BEYOND QUANTITATIVE RISK ANALYSIS RESULTS

Part I: Explosions & Blast Phenomena Characterization

Written By: Jordi Dunjó, Ph.D, Senior Consultant dunjo.j.nh@ioMosaic.com **& Neil Prophet, Senior Partner** prophet.n.tx@ioMosaic.com

ioMosaic

Abstract

The main purpose of a Quantitative Risk Assessment (QRA) is to evaluate the risk levels of a process due to potential Loss of Containment scenarios (LOCs). Moreover, the analysis of detailed QRA results is the basis for more specific studies for facility and critical equipment siting, and domino effects analysis due to thermal radiation of fires.

This poster illustrates how QRA results can provide valuable information for blast loading characterization at a given location of interest. The analysis takes into account: (1) identification of the total number of explosion outcomes which impact a given structure under analysis; (2) individual frequency, overpressure, positive phase duration, and associated impulse of each identified outcome.

Quantitative Risk assessment

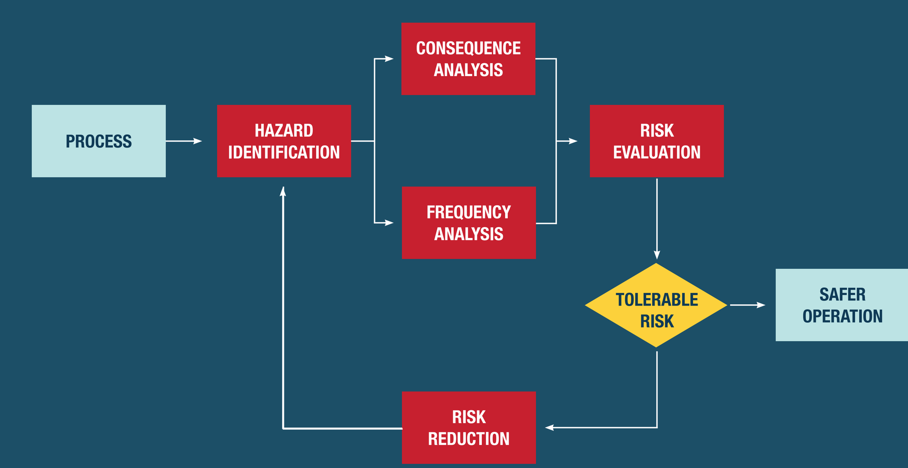

Figure 01

Simplified Quantitative Risk Assessment (QRA) Flowchart

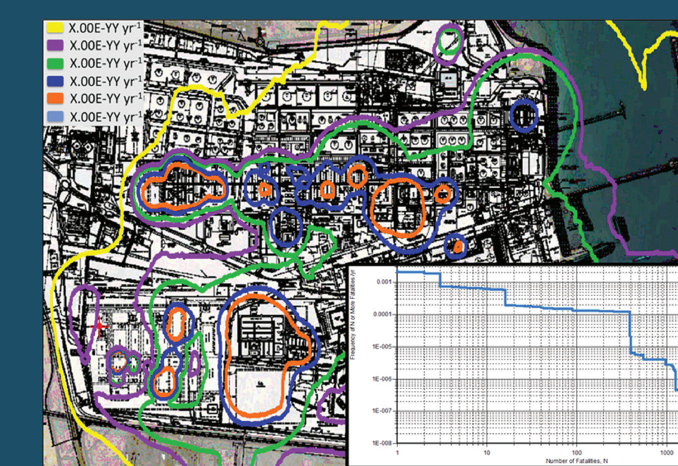

Figure 02

Example of QRA Results: Individual Risk Contours and FN Curve

QRA Results

Results from QRA development following world-wide risk-based criteria (e.g., references [1], [2], [3]) are the basis for emergency and land use planning, providing the foundation for risk reduction decision-making. However, specific analysis of explosion outcomes allow for more dedicated evaluation for complying with specific criteria for human vulnerability of occupied buildings (e.g., [4], [5]), and estimating the damage level of buildings, structures and key critical safety equipment.

Detailed risk-based facility siting study based on blast exceedence analysis

OVERPRESSURE EXCEEDENCE CURVE (OEC)

A risk-based approach requires the identification of a hazard level (e.g., overpressure value) which will not be exceeded at a given frequency threshold. Overpressure exceedance Curves (OECs) can then be developed for a given location of interest:

(1) Outcomes from explosions and vessel failures, including both immediate and delayed ignition

(2) Frequencies of occurrence of outcomes producing a specific level of overpressure are added for all outcomes reaching a specific building location.

Thereafter, the cumulative frequency of all outcomes producing a given level of overpressure is calculated, and the OEC is plotted, showing the cumulative frequency versus the overpressure. Using a given cumulative frequency criteria (e.g., 1.00E-04 yr-1 based on [4]), it is possible to determine which building/structure complies with criteria and which require further evaluation.

LINKING BLAST LOADING AND OCCUPANT VULNERABILITY

Three criteria have been considered for relating building occupant vulnerability (BOV; probability of fatality) and blast loading phenomena:

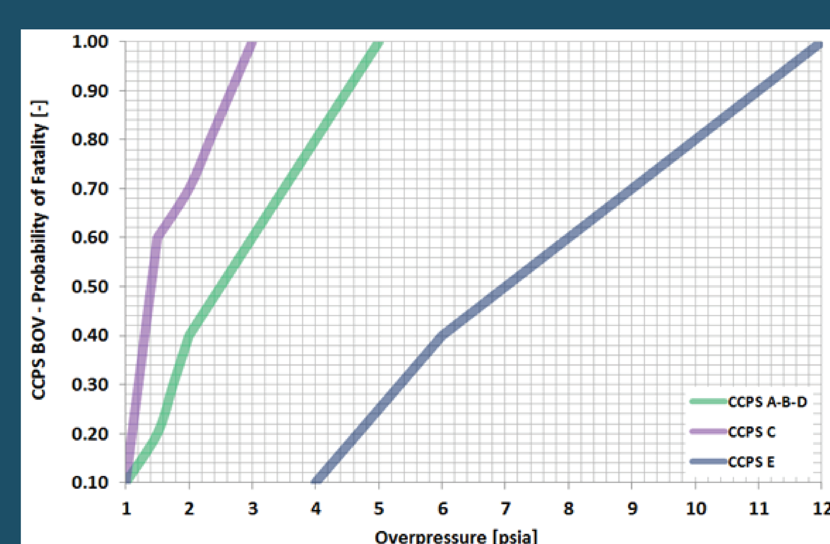

Figure 03
Human Vulnerability vs. Overpressure - CCPS

Center of Chemical Process Safety, CCPS [6]: probability of fatality is evaluated from experimental data that relates vulnerability as a function of building type (i.e., six (6) different building classes from A to F), and overpressure.

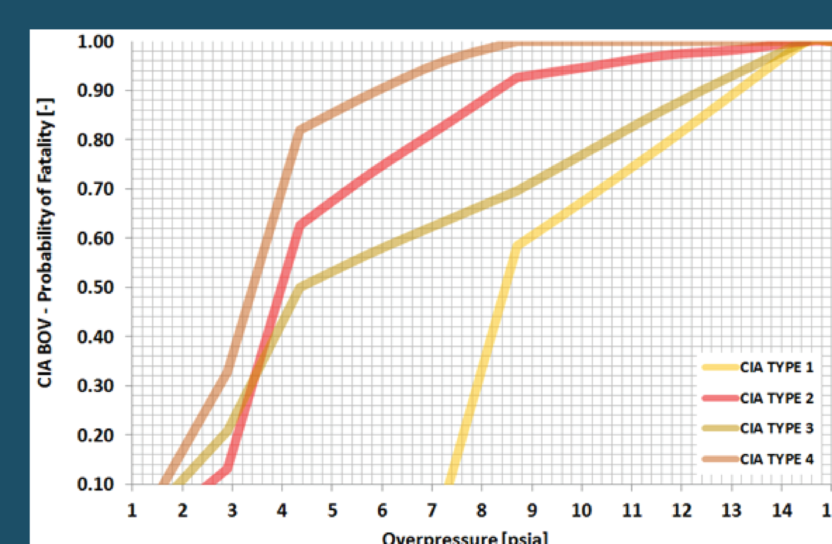

Figure 04
Human Vulnerability vs. Overpressure - CIA

Chemical Industry Association, CIA [7]: similar to criteria established in [6], the probability of fatality is evaluated from experimental data that relates vulnerability as a function of building type (i.e., four (4) different building classes from 1 to 4), and overpressure.

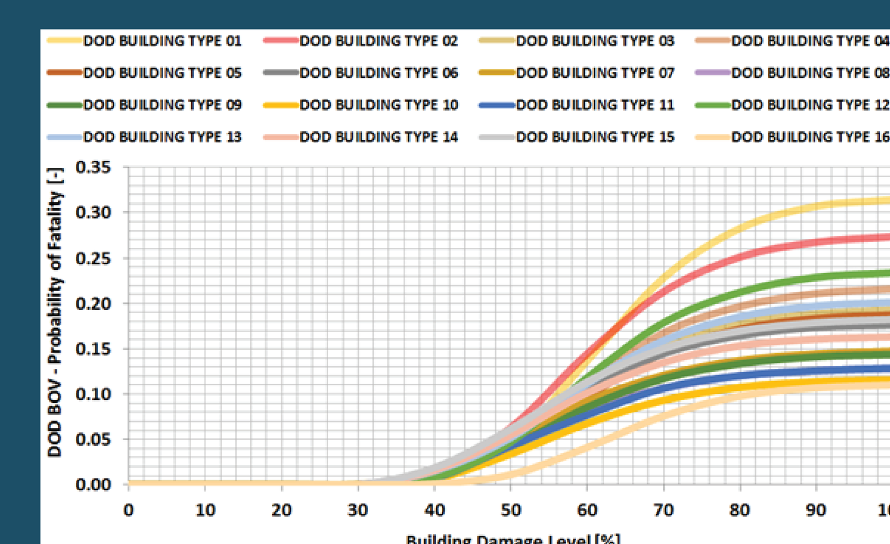

Figure 05
Human Vulnerability vs. % Building Damage Level - DOD

US Department Of Defense, DOD [8]: evaluates the probability of fatality as a function of building type and provides detailed Pressure-Impulse (P-I) Diagrams per each building class.

F-N CURVE AT A GIVEN OCCUPIED BUILDING

Taking into account the number of occupants per building **(NOB)**, including the associated presence factor, and the estimated probability of fatality BOV, the probability of fatality for a certain number of occupants (P_N) can be estimated by applying criteria illustrated in Equation 01. An F-N Curve for each occupied building can be generated by cumulating individual frequencies of all explosion outcomes as a function of number of fatalities.

Equation 01. Criteria for estimating P_N

$$P_N = \frac{NOB!}{N!\,(NOB - N)!}(BOV)^N\,(1 - BOV)^{(NOB - N)}$$

- NOB: Number of building occupants
- N: Number of fatalities
- BOV: Building Occupant Vulnerability; Probably of Fatality
- P_N: Probability of fatality for N occupants

Case Study

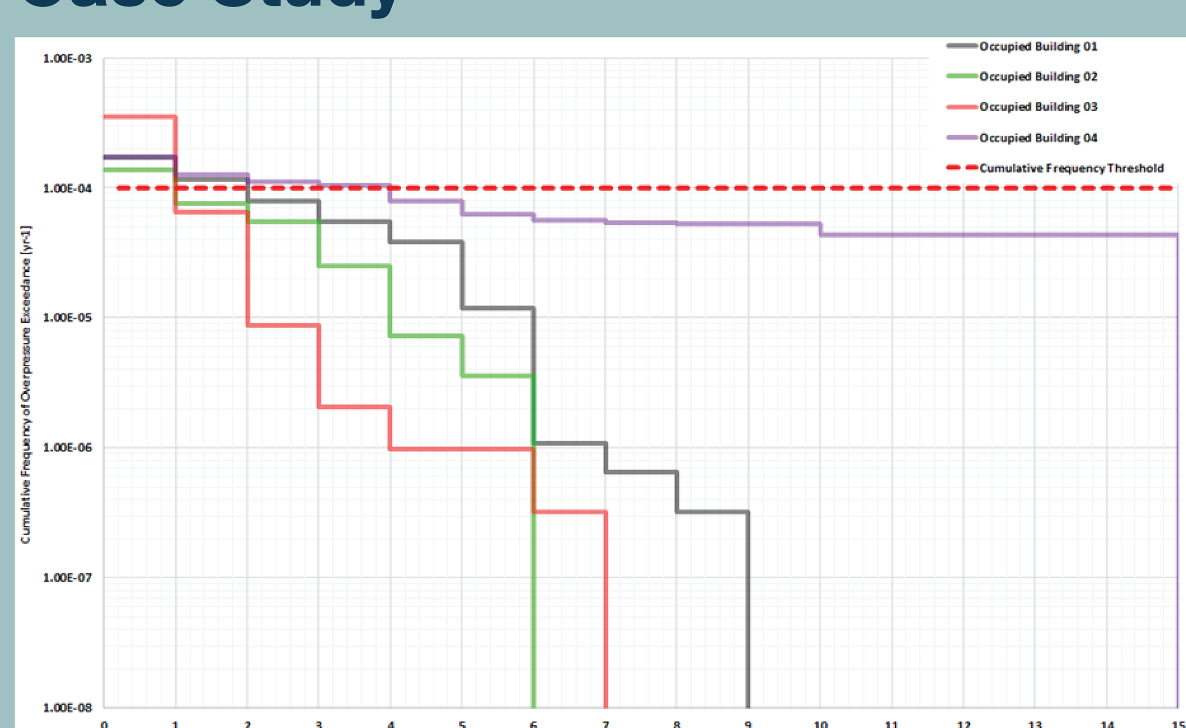

Figure 06
Overpressure Exceedence Curve

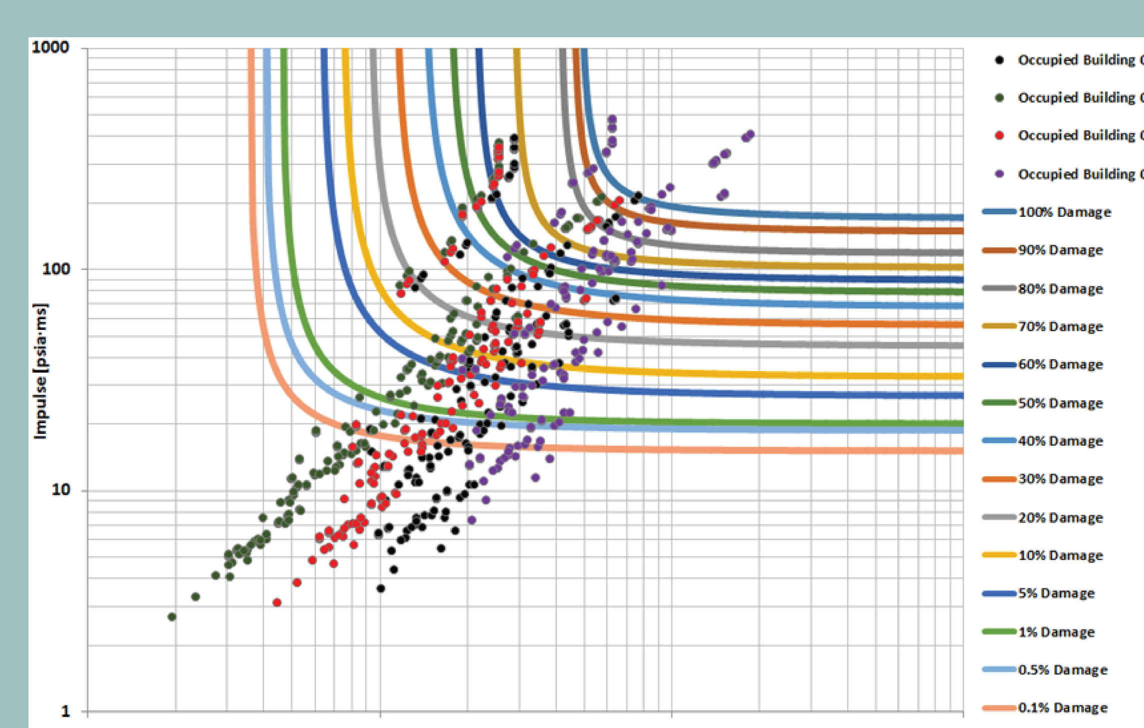

Figure 07
Building Damage Evaluation - Pressure Impulse Diagram - DOD [8]

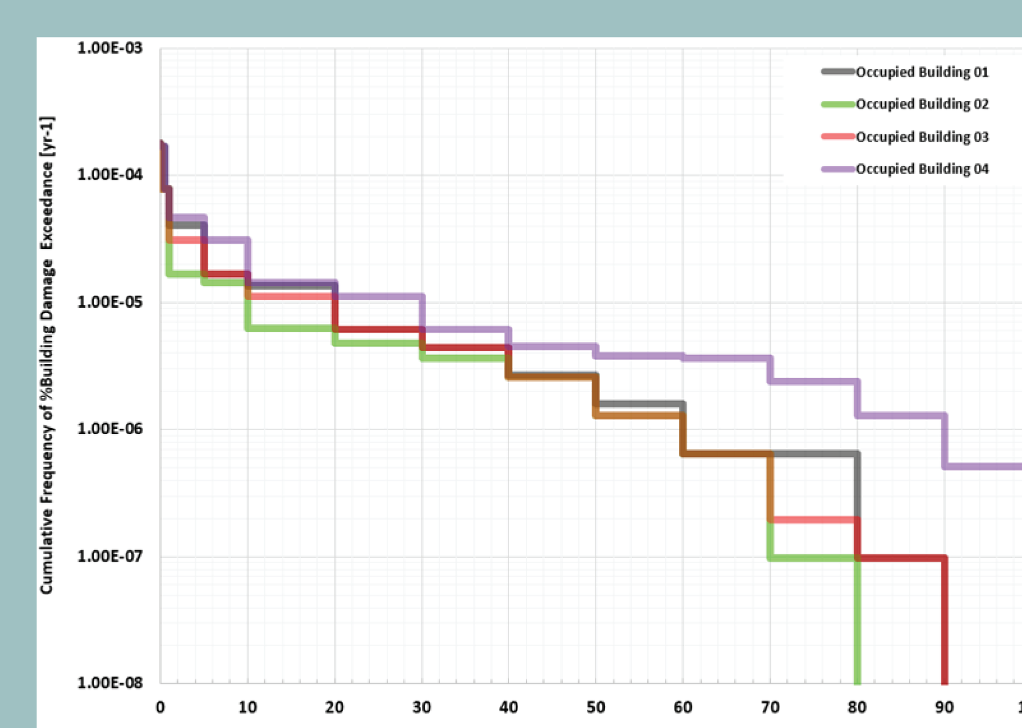

Figure 08
Building Damage Exceedence Curve - DOD [8]

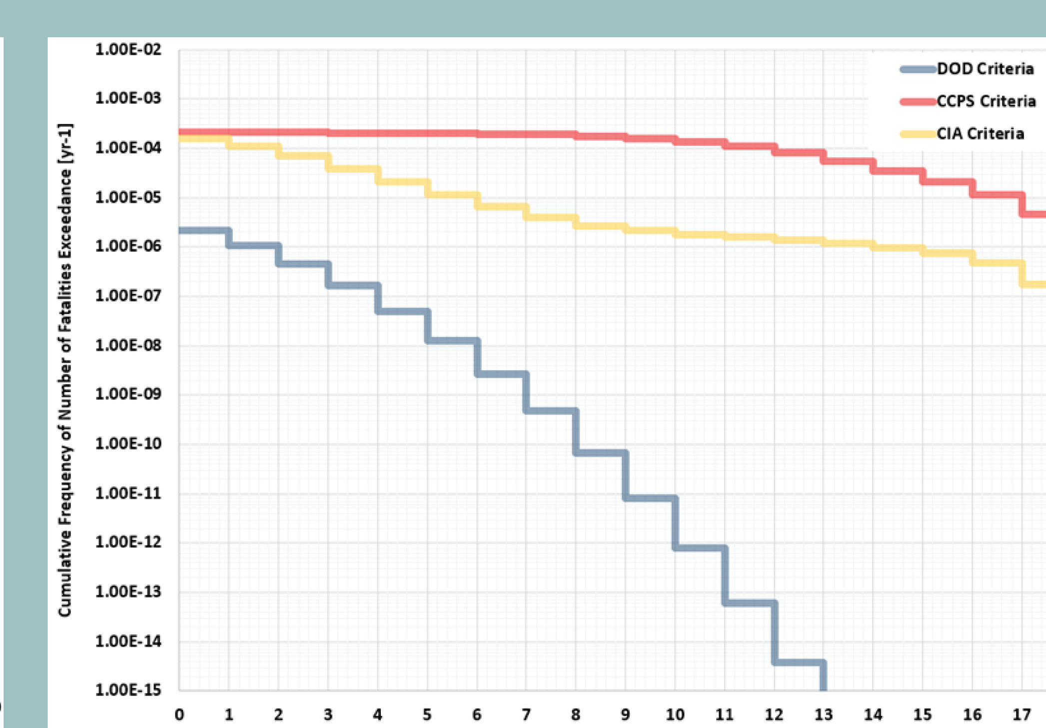

Figure 09
Number of Fatalities Exceedence Curve for Occupied Building 01 (F-N Curve)

Conclusions

A risk-based approach requires the identification of a hazard level (e.g., overpressure value) which will not be exceeded at a given frequency threshold. A detailed analysis of Quantitative Risk Assessment (QRA) results provides the basis for specific risk-based evaluations for human vulnerability of occupied buildings, and also for predicting the associated damage level. This approach is valuable for evaluating the location of occupied buildings, safety critical equipment, and any other key structures of interest. Exceedance Curves, Pressure-Impulse Diagrams, and F-N Curves have been developed with the aim to illustrate a case study by using SuperChems™ Expert V8.1 [9], a component of ioMosaic's Process Safety Office™.

References

[1] CCPS. (2000); "Guidelines for chemical process quantitative risk analysis". Second Edition. New York, Center for Chemical Process Safety of the American Institute of Chemical Engineers.
[2] VROM (2005), Guidelines for Quantitative Risk Assessment. Publication Series on Dangerous Substances (PGS3); CPR-18E.
[3] API-581 (2000); "Risk Based Inspection Base Resource Document". American Petroleum Institute, Second Edition.
[4] API Standard RP-752 (2009), "Management of Hazards Associated with Location of Process Plant Buildings", American Petroleum Institute, 3rd Edition.
[5] API Standard RP-753 (2007), "Management of Hazards Associated with Location of Process Plant Portable Buildings", American Petroleum Institute, First Edition.
[6] CCPS. (1996). "Guidelines for evaluating process plant buildings for external explosions and fire. Center for Chemical Process Safety of the American Institute of Chemical Engineers.
[7] CIA. (1998). Guidance for the location and design of occupied buildings on chemical manufacturing sites. London: Chemical Industries Association, ISBN 1858970776.
[8] DOD. (2009). Approved methods and algorithms for DOD risk-based explosives siting (Revision 4). In Technical Paper No. 14. Alexandria, VA: Department of Defense Explosives Safety Board.
[9] ioMosaic Corporation (2016). "SuperChems™ Expert 8.1", ioMosaic Corporation. www.ioMosaic.com