Process Safety News

Spring 2017
Volume 24,
Number 2



# REVISITING REACTIVE GASSY SYSTEMS VENT SIZING

By: Hans K. Fauske, D.Sc., Regent Advisor, Fauske & Associates, LLC (FAI)

For the gassy system, in the absence of any tempering (total pressure equal to the noncondensible gas pressure), the principal parameters determining the vent size requirement are the measured maximum rate of pressure rise $\dot{P}$ (psi/s) in the test apparatus like the ARSST, and the estimate of the average void fraction $\alpha$ corresponding to complete gas disengagement illustrating the potential benefit from two-phase flow during the period before turnaround in the peak venting pressure P (psia).

The required relief rate $W_{reg}$ (kg/s) for all gas venting at peak reactive condition is given by

$$W_{reg} = \frac{V(1-\alpha)\rho_\ell}{m_t} v \frac{\dot{P}}{P} \rho_g \qquad (1)$$

and considering gas critical flow the vent area A ($m^2$) is given by

$$A/V = \frac{1}{0.61} \frac{(1-\alpha)\rho_\ell v}{m_t} \frac{\dot{P}}{P} \left( \frac{M_{w,g}}{RT} \right)^{1/2} \qquad (2)$$

where V ($m^3$) is the vessel volume, R (8314 Pa-$m^3$/K-kg mole) is the gas constant, setting $M_{w,g}$ = 44 kg/kg mole and T = 400 K, and considering the ARSST test apparatus parameters of $m_t$ = 0.01kg, v = 3.5 • 10-4 $m^3$, leads to the following simple design method for gassy systems

$$A/V = \frac{3.5 \cdot 10^{-3}}{P} \dot{P}(1-\alpha) \qquad (3)$$

where $\dot{P}$ (psi/min) is the measured peak rate of pressure rise and P (psia) is the peak venting pressure.

## Mild Energetic Reactions

For these systems where complete gas disengagement is possible when reaching peak reactive conditions the corresponding average void fraction $\alpha$ is estimated by considering the churn turbulent flow regime as follows

$$\frac{V(1-\alpha)\rho_\ell}{m_t} \frac{v\dot{P}}{P} = \frac{2\alpha}{1-1.5\alpha} u_\infty A_{vessel} \qquad (4)$$

where $u_\infty$ is the bubble rise velocity (~ 0.2 m $s^{-1}$) and Avessel ($m^2$) is the cross-sectional area of vessel.

As an example of mild energetic reactive systems is the full scale 460 gallon test vessel with A/V = 0.14 $m^{-1}$ and filled with neat dicumyl peroxide vented safely with a peak relief pressure of about 35 psia (Poteet and Banks, 2002). Applying Eq. 4 for these conditions with $m_t$ = 0.01 kg, v = 3.5 • 10-4 $m^{-3}$ and maximum peak pressure rise rate $\dot{P}$ = 71.7 psi/s result in $\bar{\alpha}$ = 0.66, and from Eq. 3

$$A/V = \frac{3.5 \cdot 10^{-3}}{35} 4300(1-0.66)$$

$$= 0.146\ m^{-1}$$

which is consistent with the experimental value of 0.14 $m^{-1}$.

## Highly Energetic Reactions

For these systems, complete gas disengagement is not likely, but considering all gas venting at peak reactive condition and no reactant loss ($\alpha$ = 0), Eq. 3 gives a consistent vent area with the experimental value for neat peroxide with $\dot{P}$ = 1.49 • $10^5$ psi/min. It is of interest to note that this evaluation is also consistent with considering two-phase flow at peak reactive condition with $\alpha$ = 0.83 corresponding to the bubbly flow regime asymptotic solution (Fauske, 2011).

### References

H. K. Fauske, 2011, "A Practical Approach to Pressure Relief Sizing," DIERS Users Group Meeting, Burr Ridge, Illinois, October 11, 2011.

C. S. Poteet and M. L. Banks, 2002, "An Example of a Test Method for Vent Sizing," Process Safety Progress, Vol. 21, June 2002.

*Dr. Hans K. Fauske is an original founding partner of Fauske & Associates, LLC and currently serves as Regent Advisor*

# Letter From the President

In my last letter, I spoke about harnessing the power of positivity in order to make the world a better place. It isn't just rhetoric for the team here at Fauske & Associates, LLC (FAI). For us, it is part of our culture. We give our all to help our customers with their process safety solutions and to make their workplace safer, and we also strive to do what we can to give back to the community in which we live and work everyday.

By being active in our local chapter of Kiwanis and various chambers of commerce and community groups, and forging relationships with community leaders, I am not only able to personally have an impact but also to help FAI identify areas where we can make a difference.

Some of the many community events we have participated in as a company include:

- Kiwanis Peanut Days
- Winter Clothing Drive Benefiting Students at Elaine Locke Charter Academy
- Bears Score, Families Win campaign benefiting the Ronald McDonald House Charities® of Chicagoland & Northwest Indiana (RMHC®-CNI
- HCS Family Services in Hindsdale, Illinois
- Village of Burr Ridge Earth Day cleanup

This spring, I encourage you to consider where you can give your time, resources, or expertise to help not only the people you interact with at work, but also the people around you that contribute to your livelihood and life experience. Together, we really can make a difference.

Have a safe spring.

H. Kristian Fauske
President

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## Statement of Purpose:

FAI's "Process Safety News" is intended to be a forum on recent advances in chemical process safety and FAI's current and related offerings in this area. It will address subscriber's concerns regarding issues and practices for relief system design as well as laboratory testing and techniques for process safety management.

## Inquiries:

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# AN INTERVIEW WITH ARTURO GARZA, BDSI – FAUSKE & ASSOCIATES, LLC AGENT IN MEXICO

**By: Jeff Griffin**
**Director of Sales & Business Development**
**Fauske & Associates, LLC**

Arturo Garza Eckermann is owner/founder of Buró de Servicios Internacionales SC (BDSI). He holds a B.A. in Economics by the University of Nuevo León, an M.Phil. by the University of Glasgow and an M.Sc. by Northwestern University.

**Q:** What is your background?

**A:** I have been doing independent consulting work since 2005, specializing in fund procurement for private companies' R&D projects from different Federal and State Government sources in Mexico. I had initially worked as an associate at another consulting firm, and in 2007 I founded my own consulting firm, BDSI.

**Q:** How did you first get interested in process safety?

**A:** When I was a consultant, I witnessed the explosion of a prototype batch reactor that was meant to produce syngas from carbonic waste. The explosion occurred after the reactor had been loaded with organic (maize) dust. The prototype reactor was rendered useless and the future of the R&D project became uncertain.

That was when my interest in process safety began. I had previous knowledge about FAI at the time, and initiated the process of linking BDSI commercially as a Fauske & Associates, LLC (FAI) Agent in Mexico. This was formalized in mid-2015.

**Q:** How do you see the growth of FAI's services in Mexico?

**A:** My experience promoting FAI and its services in Mexico has been a pleasing challenge; results in sales need to be improved. We have had an increasing number of prospects in this past year, which is encouraging.

Even though nuclear industry is not a very important activity in my country, FAI's background servicing nuclear plants and processes has been a key element in promoting it in Mexico, given the outstanding recognition of FAI globally. In addition, I must say that support by FAI's staff and personnel has always been readily available and most helpful.

I find that process safety is a rather new issue that companies are addressing in Mexico. In our recent experience, several manufacturing firms that have been very successful in Mexican industry have not fully come to terms with it. Therefore, budgets allocated to consulting/ engineering services or investments for protection equipment are limited.

Awareness of risks associated with combustible dust is not very widespread. This relative lack of knowledge, along with the absence of previous accidents in the sector presents a real challenge for promotion.

A large network of EHS contacts has been developed. The experience so far is that EHS departments are pretty much at low levels within the decision making process; and I find that in many cases their existence is focused on compliance with Government regulations or requirements which may not be thoroughly binding. Nonetheless, these contacts now have some initial information about the services we are offering. Foundations are being laid.

On the other side, there are important supply chain matters that favor the growing interest in process safety. Mexican metallurgical industry companies serving the global automotive, aerospace, household goods sectors — among others — as well as food, chemical and pharmaceutical industries are important potential clients for FAI 's services. In these industries, I believe, the importance being given to safety derives from demands and requirements from their respective end-industries.

Moreover, Mexico's recent reforms will promote and boost the oil/gas and petrochemical sectors. The presence of worldwide competitors should also push the demand for specialized process safety services.

These elements point in the direction of a huge penetration of FAI into the Mexican industrial sector.

## FAI in Mexico

"We are excited to be working with Arturo Garza of BDSI to support our clients in Mexico and in Latin America. Our growth in this region stems from an increasing awareness of the importance of process safety. This sentiment is motivating companies to take action to address safety concerns. In particular, we have seen increasing interest in area classification, deflagration vent design, and combustible dust. This year - Fauske & Associates, LLC (FAI) has performed several on-site Dust Hazard Assessments (DHA's) which have been critical to addressing safety concerns. FAI has worked with several clients in the automotive, agricultural, pharmaceutical, and specialty chemical sectors to address concerns related to process safety."

*Jeff Griffin, Director of Sales & Business Development*

# FAUSKE & ASSOCIATES, LLC (FAI) & SMS ENERGETICS COLLABORATE FOR SAFETY

**By: Scott Genta, Principal Engineer, Safety Management Services, Inc.**

Fauske & Associates, LLC and Safety Management Services, Inc. (SMS™) have partnered to provide expert training on NFPA 652 and Dust Hazard Analysis (DHA). FAI and SMS have a long standing relationship supporting each other with combustible dust and energetic testing projects. FAI has over 35 years of expertise in chemical system and combustible dust characterization and SMS brings 20 years of experience testing energetic substances and articles along with a variety of explosives testing resources. SMS is also one of five laboratories authorized by the Department of Transportation to recommend shipping classifications for Class 1 substances and articles.

## SMS Test Site at TEAD

SMS has partnered with the Tooele Army Depot (TEAD) to yield a very capable test site to perform large-scale and small-scale tests of energetic substances and articles. The TEAD/SMS partnership provides a unique set of capabilities for government and commercial clients. The following tests are performed at the test site:

- ***DOT/DoD Classification Testing***
  As an Authorized Examining Agency for the US Department of Transportation (DOT) to perform explosives and other hazardous materials examination services, SMS testing services determine the transportation and/or storage hazards classification, including the proper name, hazard class and division, and compatibility group for explosive substances and articles. The SMS test site is a secure, restricted-access test facilities with proper clearances for CLASSIFIED materials.

- ***In-Process Classification Testing***
  Using the established DOT/DoD hazards classification systems in combination with other recognized tests, SMS has produced a systematic approach to classifying the hazards of in-process explosive materials (concept approval by IBC, NFPA 495 Committee, and others). A few examples of the classification tests include the following:
  - **Critical Height:** determines the height at which the sample provides enough confinement to transition from a fire to an explosion.
  - **Critical Diameter:** determines the diameter below which an existing detonation will not propagate.
  - **Worst-Case Propagation:** determines if an accidental initiation will propagate to the surrounding process.

- ***Operational Shield Testing***
  Operational Shields are barriers or enclosures constructed to protect personnel, material or from the thermal, pressure, and fragmentation hazards resulting from an accidental or intentional initiation of explosive materials. SMS tests prototype operation shields against the protection criteria of MIL-STD-398 to determine whether the shield provides adequate protection. SMS's data acquisition system measures the positive incident pressure, noise levels, and heat flux level/ exposure time.

For more information regarding the NFPA 652 -– An Introduction to Dust Hazard Analysis contact FAI University@fauske.com. For information regarding SMS, contact Mr. Scott Genta at SGenta@smsenergetics.com or Mr. Jason Ford at JFord@smsenergetics.com.

# Q&A ON PHA — THE WHO, WHAT, WHEN, AND WHY OF PROCESS HAZARD ANALYSIS

By: Ursula Malczewski, Chemical Engineer, Fauske & Associates, LLC

## Why perform a risk analysis?

Risk Analysis goes by many names and many acronyms. While the techniques differ by industry or application (see Tables 1 and 2), all are set to accomplish the same goal: to identify hazards within a process. Some industries have regulatory requirements to perform risk assessments. Others are prompted by insurers or another Authority Having Jurisdiction (AHJ) or have been initiated by internal corporate objectives.

Table 1. – Select Risk Analysis Types and Commonly Used Industry

| Type of Risk Analysis | Commonly Used Industry |
|---|---|
| Probabilistic Risk Analysis (PRA) | Nuclear, Power, Airline, Transportation, Urban Planning |
| Process Hazard Analysis (PHA) | Required for OSHA PSM [29 CFR 1910.119] or EPA RMP [40 CFR Part 68] covered chemicals; applicable to all hazardous processes |
| Dust Hazard Analysis (DHA) | Required for facilities handling combustible particulate solids |

The results of a risk analysis can be used to justify process improvements. Additionally, identifying and mitigating hazardous scenarios through risk analysis is considered a Recognized and Generally Accepted Good Engineering Practice (RAGAGEP), and ultimately makes good business sense. Continue on to read about one of the many forms of risk assessment.

## What is a Process Hazard Analysis (PHA)?

A Process Hazard Analysis (PHA) is a rigorous and systematic approach to identifying, evaluating, and controlling the hazards of processes involving highly hazardous chemicals.[1] Consequences addressed can include employee safety, environmental impact, public safety, extent of equipment/facility damage, and/or effects on public image. Causes of such situations are identified, and the scenarios are ranked on severity as well as frequency of occurring.

***The end goal of performing a PHA is not to label a process as "safe", but to detect unprotected situations and trigger the necessary safety improvements to reduce or minimize risk.***

Safeguards currently in place are accounted for, and where risk is unmitigated/deemed unacceptable, recommendations for follow up actions are provided. A management review is later conducted to determine what changes will be made. The end goal of performing a PHA is not to label a process as "safe", but to detect unprotected situations and trigger the necessary safety improvements to reduce or minimize risk.

## When should a PHA be conducted?

A risk analysis for hazardous processes should be conducted for each stage of design, operation, and shut down. [2] PHAs are required to be completed initially and revalidated every five years – however, major changes made to a process warrant a total re-do to be conducted earlier.[1] Furthermore, when either temporary or permanent modifications are made to a hazardous process, a Management of Change (MOC) PHA should be utilized to evaluate the inherent hazards that can result from the change. Table 2 shows the applicability of several PHA techniques during some of the different phases of a process lifecycle.

Table 2 – Applicability of Select PHA Techniques[2]*

| Phase of Process Design or Operation | Technique | | | | | |
|---|---|---|---|---|---|---|
| | Checklist | What-if | What-if/ Checklist | Hazard and Operability Study (HAZOP) | Failure Modes and Effects Analysis (FMEA) | Fault Tree Analysis (FTA) |
| R&D | | ✓ | | | | |
| Design | ✓ | ✓ | ✓ | | | |
| Pilot Plant Operation | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Detailed Engineering | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Construction/Startup | ✓ | ✓ | ✓ | | | |
| Routine Operation | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Modification | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Incident Investigation | | ✓ | | ✓ | ✓ | ✓ |
| Decommissioning | ✓ | ✓ | ✓ | | | |

*A PHA leader will determine the most appropriate methodology

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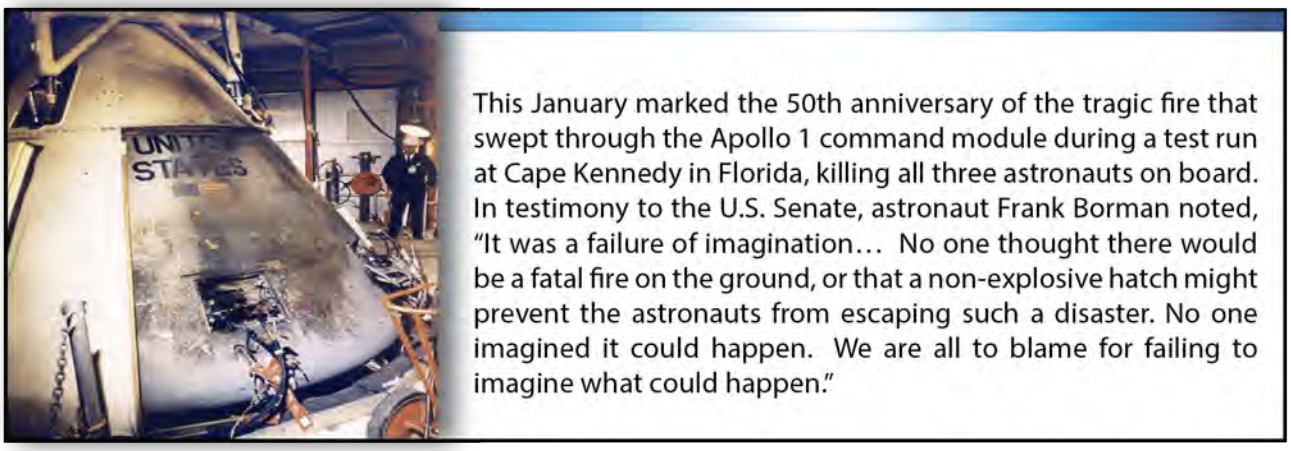
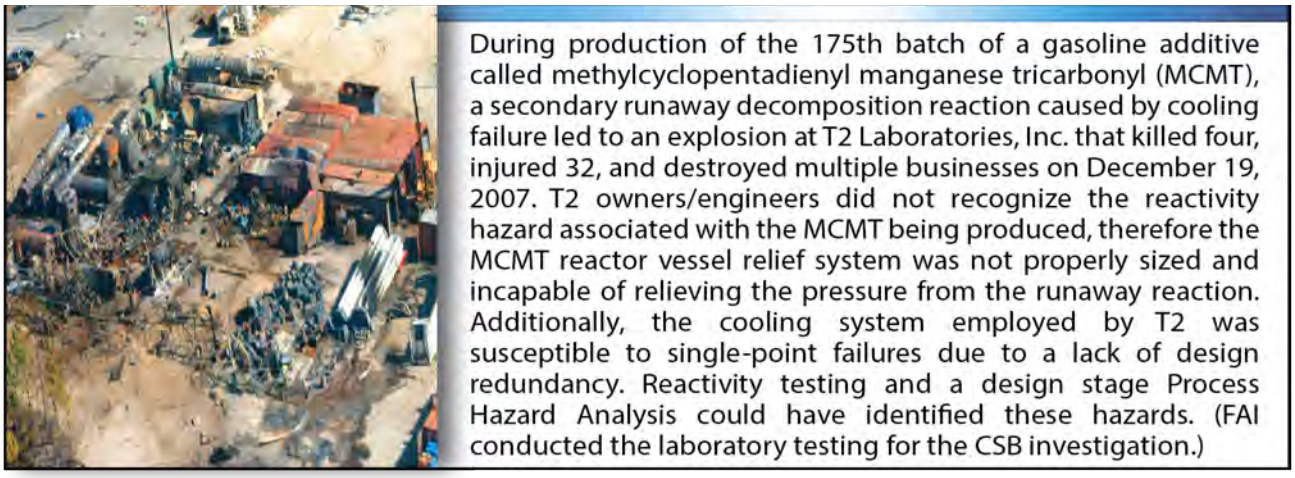
Serious safety incidents continue to occur at an alarming frequency across all industries and during all stages of operation (see Figures 1 a, b, and c for brief case studies). Awareness and unwavering attention to details are essential to avoiding serious incidents. That being said, a risk analysis is only as good as the team assembled to conduct it.

Figure 1a. – NASA Apollo 1 Ground Fire[3]



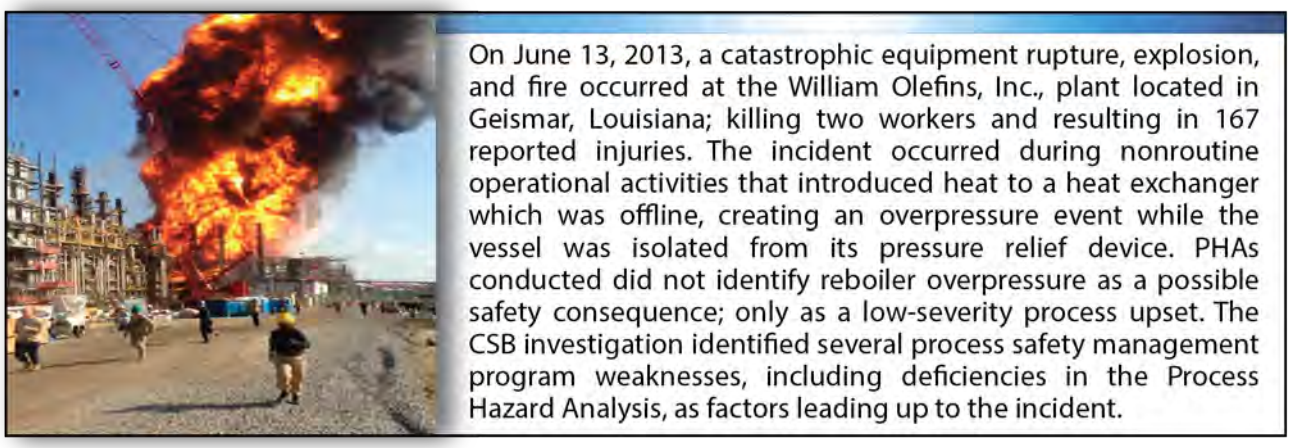
This January marked the 50th anniversary of the tragic fire that swept through the Apollo 1 command module during a test run at Cape Kennedy in Florida, killing all three astronauts on board. In testimony to the U.S. Senate, astronaut Frank Borman noted, "It was a failure of imagination… No one thought there would be a fatal fire on the ground, or that a non-explosive hatch might prevent the astronauts from escaping such a disaster. No one imagined it could happen. We are all to blame for failing to imagine what could happen."

Figure 1b. – T2 Laboratories, Inc. Runaway Reaction and Explosion[4]



During production of the 175th batch of a gasoline additive called methylcyclopentadienyl manganese tricarbonyl (MCMT), a secondary runaway decomposition reaction caused by cooling failure led to an explosion at T2 Laboratories, Inc. that killed four, injured 32, and destroyed multiple businesses on December 19, 2007. T2 owners/engineers did not recognize the reactivity hazard associated with the MCMT being produced, therefore the MCMT reactor vessel relief system was not properly sized and incapable of relieving the pressure from the runaway reaction. Additionally, the cooling system employed by T2 was susceptible to single-point failures due to a lack of design redundancy. Reactivity testing and a design stage Process Hazard Analysis could have identified these hazards. (FAI conducted the laboratory testing for the CSB investigation.)

Figure 1c. – William Olefins, Inc. Explosion and Fire[5]



On June 13, 2013, a catastrophic equipment rupture, explosion, and fire occurred at the William Olefins, Inc., plant located in Geismar, Louisiana; killing two workers and resulting in 167 reported injuries. The incident occurred during nonroutine operational activities that introduced heat to a heat exchanger which was offline, creating an overpressure event while the vessel was isolated from its pressure relief device. PHAs conducted did not identify reboiler overpressure as a possible safety consequence; only as a low-severity process upset. The CSB investigation identified several process safety management program weaknesses, including deficiencies in the Process Hazard Analysis, as factors leading up to the incident.

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# FAUSKE & ASSOCIATES, LLC (FAI) — HAVE SERVICES — WILL TRAVEL

In addition to the services provided at our state-of-the-art facilities, Fauske & Associates, LLC offers a complete range of safety services detailed below, that can be performed on-site at your location to help you understand and address hazards that pose risk to your process facility and ensure compliance.

**Combustible Dust Explosion and Fire Hazard Evaluation**

- Dust Hazard Analysis (DHA)
- Dust Management Program Development
- Equipment Hazard Evaluation
- Testing
- VSP2
- Dust
- Flammability

**Process Hazard Analysis (PHA)**

- Facilitate, Revalidate, RE-do PHAs
- Audit review PHAs
- Process, Equipment, Management of Chance (MOC)

**Hazard Identification / Risk Analysis**

- Flammability (Gas/Vapors)
- Combustible Dust
- Reactive Chemicals
- Cables

**Consequence Analysis**

- Fire and Explosion Hazards
- Vessel Overpressure Scenarios
- Chemical Reactivity Hazards
- Chemical Releases
- Vapor Cloud Dispersion

**Safety Program Development**

- Develop or Review Process Safety Programs
- Support Kilo Lab, Pilot Plants, Medium Scale and Commercial Scale Plants
- Auditing, Reporting, Documentation
- Identify and Prioritize Safety Gaps
- Consulting for Management of Change (MOC) impact
- Arc Flash Studies

**Training**

- Combustible Dust
- Flammability
- Relief System Design
- ARSST
- VSP2

For more information regarding our on-site services contact us at info@fauske.com.

FAI University offers a wide array of training courses globally to augment our customized testing, engineering and consulting services.

FAI designed these introductory courses for personnel including – but not limited to – chemists, engineers,technicians, plant managers and operational staff in R&D, process development, kilo, pilot and full-scale production in the chemical, manufacturing, nuclear, petrochemical, food, cosmetic, plastic and polymers, metals, agricultural and pharmaceutical industries to educate on compliance, safe operations and severe accident mitigation. Taught by experts from our staff as well as guest specialists in their respective areas, customers can choose from our existing courses or we can tailor courses for the requirements of the learners through engaging and informative material in a comfortable classroom or lab setting.

FAI is accredited through International Association for Continuing Education and Training (IACET) and FAI University course attendees are awarded CEUs upon meeting all the necessary requirements.

Courses can be presented at the FAI campuses, onsite at customer locations or other remote locations.

For information regarding our upcoming courses see page 11 or contact FAIUniversity@fauske.com for more information.

Fauske & Associates, LLC(FAI) recognizes Amy Theis, Director, Onsite Services, who served as Chair of the Safety & Health Division of the American Institute of Chemical Engineers (AIChE) in 2016. Amy received recognition from the current chair, Mr. Jeffrey Fox of Dow Corporation, at the Safety & Health Division dinner held in San Antonio in conjunction with the AIChE Global Congress on Process Safety. We commend Amy for an excellent year of service in which she provided direction and framework for the future of the division as well as began new programs to benefit the members. Join us in congratulating Amy on a job well done!

Dr. James P. Burelbach, Fauske & Associates, LLC (FAI) Director, Waste Technology & Systems Modeling, was awarded "Best in Track #3 Poster Presentation" at the WM2017 Conference. His poster "Safe Packaging of Chemically Reactive Radioactive Waste – Addressing the Data Needs" was selected for demonstrating knowledge, understanding and a foundation for future waste management endeavors.

Dr. Burelbach was quick to recognize his FAI teammates Elizabeth Raines, Dr. Marty Plys, Charlie Askonas and Carol Raines for their contributions to the paper that the poster was based on, saying "This project was a team effort and proves you are never to old to win a blue ribbon at a science fair." Congratulations to the team for this recognition.

# Fauske & Associates, LLC Connected to the Community

## FAI Helps Willowbrook/Burr Ridge Kiwanis Fight Homelessness

Fauske & Associates, LLC recently participated in the efforts of the Willowbrook/Burr Ridge Kiwanis, of which President Kris Fauske is a member, to provide assistance to a homeless family in the area through donations of clothes and other household goods.

Collectively the Kiwanis Club members helped a young mother and her children to get back on their feet by finding a place for the family to live, a car for the mother to drive and mentoring the mother to help her create a good future for her children. Thanks to the efforts of the Kiwanis members and community support, two young boys and their mom have been given an amazing opportunity to recover from a very sad time in their life and thrive as a family, and the children have the opportunity to go back to being kids.

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## Who should be involved in a PHA?

OSHA requires a PHA team to consist at a minimum of a process engineer, an operator, and a facilitator (leader). In order to effectively identify safety consequences, persons knowledgeable of the process and the hazards associated with it must participate in the analysis.[1] FAI engineers are subject matter experts in reactive chemistry, flammability, combustible dust, electrostatics/electrical hazards, as well as other process safety hazards, and are available to facilitate (lead) and/or participate as specialists on teams conducting risk analysis.

In addition to hazard scenario identification, FAI offers the complete package to understanding the hazards of a process including material hazard characterization, operational condition testing, determination of mitigation design parameters, calculation of emergency relief systems sizing, and chemical release dispersion analysis. Contact us for all of your process safety needs.

For more information on risk analysis, PHAs, or any of the services mentioned in this article, email info@fauske.com or call 877-328-7531.


**References**

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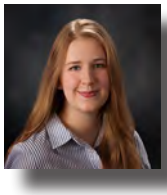

*Ursula Malczewski is a Chemical Engineer in the Onsite Safety Services department at Fauske & Associates, LLC*

FAI UNIVERSITY Process Safety Training Institute

# 2017 Course Schedule

## NFPA 652– An Introduction to Dust Hazard Analysis

| | | | |
|---|---|---|---|
| May 9-10 | JW Marriott Indianapolis | September 19-20 | Marriott St. Louis Airport |
| June 6-7 | Courtyard Seattle Sea-Tac | October 17-18 | Dallas/Fort Worth Airport Marriott |
| July 11-12 | Courtyard Pittsburgh Airport | November 14-15 | Renaissance Charlotte Suites Hotel |
| August 29-30 | Renaissance Boston Waterfront Hotel | | |

Day 1 - *NFPA 652– An Introduction to Dust Hazard Analysis* CEU's: 0.7
Day 2 - *Advanced Dust Hazard Analysis Workshop* CEU's: 0.7

## Relief Systems Design Course

May 15 -16 Fauske & Associates, LLC, Burr Ridge CEU's: 1.6

## Free User Group Forum

May 17 -19 Fauske & Associates, LLC, Burr Ridge

## Combustible Dust & Flammability Hazards Training Courses

May 23 -24 Fauske & Associates,LLC, Burr Ridge

May 23 - *Introduction to Understanding and Controlling Flammability Hazards Course* CEU's: 0.6
May 24 - *Introduction to Dust Explosion Hazards, Prevention and Protection Practices* CEU's: 0.6

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