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Process Safety News

REVISITING REACTIVE VAPOR SYSTEMS VENT SIZING

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

In order to eliminate oversizing and the potential for valve instability (chatter) the smallest vent size obtained by considering all vapor venting evaluated at the selected relief set pressure well below MAWP is recommended. In this case, if two-phase flow should occur (may be likely), only a modest overpressure will occur before turnaround in pressure (Fauske, 2006).

The required relief rate for all vapor venting is given by

$$W_{reg} = \frac{V\left(1-\alpha_o\right)\rho_\ell \cdot c \cdot \dot{T}}{\lambda} \tag{1}$$

where V (m^3) is the vessel volume, (1 - α_o) is the initial fill fraction, ρ_ℓ (kg m^{-3}) is the liquid density, c (J kg^{-1} K^{-1}) is the liquid specific heat, $\dot{T}$ (K s^{-1}) is the rate of temperature rise corresponding to the relief set pressure ($\dot{T}$ obtained from the VSP2 calorimeter is directly scalable) and λ (J kg^{-1}) is the latent heat of evaporation. In case of vapor critical flow the minimum vent area A_{min} is given by

$$A_{min} / V = \frac{\left(1-\alpha_o\right)\rho_\ell \, c\, \dot{T}}{C_D \; 0.67\, \lambda \, P}\left[\frac{RT}{M_{w,v}}\right]^{1/2} \tag{2}$$

where R (8314 Pa-m^3/K-kg mole), T (K) is the vapor temperature corresponding to the relief set pressure P (Pa), $M_{w,v}$ (kg/kg mole) is the vapor molecular weight, and C_D is the discharge coefficient.

In case necessary physical properties are lacking under the conditions of the emergency scenario (more often the case than not), the following simple design method requiring no physical properties can be used that is consistent with all relevant experimental data (Fauske, 2006)

$$A / V = \frac{C}{P\left(1+\dfrac{1.98\cdot 10^{3}}{P^{1.75}}\right)^{0.286}}\,\frac{\dot{T}}{C_D} \tag{3}$$

Where A (m^2) is the vent area, V (m^3) is the volume of reactant, P (psig) is the gauge relief set pressure, C = 3.5 • 10^{-3} for churn turbulent flow, and C = 7.0 • 10^{-3} for bubbly or viscous system. Expression 3 is a combined expression of the subcritical and critical vapor flow expressions of A/V using corresponding water physical properties (Fauske, 2000).

As an example, considering the DIERS large scale 2.2 m^3 styrene-ethylbenzene runaway test; A/V (m^{-1}) = 2.08 • 10^{-3}, P = 64.8 psig, and $\dot{T}$ (°C min^{-1}) = 21.6, and C_D = 0.45 results in

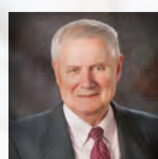
$$A / V = \frac{3.5\cdot 10^{-3}}{64.8\left(1+\dfrac{1.98\cdot 10^{-3}}{64.8}\right)^{0.286}}\,\frac{21.6}{0.45} = \underline{2.03\cdot 10^{-3}\ m^{-1}}$$

which compares to 2.08 • 10^{-3} within 2.4%. Two-phase flow occurred upon relief opening resulting in a modest overpressure based upon absolute pressure of 24%.

References

Hans K. Fauske, 2006, "Revisiting DIERS Two-Phase Methodology for Reactive Systems Twenty Years Later," Process Safety Progress, September, 2006.

Hans K. Fauske, 2000, "Properly Size Vents for Nonreactive and Reactive Chemicals," Chemical Eng. Process., February, 2000.



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

Upcoming Events

- 2017 Indiana Safety & Health Conference & Expo
  February 28-March 2, Indianapolis, IN
- 13th Global Congress on Process Safety
  March 27-29, San Antonio, TX

Letter From the President

2016 was a busy year. Global shifts in the view of nuclear energy and the growing pains that come with expansion and growth were felt company-wide. But, we closed our year on a good path and 2017 is a year of new opportunities to be conquered both personally and in business.

One thing I like to reiterate with my team is that life throws a lot at us sometimes, and it is easy to get bogged down by it all. But, it has been proven time and again that dwelling on those challenges is not only counter productive, it has a direct unhealthy impact on our well being. While having a positive outlook on life and viewing setbacks as a chance to learn and improve has shown to improve dispositions, increase happiness and enable people to accomplish more, it also demonstrates resiliance and endurance and a quiet strength that can bring encouragement and joy to those whose lives we touch daily.

This year, I am making a conscious effort to focus on the positives in life and I am encouraging everyone on my team at Fauske & Associates, LLC (FAI) to do the same. It is my hope that by working to maintain a positive approach in our business, our customers will have an even better experience working with us.

Join us in harnessing the power of positivity this year and let's make the world a better place together.

Happy New Year!

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.

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QUALITATIVE FIRE RISK ASSESSMENT USING NFPA® 550, NFPA® 551 AND THE FIRE SAFETY CONCEPTS TREE

By: James A. Huddleston, P.E., Senior Consulting Engineer, Fauske & Associates, LLC

Introduction

As an electrical engineer with almost 30 years of experience working in and around chemical, petrochemical and nuclear power plants, in addition to working for an electric utility, it is safe to say that a significant portion of my career has been dedicated to preventing and minimizing the risks associated with fires. A fire in a chemical plant, petrochemical plant, refinery, nuclear power plant, electric utility generating station or substation can lead to potentially severe consequences including loss of life, property, production, revenue, customers, etc.

It is critically important for the fire safety practitioner to have good tools, standards and guidelines for assessing the level of fire risk and for developing strategies for the prevention and mitigation of these risks. National Fire Protection Association (NFPA®) 550 [1] and NFPA 551 [2] provide excellent guidance to the fire safety practitioner in conducting a Qualitative Fire Risk Assessment (FRA) using the Fire Safety Concepts Tree.

This article provides a high level overview of Qualitative Fire Risk Assessment using NFPA 550, NFPA 551 and the Fire Safety Concepts Tree to aid the fire safety practitioner in the identification of fire risks and in the development of fire prevention and mitigation strategies to improve the overall level of fire safety and reduce the overall level of risk for any given system or facility.

Evaluation of Fire Risk Assessments (NFPA 551)

NFPA 551 provides guidance on acceptable methodologies for conducting an FRA which include qualitative, semi-quantitative and quantitative methods of analysis. It also provides guidance on FRA evaluation, which makes it clear to regulatory officials and fire safety practitioners exactly what considerations and requirements are to be included in an FRA to achieve a minimum level of technical acceptability. One of the accepted FRA methodologies discussed in NFPA 551 is the Fire Safety Concepts Tree which is a qualitative method for analyzing a given system or facility to determine the level of fire safety and risk. NFPA 550 provides guidance on conducting a Qualitative FRA using the Fire Safety Concepts Tree.

The Fire Safety Concepts Tree (NFPA 550)

NFPA 550 provides guidance to the fire safety practitioner in the proper use of a fire safety tool known as the Fire Safety Concepts Tree. The Fire Safety Concepts Tree provides an overall framework for qualitative assessment of fire prevention and mitigation strategies for the achievement of a specific Fire Safety Objective(s). The top tiers of the Fire Safety Concepts Tree are shown in Figure 1.

Figure 1 - Fire Safety Concepts Tree - Top Tiers

The Fire Safety Concepts Tree shows the relationships of both fire prevention and fire damage control strategies in working toward the achievement of the Fire Safety Objective(s) in the top tier. In the Fire Safety Concepts Tree, a 'circle' with a '+' inside of it represents a logical "or" condition, while a 'circle' with a '•' inside of it represents a logical "and" condition. For example, the achievement of the fire safety objective(s) in Figure 1 can be accomplished by either "Preventing the Ignition of a Fire" ***or*** by "Managing the Impact of a Fire."

Fire Safety Objective(s)

The top tier of the Fire Safety Concepts Tree is the Fire Safety Objective(s) which is that objective that is desired to be achieved in regard to fire safety. Although it is not intuitively obvious from looking at Figure 1, the lower tiers and logic of the Fire Safety Concepts Tree are all directed upward toward the top tier and the achievement of the fire safety objective(s). All stakeholders should participate in the development of the fire safety objective(s). In general, the fire safety objective(s) involves the protection of people and property but can be expanded to include the protection of other items that may be of value to stakeholders such as operations, revenue, the environment, activities, etc.

Fire Safety Strategies

The middle and lowest tiers of the Fire Safety Concepts Tree are fire safety strategies (or concepts) that are designed to achieve the desired Fire Safety Objective(s) in the top tier. As you get down lower and lower into the Fire Safety Concepts Tree, there is an increasing level of detail as to how each fire safety strategy is achieved.

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REVISITING CHERNOBYL - 30 YEARS LATER

By: AnnMarie Fauske, Customer Outreach & Digital Media Manager, Fauske & Associates, LLC

Chernobyl's 30th anniversary was April 26, 2016. It has been called the world's worst nuclear accident. According to the World Nuclear Association:

"The April 1986 disaster at the Chernobyl nuclear power plant in Ukraine was the product of a flawed Soviet reactor design coupled with serious mistakes made by the plant operators. It was a direct consequence of Cold War isolation and the resulting lack of any safety culture.

Chernobyl Monument and Reactor April 2012
Photo by Matt Shalvatis
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The accident destroyed the Chernobyl 4 reactor, killing 30 operators and firemen within three months and several further deaths later. Acute radiation syndrome (ARS) was originally diagnosed in 237 people on-site and involved with the clean-up and it was later confirmed in 134 cases. Of these, 28 people died as a result of ARS within a few weeks of the accident. Nineteen more subsequently died between 1987 and 2004 but their deaths cannot necessarily be attributed to radiation exposure. The Chernobyl disaster was a unique event and the only accident in the history of commercial nuclear power where radiation-related fatalities occurred."

Robert E. Henry, PhD, Emeritus Senior Vice President and Regent Consultant at Fauske & Associates, LLC was one of the U.S. Delegates selected to attend the international meeting at the International Atomic Energy Agency (IAEA) headquarters in Vienna, Austria. Since the IAEA is part of the United Nations (UN), this was the location selected for the USSR experts to explain what caused the accident, as well as what actions were taken during the aftermath. This three day presentation was entitled "Accident at The Chernobyl Nuclear Power Plant and Its Consequences" and the briefing revealed the design and operational flaws responsible for the accident. As with all accidents, it is essential to learn from the accident conditions and the long term stabilization of the core material even when the designs are greatly different from those in the U.S.

"The design for the RBMK (reaktor bolshoy moshchnosty kanalny, high-power channel reactor) nuclear power plants that were built in the Soviet Union differed considerably from the commercial nuclear power plants built in the rest of the world," states Dr. Henry. "Because of the Cold War, we had only a sketchy idea of the RBMK designs and how they were operated prior to the event. In those days, if we traveled abroad, we were always asked if you had contact with anyone from the Iron Curtain countries.

To illustrate the substantial differences in the designs, for the light water reactors that are built, licensed and operated in the U.S. and elsewhere, water cools the reactor core and also moderates the nuclear reaction. Hence, the water is an essential component of the nuclear reaction and if water were to be removed from the core as the result of an accident condition, the nuclear reaction will be inherently shutdown. Conversely, for the RBMK design, water is used to cool the reactor core inside of almost 1700 pressure tubes, but the nuclear reaction is moderated by graphite blocks which surround the pressure tubes. Therefore, water is a poison to the nuclear reaction for this design and, if water is removed from the core by an accident condition, the nuclear reaction intensifies and the power generated in the core increases rapidly. An increase in the core power acts to reduce the water inventory in the core at a faster rate resulting in further increases in core power. This characteristic is known as a positive void coefficient for the nuclear fission reaction. As a consequence of this core design characteristic, the accident that occurred in Chernobyl Unit 4 reactor was the first ever runaway nuclear reaction in a power plant, with the core power increasing exponentially to about 500 times the maximum design value over an interval of approximately 20 seconds."

This accident resulted from a desire to use the energy of a coasting-down turbine to power water injection into the reactor core if an accident condition were to result in a loss of electrical power to the plant. To investigate the real plant response, USSR scientists and engineers decided to test this concept on one of their plants. The intent was to initiate a loss of power transient for a reactor that was about to be shut down for refueling. As the reactor was in the process of being shut down and prepared for the test, the Kiev power dispatcher requested more power from the site and the reactor power had to be increased for a period of time.

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Design and construction features, in addition to fire prevention and mitigation strategies, are included in the middle and lowest tiers of the Fire Safety Concepts Tree for the achievement (success) of each successively higher fire safety strategy.

Prevent Fire Ignition

The "Prevent Fire Ignition" fire safety strategy and middle tier branches in the Fire Safety Concepts Tree are shown in Figure 2. As can be seen from Figure 2, the achievement of the "Prevent Fire Ignition" fire safety strategy can be accomplished by "Controlling Heat-Energy Source(s)" ***or*** "Controlling Source-Fuel Interactions" ***or*** "Controlling the Fuel."

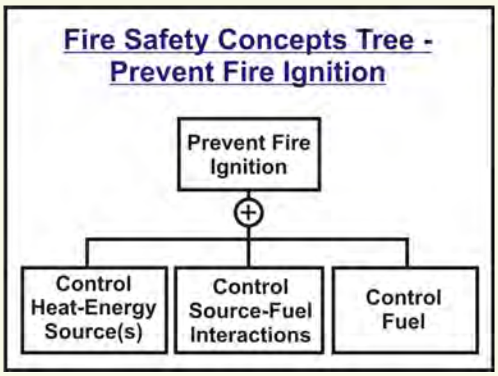

Figure 2 - Fire Safety Concepts Tree - Middle Tiers of Prevent Fire Ignition

By digging down deeper into the lower and lowest tiers of the "Prevent Fire Ignition" branches of the Fire Safety Concepts Tree (as provided in NFPA 550), the following fire safety strategies can be used to achieve the higher tier fire safety strategy of "Preventing Fire Ignition":

1. Eliminating Heat-Energy Source(s) ***or***
2. Controlling the Rate of Heat-Energy Release ***or***
3. Controlling Heat-Energy Source Transport by using "Barrier(s)" ***or*** "Separation" ***and***
4. Controlling Heat-Energy Transfer Processes by Controlling "Conduction", "Convection" ***and*** "Radiation" ***and***
5. Controlling Fuel Transport by using "Barrier(s)" ***or*** "Separation" ***or***
6. Eliminating Fuel(s) ***or***
7. Controlling Fuel Ignitibility by Controlling "Fuel properties" ***or*** "the Environment"

As you can see, the lower and lowest tiers of the "Prevent Fire Ignition" branches of the Fire Safety Concepts Tree provide an increased level of detail as to how each successively higher fire safety strategy can be achieved. Lower tiers can be added to the Fire Safety Concepts Tree to include an additional level of detail. Also, additional fire safety strategies can be included as necessary to improve the reliability of the fire protection, prevention and mitigation strategies. Please note that the lowest tiers of the Fire Safety Concepts Tree (in NFPA 550) are not shown in this article due to space limitations. The reader is encouraged to review Figures 4.3, 4.4.1, 4.5.1 and 4.5.2.1 in NFPA 550 to better understand how the top, middle and lowest tiers of the Fire Safety Concepts Tree work together to achieve the desired fire safety objective(s).

Manage Fire

The "Manage Fire" fire safety strategy and middle tier branches in the Fire Safety Concepts Tree are shown in Figure 3. The achievement of the "Manage Fire" fire safety strategy can be accomplished by "Controlling the Combustion Process" ***or*** "Suppressing the Fire" ***or*** "Controlling the Fire by Construction."

Figure 3 - Fire Safety Concepts Tree - Middle Tiers of Manage Fire

By digging down deeper into the lower and lowest tiers of the "Manage Fire" branches of the Fire Safety Concepts Tree (as provided in NFPA 550), the following fire safety strategies can be used to achieve the higher tier fire safety strategy of "Manage Fire":

1. Controlling the Fuel by Controlling the "Fuel Properties" ***or*** "Fuel Distribution" ***or*** by "Limiting the Quantity of Fuel" **or**
2. Controlling the Environment by Controlling the "Physical Properties of the Environment" **or** "Chemical Composition of the Environment" **or**
3. Automatically Suppressing the fire by "Detecting the Fire" ***and*** "Applying Sufficient Suppressant" ***or***
4. Manually Suppressing the fire by "Detecting the Fire" **and** "Communicating the Signal" **and** "Deciding an Action" ***and*** "Responding to the Site" ***and*** "Applying Sufficient Suppressant" **or**
5. Controlling the Movement of the Fire by "Venting the Fire" **or** "Confining/Containing the Fire" **and**
6. Providing Structural Stability for the safety of fire fighters and the exposed

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Again, lower tiers can be added to the Fire Safety Concepts Tree to include an additional level of detail. Also, additional fire safety strategies can be included as necessary to improve the reliability of the fire protection, prevention and mitigation strategies.

Manage Exposed

The "Manage Exposed" fire safety strategy and middle tier branches in the Fire Safety Concepts Tree are shown in Figure 4. The achievement of the "Manage Exposed" fire safety strategy can be accomplished by "Limiting the Amount of the Exposed" ***or*** "Safeguarding the Exposed." The "Exposed" are generally people and property and any other item(s) included in the fire safety objective(s).

Figure 4 - Fire Safety Concepts Tree - Middle Tiers of Manage Exposed

By digging down deeper into the lower and lowest tiers of the "Manage Exposed" branches of the Fire Safety Concepts Tree (as provided in NFPA 550), the following fire safety strategies can be used to achieve the higher tier fire safety strategy of "Manage Exposed":

1. Limiting the Maximum Number or Amount of the Exposed ***or***
2. Defending the Exposed In-Place by "Restricting the Movement of the Exposed" ***and*** "Defending the Place against fire Products" and "Providing Structural Stability" ***and*** "Maintaining an Essential Environment" ***or***
3. Moving the Exposed by "Causing Movement of the Exposed" ***and*** "Providing a Means for Movement" ***and*** "Providing a safe Destination"

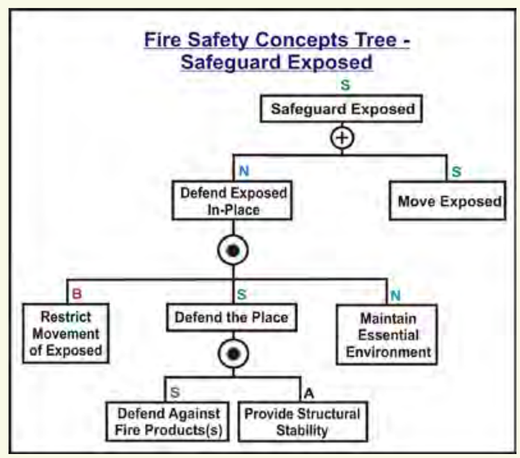

Figure 5 - Fire Safety Concepts Tree - Lowest Tiers of Safeguard Exposed

Fire Safety Strategy Assessment and Ranking

Each of the fire safety strategies in the Fire Safety Concepts Tree must be assessed to determine if there are existing design, construction, prevention and/or mitigation features that allow for the achievement (success) of each fire safety strategy. Based upon this assessment, each of the fire safety strategies is to be ranked and marked with an **N**, **B**, **S** or **A** as follows:

- **N** - Features are **Non-Existent** for the Achievement (Success) of the Strategy
- **B** - Features are **Below Standards** for the Achievement (Success) of the Strategy
- **S** - Features **Meet Standards** for the Achievement (Success) of the Strategy
- **A** - Features are **Above Standards** for the Achievement (Success) of the Strategy

Figure 5 provides an example of how fire safety strategies are assessed, ranked and marked. The fire safety strategies in the lowest tier of the Fire Safety Concepts Tree are assessed, ranked and marked first. The higher tier fire safety strategies are then marked based upon the rankings of the lower tier fire safety strategies and their "and/or" logic relationships.

Fire safety strategies that are connected by a logical "and" condition propagate the **lowest** ranking up to the next higher tier fire safety strategy. For example, four fire safety strategies that are connected by a logical "and" with Strategy 1 marked with an '**N**', Strategy 2 marked with a '**B**', Strategy 3 marked with an '**S**' and Strategy 4 marked with an '**A**' would propagate an '**N**' to the next higher tier fire safety strategy. This can be seen in Figure 5.

Fire safety strategies that are connected by a logical "or" condition propagate the **highest** ranking up to the next higher tier fire safety strategy. For example, four fire safety strategies that are connected by a logical "or" with Strategy 1 marked with an '**N**', Strategy 2 marked with a '**B**', Strategy 3 marked with an '**S**' and Strategy 4 marked with an '**A**' would propagate an '**A**' to the next higher tier fire safety strategy. This can also be seen in Figure 5.

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This process is completed for each successively higher tier of the Fire Safety Concepts Tree until the fire safety objective(s) in the top tier is marked. The fire safety objective(s) can only be marked with an 'S' or an 'A' indicating achievement (success) if the lower tier fire safety strategies and the "and/or" logic propagate an 'S' or an 'A' upward to the top tier.

Qualitative Fire Risk Assessment

Qualitative Fire Risk Assessment is the non-numerical determination of "risk" based upon "likelihood" and "consequences" of a fire. This assessment requires a certain amount of judgment on the part of the fire safety practitioner. The "likelihood" of a fire can be determined from the Fire Safety Concepts Tree and the rankings of each of the fire safety strategies and the fire safety objective(s). The determination of the consequences of a fire relies heavily upon the judgment of the fire safety practitioner.

In general, as the likelihood and consequences increase, the level of risk increases; as the likelihood and consequences decrease, the level of risk decreases. A risk matrix (shown in Figure 6) is a very good tool for determining the level of risk when the likelihood and consequences are somewhere in the middle or at opposite extremes.

Risk Matrix		Potential Consequences				
		Insignificant	Minor	Moderate	Major	Severe
Likelihood	Very Likely	Medium	High	Very High	Very High	Very High
	Likely	Medium	High	High	Very High	Very High
	Possible	Low	Medium	High	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Very Unlikely	Low	Low	Low	Low	Medium

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Figure 6 - One Example of a Risk Matrix

Conclusion

Due to the potentially severe consequences of a fire in a chemical plant, petrochemical plant, refinery, nuclear power plant, electric utility generating station or substation, it is critically important that the risks associated with a fire be identified and strategies be developed for the prevention and mitigation of these risks. The Fire Safety Concepts Tree is an excellent tool which provides an overall framework for the fire safety practitioner to be used in the identification of fire risk and in the development of fire prevention and mitigation strategies to reduce the overall level of fire risk in any given system or facility.

This article provided a high level overview of Qualitative Fire Risk Assessment using NFPA 550, NFPA 551 and the Fire Safety Concepts Tree to aid the fire safety practitioner in the identification of fire risks and in the development of fire prevention and mitigation strategies to improve the overall level of fire safety and reduce the overall level of fire risk for any given system or facility.

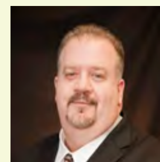
Fauske & Associates, LLC (FAI) has a staff of highly qualified engineers and scientists with many years of experience conducting Fire Risk Assessments using qualitative, semi-quantitative and quantitative methods including Fire Probabilistic Risk Assessment (PRA).

For more information, please contact Jens Conzen at (630) 887-5203 or Jim Huddleston at (630) 887-5265.

References

1. National Fire Protection Association (NFPA®) 550, Guide to the Fire Safety Concepts Tree, 2012 Edition

2. National Fire Protection Association (NFPA®) 551, Guide for the Evaluation of Fire Risk Assessments, 2016 Edition



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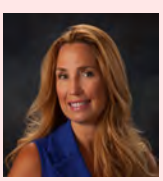
Continues Dr. Henry, "A return to power from the plant state was complicated and the manner in which it was accomplished led to the violation of procedures that were in-place for safe operation of the plant. Another complicating feature leading up to the accident was that the test to be conducted was on the plant electrical equipment, so an electrical engineer was in charge, in the control room, for the test to be conducted that night. He had no understanding of the reactor core configuration caused by the return to power, the influence of a "positive void coefficient", etc.

Another difference between the RBMK design and those used in the United States and elsewhere is the protection of a high pressure leak-tight containment building that surrounds the nuclear core and the reactor cooling system. A high pressure leak-tight containment is an important aspect of the plant design and licensing evaluations in the western world, but this was not part of the design for the Chernobyl plants. Therefore, the runaway power escalation rapidly over-pressurized the reactor coolant system such that it burst open, discharging the nuclear fuel and radioactive fission products into the surrounding environment. The gaseous and aerosolized fission products were ejected high into the air above the plant and these circulated to the north over the next two and a half days until an engineer walked in from the parking lot and into the Forsmark plant on a rainy Monday morning in Sweden. On entering the plant, he set off the plant radiation alarms because his shoes picked up radioactive iodine and cesium fission products that had been captured by the rain as they passed overhead. This was the first that the western world knew of the nuclear accident in the USSR and at the Chernobyl site specifically. When the satellite cameras were reviewed for early on Saturday morning of April 26th, 1986, the flash from the bursting of the reactor coolant system and the discharged of fuel bundles out of the plant building could be seen from space.

Radioactive fission products from the Chernobyl were detected in the air in the Iron Curtain countries and Italy, France, Germany, Sweden and others. In fact, the radiation level in Harrisburg, Pennsylvania due to the Chernobyl accident was three times higher than peak observed from the TMI-2 accident in 1979. Fear of the unknown is a powerful emotion and it caused milk and food to be confiscated in some counties and also resulted in the shutdown of the one nuclear plant that was operating in Italy at the time as well as the stoppage of construction of one that was being built."

Following the TMI-2 and Chernobyl accidents, Fauske and Associates, LLC assisted a number of U.S. utilities, including Commonwealth Edison in the evaluations of individual commercial nuclear plants with respect to their defensive-in-depth capabilities for a large range of accident scenarios. The results of these studies were entitled Individual Plant Examinations (IPEs) and they were submitted to the NRC for their review. Most of these were eventually expanded into full Probabilistic Safety Assessments (PSAs). In addition, in the early 90's, FAI was selected by EPRI to formulate the Technical Basis Report to would characterized the status of the important phenomena that could occur during a core damage event in a sufficient manner to formulate Severe Accident Management Guidelines (SAMGs) for both BWR and PWR designs and all types of high pressure leak-tight containments. As part of this, a new version of the MAAP code (MAAP4) was chartered to support the evaluations of SAMGs for different designs for a large spectrum of accident conditions. All of these have added to increase the defense-in-depth for protection against accident conditions that could result in overheating of reactor cores.



AnnMarie Fauske is Customer Outreach & Digital Media Manager at Fauske & Associates, LLC

NEW IN FLAMMABILITY: THE DISCOVERY HYBRID RHEOMETER

By: Megan Piotrowski, Lab Chemist, Fauske & Associates, LLC

The Flammability Team recently acquired a new toy – the Discovery Hybrid Rheometer (DHR) from TA Instruments. Unlike commonly used viscometers, rheometers can make both viscosity and viscoeleastic measurements. The DHR can measure both a fluid's resistance to flow and how it behaves before flowing. Even further, the Discovery HR-2 achieves this with some of the highest precision and sensitivity in the field.

Figure 1 - DHR-2 from TA Instruments
http://www.tainstruments.com/dhr-2/

Rheology Basics

Rheometers characterize fluids and solids in terms of flow and deformation. These measurements are useful for a wide range of chemical industries including polymers and solvents, food and agriculture, oil and petroleum and many others. Viscosity, in particular, is an important measurement of flow. It determines the thickness of a material and how it can be applied and manipulated during processing. Viscosity is also an important safety consideration. From an environmental standpoint, if a material is too thin, it may leach into soil or groundwater, causing contamination.

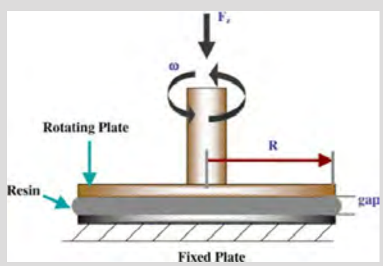


Figure 3 – Parallel Plate with Sample
https://www.researchgate.net/figure/236007972_fig10_Figure-16-Parallel-plate-geometry-setup-60

On the other end of the spectrum, there are viscoelastic property determinations. When a material is neither completely solid nor completely liquid, it's called viscoelastic. Viscoelastic properties like complex modulus and phase angle are measured by rheometers, and they help determine these solid or liquid-like characteristics. They measure the stiffness or toughness of a material as well as its pourability. These properties often come into play when materials have the same viscosity but behave differently. They help characterize these differences and can aid in product formulation to quality control and assurance.

Rheometers use the forces of shear stress and shear strain to make the above-mentioned and other important material characterization measurements. A rheometer accomplishes this by applying shear stress and strain forces to two metal plates with a sample sandwiched between them. When calculating viscosity, the rheometer applies a continuous rotational force in one direction to the top plate. When calculating modulus, or viscoelasticity, however, the plate rotates back and forth, or oscillates. The DHR rheometer allows the user to easily switch between rotational and oscillation modes in order to make viscosity or viscoelastic measurements.

DHR Series Specifics

Due to the importance of rheological measurements, TA Instruments designed their Discovery Hybrid rheometers to be as precise and accurate as possible. The hybrid systems achieve this through a mix of patented and patent-pending innovations such as an optical encoder dual reader, advanced drag cup motor, second-generation magnetic bearing, New True Position Sensor and an Active Temperature Control. These features contribute to better displacement measurements, reduced noise, smoother motor acceleration, reduced friction, higher gap accuracy and the most precise control of upper and lower plate temperatures. As a result of these advancements, the Discovery Hybrid rheometer is able to handle testing over a wide range of conditions while producing highly accurate and reproducible data.

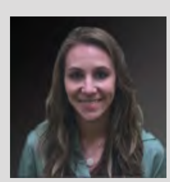
Rheology and Process Safety

As the Flammability Group receives a wide range of chemicals for process safety related testing, the DHR-2 is a great addition to our capabilities. For instance, customers and clients can now include viscosity measurements in their Safety Data Sheet (SDS) completion needs. In terms of process safety, these properties are often vital when devising scale-up procedures. Viscosity and viscoelasticty often change with heating and mixing, and when mixing large batches, it's important to consider whether stirring and storage of the material could be hindered by these changes. For instance, in the case of certain chemicals, if stirring were to stop or slow down significantly, reactions may stop before completion. This may not only impact the integrity of the batch, but it could also impact the safety of the workers and operators around it. Therefore, it's important to take viscosity and viscoelastic measurements into account when modifying or implementing chemical processes and their safety considerations.

References

TA Instruments website, Discovery Hybrid Rheometers brochure: http://www.tainstruments.com/wp-content/uploads/dhr_brochure.pdf

Rheology Basics: Introducing the Malvern Kinexus a Practical Measurement Perspective by Dr. Adrian Hill; http://www.atascientific.com.au/eventsandtraining/eventsandtraining/wp-content/uploads/2013/01/Rheology-Basics-Introduction-to-Rheology-and-Kinexus.pdf



Megan Piotrowski is a lab chemist in the , Flammability Testing and Consulting Services Group at Fauske & Associates, LLC

Fauske & Associates, LLC (FAI) shares Nuclear Decommisioning Authority Supply Chain Award with the National Nuclear Laboratory (NNL) and Sellafield Ltd

FAI was awarded the Technology Innovation/Implementation Award in partnership with the National Nuclear Laboratory (NNL) and Sellafield Ltd for work on Magnox Swarf Storage Silo (MSSS) reactive materials. Pictured above left, Dr. Martin Plys of FAI holds the award with Mick Gornall, WEC Managing Director, UK.

The expertise of the group has vastly improved understanding of the behavior of stored nuclear waste, creating a paradigm shift that will result in an estimated 1 Billion GBP savings.

Congratulations to FAI team members, above right, left to right: Jim Burelbach, Ben Doup, Marty Plys, Matt Kennedy and Elizabeth Raines.

Fauske & Associates, LLC Connected to the Community

FAI Fights Hunger with Holiday Food Drive

During the 2016 holiday season, Fauske & Associates, LLC (FAI) conducted a Thanksgiving Food Drive. Thanks to the generosity of the FAI staff we were able to collect a generous amount of food and monetary contributions to support the community through the services of HCS Family Services in the neighboring town of Hinsdale, Illinois.

A not-for-profit organization, HCS Family Services supports improving the lives of low-income residents Southeast DuPage County to fight homelessness and food insecurity.

THREE CRITICAL OVERSIGHTS THAT PRECEDE COMBUSTIBLE DUST INCIDENTS

By: Tim Cullina, MS. PE, Senior Safety and Environmental Consulting Engineer, Fauske & Associates, LLC
& Ursula Malczewski, Chemical Engineer, Fauske & Associates, LLC

Combustible dust is present across virtually all industries; sometimes as a raw material or final product, other times as an undesired waste. Near misses, fires, and explosions happen every day. Fauske & Associates, LLC has been in the chemical process safety industry for over 36 years; needless to say, we've seen a lot: the good, the bad, and the disastrous. A lack of attention to leading safety indicators can result in critical oversights that can precede an incident. Three crucial errors a facility can make regarding dust and their corresponding solutions are summarized in Figure 1 and explained in detail below.

Figure 1 – Summary Three Critical Combustible Dust Errors and their Corresponding Solutions

1. Unaware of the Hazard

The first sign of a looming dust fire or explosion is simply not being aware of the hazard. Part of this problem is with the naming convention. Dust can mean anything from powder to particulate solids, and it can be a hazard inside as well as outside of the equipment handling it. Wherever a combustible material is processed, smaller, more hazardous particles can be generated. Some materials, such as certain metals, may not be combustible in large sizes but when reduced to fine particulate produce hazardous characteristics.

NFPA 652 puts responsibility on the owner/operator of a facility with potentially combustible dusts to determine whether the materials are combustible or explosible. The absence of previous incidents is not allowed to be used as the basis for deeming a particulate to not be combustible or explosible. If a dust is deemed noncombustible, documentation must be kept indicating so and needs to be re-evaluated when changes to the process occur. Changes that should trigger dust hazard considerations include, but are not limited to, change in raw material (i.e. composition, supplier, particle size), new operating conditions, changes in handling equipment, etc. Evaluations should occur in order to determine how these changes impact the safety measures within the process.

In the past, some clients have contacted us only after an incident or after OSHA inspected their facility. There has been a shift now that the new NFPA 652 standard and NFPA 654 revision have been published. Companies are being proactive by conducting dust hazard analyses (DHAs) to identify and manage the flammable and/or explosive dust hazards in their facility. These updated standards require owner/operators to conduct DHAs on their processes in the next few years.

2. Underestimate the Hazard

The second marker for an imminent dust incident is underestimating the hazard. There are many ways we see facilities and personnel underestimate the hazards associated with combustible particulate. The most common mistake is assuming that a low K_{St} means that there is no hazard. As a matter of fact, most of the combustible dust incident case studies investigated by the Chemical Safety Board (CSB) involved St Class 1 (K_{St} < 200 bar-m/sec) material (Table 1). OSHA National Emphasis Program on Combustible Dusts identifies St Class 1 materials as capable of producing a "weak explosion" but as evidenced by the aftermath of these events, the results can be devastating. [1], [2]

Table 1 – Summary of Completed CSB Case Studies Involving Combustible Dust [1]

Company	Material	K_{St} (bar-m/sec)	Aftermath
Hoeganaes	Iron	19	5 fatalities within a 6 month period
Imperial Sugar	Sugar	35	14 fatalities, 38 injuries, property destruction
Al Solutions	Zirconium	75	3 fatalities, dissolution of company
Hayes Lammerz	Aluminum	131	1 fatality, 2 injuries, property destruction
West Pharmaceutical	Polyethylene	140	6 fatalities, dozens of injuries, property destruction
CTA Acoustics	Phenolic Resin	165	7 fatalities, property damage
US Ink/ Sun Chemical	Various	98-235	7 injured, property damage

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The K_{St} value is the normalized rate of pressure rise; a measure of the relative explosion severity compared to other dusts. The only non-exploding value of K_{St} is 0 bar-m/sec. That being said, explosions aren't the only combustible hazard that can cause property damage and death. Fires and flash fires claim lives and cause equipment and facility damage and may be under reported depending on their severity. Other important characteristics to determine the material hazards are described in Table 2.

Data from sources such as literature may help you identify if you have a combustible material but should not be used to design mitigation or prevention efforts in your facility. This is because different particle size ranges of the same material can have different ignitability and explosibility characteristics, depending upon many variables such as particle size distribution, shape, and moisture content. Additionally, these variables can change while the material is passing through process equipment. For this reason, published tables of dust explosibility data may be of limited practical value.

To add to the confusion, testing done by OSHA's laboratory will identify if your material is combustible, however, it does not follow the methodology needed to produce values that can be used for design. Despite the fact that OSHA warns against it, these values have been used by people without clear understanding of their purpose. Therefore, having representative data from your specific process is key to properly addressing the hazards in your facility.

Intentionally or unintentionally, by collecting samples from the wrong location (for example, off the floor) you are doing yourself and your employees a grave disservice. Samples should reflect the smallest particles in the area of analysis; i.e. within the piece of equipment you are trying to protect. Testing material from an inappropriate location can result in underperforming protection equipment which will not save you any money and it won't save your facility. If you catch this mistake ahead of time, you will likely need to pay for additional testing to get the proper values; if not, you run the risk of installing mitigation or prevention equipment that may not be sized properly to limit the effects of a fire or explosion in your process.

Once you have the right data, it is also important to understand how to use it. Results from your specific sample are used to design and install appropriate equipment and decide other operational precautions. Mitigating combustible dust hazards needs to be a comprehensive effort. Partially protecting a process can be just as bad as doing nothing at all.

Table 2 – Recommended Tests for Material Hazard Characterization

Characteristic	Reason for Testing
Moisture Content & Particle Size Analysis	Hazards are inversely proportional to moisture content and particle size. Also helps determine if past/future testing is on similar material.
Sample Prep per ASTM Guidelines	Need to test fine dust in order to assess the worst case scenario. Looks at the component of the sample that is less than 500µm. If designing protective equipment, sub 75µm particles would be appropriate.
Explosion Severity (K_{St}, dP/dt_{max} , P_{max})	Determines the maximum pressure output and the maximum rate of pressure rise. Values are used in the design of equipment and protective measures.
Minimum Ignition Energy (MIE)	Predicts the ease and likelihood of ignition of a dispersed dust cloud. Can be run with or without inductance (with inductance produces a more conservative value).
Minimum Explosible Concentration (MEC)	Determines if a hazardous concentration is attainable during normal process conditions. Can be used to justify alternative means of protection.
Minimum Ignition Temperature Cloud (MIT)	Identifies the temperature at which a dust cloud will auto-ignite. Can be used to identify safe operating temperatures and environmental conditions.
Layer Ignition Temperature (LIT)	Identifies the temperature needed to ignite a layer of accumulated material. Useful to determine if accumulations on hot surfaces (motors, hot pieces of equipment) are hazardous.

3. Apathy Towards the Hazard

The third sign that a facility is going to have a combustible dust event is apathy towards the hazards by personnel. It may be obvious that there is a problem but "it has always been that way", "we never had any issues before", etc. Most commonly, fugitive dust accumulations are the combustible elephant in the room (and on walls and ceiling beams). Warnings of thermal events include employee complaints of electrostatic shock, visible sparks, charred or smoldering product, discoloration of product or equipment, and unexpected or unusual smoking. It is important to realize that one of these may be the only warning sign of an impending fire or explosion.

Select Warning Signs of Thermal Events:

- Employee complaints of electrostatic shock
- Visible sparks
- Charred or smoldering product
- Discoloration of product or equipment
- Unexpected or unusual smoking

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Spring 2017 Course Schedule

NFPA 652– An Introduction to Dust Hazard Analysis

- March 21-22 Courtyard Phoenix Airport
- April 11-12 Courtyard Old Town San Diego
- April 18-19 Fauske & Associates, LLC, Burr Ridge
- May 9-10 JW Marriott Indianapolis
- June 6-7 Courtyard Seattle Sea-Tac
- July 11-12 Courtyard Pittsburgh Airport
- August 29-30 Renaissance Boston Waterfront Hotel
- September 19-20 Marriott St. Louis Airport
- October 17-18 Dallas/Fort Worth Airport Marriott- -
- November 14-15 Renaissance Charlotte Suites Hotel

- Day 1 - *NFPA 652– An Introduction to Dust Hazard Analysis* CEU's: 0.7
- Day 2 - *Advanced Hands On DHA Workshop Utilizing Various Risk Assessment Methodologies* 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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To register or learn more about any of these courses
call (630) 323-8750 or email FAIUniversity@Fauske.com

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Without change, employees and management can become complacent towards the problem. Ultimately, this is a systemic problem; the entire company, from top management to operators, needs to prioritize safety culture. The first step to mitigating apathy is training.

One of the top OSHA citations in terms of combustible dust is hazard communication. These requirements include proper labeling of hazardous chemical containers, the collection and use of SDSs, and employee training. Workers – including contractors – need to be told that combustible dust is present and be taught how to prevent fires and explosions. Training should include how to recognize and prevent the hazards of the dust in the facility, recognize unsafe conditions, and take preventative action and alert management. Management needs to understand how to take effective action regarding information about the identified hazards and utilize a management of change (MOC) program that investigates the safety implications of changes to processes with combustible materials. Design work needs to be completed in accordance to industry or commodity specific standards. Engineers need to be aware of the hazards associated with combustible particulate solids in order to minimize the risks in the plant and to seek professional expertise when required. Regardless of if it is fugitive or contained within the equipment, combustible dust hazards need to be given the respect they deserve. [3], [4]

Conclusion

Having a process that handles or generates combustible particulates, solids, powders, or dusts requires an ongoing effort to mitigate or prevent the risk of fires and explosions. Personnel must remain vigilant in order to stay safe. Just like other hazardous chemicals, combustible dust requires several engineered and administrative controls in order to protect your employees and business.

If you or your facility have any questions regarding onsite facility assessments, performing testing, or are interested in training, don't hesitate to contact us.

References

1. Completed Investigations - Combustible Dust Explosions and Flash Fires. U.S. Chemical Safety Board. Web. , 13 Jan. 2017. <http://www.csb.gov/>.
2. United States. Department of Labor. Occupational Safety and Health Admin. CPL 03-00-008. Combustible Dust National Emphasis Program (Reissued). Washington, D.C.: U.S. Department of Labor, Occupational Safety and Health Administration, 2008.
3. United States. Department of Labor. Occupational Safety and Health Admin. OSHA 3371-08 2009. Hazard Communication Guidance for Combustible Dust. Washington, D.C.: U.S. Department of Labor, Occupational Safety and Health Administration, 2009.
4. Geddie, J. Edgar. A Guide to Combustible Dusts. Raleigh, NC: N.C. Dept. of Labor, Division of Occupational Safety and Health, 2009. Print.

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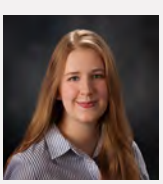

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Ursula Malczewski will present a poster

Review and Analysis of Recent Cyber Security Attacks

Monday, March 27

at the 13th Global Congress on Process Safety San Antonio, TX