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Design Factor Influences on Total Determined Explosives Site Risk

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STONE

Security Engineering

Conventional Q-D Siting

- Generally separate Exposed Site (ES) buildings from Potential Explosion Site (PES) buildings by standoff $KW^{1/3}$:
  - K6/K11: InterMagazine Distance (IMD);
  - K9/K18: IntraLine Distance (ILD);
  - K24/K30: Public Traffic Route Distance (PTRD);
  - K40/K50: Inhabited Building Distance (IBD).
- These distances correspond to:
  - Free-field overpressure;
  - Rough expected level of damage for the ES.
- However, IBD may default to Hazardous Fragment Distance (HFD) controlled by debris generated at the PES.

Note: W in pounds, $KW^{1/3}$ in feet.

Comparisons of K40 to HFD

K40 Separation (1.2 psi)

- **46 feet** for 10 pounds.
- 186 feet for 100 pounds.
- **400 feet** for 1000 pounds.
- 862 feet for 10,000 pounds.

HFD

- **474 feet** for open PES,
  200 feet for structured PES
  with 10 pounds.
- 658 feet for 100 pounds.
- **1250 feet** for 1000 pounds.
- 1250 feet for 10,000 pounds.

- For these example cases, HFD ranges from **1.5x** to over **10x** K40 separation.
- If space on the site is at a premium, it may be difficult to achieve default HFDs.

Alternative Siting Options

- Reduce charge size at PES to achieve lower default HFDs.
- Analyze PES and determine more precise value of HFD based on primary/secondary fragments generated.
- Provide barriers as needed to reduce projection of hazardous fragments.
- Harden PES and/or ES.
- Use risk-based siting approach.

Risk-Based Siting Requirements

- Per **DoDM 6055.09-M-V6**, a waiver/exemption must be in place for proposed siting approach.
- Use approved code/analysis tool or equivalent methodology.
  - Refer to **DDESB Technical Paper 14**.
- Accept the risks not evaluated by approved code (e.g., facilities, equipment, assets, and mission).

Risk-Based Siting Acceptance Criteria

Table V6.E5.T7 from DoDM 6055.09-M-V6

Risk to:	Criteria:
Any one related individual – Related P_f	$\leq 1x10^{-4}$ per year
All related individuals – Related E_f	$\leq 1x10^{-3}$ per year
Any one unrelated individual – Unrelated P_f	$\leq 1x10^{-6}$ per year
All unrelated individuals – Unrelated E_f	$\leq 1x10^{-5}$ per year

- *P_f is probability of fatality (individual)*
- *E_f is expected fatalities (group)*
- While these criteria are developed from understandable probability concepts, they do not readily relate to typical deterministic blast response criteria.

Building Damage: Support Rotation & Ductility

- These two most commonly used response criteria in blast design are typically linked to an SDOF model.
- **Support Rotation:** Measures maximum deflection relative to geometry (angle formed at peak response)

Ref: UFC 3-340-02

- **Ductility:** Ratio of maximum deflection to elastic limit deflection (denoted as μ)
  - Value less than unity denotes elastic response
  - Value greater than unity denotes plastic response

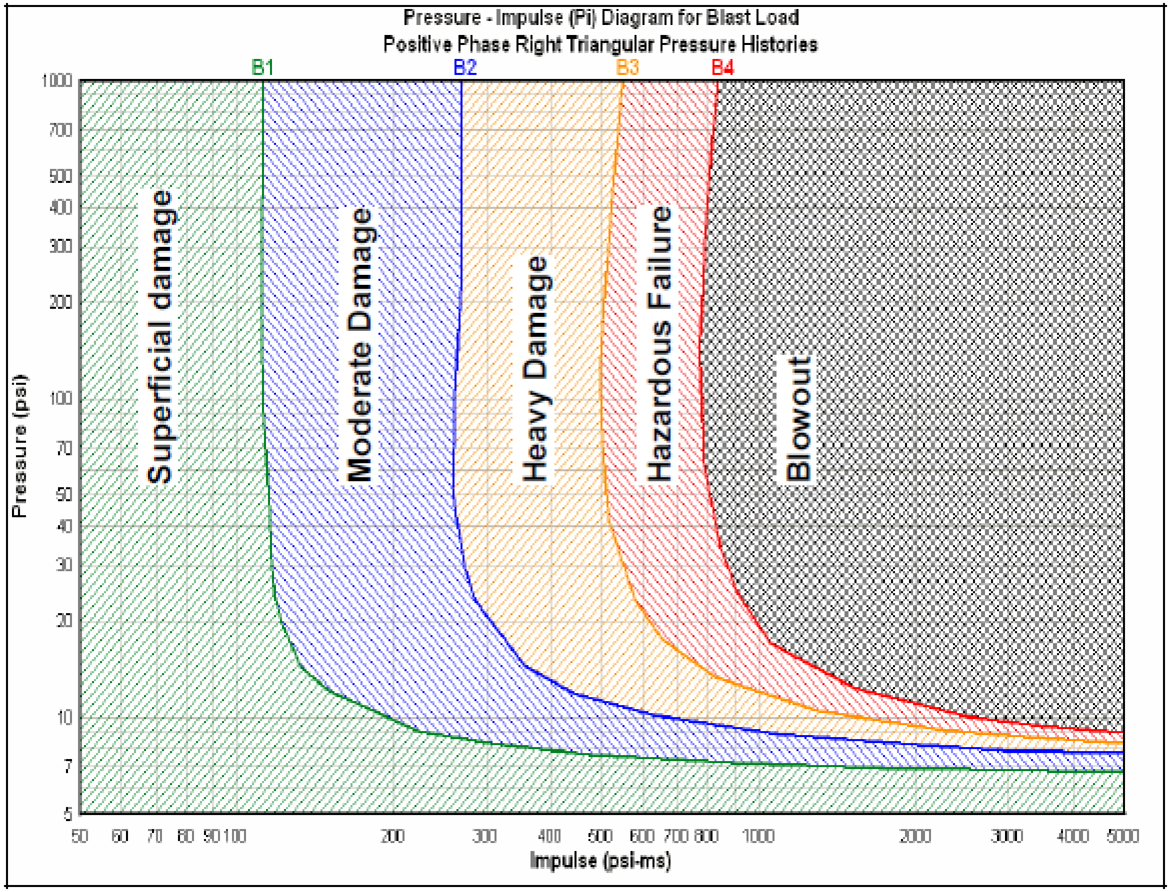
Sample Response Limits (PDC)

Flexural Component	Damage Levels					
	Superficial		Moderate		Heavy	
	μ_{max}	θ_{max}	μ_{max}	θ_{max}	μ_{max}	θ_{max}
Reinforced Concrete Slab (No Shear Reinf.)	1	-	-	2°	-	5°
Compact Hot-Rolled Steel Beam	1	-	3	3°	12	10°
Cold-Formed Girt/Purlin	1	-	-	3°	-	10°
Wood Stud	1	-	2	-	3	-

Sample Component Damage Levels (PDC)

- Superficial: Component has no visible permanent damage
- Moderate: Component has some permanent deflection
  - Generally repairable, but replacement may be more economical and aesthetical
- Heavy: Component has not failed, but has significant permanent deflections making it unrepairable
- Component damage levels can be translated into an overall building damage level, which can be correlated to a probability of fatality.

Component Pressure-Impulse Diagrams



Note: Logarithmic Scale

Ref: PDC-TR 06-08

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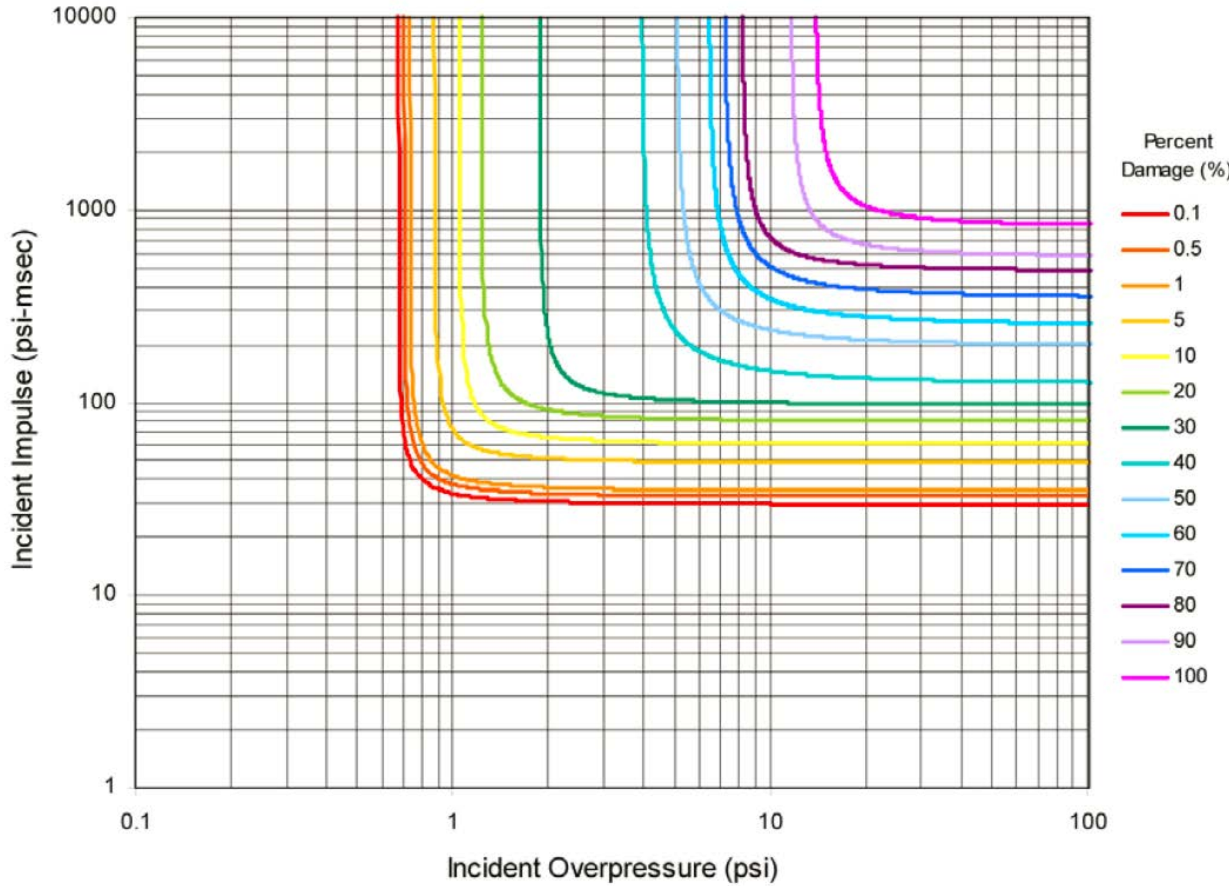
Building Pressure-Impulse Diagrams



Note: Swap of Axes

Ref: DDESB TP 14

Other Items that Contribute to P_f

- Overpressure effects
  - Lung rupture, whole body displacement, and skull fracture
- Projected glazing hazards within ES
- Projected debris from PES
  - Primary/secondary fragments and crater ejecta
- Probability of an event occurring
- Uncertainty multipliers

Key Questions

- How much influence do each of these factors have on the calculated risk?
- How can each significant source of risk be effectively mitigated in order to satisfy acceptance criteria?

Analysis Assumptions

- Limited variation of parameters:
  - Two HD 1.1 charge weights in bulk/light case
  - No thermal component to risk
- Consider the following cases:
  - New PES impacting an existing ES;
  - Existing PES impacting a new ES.
- Other PESs' contribution to ES building risk taken as a percentage of the allowable limits.

Example 1:
New PES Impacting an Existing ES

Charge 1 Case

- Overpressure influence
- Building collapse influence
- Glazing debris influence
- PES debris influence
- Uncertainty influence

Charge 2 Case

- Overpressure influence
- Building collapse influence
- Glazing debris influence
- PES debris influence
- Uncertainty influence

Example 2:
Existing PES Impacting a New ES

Charge 1 Case

- Overpressure influence
- Building collapse influence
- Glazing debris influence
- PES debris influence
- Uncertainty influence

Charge 2 Case

- Overpressure influence
- Building collapse influence
- Glazing debris influence
- PES debris influence
- Uncertainty influence

Takeaways

- Consider using a lightweight PES to limit the projection of heavy (hazardous) debris.
- Be strategic when designing new ESs:
  - Use construction types that limit extent of building damage/collapse due to acting blast loads.
  - Limit the amount of ES glazing in the direction of any PESs.
- Limit personnel exposure, particularly to meet group response criteria.
- Know your explosives and operations.
  - And thereby reduce likelihood of event occurrence and allowances for uncertainties.