MEASURING PROCESS SAFETY

Dennis C. Hendershot

There is an often quoted saying, “You can’t manage what you can’t (don’t) measure.” The origin of this saying is somewhat obscure – it has been attributed to management consultant and author Peter Drucker, software engineering author and teacher Tom DeMarco, and others. There is a lot of truth in this idea, although W. Edwards Deming has also pointed out the need to manage things that cannot be measured. But, it is more difficult to manage things that are not measured. How do you set goals and measure progress toward those goals? How do you compare this year’s performance to last year’s? How can you compare the performance of one part of a company – a plant, a business, a group of businesses, for example – to another?

In particular, how do we measure process safety performance? We have tools for measuring overall safety performance – OSHA recordable rates, lost time injuries, days away from work, and other injury measures. These measures combine injuries from all causes into a single safety measure, and do not distinguish between process safety injuries – those arising from the hazardous properties of the materials and the manufacturing processes – and other injuries caused by general workplace hazards – slips, trips, falls, “struck by” type injuries. The report of the BP North American Refineries Independent Safety Panel (the “Baker Panel”, of which I was a member), issued in January 2007, pointed out that these measures of overall safety can be misleading with regard to process safety performance. Good workplace safety does not ensure good process safety. Both are important, but the activities required to manage process safety are not the same as those required to manage general workplace safety. When you think about it, this makes sense. As an analogy, in the air transportation system, a significant contributor to injuries is handling of baggage. But no airline would make the mistake of believing that the activities required to prevent this type of injury would have any impact on flight safety. There is some relationship in terms of overall attitude and culture, but the safety management activities are different, and good performance in one area does not ensure good performance in the other.

To date, we have not had a good set of tools for measuring process safety performance. Industry and the chemical engineering profession have recognized this problem, and there have been a number of efforts to develop appropriate measures over recent years. A recent and promising development is the publication of a new CCPS document, Process Safety Leading and Lagging Metrics, which can be downloaded from the CCPS web site1.

1 http://www.aiche.org/ccps/metrics/index.aspx
The CCPS publication offers suggestions for both leading and lagging metrics for process safety. Lagging indicators will tell us where we are, where we have been, how different parts of the organization are performing relative to each other. They measure actual outcomes of interest – fires, explosions, process related injuries, leaks, releases, near misses, for example. They tell us how the process safety systems are actually performing – how well they are meeting their objective of preventing the release of hazardous material or energy. Management can set goals for improvement, and the lagging indicators will be useful in determining where resources should be directed to most effectively meet those goals.

Leading indicators will usually measure activities which we carry out in order to manage process safety. We believe that process safety performance will improve if we do these activities well. Some potential leading indicators might include things like the percentage of required process hazard analyses (PHAs) completed within the required time frame, the percentage of safety related action items from all sources (PHAs, incident investigations, management of change reviews, etc.) completed within the specified completion time, the percentage of inspections and tests of safety critical instruments and equipment completed within the required time period, or the fraction of required mechanical integrity inspections and tests of process equipment completed within the scheduled time period.

The new CCPS publication offers a good basis for establishing process safety metrics for a company. You should review this document and consider adapting some of its suggested metrics for use in your organization. These measures have the potential for helping management understand where the company stands in process safety management, to establish future goals, and to measure progress toward those goals.

SAFETY & HEALTH DIVISION UPDATE

Bob Johnson, Chair

With this issue, the compiling of our Division’s newsletter is taking a step towards passing from one very capable and dedicated person to two other very capable and dedicated persons.

A. Sumner (Sam) West has been our Division’s newsletter editor for many years, and has done a fantastic job over those years of keeping us informed with timely and interesting Safety & Health News. Sam now holds the esteemed title of Editor Emeritus and will continue to help out as he is able. Please send Sam a note or email (3896 Sidney Road, Huntington Valley, PA 19006, aswest@worldnet.att.net) or give him a call (215-938-7181) to express your appreciation for his great work on behalf of the Division.

Our newsletter’s co-editors are now Dennis Hendershot and John Murphy, who have given Division activities excellent leadership in many other areas, as I’m sure you are aware. Dennis and John are our two most recent recipients of the Division’s Walter-Miller Award, our most prestigious award for outstanding contributions to the Safety and Health profession within chemical engineering. So it is our great privilege for them to carry forward our key means of communication within the Division.
As to the current state of the Safety & Health Division, we are one of the largest Divisions within AIChE, and now have 1,175 members in 36 countries. That’s really something to think about! You are a member of a safety engineering professional community that extends into nearly every state and province and across the globe. Hundreds of our Division members hold safety leadership positions within their companies, and many are in senior management positions. I’d like you to be thinking of ways we can use the depth and breadth of this community to make major strides together in the coming years in the process safety, industrial safety, health and hygiene fields, building on our common interest in chemical engineering. Take time to send me a note at rjohnson@unwin-co.com, and I will compile and report your ideas at our Division’s Executive Committee meeting in New Orleans.

Our Division’s major activities for this year, as in previous years, are the superb opportunities for sharing technical advances and lessons learned, networking and camaraderie with fellow safety professionals at the Global Congress on Process Safety in New Orleans and at the Ammonia Conference in San Antonio.

And, incidentally, our Division is in very good shape financially. The conferences and annual Division dinner pretty much pay for themselves. Our dues support our Division’s peer-reviewed publication, Process Safety Progress, which is available in both print and electronic versions so you can make use of its content and pass your hardcopy around as well. We will be looking this year at ways to encourage students to join the Safety & Health Division as well as AIChE.

Many thanks go to our outgoing Division Chair, Dr. Ronald J. Willey of Northeastern University. Ron has put a lot of time into our previous year’s highly successful activities, and will continue to be on the Executive Committee as Past Chair. And congratulations to our newly elected Directors Brian Dunbobbin of Air Products and Brian Kelly of Bririsk Consulting, and to Pete Lodal of Eastman Chemical for his election to Second Vice Chair. I know our Division will greatly benefit by having these enthusiastic and highly competent gentlemen leading us forward in the years ahead.

And finally, if you have read this far, allow me to introduce myself as your Division Chair for the year 2008. I consider myself first a chemical engineer, and also a process safety consultant, author and teacher. After earning my BS and MS in chemical engineering from Purdue, I took a job at a Hercules plant that made solid rocket propellant motors. It was a great place to learn the technical and analytical aspects of safety. I then worked in large organizations (Du Pont and Battelle) before going to the other extreme and joining a three-person consultancy in Columbus, where I am now President. Our company now has over 100 employees after winning a major U.S. Department of Energy contract for providing safety and security support to the Office of Independent Oversight. I’ve had the privilege of being primary author of three CCPS books, and teach AIChE Continuing Education courses on HAZOP Studies and chemical reactivity. I’m also on the CCPS SACHE committee and teach loss prevention topics to senior chemical engineering students at the University of Cincinnati. My wife Sharon and I have five children and one grandson.

I hope you can join us in New Orleans this April for our annual S&H Division Dinner on Monday night on the Creole Queen. You are also welcome to sit in on your Division’s Executive Committee meeting on Tuesday night. I look forward to a great year together with you, as our Institute celebrates its 100th Anniversary with special events throughout the year.

Bob Johnson
IN MEMORIUM

T. A. Ventrone (1925–2007)

Theodore A. Ventrone died on February 5, 2008 in Plainfield, NJ at the age of 92. Ted graduated with a bachelor’s degree in chemical engineering from the University of Rhode Island in 1937. He was a pioneer in loss prevention and process safety, one of the key people in the early organization of the Loss Prevention Symposium, and was involved in the founding of the Safety and Health Division of AIChE. Ted was first employed at Factory Insurance Association (FIA) as a field inspector for process plants. During World War II, he served in the European Theater in the Army’s Engineer Combat Battalion, was discharged as a major, and received the Bronze Star. Following the war, Ted returned to FIA until becoming loss prevention manager for American Cyanamid’s Calco Division in Bound Brook in 1953. He continued in that position for 26 years, retiring in 1980. Ted was the founding editor of Plant/Operations Progress, later Process Safety Progress, and held that position for 22 years. Ted was an AIChE Fellow, and received the Walton/Miller Award in 1992 for his contributions to chemical process safety. Ted Ventrone was always particularly pleased by the annual presentation of the Ted Ventrone Award for Application of the Principles of Inherent Safety in the annual AIChE student design competition, presented in his honor each year by the Safety and Health Division to recognize process safety achievement in the next generation of chemical engineers.

Ted Ventrone was one of the early leaders in process safety and loss prevention, and will be missed by his many colleagues and friends in the field.

SAFETY AND HEALTH DIVISION 2008 ELECTION RESULTS

The results of the ballot for this year’s slate of officers are as follows:

Chair: Robert Johnson (by succession)
First Vice Chair: Katherine Pearson (by succession)
Second Vice Chair: Peter Lodal
Treasurer: Albert Ness
Directors – 2008 to 2010: Brian Dunbobbin
Brian Kelly

Congratulations to all, and thank you for your efforts on behalf of the Division.

If you are interested in participating in Safety and Health Division activities as an officer, Past Chair Ron Willey will be responsible for submitting a slate of candidates for the 2009 election. Please contact Ron (see contact information in the list of Division officers in this newsletter) by September 2008, so he has plenty of time to get the information necessary to prepare the ballot. As usual, we will be electing two Directors for a three year term (2009 to 2011), a Treasurer, and a Second Vice Chair. The current Second Vice Chair will move up to First Vice Chair, and the First Vice Chair will become the Division Chair for 2009.
ARTICLES AND PAPERS OF INTEREST


The AWARD (Advanced Warning and Runaway Disposal) Project addressed the needs to detect runaway initiation in advance so that appropriate countermeasures can be taken and to design emergency relief systems. The missing step in design of runaway reactor relief systems was the availability of reliable methods for predicting level swell in the reactor during venting and hence the quality of liquid requiring to be dealt with by a disposal system (quench tank, catch tank, etc.). The primary objective of the DISPOSAL part of AWARD was “To produce a methodology for the design of disposal systems to protect the workers and the environment from the effects of pressure relief of runaway chemical reactions. The methodology needs to be capable of producing a disposal system, which is adequate but not significantly oversized.”


Many industrial incidents are caused by thermal runaway reactions. Therefore, a good understanding of runaway reactions is necessary to predict and control reactive hazards. A detailed kinetic modeling approach is proposed to simulate runaway reactions under industrial conditions. This paper addresses the first step of this approach—mechanism generation. Computational chemistry was employed to estimate thermodynamic properties of reactants, intermediates, and products, and the Evans-Polanyi linear free energy relationship was used to estimate activation barriers of elementary reactions. To illustrate this mechanism generation approach, hydroxylamine is used as an example. The distribution of the predicted final products agrees with experimental results.


Runaway reactions continue to be a problem in the chemical industry. A recent study showed that 26.5% of major chemical plant accident is due to runaways. Runaways are caused by (a) mischarges of the reactants, catalysts, or contaminants or (b) loss of temperature control. Our studies cover the concept of shortstopping the runaway reactions to prevent accident scenarios. Experiments were conducted with CFD (Fluent) models. Shortstopping runaway reactions can be carried out by (a) adding an inhibitor to neutralize the reaction and/or (b) adding a cold diluent to lower the rate of reaction. In this present work we study the characteristics of runaway reactions and inhibition techniques with a full 3-D CFD simulation to explore nonsymmetric addition points for inhibition. Our 3-D simulations are performed using the multiple reference frame method, and reactions are enabled using user-defined functions in Fluent. These CFD results show the distribution of hotspots that characterizes the shortstopping performance. They also clearly demonstrate the value of using CFD simulations in situations that are experimentally prohibitive.
There are tens of thousands of industrial manufacturing facilities operating throughout the world. Each chemical plant, petroleum refinery, pharmaceutical plant, and other manufacturing facility has equipment and piping systems that operate under pressure. In the event of excessive overpressure, equipment or piping failures could result in economic loss to business, environmental contamination, and health and safety risks. To reduce such risks, equipment and piping systems that operate under pressure must be protected from excessive overpressure. This is accomplished with the installation of pressure-relief devices which must be properly sized and specified for the intended service conditions. More specifically, overpressure protection is provided by pressure-relief devices that are sized, selected, specified and installed for the postulated governing overpressure contingency. To adequately size a pressure-relief device to provide overpressure protection for equipment and piping, several relief event scenarios always should be considered. In the U.S.A., federal and state regulations require operating industrial facilities to have risk management programs in place that include the design basis for safety-relief systems installed to protect pressurized equipment from overpressure. For new installations, the pressure-relief system philosophy should be established during the project design phase. However, for process facilities that have been in operation for many years, the original design basis and calculations for safety-relief devices often are no longer available. For existing pressure-relief, fitness-for-service assessments should include verification of the relief device size and specification, and review and substantiation of require documentation. This paper presents results from a study intended to examine which overpressure relief contingency, if any, most often governs the size of relief devices that are used to protect equipment and piping systems. The required elements of a pressure-relieving system sizing documentation program are described. The author emphasizes seven relief contingencies to be considered when sizing pressure-relief devices. Some restrictions and limitations of the codes and standards that are applied for design guidance of pressure-relief systems are challenged. For this study, relief device sizing data are compiled from a number of chemical and petrochemical project applications to provide a reasonable sample of contingencies that governed the sizes of existing and new safety-relief valves and rupture disks. The study results show that a significant number of pressure-relief devices presently installed in the U.S.A. likely are undersized. This further suggests, that, worldwide, an alarming number of pressure-relief devices may be undersized.

Various kinetic models for thermally initiated polymerization of styrene are compared concerning their description of isothermal batch polymerization as well as their prediction for runaway reactions. All models show good agreement for conversion in both isothermal and adiabatic situations, whereas predictions for molecular weight differ considerably. Pressure predictions according to Flory-Huggins and perturbed-chain statistical associating fluid theory equation of state (PC-SAFT EOS) also show good agreement considering a system from styrene/polystyrene only. For heterogeneous systems, such as suspension polymerization of styrene, various hazardous situations, like failure of the cooling system or cooling system and stirrer are assumed. The pressure predictions for runaway reactions mainly depend on the assumptions for the phase behavior. Realistic predictions, which take into account the solubility of water in styrene/polystyrene, are only possible with PC-SAFT EOS.

As part of safety concept, reactors and other high pressure containments have to be protected against excessive pressure by pressure relief devices such as burst disks or relief valves. Most design criteria and simulation tools have been developed for one and two-phase systems. Hence, to design foaming and non-foaming three-phase systems experimental investigations on the unsteady level swell and their discharge flow are still necessary. In order to gain a deeper knowledge under upset conditions, systematic studies were performed using a modified Adiabatic Pressure Dewar Calorimeter (ADC11). This project will finally lead to design criteria for an emergency relief system of reactive multiphase mixtures under various boundary conditions. In this experimental set-up, pressure and temperature profiles, as well as the total vented solid/liquid mass were measured. Non-stirred foaming systems consisting of two different surfactants with various concentrations in water and different solids were studied. Here, the filling level, solid mass fraction, initial discharge pressure, and vent size were kept constant. For each experiment the level swell was observed during the pressure relief through a camera. Moreover, stirred foaming three-phase systems were investigated.


The exothermic decomposition of cumene hydroperoxide (CHP) in cumene was characterized by isothermal microcalorimetry, using the thermal activity monitor (TAM). Unlike the exothermic behavior previously determined from an adiabatic calorimeter, such as the vent sizing package 2 (VSP2), or differential scanning calorimetry (DSC), a TAM thermal curve revealed that CHP undergoes an autocatalytic thermal decomposition detectable between 75 and 90°C. Previous studies have shown that the CHP in the temperature range higher than 100°C conformed to an n-th order reaction rate model. CHP heat of decomposition and autocatalytic kinetics behaviors were measured and compared with previous literature, and the methodology and the advantages of using the TAM to obtain an autocatalytic model by curve fitting are discussed here. With various autocatalytic models, such as the Prout-Tomokins and the Avrami-Erofeev rate law, the best curves fit among models were also investigated and proposed.


Thermal runaway reactions associated with exothermic behaviors of tert-butyl hydroperoxide (TBHP) solutions reacting with alkaline contaminants were studied. A differential scanning calorimetry (DSC) was used to characterize these inherent behaviors of TBHP solutions with KOH, NaOH, LiOH, and NH4OH. By thermal analysis, we compared various heats of decomposition of TBHP solutions with alkaline impurities, and determined the incompatible hazards of various TBHP solutions with alkaline contaminants.

Tert-butyl peroxybenzoate (TBPB) is one of the sensitive and hazardous chemicals which have been popularly employed in petrifaction industries in the past. This study attempted to elucidate its unsafe characteristics and thermally sensitive structure so as to help prevent runaway reactions, fires or explosions in the process environment. We employed differential scanning calorimetry (DSC) to assess the kinetic parameters, such as exothermic onset temperature (To), heat of reaction (ΔH), frequency factor (A), and the other safety parameters using four different scanning rates (1, 2, 4, and 10°C min-1) combined with a curve-fitting method. The results indicated that TBPB becomes very dangerous during decomposition reactions; the onset temperature and reaction heat were about 100°C and 1,300 Jg-1, respectively. Through this study, TBPB accidents could be reduced to an accepted level with safety parameters under control. According to the findings in this study and the concept of inherent safety, TBPB runaway reactions could be thoroughly prevented in the relevant plants.


In Asia, due to its unstably reactive nature, dicumyl peroxide (DCPO) has caused many thermal explosions and runaway reaction incidents in the manufacturing process. To analyze runaway behaviors of DCPO in the batch reactor, we studied thermokinetic parameters, such as heat of reaction (ΔHd), exothermic onset temperature (To), maximum temperature rise (dT/dt)max, maximum pressure rise (dP/dt), and self-heating rate, etc, via differential scanning calorimetry (DSC) and vent sizing package 2 (VSP2). The thermokinetic parameters were exploited to calculate and predict the self-accelerating decomposition temperature (SADT), temperature of no return (TNR), and time to maximum rate (TMR) by thermal safety software (TSS) series. The important values, such as SADT, TNR, TMR, are necessary and useful to predict hazardous conditions in the early assessment of a chemical process using DCPO.

NEW ORLEANS PROGRAMMING

The Center for Chemical Process Safety (CCPS), the Loss Prevention Symposium (LPS), and the Process Plant Safety Symposium (PPSS) are coordinating conferences again in 2008 to present the 4th Global Congress on Process Safety. This annual event is the primary forum for practitioners from the chemical and allied industries, academia, and government to share practical and technological advances in all aspects of process safety. The complete program for the Global Congress is summarized in the following pages. Also, you will find information about programming sponsored by the ACS Division of Chemical Health and Safety at the ACS Meeting, which will also be held in New Orleans at the same time as the AIChE meeting. ACS DCHAS and the AIChE Safety and Health Division are co-sponsoring several of the program sessions.
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**Session Co-Chairs:** Daniel Crowl & Walt Frank | **Session Co-Chairs:** Kathy Pearson & Steven Emerson | **Session Chair:** Jim Mucolo |

- The AIChE Chem-E-Car Safety Program, Ronald Willey
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**Session Co-Chairs:** John E. Going & Henry L. Febo | **Session Co-Chairs:** James Thompson & Douglas Ferguson | **Session Chair:** Tom Dileo |

- Experimental Study of Effective Water Spray Curtain Application in Controlling LNG Vapor Clouds, Monshed Rana
- The Victaulic “Vortex” Multiple Agent Fire Extinguishing System, Bill Reilly
- Effects of System and Agent Properties on Room Pressurization, John Schaefer
- Improving Process Safety by Addressing the Human Element, John Haesle
- Evaluating Operational Discipline in PSM Audits, James Klein
- A Site-Based Workshop for Improving Operational Discipline, James Klein

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<th>Session #122: Conduct of Operations for Process Safety</th>
<th>Session #124: Layers of Protection Analysis (LOPA)</th>
<th>Session #147: Inherent Risk</th>
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<td><strong>Location:</strong> Morial Convention Center, Room 352</td>
<td><strong>Location:</strong> Morial Convention Center, Rooms 353-355</td>
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**Session Co-Chairs:** John E. Going & Henry L. Febo | **Session Co-Chairs:** James Thompson & Douglas Ferguson | **Session Chair:** Steve Mezaros |

- Simulation of explosion suppression systems and extinguishing barriers using the CFD code DESC, Trygve Skjeld
- Automatic Fire & Explosion Detection and Suppression for Special Hazards, Estee Jacobson
- Advances in Explosion Suppression Product Safety, Reliability, and Performance, Emre Ergun
- Improvements in the Safety Screening of Resin Manufacturing Processes, George Kalfas
- Application of an Emergency Egress Risk Index System and Evaluation of Protection Layers in the Determination of Life Safety Requirements for Open Structure Industrial Occupancies, Kelly Mansfield, Tom Rodante

**LUNCH WITH SPEAKER - Mark Dreux**
DIVISION OF CHEMICAL HEALTH & SAFETY

Monday, April 7, 2008

EVENING

8:00 PM-10:00 PM
Sci-Mix
Morial Convention Center -- Hall A

Tuesday, April 8, 2008

MORNING

9:00 AM-12:00 PM
Laboratory Safety Incidents and Near Misses: Case Studies and Lessons Learned
ACS Division of Chemical Health & Safety and AIChE Loss Prevention Symposium (Area 11a), Division of Professional Relations, and ACS and AIChE Cosponsored Programming‡
Morial Convention Center -- Rm. 336

AFTERNOON

1:30 PM-4:00 PM
Laboratory Safety Incidents and Near Misses: Case Studies and Lessons Learned
ACS Division of Chemical Health & Safety and AIChE Loss Prevention Symposium (Area 11a), Division of Professional Relations, and ACS and AIChE Cosponsored Programming‡
Morial Convention Center -- Rm. 336

Wednesday, April 9, 2008

MORNING

9:00 AM-12:30 PM
Risk Assessment and Assessment of Toxicology Using Control Banding
Morial Convention Center -- Rm. 336

The 235th ACS National Meeting, New Orleans, LA, April 6-10, 2008