-On Pressure (psig)</th>
<th>Pressure Ratio (Shielded / Unshielded)</th>
<th>Impulse Ratio (Shielded / Unshielded)</th>
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Overview of Benchmarks

- BakerRisk’s Blast Wave Target Interaction (BWTI) CFD code employed
  - Generation and propagation of blast & shock waves
  - Interaction of wave with structures

- Utilized 2D model
  - Focus of comparison is on initial wave interactions

- Benchmark results:
  - L-Shaped, normal, 4 psig, 20 foot driver
  - Pressure traces at several key locations
  - Pressure contour animations
Normal Orientation
(4 psig, 20 foot driver)
Normal Orientation
(4 psig, 20 foot driver)
Benchmark calculations support use of BWTI to evaluate performance at full-scale (4’ x 8’) with alternative blast loads

Defined “typical” blast loads at 200’ standoff

- **VCE (200’x100’x15’, $M_f=0.4$, $3\times10^{10}$ in-lb$_f$)**
  - Reflected load of 1.9 psig & 86 psi-ms (92 ms)
    - Severe damage to conventional door (3’x7’ single metal door)
    - Need factor of 2 reduction in pressure to reach minor damage

- **BPV (10,000 gallon, 750 psig failure pressure)**
  - Reflected load of 3.5 psig & 43 psi-ms (25 ms)
    - Severe damage to conventional door (3’x7’ single metal door)
    - Need factor of 2 reduction in impulse to reach minor damage
## Numerical Model

### Door Blast Shield Results

<table>
<thead>
<tr>
<th>Blast Source</th>
<th>Blast Orientation</th>
<th>Pressure Ratio (Shielded / Unshielded)</th>
<th>Impulse Ratio (Shielded / Unshielded)</th>
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### BPV Blast Load (normal orientation)

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<th>Image 1</th>
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<th>Image 3</th>
<th>Image 4</th>
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Overall Conclusions

- “L-Shaped” door blast shield ineffective
  - Little or no benefit
  - Can increase door blast load

- Does not indicate removal is best option
  - Still provides measure of protection
  - May need to employ outer door
  - Failure of outer door poses hazard

- Alternative shield design may be desirable
  - New construction or upgrade
  - Where outer door cannot be utilized