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Electrical Checks for ARSST Operation



Using ASTM E2316 to Evaluate Dust Hazards



Safer Scale-Up Series Part 1 • 11 •



## Process Safety News Spring 2019 • Vol. No. 26 • Number 2

## Peak Pool Boiling Critical Heat Flux True Hydrodynamic Limitation

By Hans K. Fauske, D.Sc., Emeritus President, ANS Fellow, AIChE Fellow, NAE Member

As often claimed, the classic hydrodynamic instability theory by Zuber (1958) does not provide the upper external hydrodynamic limitation to onset of the heat transfer crisis for well-wetted horizontal surface,

$$q_{CHF,Z}^{''} = 0.13 \,\lambda \rho_v^{1/2} \left[ g\sigma \left( \rho_\ell - \rho_v \right) \right]^{1/4}$$

where  $q_{CHF,z}^{"}$  (w m<sup>-2</sup>) = pool boiling critical heat flux,  $\lambda$  (J kg<sup>-1</sup>) = latent heat of evaporation,  $\rho_v$  (kg m<sup>-3</sup>) = vapor density, g (9.8 m s<sup>-2</sup>) = gravitational constant,  $\sigma$  (kg s<sup>-2</sup>) = liquid surface tension, and  $\rho_\ell$  (kg m<sup>-3</sup>) = liquid density. Here, I propose that the upper limiting value of the heat flux (independent of surface conditions such as porous, polished, or nanoscopically smooth surfaces) is determined by the onset of fluidization, i.e., change in flow regime from liquid to vapor continuous condition.

The superficial vapor velocity  $\dot{j}_v$  corresponding to fluidization can be estimated from (Wallis, 1969),

$$j_{\mu} = v_{\mu} (1 - \alpha)^2$$

where  $\alpha$  is the volume fraction of liquid droplets, and  $v_{\infty}$  (m s<sup>-1</sup>) is the terminal droplet velocity given by (Levich, 1962),

$$\mathbf{v}_{\infty} = \left[\frac{4g\sigma(\rho_{\ell} - \rho_{v})}{C_{\rm D}\rho_{v}^{2}}\right]$$
(3)

Combining Eqs. (2) and (3) and setting  $C_D = 1$  and  $\alpha = 0.6$  (corresponding to a state when spherical liquid droplets no longer are touching each other) results in the minimum fluidization velocity,

$$j_{mf} \approx 0.23 \left[ \frac{g\sigma \left(\rho_{\ell} - \rho_{v}\right)}{\rho_{v}^{2}} \right]$$
(4)  
and the peak critical heat flux  $q_{CHE mf}^{''} = 0.23 \lambda \rho_{v}^{1/2} \left[ g\sigma \left(\rho_{\ell} - \rho_{v}\right) \right]^{1/4}$ 
(5)

It follows that  $q_{CHF,mf}^{''} / q_{CHF,Z} = 1.77$ . Here we note that the highest measured deviations from Zuber's instability theory is a factor of 1.78 obtained on microporous surfaces with the highly-wetting FC-72 fluid (Rainey et al., 2003).

In summary, considering an appropriate hydrodynamic limit based upon a flow regime change from liquid to vapor continuous condition due to incipient fluidization (Eq. 5), this limit is clearly substantiated based upon the highest reported heat flux values obtained with well-wetting surfaces at different pressures. As such, the microporous surfaces used by Rainey et al., provide the maximum possible heat removal rates.

REFERENCES

LEVICH, V. G., 1962, "PHYSIOCHEMICAL HYDRODYNAMICS," PRENTICE HALL.

RAINEY, K. N., ET AL., 2003, "Pool Boiling Heat Transfer Microporous Surfaces in Surfaces in FL-72," Journal of Heat Transfer, Vol. 125/75 (February).

Wallis, G. B., 1969, "One-Dimensional Two-Phase Flow," McGraw-Hill.

ZUBER, N., 1958, "ON THE STABILITY OF BOILING HEAT TRANSFER," ASME J. HEAT TRANSFER 80(2), PP. 711-720.

# Letter From The President

Dear Customer,

Happy Spring! We are hoping your buds are blooming and your safety programs inspired.



Here at FAI, we are hopping with new strategies and actionable items to better serve our customers. Hopefully, you are a subscriber to our blog which just received a Top Ten Award for Chemical Engineering by Feedspot.com. Among the blogs is a new video case study describing a wood processing combustible dust incident we addressed. Follow the links to the right to learn more.

We are introducing new outbound and education efforts in order to stay ahead of your chemical processing, thermal hazards, flammability, combustible dust and nuclear safety needs. We appreciate you continuing to think of an independent testing and engineering lab such as ours for every step of your processes from building a new facility, setting up labs or processes, writing a process safety management plan, review systems and audits, testing, accident prevention, follow-up and maintenance.

As always, please let us know how we can help. You inspire us!

Very Best,

LW Formalt

John W. Fasnacht, President





Congratulations to Dr. Jim Burelbach and Dr. Chris Henry for 30 years of service to Fauske & Associates, LLC, and special recognition to Dr. Marty Plys, Vice President, Waste Technology (pictured with President John Fasnacht) for 35 years of service to Fauske & Associates, LLC.



In this video, Dr. Ashok Ghose Dastidar breaks down details from a deflagration incident (explosion) at a wood pellet manufacturing plant along with the steps FAI took to mitigate any future combustion risks. To see the video or read the full case study visit www.fauske.com/blog/video-case-study-wood-processing-corporation.



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## **ARSST - Things to Check to Perform a Successful Test**

The ARSST is a simple yet robust piece of equipment that provides essential data for relief system design and process scale-up. A key aspect of the design is that many of the ARSST parts are easily replaceable to allow for testing a wide range of chemical systems.

### By Elizabeth Raines, Chemical Engineer

In order to perform a successful ARSST test and collect meaningful data, it is crucial to ensure that all the parts are functioning properly. Here are some quick things to check to ensure that the ARSST is ready for testing:

- 1. Have you verified that all the consumable parts are in good working condition?
- 2. Is the containment vessel and thermocouple properly grounded?
- 3. Is the ARSST control box and heater turned on?
- 4. Is a fuse blown in the back of the ARSST control box (this may be a problem if, when you turn on the box, you don't hear the fan kick on)?
- 5. Are the cables (thermocouple cable, heater cable, and pressure cable) separated from each other?
- 6. Have you verified that the voltage through the heater cable is what it should be?
- 7. Are the pressure transducer and thermocouple properly calibrated?

This article and the accompanying video focus on item 1 above; verify that all consumables are working and replace them if they are questionable.



For the ARSST, there are four primary consumable parts that benefit from electrical checks prior to testing: the thermocouple, the heater, and their respective glands. *Note, in the following pictures, the locations where the multimeter (voltmeter) leads should make contact are identified by blue and red dots, respectively.* 

#### Thermocouple

There are two primary checks to be performed to ensure your thermocouple is in good working condition:

- A. Verify that the resistance across the thermocouple is 3-6 ohms (for a stainless steel thermocouple)
  - Turn your multimeter on and set to read resistance (might be shown with the Greek letter omega, Ω, or the word "ohms")
  - Connect one of the leads from the multimeter onto each of the thermocouple "prongs":



- The resistance across these two locations should read the specified resistance in ohms (note the resistance is thermocouple specific and varies based on material and length)
- B. Verify that the thermocouple is not shorted out by checking that the resistance to the sheath is > 10 Mega ohms
  - Turn your multimeter on and set to read resistance
  - Connect one of the leads from the multimeter to one of the thermocouple prongs and the other lead to the end of the thermocouple:



- The resistance across these two locations should read a very large resistance indicating that the thermocouple is not shorted out

#### **Thermocouple Gland**

There are two primary checks to be performed to ensure your thermocouple gland is in good working condition:

- A. Plug the thermocouple into the thermocouple gland. Verify that the resistance across the thermocouple gland is 3-6 ohms (for a stainless steel thermocouple)
  - Turn your multimeter on and set to read resistance
  - Connect each of the leads from the multimeter onto each of the thermocouple gland prongs:

#### Continued From page 3

## JACKY SHOULDERS JOINS FAI AS MANAGER OF NUCLEAR SERVICES



Mr. Shoulders has more than 10 years of experience in various positions of increased responsibility in the nuclear industry.

He is a mechanical engineer with a material science concentration and he began his Westinghouse Electric Company career as a Technical Lead for the AP1000 Pipe Rupture Hazards Analysis project. He then moved to Oak Ridge National Laboratory as a systems engineer for fueling and disruption mitigation on the US ITER (International Thermonuclear Experimental Reactor) project.

Most recently, he served as the Westinghouse Resident Site Manager/Customer Account Manager for Exelon's Braidwood and Byron stations.

... he began his Westinghouse career as a Technical Lead for the AP1000 Pipe Rupture Hazards Analysis project.

Receiving his Masters in Mechanical Engineering with a concentration in Material Science from Tennessee Technological University, Mr. Shoulders now leads the nuclear energy and waste management areas at FAI.

We are happy to welcome Jacky to the FAI team.



- The resistance across these two locations should read the specified resistance in ohms for the thermocouple
- B. Verify that the thermocouple is not shorted out to the vessel and that the resistance is > 10 Mega ohms
  - Turn your multimeter on and set to read resistance
  - Connect one of the leads from the multimeter to one side of the thermocouple gland prong and the other lead somewhere on the vessel:



- The resistance across these two locations should read a very large resistance (>10 Mega ohms) indicating that the thermocouple is not shorted to the vessel

#### Heater

There are two primary checks to be performed to ensure your heater is in good working condition:

- A. Verify that the resistance across the heater is 23.5-24.5 ohms
  - Turn your multimeter on and set to read resistance
  - Connect each of the leads from the multimeter onto each prong of the heater



- The resistance across these two locations should read approximately 23.5-24.5 ohms
- B. Verify that the heater is not shorted out and that the resistance is > 10 Mega ohms
  - Turn your multimeter on and set to read resistance
  - Connect one of the leads from the multimeter to one of the heater wire prongs and the other lead to the foil part of the heater:

## 5 Things Every Plant Manager Needs to Know About Combustible Dusts

By Zachary Hachmeister, Chief Operating Officer

## **Combustible Dust is Fuel**

This may sound obvious, but it's really important. You need to think of dust deposits on surfaces or dust leakage from equipment as uncontrolled fuel in your facility. This, of course, is only true for dusts that are combustible. The reason this is so important is that it will help shift you and your employees' perspective on dust from a nuisance that reflects a lack of cleanliness to a potential hazard that is putting you, your co-workers, and your assets at risk. (This slight shift in perspective can translate to an increased awareness of combustible dust hazards and by doing so, can help you identify where dust is escaping from your process into your facility.)



### **Keep it Clean**

If gasoline is spilled, there is an immediate hazard. Flammable vapors rapidly spread throughout the area and if they contact an ignition source, it is likely an explosion or flash fire will occur. If no ignition source is present though, the fuel evaporates and the flammable atmosphere dissipates until the hazard no longer exists. Solid fuels, like combustible dust are different in that they need to be physically removed. Hopefully this is accomplished through safe cleaning practices. However, if left untouched the material becomes susceptible to other means of dispersion that can lead to a catastrophic explosion.

### **Take Control at Transfer Points**

The dust that has escaped the confines of your process, a.k.a. fugitive dust, typically originates from unconfined dust generating operations that are not properly ventilated. Transfer points in particular are susceptible as many processes use a series of conveyors, screws, and hoppers to move material from one part of the process to another. Often there is a short distance of free fall where the material is suspended as it changes elevation. Cutting and grinding operations are a couple of other common sources that come to mind as well. Enclosing, or partially enclosing and providing industrial ventilation for these dust generating operations can greatly reduce the amount of fugitive dust in your facility. Though the equipment comes at a price, a cost savings can also be recognized from the reduction in man hours needed for housekeeping activities.

## **Contain and Mitigate**

Taking control of dust that is escaping your process through proper industrial ventilation design and employing good housekeeping measures to keep your facility clean can greatly reduce the risk of a catastrophic dust explosion that could compromise your entire facility. However, now that dust is contained to the system, proper mitigation of explosion hazards for these systems is imperative. Installing explosion protection equipment such as explosion relief venting, suppression, and/or isolation on equipment that handles combustible dust will further reduce the risk of injury or loss of assets. An example of typical equipment to focus mitigation efforts on includes dust collectors, cyclones, silos and spray dyers. The need for protection of industrial equipment is determined through the presence of sufficient quantities or dust, credible ignition sources, and credible dispersion mechanisms.

### The Onus is on You

NFPA 652 Standard on the Fundamentals of Combustible Dust specifically states that the owner/operator is responsible for characterizing the combustible materials in their facility, identifying combustible dust hazards associated with those materials, mitigating identified hazards, and communicating these hazards to the workforce. Though NFPA is not an enforcement body, OSHA, fire marshals, building inspectors, and insurance underwriters do enforce NFPA standards. Therefore, compliance with NFPA not only makes sense from a safety standpoint – it is expected by these governing bodies.

Characterization of your materials is the first step in determining if you have combustible dust onsite. This can be accomplished by creating an inventory of your powdered materials and identifying which are combustible and which are not. A literature search of your materials can be used to identify known combustibles. However, your most concrete evidence of combustible versus non-combustible will be generated through laboratory experiments conducted on representative samples of your materials.

A dust hazard analysis (DHA) per NFPA 652 can be employed to identify the combustible dust hazards that are present in your facility. Essentially, DHA is a documented systematic evaluation of each piece of equipment and building that handles or contains combustible dust to identify where these hazards exist. A proper DHA will review current administrative and engineering controls that are used to manage these hazards and offer recommendations to mitigate unsafe conditions.

Still have questions? Contact our team at dust@fauske.com for more information.

## My Material Doesn't Look Like a Dust, Do I Still Need to Test It for Explosibility In a Dust Cloud?

By Rachelle Andreasen, Manager, Dust Testing Operations, Earl Johnson, Lab Technician and Ashok Ghose Dastidar, Ph.D. MBA, Vice President, Dust & Flammability Testing and Consulting Services

## In an effort to help our customers understand the importance of evaluating the "dust" hazards within their facility, we have taken a current ASTM method and modified the purpose to answer the "is my material a dust" question.

ASTM E2316 Standard Test Method for Determination of Particles Resulting from the Attrition of Granular Pesticides was originally authored to provide information on health hazards such as inhalation risks based on the amount of pesticide dust present within a working area. The method looks at the original size of the dust and simulates breakage from normal manufacturing and handling processes. The fines generated from this testing procedure are labeled as the "fines from attrition".

## The method looks at the original size of the dust and simulates breakage from normal manufacturing and handling process

As the amount of dust increases, the greater the risk for not only inhalation concerns, but for explosion hazards as well. As previously mentioned, this test procedure was modified to simulate the amount of dust that could be generated by transport via pneumatic and mechanical means within a facility or in containers on the road (i.e. sea or air).

Most recent revisions of the NFPA standards related to dust define a "dust" as a particulate with a particle size of 500 µm or smaller. For this reason, this analysis was performed by taking a sample of material and sieving the material to less than 500 µm to remove the inherent fines (i.e. the powder/dust at the bottom of the bag of cereal). Once the inherent fines were removed, the material was placed within a glass jar with an equal weight of glass beads. The material was tumbled, with the glass beads, for approximately 4500 rotations thus creating an attrition scenario. Once again, the material was sieved to less than 500 µm to remove the fines from attrition. The total quantity of fines then becomes an estimate of the amount of powder/dust that can be present in your material after transport.

As you can see from the histogram below, the commercial particle size of granulated sugar was 54% less than 500  $\mu$ m (see Figure 1). After the tumbling process, the material was determined to have a particle size of 62% less than 500  $\mu$ m (see figure 2). The table below also details the data generated from the analysis. The fines % was increased by approximately 8%, which is nearly a 15% increase in fines.

#### Table 1 Average weight % of particles with a 500 µm diameter or smaller

Material	Inherent Fines,	Attrited Fines,	Total Fines,
	Wt.%	Wt.%	wt.%
Granulated Sugar	46	4	50



Figure 1: "as received" particle size distribution

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 The resistance across these two locations should read a very large resistance indicating that the heater is not shorted to the foil (>10 Mega ohms)

#### **Heater Gland**

There are four primary checks to be performed to ensure your heater gland is in good working condition:

A. Verify the heater gland continuity through the vessel

- Turn your multimeter on and set to read continuity (it might look like this symbol ))), otherwise set to resistance)
- Connect one of the multimeter leads into one of the female heater gland locations (on the interior side of the vessel) and connect the other lead to the male prong on the exterior side of the vessel (touch the metal part on each side):



- When a complete path is reached, the multimeter will beep (and show a resistance of ~0.3-0.5 ohms).
- Swap pairs and test that the other wire is intact
- Each conductor/wire should show good continuity for the tested male/female connectors, but not with the other connectors (no short between the conductors)
- B. Verify the heater gland wires are not shorted to the vessel and that the resistance > 10 Mega ohms
  - Turn your multimeter on and set to read resistance
  - Connect one of the multimeter leads onto one of the male heater gland prongs and connect the other lead to the vessel:



- The resistance between these two locations should read a very large resistance (>10 Mega ohms) indicating that the heater gland is not shorted to the vessel
- Repeat and test the other prong
- C. Plug the heater into the heater gland and verify that the resistance across the heater gland is 23.5-24.5 ohms
  - Turn your multimeter on and set to read resistance
  - Connect each of the leads from the multimeter onto each side of the prongs on the heater gland exterior:



- With the heater plugged in, the resistance across these two locations should read approximately 23.5-24.5 ohms
- D. Plug the heater into the heater gland and verify that the heater and gland is not shorted out to the vessel and that the resistance is > 10 Mega ohms
  - Turn your multimeter on and set to read resistance
  - Connect one of the multimeter leads onto one of the male heater gland prongs and connect the other lead to the vessel:



- The resistance between these two locations should read a very large resistance (>10 Mega ohms) indicating that the heater gland is not shorted to the vessel
- Repeat and test the other prong

Contact thermalhazardsgroup@fauske.com to learn more.

## PROCESS SAFETY NEWS IS PUBLISHED QUARTERLY BY

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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 subscribers' concerns regarding issues and practices for relief system design as well as laboratory testing and techniques for process safety management.

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Figure 2: Particle Size distribution after attrition

The data generated in this analysis clearly shows that even though your material may be in granular form (or larger), the potential for particle attrition based on your or the end users' process should be evaluated.

There is not a definitive particle size that governs whether or not a material is explosible in dust cloud form. The explosion characteristics can be altered based on a materials particle size distribution, moisture content and even particle morphology. Care should be taken when operating within a facility with explosible dust.

If you have additional questions regarding combustible dust, contact our dust team at dust@fauske.com.



Fauske & Associates, LLC hosted chemistry students from Marquette Manor Baptist Academy for a tour of our dust, flammability and thermal hazards labs. Chief Testing and Safety Engineer Charlie Askonas and Flammability Project Manager TJ Frawley provided great insight to budding engineers.

## Temperature As An Ignition Source: Which Test Do I Choose?

It is well known throughout the process safety industry that any fire, explosion, detonation, or form of combustion is the product of a combination of hazardous elements. Whether it is a leg of the flammability triangle or part of the pentagon of dust explosibility, the presence of an ignition source is always a threat, especially in high temperature environments.

#### By TJ Frawley, Flammability Projects Manager

This article will focus on temperature acting as the ignition source.

Here, at Fauske and Associates LLC (FAI), we have multiple test methods to determine the temperature in which a material will auto-ignite. These methods are split into two categories, the auto-ignition of solids in the form of dust and the auto-ignition of vapors and gases. It may seem that these differences are fairly obvious, however, there is some overlap. For example, if you need a solid material tested but it has a low melting point, do you test for the explosive properties while in a solid state? Or ,do you test for the ignition temperature of the vapors given off as the material transitions into a liquid? Or, which test is best suited for a solid saturated in a liquid?

This article is here to help you answer these questions and others like it. Let us begin with the test methods that are focused around solids.

First, a **Layer Ignition Temperature (LIT) test**. This test determines the temperature at which a layer of dust will combust when placed on a hot surface. This may also be referred to as spontaneous combustion. As the temperature of hot surface increases, the likelihood of a material reaching its auto-ignition temperature also increases. The heat generated in the dust layer is greater than the amount of heat dissipated into the environment and eventually the temperature within the dust layer will run away to point the material ignites.

Continuing with solids auto-igniting, next we look at the **Minimum Ignition Temperature (MIT) test**. This may also be known as a BAM oven test. This test determines the temperature that a dust cloud will auto-ignite. Here, a dust is dispersed into an oven at a given temperature. The temperature is decreased until no ignition is observed. The test is then repeated over a range of concentrations.

The LIT and MIT tests are alluded to in NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids.* Section 9.7, *Hot Surfaces* states:

"In areas where a dust explosion hazard or dust flash fire hazard exists, the temperature of external surfaces, such as compressors; steam, water, or process piping; ducts; and process equipment shall be maintained below 80 percent (in degrees Celsius) of the lower of the dust surface ignition temperature or the dust-cloud ignition temperature." Now, we will begin the transition from testing solids to testing gases and vapors. We will determine the highlighted section of the accompanying graph.



The next test is where we may see some overlap between testing solids and vapors. This is the **Spontaneous Ignition Temperature (SIT) test**. The SIT is best for solids with low melting points that may produce flammable vapors. These type of products include, but are not limited to plastics and rubbers. The SIT also applies to solids that may contain liquids or are saturated in liquids. In the illustration of the SIT apparatus, the solid sample would be placed within the sample cup and then lowered into the furnace/oven. Over a period of time, the sample will melt and produce vapors. Air is flowing up through the furnace to ensure there is a sufficient quantity of oxygen to propagate an ignition.



Last and certainly not least, especially from a safety perspective, is the **Auto-Ignition Temperature (AIT) test**. The AIT focuses on the autoignition of vapors and gases. Typically, but not in every case, the AIT will result in a lower ignition temperature due to the ease in which those particles are excited compared to the solid counterparts. It is also important to note that the ASTM standard for the AIT requires

#### Continued From Page 9

a more accurate testing range than the previously mentioned tests.

If you have a process that includes drying or curing a material in an oven, it is best to know the SIT and/or AIT of your material and operate below that temperature. Also, the SIT and AIT tests are especially applicable when adhering to NFPA 70, *National Electrical Code*. The following is an excerpt from that code, *Article 500 – Hazardous (Classified) Locations, Classes I, II, and III, Divisions 1 and 2:* 

"Equipment shall be identified not only for the class of location but also for the explosive, combustible, or ignitible properties of the specific gas, vapor, dust, or fibers/flyings that will be present. In addition, Class I equipment shall not have any exposed surface that operates at a temperature in excess of the auto-ignition temperature of the specific gas or vapor. Class II equipment shall not have an external temperature higher than that specified in 500.8(D)(2). Class III equipment shall not exceed the maximum surface temperatures."



Auto-ignition temperature data, whether for solids or liquids, are essential to designing an inherently safe process. If you require auto-ignition testing on a solid, please contact Mark Yukich at yukich@fauske.com If you require testing of liquids or gases, please contact TJ Frawley at frawley@fauske.com, or call either at (630) 323-8750.

## UPCOMING EVENTS IN 2019

Visit with representatives from Fauske & Associates, LLC at these tradeshows and conferences in 2019:

- AIHce EXP 2019
   May 20-22, Minneapolis, MN
- NSC 2019 Expo - September 9-11, San Diego, CA
- Relief System Design Course - October 16-18, Burr Ridge, IL
  - 2019 AIChE Annual Meeting - November 10-15, 2019, Orlando, FL

We look forward to seeing you!



Come and see Fauske & Associates, LLC (FAI) at the

## Fall 2019 DIERS Meeting September 16-18 Chicago Marriott Southwest at Burr Ridge Burr Ridge, Illinois



Don't miss this opportunity to hear featured keynote speaker, Dr. Hans K. Fauske, present on predicting equilibrium and non-equilibrium flow.

Dr. Fauske provided overall technical direction for

the AIChE's acclaimed DIERS program formed in 1976 as a consortium of 29 companies to develop methods for the design of emergency relief systems to handle runaway reactions. Currently, Dr. Fauske is performing a key role in resolving potential process safety issues and the development of inherently safe nuclear and chemical process reactor concepts.

On Tuesday, September 17, FAI will host DIERS meeting attendees at our Burr Ridge, IL campus for lunch and a tour of our state of the art laboratory facilities.

To learn more about the Fall 2019 DIERS Meeting and how to register visit: https://www.aiche.org/design-institute-emergency-relief-systems-diers. We look forward to seeing you in September!



## Safer Scale-up of Batch and Semi-Batch Reactions

Fauske & Associates, LLC (FAI) will be publishing four articles on the topic of safer scale-up for batch and semi-batch reactions. This initial article is on desktop reviews and preliminary hazard analysis.

By: Richard Kwasny, Ph.D., Senior Consulting Engineer

Thermal runaway incidents continue to occur in batch production facilities in the chemical and pharmaceutical industries. Serious incidents can result in death, injury, capital loss, and business interruptions. Despite the best efforts of the chemical/pharmaceutical industries to be responsible, major incidents cast a negative light on this industry as a whole. In order to prevent incidents from occurring there is a need for all R&D, process development, and batch production facilities to have an effective process safety strategy in place including sound safety-management systems. Prior to scale-up, it is critical to have a clear understanding of the reactivity of all process chemicals as well as the energetics of both desired reaction(s) and undesired reactions, defining worst-case scenarios, characterizing the resulting adverse reaction, and understanding how to mitigate the process safety impact. A partial flowchart detailing these steps is shown in Figure 1. Processes that cannot be adequately controlled must be redesigned if possible or utilize less hazardous material.

This article attempts to provide guidelines that can be used as a basis for developing and designing safer new processes. It can also be used to identify process safety information gaps when existing processes undergo periodic reviews, as required in part by OSHA Process Safety Management 1910.119, Hazard Communication 1910.1200, and the General Duty Clause.

### **Causes of Thermal Runaway Reactions**

Studies have determined that thermal runaway reactions occur due to the following four reasons:

- Insufficient understanding of the process chemistry and the energy/kinetics for the desired reactions
- 2. Improper design of the heat transfer capacity required at the plant level
- 3. Insufficient understanding of the adverse reaction and controls including plant-safety back-up systems, as well as adequate emergency venting
- 4. Inadequate written batch procedures and poor operator training.



Figure 1 Flowchart of a Preliminary Hazard Assessment

#### Continued From Page 11

Never assume a chemical is not hazardous because of a low-hazard rating. Many incidents involve materials that have NFPA hazard ratings of 0 and 1. It is best to develop a proper testing program to identify and characterize all reactive materials and reaction mixtures under a variety of process conditions. If your company does not have a testing facility, FAI will be pleased to work with you to identify and conduct appropriate tests. Subsequently, a process hazard analysis can then be used to assign appropriate controls and safeguards to reduce risk of an adverse event. It is important to remember to update the process safety information, as a process undergoes changes during its lifecycle. The interim process-safety information reports can then serve as a reference for technology-transfer purposes as the process scales from R&D, kilolab, pilot plant to commercial-production stage. Once the process has been set, the final process safety report can then be used by a variety of end users either in-house or by outsource facilities. When developing safety documentation, it is important to keep in mind that it must comply with company policies and procedures as well as country and local regulations.

## Never assume a chemical is not hazardous because of a low-hazard rating.

#### **Desktop Reviews and Screening Tests**

The following items should be considered in relation to a process safety hazard evaluation.

#### Decision to Scale-Up

When management wants to scale-up a chemical reaction in an existing facility, the amount of information available can vary significantly. Therefore, it is essential to review the desired process and inform the organization if there are any issues that need to be addressed. Therefore, there is a need for a preliminary hazard assessment based on a balanced equation of the desired chemistry.

Preliminary hazard assessment:

- Develop an inventory of all process materials including but not limited to:
  - o Starting and product substrates,

- o Reagents,
- o Catalyst,
- o Solvents
- o By-products
- o Off-gasses
- Identification of material properties, hazards, and other potential problematic issues:
  - o Physical properties
  - o Health hazards
  - o Flammability and static properties
  - o Thermal stability of materials including the potential for shock sensitivity and explosion propagation
  - o Review the molecular structure of the reaction materials for highly reactive functional groups
  - Conduct preliminary screening testing using differential scanning calorimetry (DSC) to identify thermal instability in the starting and final substrates
  - o Vapor phase reactivity
  - o Material of construction issues (catalytic, corrosion, compatibility, and so forth)
  - o Special hazards (oxidizers, pyrophoric, water-reactive, and so forth)
- Methodologies:
  - Conduct a literature search for the above mentioned information and work with production/ process engineers to better understand process limitations
  - o Estimate the heat of reaction using estimation techniques
  - o Quantitate the non-condensable off-gases to estimate volume and rate
  - Interpret the potential hazards with respect to the process temperature and pressure including other critical issues

#### **Initial Evaluation of the Reaction**

Once we have all of the above mentioned information, we are in a better position to determine if there are any potential issues that would prevent scale-up.

For example, if the reaction involved a simple crystallization for the formation of a substrate salt with no off-gassing and a calculated adiabatic temperature rise that could be easily controlled through available agitation/heating/cooling of the reaction mass, then probably no additional testing is needed. However, for quality purposes we may need a more quantitative heat balance if there is crash crystallization. Then we could perform reaction calorimetry for this purpose.

There are times when the desired and quench reactions involve reactive functional groups that may become unstable. Therefore, the use of a preliminary hazard analysis will facilitate identification of problematic reactions that under certain circumstances can be a potential hazard or become one if we lose control of the reaction. There are several ways in which this can occur; one is through a thermal runaway reaction, a fire, or process deviations due to misoperations such as mischarging, and so forth.

#### **Quantification of the Desired Reaction**

If we have a potentially problematic reaction then, the next step is to quantify the amount and rate at which heat is generated. Similarly, if there is off-gassing, we would require quantification of the evolved gas rate to ensure the process vent capacity is adequate.

Therefore, the second article in this series will deal with how to characterize the desired reaction, as needed, based on issues encountered in the preliminary hazard assessment. Subsequent articles will include quantification of the adverse reaction and case studies.

#### REFERENCES

- HENDERSHOT, D. C., "A CHECKLIST FOR INHERENTLY SAFER CHEMICAL REACTION PROCESS DESIGN AND OPERATION," CENTER FOR CHEMICAL PROCESS SAFETY INTERNATIONAL CONFERENCE AND WORKSHOP ON RISK AND RELIABILITY, 2002.
- 2. Kwasny, R. S., "Hazard Assessment Strategies for Reduction Reactions," London Southbank University, UK, 1999.
- 3. BARTON, J. AND ROGERS, R., "CHEMICAL REACTION HAZARDS," SECOND EDITION, GULF PUBLISHING, 1997.
- 4. BRETHERICK, L., "BRETHERICK'S HANDBOOK OF REACTIVE CHEMICAL HAZARDS," SEVENTH EDITION, BUTTERWORTH HEINEMANN, 2008.
- 5. STOESSEL, F., "THERMAL SAFETY OF CHEMICAL PROCESSES: RISK ASSESSMENT AND PROCESS DESIGN," WILEY-VCH, 2008.
- MERRITT, C. W., 2004. "CHEMICAL PROCESS SAFETY AT A CROSSROADS," ENVIRONMENTAL HEALTH PERSPECTIVES, 112:A332-A333. doi:10. 1289/ EHP.112-A332, 2004.

FAUSKE



Location: Fauske & Associates, LLC, 16W070 83rd Street, Burr Ridge, IL

Date: October 16 - 18, 2019

CEUs: 2.0 (20 PDH)

Time: October 16 and 17 (8:00 am - 4:00 pm) October 18 (8:00 am - 12:00 pm)\* Price: \$2,000

\* A laboratory session demonstrating experimental techniques will be held the afternoon of October 18, but is optional.

#### **Course Description**

Unlike other emergency vent sizing courses, this curriculum highlights simplified calculation methods capable of giving safe - but not overly conservative - relief system designs, with an emphasis on reactive chemistries and the role of two-phase flow.

Benchmarking of these methods will be illustrated with incidents and available plant data. Utilization of methods and equations will be demonstrated through practical design examples, covering vapor, gassy and hybrid systems.

Attendees will participate in group workshops and complete an independent quiz at the end of the course in order to ensure comprehension of the material.

\*A laboratory session demonstrating experimental techniques will be held the afternoon of October 18, but is optional.



#### **Course Topics - Day 1**

- Introduction to Vent Sizing and Case Study
- Vent Sizing Fundamentals
- Codes and Standards Explanation
- History of DIERS
- Two-Phase Flow Considerations
- Experimental Considerations
- Vent Sizing Based on All Gas or Vapor Venting

#### **Course Topics - Day 2**

- Vapor System Vent Sizing
- Gassy System Vent Sizing
- Hybrid System Vent Sizing
- Simplified Two-Phase Flow Methods for Vapor, Hybrid, and Gassy Systems
- Non-Reactive Fire Sizing

#### **Course Topics - Day 3**

- Stable Relief Valve Operation
- Discharge Coefficient Evaluation
- Containment and Disposal Considerations
- Lab Demonstrations (optional)

#### Learning Outcomes

- Understand up-to-date DIERS vent sizing methodologies and models, as well as the role of single and two-phase flow in venting behavior
- Perform vent sizing calculations using the correct models and methodologies
- Apply adiabatic calorimetry data
- Be able to use hands-on techniques and "rules of thumb" to ensure that realistic vessel and vent size conditions are specified

For hotel information or to register, please contact: FAIUniversity@fauske.com Please direct course related questions to the FAI Thermal Hazards team: thermalhazardsgroup@fauske.com

www.fauske.com

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(630) 323-8750

# Relief Systems Design Course



## **REGISTRATION FORM**

Location: Fauske & Associates Date: October 16 - 18, 201 Time: October 16 and 17 ( *Please check the box to the right if	LLC, 16W070 83rd Street, Burr Ridge, IL 9 Price: \$2,000 3:00 am - 4:00 pm); October 18 (8:00 am - 12:00 pm) you plan to attend the optional laboratory session the afternoon of October 18	PDH)
First Name:	Last Name:	
Company Name:	Position:	_
Address:		
City:	State: Zip:	
Phone: Cell:	Fax:	
Email:		
<sup>p</sup> ayment Method: Visa	Mastercard AmEx Purchase Order Company Check	
Name on Account:		
Account Number:	Expiration Date:	
Signature authorizing Fauske & Asso	ciates, LLC to charge credit card:	
<ul> <li>Fees must l</li> <li>Hotel accor</li> <li>Fees includ</li> </ul>	e received prior to course commencement nmodations and travel expenses are the responsibility of the participant e course notes, continental breakfast and lunch	
lechnological/ Education Requirem Although there are no strict educat recommended. The workshops and for participation.	ents: onal requirements for this course, a bachelor's degree in engineering is strongly course assessment contain calculations so a scientific calculator or laptop is requir	ed
CEU Credit Eligibility: FAI is an IACE n order to be eligible for CEU credit nigher on the course assessment ar	(International Association for Continuing Education & Training) Authorized Provide (2.0 per course), attendees must be present for the duration of the course, score 85 d complete the course evaluation.	er. i% or
Privacy: Fauske & Associates, LLC ha nformation. Training records will or record will be released to the partic	s a written policy to ensure privacy and confidentiality of participant training recordly be released with the expressed written permission of the participant. The partici pant or designated third party within 14 business days of the request.	ds and pant
Cancellation Policy: Cancellations v	ill be accepted up to one month prior to course date.	
Hotel accommo *A list of area	lations* and travel expenses are the responsibility of the participant hotels will be provided upon receipt of completed registration form	

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