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Process Equipment Buildings: Manageable Risk or Danger Lurking for Synthetic Gas Processes?

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SynGas Association

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1. INTRODUCTION

Hydrogen is a primary product in synthetic gas processes. The impacts of hydrogen releases and potential fire and explosion in these process areas vary depending on several factors. OSHA's requirement to study these impacts has revealed many unintended consequences during JCL Risk Services' Facility Siting studies especially when reviewing enclosed processes containing hydrogen gases.

There are many reasons that facilities construct buildings around process equipment. Operators may work more efficiently when working out of the heat of the sun or cold of snow and blowing rain. Process equipment may be subject to freezing or overheating when exposed to extremes of climate. A building or shelter of some type may seem like a relatively inexpensive way to moderate conditions surrounding the equipment for operational or operator concerns.

An important side-effect of enclosing process equipment, however, is the creation of a confined environment that will enhance the severity of any flammable cloud ignition and could turn a relatively minor process upset or release into a devastating facility-impacting catastrophe. Careful examination of the nature of the flammable materials in the synthetic gas processes and the characteristics of the building protecting the equipment can lead to the identification of potentially severe explosion hazards and suggest methods that may be used to reduce or eliminate the danger posed to operators and other equipment at the facility.

Our presentation will cover these subjects and provide examples of the hazard mitigation recommendations that JCL Risk Services has presented to operating companies.

2. REQUIREMENTS TO PERFORM FACILITY SITING STUDIES

The Occupational Safety and Health Administration's (OSHA) Process Safety Management (PSM) regulations require facility siting evaluations to address the safety of building occupants. The PSM regulations require the use of Good Engineering Practice (GEP) which leads most companies to use the recommended methods and practices from the Center of Chemical Process Safety (CCPS) and from the American Petroleum Institute (API) Recommended Practices 752 and 753. These references are compatible in technical approach in order to be certain that occupants are safe within buildings in and near industrial sites that are required to comply with PSM.

These studies are commonly referred to as building or facility siting evaluations and they require both an understanding of the process impacts due to fires, explosions, and toxic releases and of the structure of buildings with occupants (control rooms, administrative buildings, maintenance buildings and other occupied structures). Refer to the references listed for more information.

The primary purpose of our paper is to illustrate some important concepts found in the Synthetic Gas industries due to the presence of hydrogen.

Explosions associated with hydrogen are among the largest in industry even though the explosions may not be the most common. Hydrogen has an impact more than five (5) times the explosive force for the same industrial conditions if the release was ammonia or natural gas. Instead of an explosion force that nearby buildings could withstand if natural gas or ammonia releases have delayed ignition, a hydrogen explosion can create very high explosive forces that most buildings cannot withstand resulting in a high probability of fatalities.

The results of facility siting evaluations can be surprising for many facilities due to the misunderstanding of past studies under representing the presence of hydrogen. Facilities should be aware of enclosing any process or equipment that contains hydrogen due to severe magnification of the explosion and the increased possibility of accumulated gas within the enclosed structures (such as compressor buildings and process control skids).

3. WORST CASE IMPACTS, MAXIMUM CREDIBLE EVENT

When evaluating the worst-case impacts on an occupied building, the maximum credible event is considered. This MCE is the release event that has the largest possible consequence that is physically possible. The probability of this even occurring is not a factor at this stage, only the fact that it is physically possible. An example of a maximum credible even for a large iso-butylene sphere would be the guillotine failure of the largest line feeding the sphere. Physically impossible scenarios, such as the sudden disappearance of the containing sphere are not credible and not considered. If the consequences of the maximum credible event are unacceptable, a risk-based approach may be used to incorporate the likelihood of the event occurring in practice. The events we will examine in this paper are only the maximum credible events. The more frequent, small leaks or fugitive emissions are generally mitigated by the basic ventilation systems of a process building. Maximum credible events can easily overwhelm building ventilation and cause catastrophic damage if they occur.

4. SIDE-ON OVERPRESSURES

For screening existing occupied buildings, peak side-on overpressure is the parameter that is used to determine the potential threat to personnel. New buildings should be designed using more detailed analyses that include the impulse or positive phase duration of the potential overpressure exposure. Overpressure levels of interest in screening existing occupied buildings are given in Figure 1 below along with their typical consequences found in Table 1 on the following page.

Figure 1: Incident Overpressure Damage to a Medium Metal Structure with noted Hydrogen and Methane VCE Values
(Figure 7 from "APPROVED METHODS AND ALGORITHMS FOR DOD RISK-BASED EXPLOSIVES SITING")

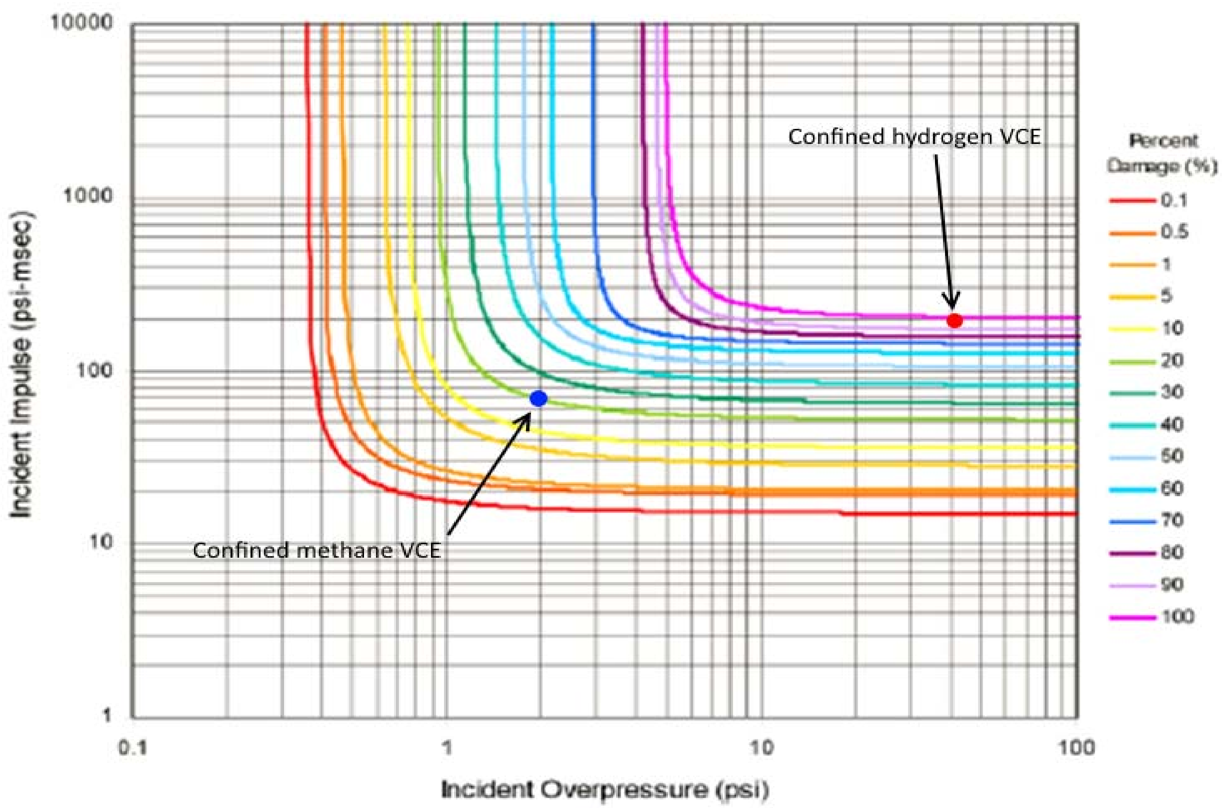

Figure 7. Medium Metal Structure (~10,000 sq ft)

Table 1: Overpressure Levels of Interest in Typical Building Siting Study

Peak Side-On Overpressure, psig	Building or Asset Consequences	Occupant Consequence
0.6	Light Wood Trailer is damaged in localized areas. Window breakage and falling overhead items are expected. Studs on the reflected wall (the wall facing the explosion) are expected to crack but remain in place.	Injury to personnel unlikely
0.9	Light Wood Trailer damage is widespread, but structural collapse is not expected. Wall components facing the blast sustain major damage and may fail. Window breakage and falling overhead items are expected.	Possible injury from flying glass, light fixtures
1.0	Possible minor structural damage to buildings and severe damage to trailer-type buildings and unreinforced masonry load-bearing wall building	Personnel injury from debris is likely
2.0	Local failure of isolated parts of buildings and collapse of trailer-type buildings and unreinforced masonry load-bearing wall building	Possible serious injury or fatality of some occupants
3.0	Collapse of buildings (brick and metal structures) Damage to cooling towers	Probable serious injury or fatality of many occupants
5.0	Potential rating of blast resistant modules for control rooms. Between 5 psi overpressure and 12.0 psi overpressure: overpressures could be sufficient to cause connection failures or frame damage to horizontal pressure vessels and cause connection failures in typical heat exchangers	Probable serious injury or fatality of many occupants
10.0	Probable total destruction of non-blast-resistant buildings and significant damage to blast resistant buildings	Probable 100% fatalities
>12.0	Blast overpressure will be sufficient to cause horizontal pressure vessels and typical heat exchangers to overturn or be destroyed and cause vertical pressure vessels to be moved enough to cause connected piping to fail. Depending on the peak overpressure attained, blast overpressure may be sufficient to overturn or destroy vertical pressure vessels as well. High level of concern for a "domino effect" with extensive damage to the surrounding areas as additional releases of flammable materials lead to numerous VCE events in other areas of the facility.	Probable 100% fatalities

The models typically used to predict the overpressure consequences for vapor cloud explosions in building siting calculations are the Baker-Strehlow-Tang (BST) model and the TNO Multi-Energy model. JCL Risk Services uses the Multi-Energy model blast curves to predict the explosion consequences and uses a hybrid of several techniques to characterize the severity of the explosion.

5. VAPOR CLOUD EXPLOSION PHENOMENOLOGY

A vapor cloud explosion (VCE) occurs when a fuel-air mixture ignites and generates a pressure wave due to the expansion of the products of combustion. If the products of combustion are allowed to expand at a constant pressure, the final volume they will occupy is typically five to eight times the initial volume. In the real world, the combustion gases will not be free to expand without restrictions and most buildings that might contain combustible mixtures will not be strong enough to contain the maximum pressure that could theoretically be generated. The actual pressure experienced will be a function of the strength of the building, the manner in which the building fails, the nature of the exploding fuel-air mixture, and the geometry of the interior of the building and the building's surroundings.

The overpressure produced by a propagating flame front is directly related to the velocity of propagation of the flame through the unburned mixture. Low flame speeds generate very low overpressure while faster flames generate much higher overpressures. Flames propagating below the speed of sound in the unburned fuel-air mixture are referred to deflagrations while flames propagating at speeds greater than the speed of sound are called detonations. Deflagrations may speed up or slow down as the environment of the flame changes. As an initially slow flame accelerates, it may accelerate to the point that it becomes a detonation. This process is called a deflagration-to-detonation transition (DDT). A detonation will continue to propagate as a detonation until it has consumed all of the flammable gas mixture available regardless of the surroundings or congestion or lack thereof.

There are three factors that influence the speed of a propagating flame: reactivity of the fuel, congestion or obstacles in the flow field, and confinement of the flammable mixture. Each of these factors and how they are characterized in appropriate models is discussed in the following sections.

5.1. Reactivity

Fuel reactivity is a measure of the propensity of the flame front in a given flammable mixture to accelerate and create overpressures or potentially undergo a deflagration-to-detonation transition (DDT). Reactivity is typically classified as high, medium, or low based on the laminar flame speed of the fuel-air mixture. These categories have been given boundaries, effectively placing certain materials in each category. Ammonia and pure methane are classified as low reactivity materials. Hydrogen is classified as a high reactivity material. Most other common industrial gases (e.g., propane or butane) are classified as medium reactivity materials.

Table 2: Comparison of Hydrogen, Methane, and Ammonia Flame Characteristics

Gas	Reactivity Class	Flammable Range, volume %	Laminar Flame Speed, cm/s
Ammonia	**Low**	15 - 28	7
Methane	**Low**	5 - 15	40
Hydrogen	**High**	4 - 75	312

5.2. Congestion

Congestion is usually characterized by the density of obstacles in the explosion flow field, either based on the percentage of the viewed area blocked by obstacles (area blockage ratio) or the percentage of a given volume that is occupied by obstacles (volume blockage ratio). The size and configuration of obstacles will also affect the flame acceleration. A congested region with smaller obstacles will generate higher flame accelerations and consequently more severe explosions than a region with larger obstacles given the same area or volume blockage ratio. Obstacle density is categorized as either low, medium, or high using the following criteria:

Low Obstacle Density

- Rigorous: ABR < 15% and Pitch-to-Diameter Ratio > 8
- Simple: One or Two Layers of Widely-Spaced Obstacles
- Qualitative: "If You Can Easily Walk Through the Area Without Ducking Your Head and Can Travel Relatively Unimpeded from Inside to Outside"

High Obstacle Density

- Rigorous: ABR $\geq$ 30% and Pitch-to-Diameter Ratio $\leq$ 4
- Simple: Three or More Layers of Closely-Spaced Obstacles
- Qualitative: "You Cannot Possibly Walk Through the Area, and Little Light Penetrates through the Congestion"

Medium Obstacle Density

- Rigorous: ABR = 15 to 30% and Pitch-to-Diameter Ratio = 4 to 8
- Simple: Volume Does Not Fit in Either Low or High Categories
- Qualitative: "You Can Walk Through the Area, But You Must Duck Your Head Occasionally and Must Take an Indirect Path from Inside to Outside"

5.3. Confinement

The final factor that influences the severity of a vapor cloud explosion is the degree of confinement of the products of combustion. When a flammable fuel-air mixture burns, the product gases expand to fill a volume roughly seven times the initial volume. If there are solid barriers that prevent the gases from expanding in a given direction, the gases will expand faster in the remaining directions. If the gases are confined in a strong enclosure, the gases will not be able to expand and the pressure in the structure will rise to approximately seven times the initial pressure. For unconfined explosions, there are three categories used to characterize the effect of confinement on the severity of the explosion. These are:

3D No confinement, hemispherical expansion in all three dimensions. Relatively slow flame speed and weak blast wave

2D Under or in-between solid decks. Gas expansion in two dimensions. Flame speed is significantly faster with a correspondingly stronger blast wave.

1D Inside pipes, conduits, tunnels. Gas can only expand in one direction. Flame speed is significantly higher than 2D expansion and blast wave is very strong. DDT is likely even for fairly low reactivity materials.

Confined explosions are the most severe category of vapor cloud explosions. Even gases that do not tend to generate damaging blast waves when unconfined can become exceptionally hazardous when confined in an enclosure.

5.4. Confined Explosions

Strong enclosures allow exceptionally high pressures to build within the enclosure before causing the enclosure to fail. In addition, the failure mode of the enclosure can enhance the blast effect outside of the enclosure. Combustion products and unburned gases jetting through failed seams create intense turbulence that enhance flame acceleration even after the unburned gases have expanded. *NFPA 68: Standard on Explosion Protection by*

Deflagration Venting, contains guidance on providing adequate deflagration venting for enclosures where there is the potential for a deflagration. One of the assumptions made by this standard, however, is that the venting will prevent the failure of the enclosure. In most cases involving buildings constructed around process equipment, however, the building is not strong enough to withstand the pressure generated by deflagrations within the building. NFPA 68 is only able to help estimate the relative effectiveness of adding venting, weakened wall panels, or removing walls to mitigate the consequence of an explosion in the building.

The high overpressure generated by enclosing hydrogen processes in buildings increases the range of explosion impacts which can alter the distances for placement of portable buildings and non-essential personnel housing, along with the distance of non-structural damage to public buildings (e.g. glass shattering in commercial or residential buildings that do not have tempered glass requirements).

6. PROCESS EQUIPMENT BUILDING HAZARDS

For illustrative purposes, we will be looking at the effects of openings and the type of flammable gas on a deflagration in a typical steel-framed, steel clad building measuring ten meters square with a flat roof five meters from the ground (10m x 10m x 5m ~~ 33 ft x 33 ft x 16 ft). The building is assumed to be filled with a stoichiometric mixture of the fuel gas in air. The pertinent characteristics of this building are listed in Table 3 below.

Table 3: Process Equipment Building Parameters, Case Study

Process Equipment Building Parameter	Dimension
Length	33 ft.
Width	33 ft.
Height	16 ft.
Volume	17,424 cu. ft. (~500 cu. meters)
Floor Area	1076 sq. ft.
Roof Area	1076 sq. ft.
Total Wall Area	2153 sq. ft.
Total Surface Area	4306 sq. ft.

We will be using the methods given in NFPA 68 to look at factors which affect the severity of a major release in this process equipment building.

We will be examining three flammable gases that are widely encountered in SynGas processes: ammonia, methane, and hydrogen. We first calculated the vent area (wall or roof surface area openings) that would be necessary to limit the explosion pressure in the building to 1.5 psig. The results of these calculations are found in Table 4 on the following page.

Table 4: Process Building's Vent Area Needed to Limit Pressure

Flammable Gas	Max. Pressure with No Vent (psig)	Required Vent Area to Limit Pressure to 1.5 psig (sq.ft.)
Ammonia	78	253 (12% of the total wall surface area)
Methane	113	732 (34% of the total wall surface area)
Hydrogen	99	6867 (>> 100% of all surfaces)

For a release of ammonia, removing roughly half of one wall would provide enough vent area to limit the pressure to 1.5 psig. If methane was released in the same building, it would be necessary to remove one entire wall and roughly one-third of a second wall to limit the pressure in the structure to 1.5 psig. Finally, we can see that the vent area required to limit the pressure in the building to 1.5 psig if hydrogen were released into the building exceeds the total area off the walls, roof, and floor. While this is a physically unrealistic result that is beyond the applicability limits of the model, it demonstrates the much higher hazard posed by hydrogen compared to either methane or ammonia.

Another way to look this problem is to determine the peak overpressure that would be achieved in the building if a fixed vent area is assumed. For this series of calculations, we will assume that one wall is set up as a vent giving a vent area of 528 sq. ft. We will also show the distance required for the overpressure to decay to 0.6 psig and 3 psig. The distance to 0.6 psig is the closest distance that occupied (e.g. with non-essential personnel, such as administrative staff) portable buildings could be located to the accident building. The distance to 3.0 psig is the distance within which a steel-framed, steel-clad permanent building would be severely damaged, injuring or killing personnel inside.

The results of these calculations are shown in Table 5 below.

Table 5: Peak Overpressure Distances, Case Study

Flammable Gas	Maximum Pressure in Building (psig)	Distance to 0.6 psig (ft)	Distance to 3.0 psig (ft)	Distance to 5.0 psig (ft)
Ammonia	0.6	60	-	-
Methane	2.9	262	-	-
Hydrogen	38	2340	468	286

These results again illustrate that confined hydrogen explosions pose a much more serious hazard to a facility than do confined ammonia or methane explosions. It also illustrates the significant difficulty encountered in attempting to mitigate the hazards of confined hydrogen explosions through venting alone.

A final consideration when dealing with hydrogen releases is the relative ease with which a hydrogen-air deflagration may undergo DDT becoming a detonation. While a deflagration will slow down and become less hazardous when a confining structure is destroyed, or the gas cloud expands to a region with lower degrees of obstruction or congestion, a detonation continues to generate severe overpressure levels even after it has expanded and is no longer confined or obstructed. This results in not only high maximum overpressures but a much larger source region and overall explosive energy with much larger explosion impact distances.

7. PROCESS EQUIPMENT BUILDING VENTILATION

The most important design for process building ventilation is to maintain a safe working environment for operators (avoiding toxicity) due to the possibility of process gas leaks and to avoid accumulation of gases over time. The buildings need proper ventilation of routine leaks and fugitive emissions. The more frequent, small leaks or fugitive emissions are generally mitigated by vapor detection and emergency shutdown systems with automated draft fans (e.g., design for a compressor seal failure in large compressor buildings) or continual venting with motorized fans or passive natural draft of a building due to open ducts or roof slots with smaller ground level vents to produce a chimney effect for air space turnovers.

It should never be assumed that a building's ventilation system is designed to prevent an explosive mixture if large leaks occur. The flammable range of hydrogen is noted above and would be difficult to design and maintain sufficient air turnovers to prevent an explosive mixture from a large leak.

The previously noted assumptions for ventilation are based on the process containing only light, buoyant hydrocarbons such as methane or hydrogen. Large releases of highly pressurized gas are most likely not buoyant (discharges may be dense gases for significant distances) when immediately discharged. Additionally, extremely cold temperatures may create a high-density gas (e.g., near saturation for liquification/condensation processes).

8. OTHER CONCEPTS RELATED TO THIS DOCUMENT

Other concepts related to the subject of this document may be of interest to the reader to fully understand the issues presented:

- Probability of ignition varies by chemical;
- Hydrogen's probability of ignition is very high (potential fire on small leaks, potential delayed ignition with explosion on larger leaks);
- Probability of explosion doubles when processes are enclosed in buildings;
- Frequency of explosions in industries;
- Impacts on buildings varies based on its structure;
- Enclosed buildings should have natural ventilation to prevent accumulation of fugitive leaks and to maintain a habitable working space for operators; and
- Non-structural damage to/within buildings from explosions include glass breakage and falling bookcases/lockers that are not properly secured to walls.

APPENDIX A: REFERENCES

Jason Gill, Graham Atkinson, Edmund Cowpe, and David Painter. "Vapour Cloud Explosions in Steel Clad Structures." Edinburgh International Conference Centre, Edinburgh, UK on 24-26 May 2016: IChemE, 2016.

National Fire Protection Association, and Explosion Protection Systems. *NFPA 68: Standard on Explosion Protection by Deflagration Venting.*, 2013.

Thomas, James Kelly, Craig Eastwood, and Martin Goodrich. "Are Unconfined Hydrogen Vapor Cloud Explosions Credible?" *Process Safety Progress* 34, no. 1 (March 2015): 36–43. https://doi.org/10.1002/prs.11685.

Ettner, Florian, Klaus G. Vollmer, and Thomas Sattelmayer. "Numerical Simulation of the Deflagration-to-Detonation Transition in Inhomogeneous Mixtures." *Journal of Combustion* 2014 (2014): 1–15. https://doi.org/10.1155/2014/686347.

"Firexplo_Explosion_Venting_Report.Pdf." Accessed January 20, 2018. https://www.nfpa.org/Assets/files/AboutTheCodes/68/Firexplo_Explosion_Venting_Report.pdf.

Jo, Young-Do, and Daniel A. Crowl. "Flame Growth Model for Confined Gas Explosion." *Process Safety Progress* 28, no. 2 (June 2009): 141–46. https://doi.org/10.1002/prs.10289.

Middha, Prankul, and Olav R. Hansen. "Predicting Deflagration to Detonation Transition in Hydrogen Explosions." *Process Safety Progress* 27, no. 3 (September 2008): 192–204. https://doi.org/10.1002/prs.10242.

Sezer, Hayri, Francis Kronz, V'yacheslav Akkerman, and Ali S. Rangwala. "Methane-Induced Explosions in Vented Enclosures." *Journal of Loss Prevention in the Process Industries* 48 (July 2017): 199–206. https://doi.org/10.1016/j.jlp.2017.04.009.

Department of Defense Explosives Safety Board; "APPROVED METHODS AND ALGORITHMS FOR DOD RISK-BASED EXPLOSIVES SITING." Alexandria, VA; 21 July 2009.

Management of Hazards Associated with the Location of Process Plant Portable Buildings, API 753 2007 http://www.api.org/environment-health-and-safety/process-safety/processsafety-standards/standard-rp-753.

Management of Hazards Associated with the Location of Process Plant Permanent Buildings, API 752 2009 http://www.api.org/environment-health-and-safety/process-safety/processsafety-standards/standard-rp-752.

Guidelines for Evaluating Process Plant Buildings for External Explosions, Fires, and Toxic Releases; Center for Chemical Process Safety, Second Edition in 2012; Wiley & sons, Inc. Publication.

APPENDIX B: AUTHORS

Timothy Allen Melton, Ph.D., P.E., Chemical Engineering

Chief Consultant – Process Safety Services

Summary

As Chief Consultant, Process Safety Services for JCL Risk Services, Dr. Melton is a highly qualified chemical engineer with more than 24 years of experience using and developing software to solve complex modeling problems in the field of consequence analysis and risk assessment for the chemical and petrochemical industries. He has extensive experience modeling the vaporization and dispersion of toxic and flammable vapor clouds using both existing models and custom models developed for specific circumstances. He has been involved in many consequence analysis studies, including building siting, plant spacing and layout for regulatory compliance, pipeline integrity management program calculations, flare sizing and siting, and explosion impact analyses. Dr. Melton has used various consequence modeling packages to perform vapor dispersion, explosion, and fire radiation calculations for gas and liquids pipelines, LNG and LPG terminals, offshore platforms, chemical plants, and gas plants. He has participated in several quantitative risk analysis (QRA) projects, selecting release scenarios, and estimating the probability of occurrence of the scenarios. The processes evaluated included several refinery units, highly toxic system (H_2S, HF) analysis, natural gas processing plants, exploration and production facilities, pipelines, LPG terminals, and tank trucks. His qualifications include B.S., M.S., and Ph.D. degrees in chemical engineering.

Dr. Melton has presented at AIChE's CCPS and Mary Kay O'Connor Process Safety Center concerning LNG modeling, overpressure modeling, and estimating flame speeds. His work has been published in peer-reviewed international journals.

Dr. Melton specializes in designing, developing, implementing and reviewing process safety and risk assessments. His major projects have included:

- Vapor cloud explosion modeling for use in facility siting and risk assessment calculations.
- Modeling sour gas cleanup with amines and mixed amines in packed and tray towers.
- Development of a flame speed-based analytical model to evaluate unconfined vapor cloud explosions in risk-based analyses.
- Development of an analytical model for predicting the vaporization rate from multi-component, low-volatility liquid pools.
- Research on the behavior of two-phase jet releases. This included the development of a computer code to model the thermodynamics of aerosol plumes created by such releases.
- Creation of novel boundary conditions for Monte Carlo and molecular dynamics simulations.

Other consulting service offerings include:

- Short course instruction on Principles of Liquefied Gas Safety, Risk Analysis Methodology, and Introduction to Consequence Analysis.

Kay A Modi

Senior Process Safety Consultant

Summary

Ms. Modi has 30+ years of petroleum and petrochemical experience and is well-seasoned in Process Safety Management Systems and Practices and large project management. She possesses a rare blend of process engineering, process hazard analysis, facility siting evaluations, risk analysis (consequence and quantitative), emergency release modeling, employee exposure modeling, incident investigation, and environmental consequences. Ms. Modi has participated in new plant start-ups, FEED/new construction reviews, plant optimizations, plant turnarounds, and corporate risk oversight. She has extensive knowledge of chemical and petroleum refining process technologies. Ms. Modi provides training to clients on many subjects: when to select qualitative, semi-quantitative, and quantitative analyses of hazards and review of methodologies; basis of facility siting field assessments to improve new plant layouts; unrevealed failure analyses within process hazard studies; and basics of risk assessments in health and environmental consequence reviews. Large projects have included staff and technical responsibilities for major pipeline (gas, liquids, terminals, and gas facilities) systems database development of assets and EHS regulatory tracking. Asset and due diligence assessments of facilities for transactions with site visits. Management of engineering and administrative staff for safety services companies. Short-term contract to provide environmental and health regulatory affairs management within major pipeline corporation during staff transitions.

Prior to working with JCL Risk Services, Ms. Modi worked with Shell Oil and Shell Chemical Company at the Deer Park, Texas and Mobile, Alabama locations. Ms. Modi worked with the teams for the startup of pesticide with waste destruction facilities and for the startup of high pressure hydrotreating units. Ms. Modi has process experience with vacuum distillation, catalytic systems, hydrotreating, gas processing, chemical processes, and marine terminals. Ms. Modi has performed numerous risk dispersion modeling projects associated with low level exposures to carcinogenic materials and catastrophic releases with highly toxic chemicals stored in significant quantities (OSHA/EPA/WHO thresholds). Ms. Modi has been conducting risk analyses since the 1980s with employee and public health focus. Additionally, she has trained staff and public stakeholders on risk of health due to industrial operations for all media (water, land, and air).

Ms. Modi oversaw engineering project's HSE assessments for consulting firms. She has developed risk assessments for HSE in various countries and predominantly in the petroleum upstream and downstream processes for new business and new construction.

Selected Projects

- Facility Siting Evaluations to reduce the footprint of overpressure sources
- Major Pipeline (Oil and Gas Systems, Marine Terminals) Database developed for HSE regulatory and asset tracking of 50+ facilities plus minor assets
- Development of PHA/LOPA/Enabling Modifiers procedures with Quantitative Methods for setting Targeted Mitigation Event Likelihoods for new construction projects to optimize SIS designs in specialty chemical processes
- Quantitative risk assessments for explosions from LOC within chemical process units with highly flammable raw materials

Education

Bachelor of Science, Chemical Engineering – University of Missouri-Rolla