FAUSKE & ASSOCIATES, LLC

Process Safety News

Summer 2018 • Vol. No. 25 • Number 3

IN THIS ISSUE

A Simple and Accurate Non-Equilibrium Two-Phase Flashing Flow Model Compared to Safety Relief Valve Data

In contrast to the two-fluid models that require numerous assumptions and the corresponding closure equations, the simple model can be stated as:

By Hans K. Fauske, D.Sc., Regent Advisor

$$G = \left[G_{sc}^2 + \left(\frac{1-Y}{G_0^2} + \frac{Y}{G_1^2} \right)^{-1} \right]^{1/2} \qquad (1)$$

where G ($kg\ m^{-2}\ s^{-1}$) is the two-phase flow rate including the effects of Subcooling (G_{sc}) and non-equilibrium, Y is the dimensionless independent variable ranging from 0 to 1 and G_0 and G_1 are the corresponding asymptotic flow rate limits. If all liquid exist at the stagnation condition, extensive data suggest that a simple length criterion L of the order of 100 mm characterizes the residence time requirement for approaching equilibrium flashing flow in ducts which are well described by the Equilibrium Rate Model (ERM), (Fauske, 1985). In this case Y in Eq. (1) represents the dimensionless length $L^+ = L/100$ ranging from 0 to 1. For all specified stagnation conditions the easy to estimate G values with no arbitrary adjustable parameters are in remarkable agreement with available experimental data. An example is illustrated in Figure 1 comparing Eq. (1) with subcooled and saturated non-equilibrium flashing valve data.

MODEL PREDICTIONS FOR FIGURE 1, FROM EQ. (1)

0 – Subcooling saturated liquid at stagnation pressure P_0 = 4.7 bar, $G_{sc}^2 = 0$, and the saturated flow limits are $G_0^2 = 2\,(P_0 - P_b)\,\rho_l = 2\,(4.7 - 1.013)\,10^5 \cdot 917 = 6.7620 \cdot 10^8$, and $G_1^2 = ERM^2 = (\lambda / v_{fg})^2\,(TC)^{-1} = (2.1148 \cdot 10^6 / 0.3915)^2\,(423 \cdot 4306)^{-1} = 1.6022 \cdot 10^7$, and the non-equilibrium flow rate from Eq. (1) is

$$G = \left(\frac{1 - 10.4/100}{6.7620 \cdot 10^8} + \frac{10.4/100}{1.6022 \cdot 10^7} \right)^{-1/2}$$

$$= 11,311\ kg\ m^{-2}\ s^{-1} \text{ or } G/G_{20} = 11,311/27,131 = \underline{0.417}$$

in excellent agreement with experimental data 0.42.

5°C Subcooling T_n = 144.5°C leads to a saturation pressure P_s = 4.0934 bar with P_0 = 4.7 bar and $G_{sc}^2 = 2\,(P_0 - P_s)\,\rho_l = 2\,(4.7 - 4.0934) \cdot 922.84 \cdot 10^5 = 1.1196 \cdot 10^8$, and the saturated liquid flow limits are $G_0^2 = 2\,(P_s - P_b)\,\rho_l = 2\,(4.0934 - 1.013) \cdot 922.84 \cdot 10^5 = 5.6854 \cdot 10^8$, and $G_1^2 = ERM^2 = (\rho_{fg} \cdot \lambda)^2\,(TC)^{-2} = (2.2206 \cdot 2.1299 \cdot 10^6)^2\,(417.65 \cdot 4290)^{-1} = 1.2473 \cdot 10^7$,

Continued on page 3

Letter From The President

Please Welcome John Fasnacht!

FAI welcomes newly appointed President John Fasnacht. We are excited to have John continue to build on our reputation of solving complex process safety and severe accident prevention management in process safety, nuclear, dust explosibility, and other industries. John has more than 30 years of diverse engineering and management experience at Westinghouse, including leadership roles with the Primary Systems Design & Repair and Architect Engineering Services groups, and AP1000 Offshore China Projects and Engineering Delivery teams. John most recently served as director, Product Global Growth & Strategy. He is a registered Professional Engineer and is certified as a Lean Six Sigma Master Black Belt.

Dear FAI Customer,

I look forward to serving you as president of FAI by providing continued leadership in business operations as well as a vision for growth. This month, we wanted to highlight the appreciation of employees. I'd already had the pleasure of working with a few FAI employees over my many years with Westinghouse, but have really begun to get an appreciation for the dedication to both customers and quality of work that emanates from this great organization. It is a pleasure to serve you.

Best Regards,

John W. Fasnacht, President

A Fauske & Associates, LLC combustible dust technician prepares the 20L chamber for testing

Members of Fauske & Associates, LLC's combustible dust team volunteered at Feed My Starving Children. During their session 216 boxes of food (46,656 meals) were packed which will feed 128 kids for a whole year

Representatives from Fauske & Associates, LLC once again volunteered at the 20th Annual Miracle Michael Golf Outing to generate financial support for on-going research of Osteogenesis Imperfecta also known as brittle bone disease

Follow us on social media for industry and company updates

COMBUSTIBLE VS. EXPLOSIBLE...THERE IS A DIFFERENCE

By Mark Yukich, Customer Service Lead

A common misunderstanding is how terms "explosible" and "combustible" dust are used to describe dust testing objectives and their results. Understanding the difference between the two will guide you on the correct path toward characterizing your material. The difference between the two is the following:

- "Explosible" material is when a sample found to be able to support a rapid reaction in a suspended cloud of dust/powder; the technical term for the rapid chemical oxidation reaction is *deflagration*.

- "Combustible" material is a sample that is found to support self-sustaining flame propagation while in a pile or layer

One of the most common tests that many are familiar with is the "Go/No Go" or the Explosibility Screening Test. It is common to hear a customer tell us that their material is a "combustible dust" because it was a "Go" in the Go/No Go Test. In truth, that material was found to be an "explosible dust". To assess the combustibility of your sample it would be advisable to conduct a Burning Behavior Test. It is possible to have a material be explosible and not combustible or a material to be combustible and not explosible. Running both the Explosibility and

Continued on page 5

Continued From Page 1

and the non-equilibrium two-phase flow rate from Eq. (1) is

$$G = \left[1.1196 \cdot 10^{8} + \left(\frac{1 - 10.4/100}{5.6854 \cdot 10^{8}} + \frac{10.4/100}{1.2473 \cdot 10^{7}} \right)^{-1} \right]^{-1/2} = 14,589 \text{ kg m}^{-2} \text{ s}^{-1},$$

or $G/G_{20} = 14,589 / 27,131 = 0.5397$, in excellent agreement with experimental data = 0.54.

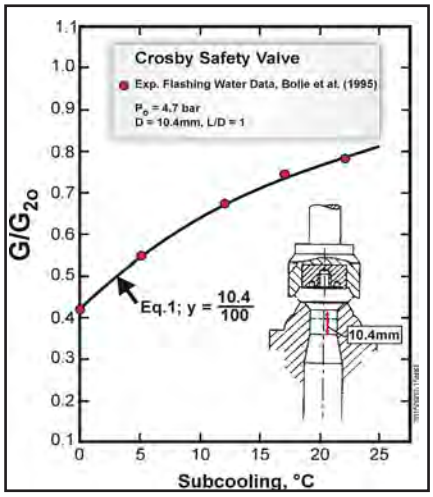


Figure 1

REFERENCES

"Bolle, J. et al., 1995, "Flashing Water Flow Through a Safety Valve," J. Loss Prev. Process Ind. 8(2), p. 111 (1995).

Fauske, H. K., 1985, "Flashing Flows: Some Practical Guidelines for Emergency Releases," Plant/Operation. Prog. 4(3), pp.132-134 (July 1985).

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

Employee Recognition

Thank You!

Thank you, Mike, for the many extra hours spent keeping up with the high volume of work in our our dust testing business while your colleague was on maternity leave

Thank you, Paul, for your many extra hours spent supporting and building the Flammability Testing and Consulting business

Combustible Nano-Dust: Smaller Particle Sizes Lead to Faster, Stronger Explosions

Credit for launching the nanotechnology revolution frequently goes to Richard Feynman's 1959 talk to the American Physical Society, "There's Plenty of Room at the Bottom".

By: Timothy Cullina, Senior Consulting Engineer

And even if you disagree with this credit, I hope you can agree that Feynman's enthusiasm for "small science" certainly fed the imaginations of scientists, philosophers, and deep thinkers about a future built upon nanotechnologies.

Others, maybe Eric Drexler, or was it Omni Magazine, forecast a darker future for nanotechnology with predictions of self-replicating nanobots gone rogue, consuming nearly all resources, and leaving only a dark, dead, world composed of nothing but useless nanobots forming endless piles of "grey goo".

More than a half century later, the nano engines of creation are quietly humming away, the alarms over grey goo have gone nearly silent, and many of today's industries move steadily toward producing smaller particulate, even if most are still quite a ways from true nanometer particle size.

Particle size is the dominant physical parameter that affects explosion severity and ease of ignition for combustible dusts. And particulate size is trending down in many industries. This is true for pigment, toners, electronics, cosmetics, pharmaceuticals, specialty chemicals, additive manufacturing, food and many more. As with toner, the reason may be improved quality and new transfer technologies. Other advantages may be related to improving mixing efficiencies and reducing production times.

Of course, some particle size reductions may go unnoticed if your management of change (MOC) program is blind to particle size considerations. While there are advantages to working with a smaller particle size that is specific to each application, there is also an increased combustible dust risk associated with smaller particle sizes that needs to be managed.

For example, 10 years ago printer toner particulate sizes averaged 30 to 50 microns. To improve the appearance of type, manufacturers have worked to produce finer and finer toner particulate. Today, toner manufacturers are pushing the size boundaries to, and even below, 10 microns. Ten years ago, K_{St} values for many toners were in the Class II range, that is 200 to 300 bar-meter per second. Today's smaller toner particulates have K_{St} values well over 300 bar-m/s. In some cases the protection strategies employed 10 years ago are no longer adequate. Explosion vent sizes may be too small or suppression reaction times too slow.

The decrease in particle size reduces the required energy to initiate a deflagration. It is easier to meet the conditions necessary for a deflagration or explosion by decreasing the minimum explosible concentration (MEC) decreasing the minimum ignition energy (MIE) needed to ignite the material, and decreasing the temperature at which the material may autoignite (AIT). A smaller particulate also creates a faster and stronger explosion since this greatly increases the maximum rate of pressure rise $(dP/dt)_{max}$. It may also result in a more powerful pressure wave. All of which makes the material more hazardous.

Particle size may also "unexpectedly" or inadvertently be decreased by process changes or improvements, some even as inconspicuous as replacing mill components or suppliers. For these reasons it is important to understand the impact that smaller sizes will have on your material. A summary of the recommended testing campaign and the effects of particle size on the results are provided in Table 1.

Table 1 – Recommended Tests for Material Hazard Characterization

Characteristic	Reason for Testing	Effect of Decrease in Particle Size
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.	N/A
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.	N/A
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.	Increase in explosion severity; a faster, more powerful explosion.
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).	Decrease in MIE; material is more susceptible to ignition.
Minimum Explosible Concentration (MEC)	Determines if a hazardous concentration is attainable during normal process conditions. Can be used to justify alternative means of protection.	Decrease in MEC; less material necessary to create an explosion.
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.	Decrease in MIT; an airborne cloud of the material will auto-ignite at a lower temperature.
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.	Decrease in LIT; a layer of the material will ignite at a lower temperature.

Continued from Page 3

Combustibility Screening tests is the first step that should be considered when starting the process of characterizing your material. If your material has been determined to be Explosible, some additional tests you may want to consider are the following:

- Explosion Severity Test or K_{St} – Determines how strong and how fast of reaction may be present when your material reacts.
- Minimum Explosible Concentration (MEC) – Demonstrates the minimum concentration of a dust in air that will propagate a deflagration
- Minimum Ignition Energy (MIE) – Determine the minimum amount of ignition energy needed to create/start a deflagration reaction within a cloud of dust/powder

It is possible to have a material be explosible and not combustible or a material to be combustible and not explosible

- Minimum Ignition Temperature (MIT) – Determine the minimum amount of temperature needed to create a deflagration reaction within a dust cloud

If your material has been determined to be Combustible, some additional tests that you may want to consider are the following:

- UN 4.1 Flammable Solids – Determine the ability of a substance to propagate combustion when ignited and its burning time or rate
- Layer Ignition Temperature (LIT) – Determines the hot-surface ignition temperature needed to ignite material in the dust layer form.

continued on page 6

Flow Regime Characterization in Emergency Relief System Design

Flow regime characterization in emergency relief system (ERS) design is important because it can impact your required vent size and will impact the quantity and rate of liquid material that is vented.

By Benjamin Doup Ph.D., Senior Nuclear and Chemical Engineer

The quantity and rate of liquid material that is vented will affect the design of downstream effluent handling equipment. The flow regime, in the context of emergency relief system design, refers to the interplay between vapor (and/or gas) and liquid phases in a vessel. The flow regime is a characteristic of the venting material during an emergency relief.

The Design Institute for Emergency Relief Systems (DIERS) program [1] contributed to the understanding of the behavior of the vapor-liquid two-phase flow in vessels and supplied reasonably easy to use correlations that generally describe the two-phase flow behavior. The resulting correlations are based upon a drift flux model [2-3] approach. The drift flux model treats the vapor and liquid phases as a single homogeneous mixture, but then describes the difference in velocity and the non-uniform distribution of the two phases using constitutive correlations. The drift velocity, which models the velocity difference between the vapor and liquid, is defined as

$$V_{gj} = \frac{\langle \alpha (u_g - j) \rangle}{\langle \alpha \rangle} \qquad (1)$$

where j = summation of the local vapor and liquid superficial velocities, m/s
u_g = local vapor velocity, m/s
V_{gj} = vapor drift velocity, m/s
α = local vapor void fraction, -
$\langle\ \rangle$ = indicates flow area averaging, -

The distribution coefficient, which models the non-uniform distribution of the phases, is defined as

$$C_0 = \frac{\langle \alpha j \rangle}{\langle \alpha \rangle \langle j \rangle} \qquad (2)$$

where C_0 = distribution coefficient, -

Two flow regimes were initially defined in the DIERS program [1] utilizing the drift flux model. These two flow regimes are bubbly and churn-turbulent flow regimes. Other flow regimes such as the wall boiling or foamy regimes exist, but these flow regimes are not discussed further in this article.

The bubbly flow regime is characterized by smaller bubbles that are typically spherical or near spherical in shape with diameters generally less than 11 mm (for water). These bubbles have a large surface area to volume ratio and are fairly uniformly distributed in the flow field. Figure 1 shows an image of bubbly flow in a vertical air-water test section. Momentum is transferred between the vapor and liquid phases at the interface of the vapor bubbles. This indicates that an increase in the vapor bubble surface area results in tighter coupling between the vapor and liquid phases and the result is less disengagement between the vapor and liquid phases.

Courtesy of Dr. B. Doup and Dr. X. Sun (The Ohio State University)

Figure 1 Image of Bubbly Flow in a Vertical Air-Water Test Section

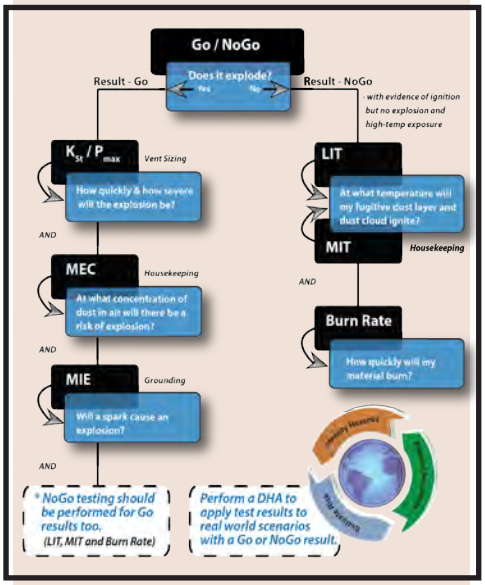
The churn-turbulent flow regime is characterized by larger bubbles that can be elongated and the flow structure is very turbulent partially due to bubble induced turbulence. These bubbles have a smaller surface area to volume ratio. Figure 2 shows an

Continued on page 6

Continued from Page 5

- Minimum Ignition Temperature (MIT) – Mentioned above for the explosible materials, but may also be considered with combustible material when you operate within hot atmospheres like ovens or heavy machinery.

The chart below provides further illustration of combustible dust vs. explosible dust:



We are available to consult with you and your team on any of your process safety projects.

Contact us at dust@fauske.com to learn how we can be a resource to you in meeting your combustible dust process safety needs.

Mark Yukich is Customer Service Lead for the Combustible Dust Team at Fauske & Associates, LLC

Continued From page 5

image of churn-turbulent flow in a vertical air-water test section. This image was obtained in a 2″ diameter cylindrical test section, which is much smaller than most vessels and the wall can impact the flow structure. These wall effects are not as pronounced in large scale vessels. The smaller surface area to volume ratio compared to the bubbly flow regime indicates that the vapor and liquid phases are not tightly coupled, resulting in more disengagement between the vapor and liquid phases for this flow regime.

Courtesy of Dr. B. Doup and Dr. X. Sun (The Ohio State University)

Figure 2 Image of Churn-turbulent Flow in a Vertical Air-Water Test Section

The form of the drift velocity used in the original DIERS program [1] is given by

$$V_{gj} = \frac{(1-\alpha)^n}{1-\alpha^m} u_\infty \qquad (3)$$

where m = 3 for the bubbly flow regime and approaches ∞ for the churn turbulent flow regime
n = 2 for the bubbly flow regime and 0 for the churn turbulent flow regime
u_∞ = bubble rise velocity, m/s

They related the vapor superficial velocity to the average void fraction by assuming the average vessel void fraction is equal to the local void fraction for bubbly flow and by averaging the void fraction in churn turbulent flow over the height of the two-phase mixture. Grolmes and Fisher [4] re-investigated these correlations and derived an alternative form of the bubbly correlation that was obtained without assuming the average vessel void fraction is equal to the local void fraction. The vapor superficial velocity relations from the original DIERS program [1] are given in Equation 4.

$$j_g = \frac{\alpha V_{gj}}{1-C_0\bar{\alpha}} = \begin{cases} \dfrac{\bar{\alpha}(1-\bar{\alpha})^2}{(1-\bar{\alpha}^3)(1-C_0\bar{\alpha})} u_\infty & \text{Bubbly} \\ \dfrac{2\bar{\alpha}}{1-C_0\bar{\alpha}} u_\infty & \text{Churn} \end{cases} \qquad (4)$$

where j_g = vapor superficial velocity, m/s
$\bar{\alpha}$ = vessel average void fraction, -

The form of the bubble rise velocity is obtained by performing a force balance on a single buble in an infinite medium (i.e., pressure force = body force + drag force). Figure 3 shows this force balance schematically.

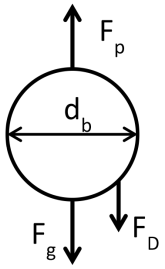


Figure 3 Schematic of Bubble Force Balance

The pressure force is defined in Equation 5

$$F_p = \frac{\pi}{6} d_b^3 g \rho_f \qquad (5)$$

where d_b = bubble diameter, m
F_p = pressure force, kg·m/s²
g = acceleration due to gravity, m/s²
ρ_f = liquid density, kg/m³

The body force is defined in Equation 6

$$F_g = \frac{\pi}{6} d_b^3 g \rho_g \qquad (6)$$

where F_g = body force, kg·m/s²
ρ_g = vapor density, kg/m³

The drag force is defined in equation 7

$$F_D = \frac{\pi}{8} C_D \rho_f d_b^2 u_\infty^2 \qquad (7)$$

where C_D = drag coefficient
F_D = drag force, kg·m/s²

Continued on page 8

The Koenen Test Apparatus

The Flammability Testing and Consulting Services department at FAI has increased our testing scope once again! We are now able to offer Koenen Testing. This test is used to measure the sensitivity of a solid or liquid sample to intense heat with varying confinement.

By: Amy Davis

The Koenen Test apparatus at FAI meets the requirements for test methods listed in the *United Nations' Recommendations on the Transport of Dangerous Goods Manual of Tests and Criteria* and the European Parliament's Council on the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). In the UN Manual, the Koenen test methods are Test 1(b), Test 2(b) and Test 8(b), while the test method in REACH is A.14 Explosive Properties found in the *Official Journal of the European Union*. Based on the test results from these procedures, shipping classifications can be determined as well as the limiting diameter.

This test is part of the Explosive Properties test series, which includes tests to determine mechanical sensitivity with respect to both shock and friction.

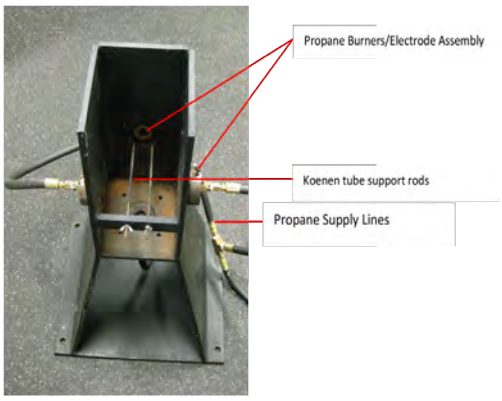


Figure 1: Koenen Test Apparatus

The sample is placed in a non-reusable tube with a reusable collar fitted with a standard orifice plate ranging from a 1 mm diameter up to a 20 mm diameter, through which the decomposition gases are vented. The tube assembly is then placed in the Koenen Test Apparatus, which contains four propane burners housed in a support frame which encloses the test tube on three sides and the bottom. The tube assembly is then exposed to direct heat from the four burners until the tube ruptures or five minutes have expired, whichever comes first. The results of the test are based on how and if the tube ruptures during testing and at what orifice size.

Figure 2: Tube pre-test

Possible effects of heating under confinement according to the Recommendations on the Transport of Dangerous Goods Manual of Tests and Criteria:

"O": Tube unchanged
"A": Bottom of tube bulged out
"B": Bottom and wall of the tube bulged out
"C": Bottom of tube split
"D": Wall of tube split
"E": Tube split into two fragments
"F": Tube fragmented into three or more mainly large pieces which in some cases may be connected with each other by a narrow strip
"G": Tube fragmented into many mainly small pieces, closing device undamaged
"H": Tube fragmenting into many very small pieces, closing device bulged out or fragmented

Figure 3: Tube that underwent effect "A"

Figure 4: Tube that underwent effect "D"

Figure 5: Tube that underwent effect "E"

Figure 6: Tube that underwent effect "F"

Figure 2 through Figure 6 are pictures of results we typically see at FAI. Tests that result in "O" to "E" effect are regarded as "no explosion" according to the UN standards. UN Division classifications are made based on results with a limiting diameter- the largest diameter of the orifice plate used which results in an explosion.

The REACH method for thermal sensitivity uses the 6.0 mm and 2.0 mm diameter orifice plate. Classifications are based on whether or not an explosion occurs at either of these conditions. This test is part of the Explosive Properties test series, which includes tests to determine mechanical sensitivity with respect to both shock and friction.

Amy Davis is former Operations Manager in the Flammability Testing and Consulting Services department at Fauske & Associates, LLC

PROCESS SAFETY NEWS IS PUBLISHED QUARTERLY BY
Fauske & Associates, LLC
16W070 83rd Street
Burr Ridge, IL 60527
info@fauske.com

EXECUTIVE DIRECTOR:
AnnMarie Fauske
ART DIRECTOR:
Sara Peters
CONTRIBUTORS.
Amy Davis
Dr. Benjamin Doup
Tim Cullina
AnnMarie Fauske
Dr. Hans K. Fauske
Sara Peters
Carol Raines
Mark Yukich

Statement of Purpose:

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

Inquiries:

FAI's "Process Safety News" is published by
Fauske & Associates, LLC
16W070 83rd Street, Burr Ridge, IL 60527
Toll Free: 877 FAUSKE1, +1-630-323-8750
Fax: +1-630-986-5481
info@fauske.com www.fauske.com

continued from Page 6

The drag coefficient can be expressed as shown in Equation 8

$$C_D = \frac{\sqrt{2}}{3}\left(\frac{\rho_f u_\infty d_b}{\mu_f}\right)\left(\frac{\mu_f}{\left[\rho_f \sigma \sqrt{\frac{\sigma}{g(\rho_f - \rho_g)}}\right]^{0.5}}\right) \quad (8)$$

where μ_f = liquid dynamic viscosity, Pa·s
σ = surface tension, N/m

The resulting bubble rise velocity is then

$$u_\infty = \sqrt{2}\left(\frac{\sigma g(\rho_f - \rho_g)}{\rho_f^2}\right)^{0.25} \quad (9)$$

Researchers have replaced the $\sqrt{2}$ factor by experimentally determined coefficients. Peebles and Garber [5] (according to Wallis [3]) present the bubble rise velocity as

$$u_\infty = 1.18\left(\frac{\sigma g(\rho_f - \rho_g)}{\rho_f^2}\right)^{0.25} \quad (10)$$

which was used in the DIERS program for the bubble rise velocity in the bubbly flow regime.

Harmathy [6] (according to Wallis [3]) presents the bubble rise velocity as

$$u_\infty = 1.53\left(\frac{\sigma g(\rho_f - \rho_g)}{\rho_f^2}\right)^{0.25} \quad (11)$$

which was used in the DIERS program for the bubble rise velocity in the churn-turbulent flow regime.

The next logical question is how to determine flow regime for a new material or new mixture of materials? The only option at this point is to test your material under emergency relief conditions.

** See the fall newsletter for a detailed flow regime testing approach and sample data.

References

1. Fisher, H.G., Forrest, H.S., Grossel, S.S., Huff, J.E., Muller, A.R., Noronha, J.A., Shaw, D.A., and Tilley, B.J., Emergency Relief System Design Using DIERS Technology, The Design Institute for Emergency Relief Systems (DIERS) – Project Manual, 1992.
2. Zuber, N. and Findlay, J.A., "Average Volumetric Concentration in Two-phase Flow Systems," Journal of Heat Transfer, November, 1965.
3. Wallis, G.B., One-dimensional Two-phase Flow, 1969.
4. Grolmes, M.A. and Fisher, H.G. "Vapor-liquid Onset/ Disengagement Modeling for Emergency Relief Discharge Evaluation," Prepared for Presentation at the AIChE 1994 Summer National Meeting, 1994.
5. Peebles, F.N. and Garber, H.J. Chemical Engineering Progress, Vol. 49, pp. 88-97, 1953.
6. Harmathy, T.Z. AIChE Journal, Vol. 6, pp. 281, 1960.

Dr. Benjamin Doup is a Senior Nuclear and Chemical Engineer in the Thermal Hazards department at Fauske & Associates, LLC

Continued From page 4

Further Details on Testing and Particle Size

ASTM International has published a series of standards (E1226, E1515, E2019, E1491, and E2021) that determine how dust samples should be tested for explosivity potential and characteristics. Without exception, ASTM recommends that tested material have a particle size of <75 microns and a moisture content of <5%. In some cases, samples must be ground, sieved, and/or dried to meet these ASTM recommendations. Sizing and drying material often produces more conservative results than testing the material "as received". Assuring consistent particle size and moisture content produces the consistent, reliable results needed for specifying explosion protection equipment (e.g., explosion vents, suppression systems). The conservative nature of the recommendations to test fine, dry material addresses many concerns about the potential for fines to accumulate in some location (e.g., duct elbow, dust collector, interior walls of bins) in the process or fine fugitive dust on elevated building surfaces like I-beams, pipes/ducts and light fixtures.

While the advantages of sizing and drying material are clear, there can also be value in testing particulate "as received" to understand how the material will behave in its specific native environment if particle segregation/classification did not take place. "As received" test data can be particularly beneficial when considering ignition sensitivity. For example, material that is sized and dried to meet ASTM recommendations may best represent the "worst case" dust characteristics that could be present inside of a dust collector where the most conservative protection techniques could be demanded.

But, "as received" samples of the same material taken from an upstream location in the process where the particulate displays a larger particle size and/or increased moisture content could (for example) present a significantly higher minimum ignition energy (MIE) value than samples that have been sized and dried. The higher MIE value in the "as received" sample could justify reducing controls at the point of the process where the sample was taken. For example, static dissipative shoes could be required when working at the dust collector where lower MIE values could be expected, but the same precaution may not be warranted at the upstream location where an elevated MIE is documented.

Many firms choose to test material in both fashions – ground and dried (if needed) and "as received". Fauske and Associates, LLC can provide support to ensure that samples are tested to appropriately characterize the hazard.

Contact us at dust@fauske.com to learn more.

Tim Cullina is a Senior Consulting Engineer in the Onsite Services Department at Fauske & Associates, LLC

NFPA 652

– An Introduction to Dust Hazard Analysis

2018 Dates and Locations:

New Dates Just Added

September 18-19, 2018, Fauske & Associates, LLC, Burr Ridge, IL

November 13-14, 2018, Fauske & Associates, LLC, Burr Ridge, IL

Course Description

Day 1 ***(Prerequisite for Day 2)*** ***Time: 8 am - 4:30 pm*** ***CEU's: 0.7***

This course will ensure all participants are aware of important issues associated with NFPA 652 and describe how this standard interacts with other relevant NFPA codes and guidelines. A special emphasis will be placed on explaining the requirements for a Dust Hazard Analysis (DHA) and an overview of the methodologies that can be employed to perform a DHA. The course will also include a logical approach to characterizing a powder's hazardous dust properties, as well as a description of various techniques used to control and/or avoid dust explosions in a safe and compliant manner.

Scheduled Agenda

- Introduction
- Overview of NFPA 652
- Fundamentals of Dust Explosions
- Introduction to DHA methodology
- Mock DHA on a Small Blending Operation

Outcomes

- Protection Options
- Daily Learning Assessment
- Questions and Answers
- Course Evaluation Instruction

Day 2 ***Time: 8 am - 4:30 pm*** ***CEU's: 0.7***

Advanced DHA Workshop

The Advanced DHA Workshop will focus on how to organize, lead, and implement the DHA study. This will include how to utilize appropriate test methods to determine potential dust hazards; as well as how to apply appropriate mitigation techniques to prevent or control combustible dust hazards. During the workshop, participants will have the opportunity to apply DHA methodologies to realistic combustible dust scenarios.

Pricing

Two Day Course: $895
Day 1 only: $495
Day 2 only: $495

Fauske & Associates, LLC is accredited by the International Association for Continuing Education and Training (IACET) and is authorized to issue the IACET CEU

For hotel information or to register, please contact: FAIUniversity@fauske.com

Please direct instructor or course related questions to Ashok G. Dastidar - dastidar@fauske.com

www.fauske.com **(630) 323-8750**

FAUSKE & ASSOCIATES, LLC
WORLD LEADER IN NUCLEAR AND CHEMICAL PROCESS SAFETY

ACCREDITED IACET PROVIDER

REGISTRATION FORM

NFPA 652 - An Introduction to Dust Hazard Analysis

Time: 8:00 am - 4:30 pm each day **CEU's:** 0.7 per day

Pricing: ◯ Day1 only - $495 ◯ Day 2 - $495 ◯ Both Days - $895

September 18 & 19, 2018, Fauske & Associates, LLC, Burr Ridge, IL
November 13 & 14, 2018, Fauske & Associates, LLC, Burr Ridge, IL

First Name: _____ Last Name: _____

Company Name: _____ Position: _____

Address: *(address must match the address of credit card used)* _____

City: _____ State: _____ Zip: _____

Phone: _____ Cell: _____ Fax: _____

Email: _____

Payment Method: ☐ Visa ☐ Mastercard ☐ AmEx ☐ Purchase Order ☐ Company Check

Name on Account: _____

Account Number: _____ Expiration Date: _____ Security Code: _____

Signature authorizing Fauske & Associates, LLC, to charge credit card: _____

- **Fees must be received prior to course commencement**
- **Hotel accommodations and travel expenses are the responsibility of the participant**
- **Fees include course notes, continental breakfast and lunch**

Technological/ Education Requirements:
There are no technological requirements for this introductory course. Grade 12 or higher education and 2-3 years professional experience are required.

CEU Credit Eligibility: FAI is an accredited by the International Association for Continuing Education & Training (IACET) and is authorized to issue the IACET CEU. In order to be eligible for CEU credit (0.7 per course), attendees must be present for the duration of the course, score 85% or higher on the course assessment and complete the course evaluation.

Privacy: Fauske & Associates, LLC has a written policy to ensure privacy and confidentiality of participant training records and information. Training records will only be released with the expressed written permission of the participant. The participant record will be released to the participant or designated third party within 14 business days of the request.

Cancellation Policy: Cancellations will be accepted up to one month prior to course date.

To register, please email: FAIUniversity@fauske.com, Fax: (630) 986-5481
(Please direct instructor or course related questions to: Ashok Dastidar, dastidar@fauske.com)

Relief Systems Design Course

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

Date: September 12 - 14, 2018 **CEUs: 2.0 (20 PDH)**

Time: September 12 and 13 (8:00 am - 4:00 pm) **Price: $2,000**
September 14 (8:00 am - 12:00 pm)*

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 September 14, but is optional.*

ACCREDITED IACET PROVIDER

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 +++ **(630) 323-8750**

Relief Systems Design Course

REGISTRATION FORM

Location: Fauske & Associates, LLC, 16W070 83rd Street, Burr Ridge, IL
Date: September 12 - 14, 2018
Time: September 12 and 13 (8:00 am - 4:00 pm); September 14 (8:00 am - 12:00 pm)*
CEUs: 2.0 (20 PDH)
Price: $2,000

** A laboratory session demonstrating experimental techniques will be held the afternoon of September 14, but is optional.*

First Name: _____ Last Name: _____

Company Name: _____ Position: _____

Address: _____

City: _____ State: _____ Zip: _____

Phone: _____ Cell: _____ Fax: _____

Email: _____

Payment Method: ☐ Visa ☐ Mastercard ☐ AmEx ☐ Purchase Order ☐ Company Check

Name on Account: _____

Account Number: _____ Expiration Date: _____

Signature authorizing Fauske & Associates, LLC to charge credit card: _____

- **Fees must be received prior to course commencement**
- **Hotel accommodations and travel expenses are the responsibility of the participant**
- **Fees include course notes, continental breakfast and lunch**

Technological/ Education Requirements:
Although there are no strict educational requirements for this course, a bachelor's degree in engineering is strongly recommended. The workshops and course assessment contain calculations so a scientific calculator or laptop is required for participation.

CEU Credit Eligibility: FAI is an IACET (International Association for Continuing Education & Training) Authorized Provider. In order to be eligible for CEU credit (2.0 per course), attendees must be present for the duration of the course, score 85% or higher on the course assessment and complete the course evaluation.

Privacy: Fauske & Associates, LLC has a written policy to ensure privacy and confidentiality of participant training records and information. Training records will only be released with the expressed written permission of the participant. The participant record will be released to the participant or designated third party within 14 business days of the request.

Cancellation Policy: Cancellations will be accepted up to one month prior to course date.

Hotel accommodations* and travel expenses are the responsibility of the participant

*A list of area hotels will be provided upon receipt of completed registration form

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 + + + **(630) 323-8750**