



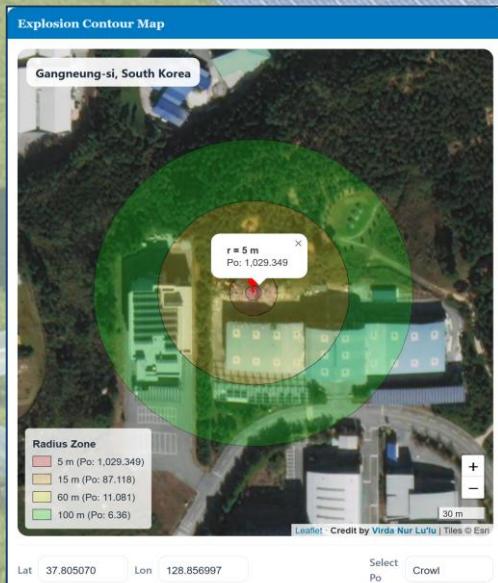
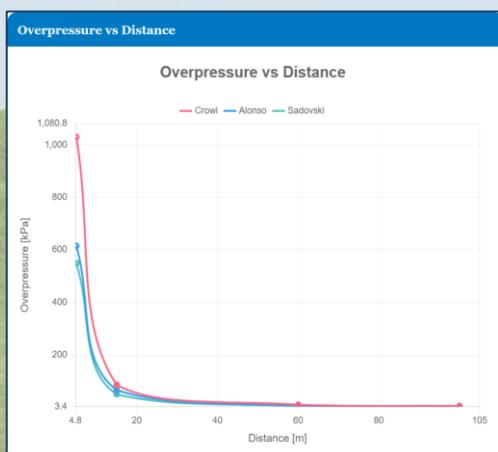
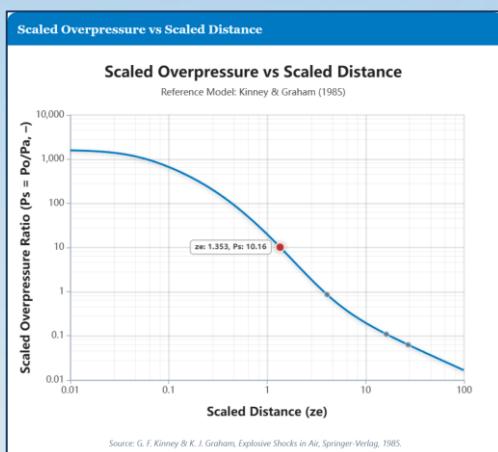
# Comparative Simulation and Modeling of Explosion Consequences based on TNT Equivalent

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**Abstract:** Explosions in process and storage facilities can cause severe damage within seconds, so safety-distance and hazard-zoning decisions require fast and transparent consequence screening. High-fidelity methods such as CFD and commercial integral models provide detailed results but need extensive data, long computation time, and licensed software. Simpler TNT-equivalent methods are suitable for early-stage assessment, but they are often applied manually, lack integrated calculations, and do not provide clear logs or map-based hazard visualization. This study develops a web-based simulation platform that automates a transparent TNT-equivalent calculation using minimal inputs (inventory and distance). The platform converts inventory into mass, estimates TNT-equivalent energy, applies Hopkinson–Cranz scaling, and predicts peak side-on overpressure using three empirical correlations (Crowl & Louvar, Díaz-Alonso, and Sadovski) under consistent assumptions. It generates traceable calculation logs, identifies correlation validity limits, and provides overpressure-distance curves and hazard-zone maps for early-stage safety evaluation. Validation was conducted using the Beirut 2020 and Tianjin 2015 explosion cases. For Beirut, predicted overpressure at 300 m ranges from 88.244 to 158.67 kPa and decreases to 3.136–5.609 kPa at 3000 m, with less than 1% deviation from reference values at 300 m. For Tianjin, predicted overpressure at 300 m ranges from 63.294 to 110.129 kPa and decreases to 2.595–4.702 kPa at 3000 m. Hydrogen validation shows that the Alonso correlation provides the best agreement with experimental data (MAE 6.006 kPa;  $R^2$  0.999), compared with Crowl & Louvar and Sadovski. Overall, the platform supports reproducible preliminary screening, compares model conservatism, and assists early-stage safety-distance interpretation.



## Novelty

- Enables rapid, transparent, and traceable early-stage consequence screening to support safety-distance and hazard-zoning decisions for hazardous-material storage and process facilities.
- Addresses the practical gap where TNT-equivalent assessments are often manual, fragmented across correlations, and lack auditable calculation logs and map-based visualization.

## Method

- Developed a web-based simulation platform that automates the TNT-equivalent workflow from minimal inputs (inventory and evaluation distance): inventory-to-mass conversion, energy-based TNT equivalent, Hopkinson–Cranz cube-root scaling, and prediction of peak side-on overpressure ( $P_o$ ) using Crowl & Louvar, Díaz-Alonso, and Sadovski under harmonized assumptions.
- The platform generates traceable calculation logs, flags correlation validity limits, and produces  $P_o$ -distance curves plus map-based contour hazard zoning.

## Main Results

- Ammonium nitrate (AN) validation:
  - Beirut 2020:  $P_o$  at 300 m = 158.67 / 120.03 / 88.244 kPa, decreases at 3000 m to 5.609 / 3.471 / 3.136 kPa, with -0.84% to -0.91% deviation vs the reference at 300 m.
  - Tianjin 2015:  $P_o$  at 300 m = 110.129 / 85.208 / 63.294 kPa, decreases at 3000 m to 4.702 / 2.848 / 2.595 kPa.
- Hydrogen ( $H_2$ ) validation against Type-IV pressure-vessel-burst data (6–18 m): Alonso achieved the best accuracy (MAE 6.006 kPa;  $R^2$  0.999), while Crowl and Sadovski produced higher MAE (18.136 kPa;  $R^2$  0.985) and (17.164 kPa;  $R^2$  0.99386).
- Gangneung 2019 plausibility check (50 kg TNT): predicted  $P_o$  = 51.1–87.1 kPa at 15 m and 3.59–6.36 kPa at 100 m.

## Conclusions

- ✓ Established an automated TNT-equivalent consequence simulation platform (inventory  $\rightarrow P_o$ ) with validity-flagging, traceable logs, and curve/map outputs to support hazard-zoning decisions for hydrogen and ammonium nitrate scenarios.
- ✓ For AN case studies (Beirut, Tianjin), the platform's outputs were evaluated against literature and observationally validated using consistency with documented damage patterns, with conservative interpretation using the highest  $P_o$  across correlations at the same distance.
- ✓ For  $H_2$ , validation shows Alonso as the most accurate representation (best-fit), while Crowl & Louvar is suitable as a conservative upper bound for screening-based safety-distance decisions; Sadovski tends to underpredict in the evaluated window.



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