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**Where Chemical
Engineering
Meets Innovation**



Confined Explosion Hazards in Enclosed Process Buildings: A Recognized Risk with Limited Guidance

**Where Chemical Engineering
Meets Innovation**



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Confined Explosions

- Hazardous processes in enclosed processing areas are common in the chemicals industry
- Confined explosions present severe safety and economic risks
- Documented impacts include:
 - Fatalities and serious injuries
 - Catastrophic damage to facilities and surrounding communities
 - Long-term business interruption and closure
- Multiple incidents have occurred across industries
- **Confined Explosion**
 - Flammable vapor accumulation in enclosed space
 - Delayed ignition leading to high overpressure events (7-20X pressure rise)
 - Catastrophic damage to original building. Extended impacts to the site and, potentially, beyond the fenceline

Confined explosions are not rare, isolated events, but a persistent and cross-industry hazard with catastrophic outcomes

Watson Grinding 2020
- 3 Fat., 2 Inj., Closed



AB Specialty Silicones 2019
- 4 Fat., 1 Inj., Closed



Yenkin Majestic 2021 -
1 Fat., 8 Inj., P. Closed



CAI, Inc and Arnel Company,
Inc 2006 - 0 Fat., 10 Inj.,
Closed





Confined Explosion Incident Samples

- Yenkin Majestic 2021 – 1 Fat., 8 Inj., Partially Closed
 - Closed kettle + naphtha (no mixing) → vapor buildup → agitation → overpressure → seal failure → vapor release into process building → ignition → explosion & fire
- Watson Grinding 2020 – 3 Fat., 2 Inj., Closed
 - Poorly crimped propylene hose → leak → vapor accumulation overnight → ignition on entry → explosion
- AB Specialty Silicones 2019 – 4 Fat., 1 Inj., Closed
 - Wrong chemical added → incompatible reaction → foaming/overflow → flammable fog formation within process building → ignition → explosion & fire
- CAI, Inc and Arnel Company, Inc 2006 – 0 Fat., 10 Inj., Closed
 - Steam valve left open → tank overheating during mixing → solvent vaporization → vapor release into building → ignition → explosion



Limitations of Current Analytical Approaches

- PHAs may not cover confined explosions and cannot provide an idea of their impacts
- Quantitative confined explosion models require:
 - CFD, Pressure rise calculations (e.g., NFPA 68), use of models not tailored for confined explosions
- **Major Gap for PHAs and Facility Siting Studies**
 - Lack of established literature for systematic consideration in PHAs and QRAs
 - DNV proposes a TNT-equivalency methodology in Phast
 - Other authors have proposed approaches using the TNO MEM model, BST, and Baker-Tang Mechanical Explosion Curves
 - **None of the methodologies above have been validated, and are not tailored for confined explosions**
 - Models tailored for confined explosions focus on internal Pressure Rise calculation. External impacts are determined by assuming deflagration venting / weak structural element configuration
 - **Venting or structural characteristics are unknown / difficult to obtain for buildings or non-rated structures**

Limited consistent approaches/tools for evaluating confined explosions hinder accurate PSM, QRA, and facility siting analyses



Results: Insights from Past Incidents

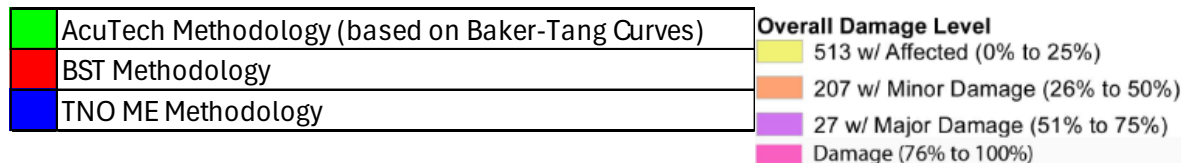
- **Limited PHAs and Comprehensiveness:** only 6/10 analyzed facilities had PHAs. Only 2 of them had identified the scenario leading to the confined explosion. 2 facilities not covered by OSHA PSM Rule (below inventory threshold)
- **Recurring Initiating Event:** Human Error leading to flammable vapor release. E.g.,
 - poorly crimped welding (Watson Grinding),
 - mixing of incompatible materials (AB Silicones),
 - improper valve action (CAI & Arnel and Little General Store), and
 - unfit instructions during operations/ maintenance (Synthron, Sterigenics)
- **Recurrent Issues:** forced ventilation not present / disconnected. E.g.,
 - Forced ventilation disconnected (Watson Grinding, CAI and Arnel Company, Inc)
 - Ventilation design worsened confined explosion impacts (AB Specialty Silicones)
- **Recurrent Materials Involved in Confined Explosions:** solvent and highly reactive materials (e.g., hydrogen, acetylene, etc)

These failures are not random: they reflect a systemic gap in how confined explosion risks are identified, evaluated, and acted upon



Ongoing Work: Developing a Standardized Methodology to Evaluate Confined Explosions in Facility Sitings

Watson Grinding, 2020



CAI Inc and Arnel Company, Inc. 2006

| Method | D to 5 psi (m) | True D 5 psi (m) | % | D to 2.3 psi (m) | True D 2.3 psi (m) | % | Distance to 1.2 psi (m) | Actual 1.2 psi (m) | % |
|--------------------------------|----------------|------------------|------|------------------|--------------------|-------|-------------------------|--------------------|-------|
| BST – 1D, L, Medium Reactivity | 48.0 | 50.0 | -4.0 | 89.0 | 111.3 | -20.0 | 155.0 | 177.1 | -12.5 |
| TNO – 8, 100% Flam cloud | 4.07 | 50.0 | -6.0 | 78.0 | 111.3 | -29.9 | 129.0 | 177.1 | -27.2 |
| B-T (Air, Pmax = 6.9 atm) | 65.4 | 50.0 | 30.8 | 110.7 | 111.3 | -0.6 | 182.0 | 177.1 | 2.8 |



Conclusions

- Confined explosions remain a frequent, high-consequence hazard across multiple industries.
- PHAs are not capturing the potential catastrophic impacts of confined explosions
- There is a clear need for systematic methodologies to evaluate confined explosion risk.
- While QRAs and facility siting studies can support impact assessment, existing modeling approaches have critical limitations:
 - Many modeling approaches are not designed or validated for confined explosion scenarios
 - Others rely on internal pressure/venting assumptions that are impractical or unavailable in real applications
- Limitations of this work: focus on CSB reports representing only a subset of confined explosion events.
- Future work: validate confined explosion modeling approaches against observed impacts from CSB cases and broader incident datasets.

Call for action: Confined explosions are not rare, isolated events, but a persistent and cross-industry hazard with catastrophic outcomes and limited guidance for evaluation



Q&A

Thank you for your time and interest.

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