WWW.CHEMICALPROCESSING.COM

CHEMICAL PROCESSING

LEADERSHIP | EXPERTISE | INNOVATION

Special Report

Safety is no Accident

Start ▶

SPONSORED BY

METTLER TOLEDO

PutmanMedia®

TABLE OF CONTENTS

Achieve Effective Process Safety Management

"Felt leadership" plays a crucial role in ensuring success

By Brian Rains, DuPont Sustainable Solutions

AFTER FATAL industrial incidents in Seveso, Italy; Bhopal, India; and Texas City, Texas, chemical makers resolved to improve process safety management (PSM) to prevent similar events from happening. And yet this year, we witnessed an explosion and fire at a fertilizer storage facility in Texas, even though the company had safety regulations in place. That disaster underscores that PSM systems only function effectively if they're adequate and implemented rigorously. Ensuring this happens isn't just the job of the SHE (safety, health and environment) manager but also depends on the company leadership. These executives' commitment to safety should be obvious to every employee — and it's what makes the difference between a firm that pays lip service to process safety and one that achieves process safety excellence.

The Baker Panel report into the disaster at BP's Texas City refinery highlights this point (see: "Panel Blasts BP's Safety Practices," www.ChemicalProcessing.com/industrynews/2007/panel-blasts-bp-s-safety-practices/). Five of the panel's ten recommendations directly address leadership requirements. One of the panel members, Paul V. Tebo, former DuPont vice president of SHE, went so far as to state that the fundamental, underlying issue at BP Texas City was "leadership, leadership, leadership."

Chemical makers rely on PSM to reduce risks with the goal of eliminating any significant process incidents. Managing these risks is one of the key responsibilities and challenges every company in the chemical industry must accept. Effective PSM ultimately is the responsibility of senior executives because that's where the buck stops. Success in PSM directly relates to the quality of decision-making by and within the organization. Leadership is all about influencing and improving the quality of this decision-making. The approach leaders follow to ensure highest-quality decision-making by the organization in managing existing operational risks is what we at DuPont call "felt leadership." It's a necessary ingredient in successful PSM implementation and execution.

WHAT IS FELT LEADERSHIP?

The term frequently is mentioned at PSM conferences and in informal conversations as a quality that management must demonstrate if PSM implementation is to succeed. It's been used to describe a style of leadership that's also necessary in complex chemical processes and operations. Felt leadership can be sensed or experienced rather than just heard or seen. It suggests leadership with passion, authenticity and even humility.

Interestingly, DuPont coined the term more than 20 years ago. Then, its context was very different. In fact, at the time felt leadership wasn't used directly for safety at all.

Back in 1990, a group of plant managers (including me) had been formed into a body called the "Plant Managers Board." We had a specific task: to identify best practices related to "high performing work systems," or HPWS for short. At the time, HPWS were described as "high involvement systems of accomplishing work in which all employees have developed the capability to connect

with and drive the quality of business results to be world class."

The board consisted of approximately ten plant managers from all regions of the world. Some didn't have much experience and others were seasoned veterans. Some managed very large plants while others ran small ones. Some were engineers and others had diverse educational backgrounds. We came together face-to-face at least quarterly for about two years. And we almost always visited different operating sites to observe and analyze. Sometimes the facilities were DuPont's. At other times, we visited external facilities such as the Honda car assembly plant in Marysville, Ohio.

After a visit to a DuPont facility in rural Illinois in 1991, our group met in a conference room and attempted to synthesize our collective observations into something usable and concise — something we could package and leverage across DuPont operations. We filled sheet after sheet of paper until we literally covered the four walls of the room. We had seen and observed so much that there were almost too much data.

Then, one of our members, who later rose to become senior vice president of operations at DuPont, took the floor and articulated in simple terms what came to be known as the "six attributes of HPWS." The first was "vision, mission and strategic intent known by all." The second was "committed and dedicated leadership 'felt' within the organization," or simply "felt leadership."

To clarify the meaning of felt leadership, we set out to define what it should include. Our board wanted leaders who could create vision and energy, stretch goals and invite positive pushback. We wanted leaders who were results- and output-oriented and could make every employee in the organization feel a sense of purpose.

We then went on to develop a self-assessment tool that senior managers could use to help ensure they would act in a way that would make them visible and their leadership felt by the entire organization. We asked them to reflect on the following questions:

- Do we, as leaders, have a clear vision for change based on the needs of all stakeholders?
- Are we visible, knowledgeable and open with people?
- Do we value upgrades from anywhere?
- Do we continually set objectives that require people to develop and grow the skills needed to move toward the vision?
- Do we engage people in a process that builds accountability, willingness and confidence to act in an empowered way?

PUTTING FELT LEADERSHIP INTO PRACTICE

As helpful and appropriate as these tools were, and continue to be, the subject of PSM leadership must be brought down to an individual, and even personal, level. Many companies strive for felt leadership but don't know how to implement it, particularly with regard to PSM.

Besides ensuring their visibility to the organization, leaders relentlessly must make time to spend with employees and contractors. Only then will people in the company do the same. Managers wanting to demonstrate felt leadership must recognize they have a teacher/trainer role. That entails developing their own safety skills and passing them along. This takes time and resources for leaders and their subordinates so both can

improve their safety skills. It's a prerequisite for improving PSM. Managers should practice what they preach. In other words, if they notice an unsafe situation, they should do something about it. This implies maintaining a good self-safety focus and ongoing self-assessment.

Effective PSM requires constant affirmation that safety is the highest priority. Managers who demonstrate a keen interest in safety can help enormously. Walking through a work area, they should comment on safety, identify and reinforce what's being done well and correct what's unsafe. At times, this will necessitate learning about the safety issues that exist on the shop floor and how they can be handled — but the effort will pay off. If a CEO takes the time to walk across the shop floor and points out to an employee a hazard that might injure the person, it sends a powerful message about the value the company places on safety.

At every level, managers should engage in conversation with employees to check whether they understand and apply the core safety principles of their tasks. That also underlines the clear focus leaders have on SHE expectations. It should be understood from the start that the expectation is zero incidents and progress towards that goal should be discussed and publicized regularly. Periodically, it helps to pay particular attention to one area that needs safety improvement. Last but not least, leaders should recognize and reward safety success.

This ideal of a manager demonstrating felt leadership contains many seemingly obvious elements — but how many leaders take the time to put them into practice or understand how to do so? How many of them know what questions to ask operations personnel, the line manager and others? We have worked with many companies in the chemical industry that struggle to visualize or project such leadership effectively into their environment or culture. They don't know how to be supportive and don't ask probing questions needed to strengthen a culture of PSM excellence.

In workshops with these companies, we've suggested a variety of different scenarios. Take a plant visit, for example. Managers can review a broad range of PSM elements on their tour. They can ask operations personnel about:

- any incidents that have occurred in other similar operations;
- the frequency and nature of emergency and disaster mock drills;
- the number and nature of recent near-misses and the follow-up from investigations into these and any other incidents that have occurred in the plant;
- the results of recent PSM audits and what weaknesses were identified; and
- whether any tests or process changes are active in the plant.

Another suggestion is to discuss the procedure governing the activity underway and ask how well it's written and followed. Managers also can ask about work permits. Posing questions shows some interest in PSM but isn't enough. Leaders must actively listen to answers and accept suggestions, take the time to review any work permits or procedures they are shown, and attentively evaluate the quality of the risk assessment and precautions taken to mitigate identified risks.

CONSIDER A PSM CHECKLIST

Internally at DuPont, we use felt leadership cards to help operations managers assess how best to

demonstrate their commitment to PSM. These cards cover our PSM checklist:

- What is my spoken and unspoken message to the organization on PSM expectations — i.e., they're integral to core values and business success or a "necessary evil?"
- What have I done this month to review PSM metrics and performance indicators for the site?
- What am I doing to reinforce operational discipline?
- Is my organization providing adequate rewards and recognition for PSM accomplishments?
- How is my organization performing versus annual PSM performance rating metrics and objectives?
- Where must we enhance short- and long-term PSM resources and organizational capabilities?
- What's the status of PSM integration improvements at recently acquired sites or businesses?
- What are my direct subordinates doing to reinforce the value, expectations and accountabilities for PSM on an ongoing and consistent basis?
- Are we providing enough support and resources to maintain site equipment and infrastructure?
- What have I done to engage new leaders in my organization who play key PSM roles to ensure personnel involved in management-of-change activities are effective?
- Have I established clear measures on overall PSM program performance (i.e., not just a focus on incidents)?

On a practical level, these guidelines translate into day-to-day actions. Leaders who genuinely want to improve PSM through felt leadership must live by example — and look, ask, listen and adapt. That includes:

- ensuring workers have the correct tools and personal protective equipment (and that all equipment is in good condition);
- encouraging reports on unsafe conditions;
- welcoming and acting on suggestions;
- rapidly responding to workers' safety concerns;
- investigating incidents promptly and fully;
- stopping work if necessary to correct unsafe practices;
- prohibiting risky shortcuts to get a job completed;
- removing unsafe employees from their task; and
- promoting discussions about safety

Unfortunately, at many companies shop floor employees could have predicted — but were too intimidated to mention beforehand — incidents that occurred. An environment in which employees feel they can't speak up or contradict managers on safety strategy is a disaster waiting to happen.

MAKE YOUR EFFORTS FELT

The successful implementation of robust PSM systems in complex chemical operations requires a high degree of order and high-quality decision-making. Senior managers play a fundamental role in creating a culture where all members of the organization respond to PSM needs and perform related tasks at a very high level. They must exercise felt leadership if PSM is to succeed. ●

BRIAN RAINS is global practice leader for process safety management at DuPont Sustainable Solutions, Wilmington, DE. E-mail him at brian.d.rains@dupont.com.

Get To The Root Of Accidents

Systems thinking can provide insights on underlying issues not just their symptoms

By Nancy Leveson, Massachusetts Institute of Technology, and Sidney Dekker, Griffith University

AN OFTEN-CLAIMED "fact" is that operators or maintenance workers cause 70–90% of accidents. It is certainly true that operators *are blamed* for 70–90%. Are we limiting what we learn from accident investigations by limiting the scope of the inquiry? By applying systems thinking to process safety, we may enhance what we learn from accidents and incidents and, in the long run, prevent more of them.

Systems thinking is an approach to problem solving that suggests the behavior of a system's components only can be understood by examining the context in which that behavior occurs. Viewing operator behavior in isolation from the surrounding system prevents full understanding of why an accident occurred — and thus the opportunity to learn from it.

We do not want to depend upon simply learning from the past to improve safety. Yet learning as much as possible from adverse events is an important tool in the safety engineering tool kit. Unfortunately, too narrow a perspective in accident and incident investigation often destroys the opportunity to improve and learn. At times, some causes are identified but not recorded because of filtering and subjectivity in accident reports, frequently for reasons involving organizational politics. In other cases, the fault lies in our approach to pinpointing causes, including root cause seduction and oversimplification, focusing on blame, and hindsight bias.

ROOT CAUSE SEDUCTION AND OVERSIMPLIFICATION

Assuming that accidents have a root cause gives us an illusion of control. Usually the investigation focuses on operator error or technical failures, while ignoring flawed management decision-making, safety culture problems, regulatory deficiencies, and so on. In most major accidents, all these factors contribute; so to prevent accidents in the future requires all to be identified and addressed. Management and systemic causal factors, for example, pressures to increase productivity, are perhaps the most important to fix in terms of preventing future accidents — but these are also the most likely to be left out of accident reports.

As a result, many companies find themselves playing a sophisticated "whack-a-mole" game: They fix symptoms without fixing the process that led to those symptoms. For example, an accident report might identify a bad valve design as the cause, and, so, might suggest replacing that valve and perhaps all the others with a similar design. However, there is no investigation of what flaws in the engineering or acquisition process led to the bad design getting through the design and review processes. Without fixing the process flaws, it is simply a matter of time before those process flaws lead to another incident. Because the symptoms differ and the accident investigation never went beyond the obvious symptoms of the deeper problems, no real improvement is made. The plant then finds itself in continual fire-fighting mode.

A similar argument can be made for the common label of "operator error." Traditionally operator error is viewed as the primary cause of accidents. The obvious solution then is to do something about the operator(s) involved: admonish, fire or retrain them. Alternatively, something may be done about operators in general, per-

haps by rigidifying their work (in ways that are bound to be impractical and thus not followed) or marginalizing them further from the process they are controlling by putting in more automation. This approach usually does not have long-lasting results and often just changes the errors made rather than eliminating or reducing errors in general.

Systems thinking considers human error to be a symptom, not a cause. All human behavior is affected by the context in which it occurs. To understand and do something about such error, we must look at the system in which people work, for example, the design of the equipment, the usefulness of procedures, and the existence of goal conflicts and production pressures. In fact, one could claim that human error is a symptom of a system that needs to be redesigned. However, instead of changing the system, we try to change the people — an approach doomed to failure.

For example, accidents often have precursors that are not adequately reported in the official error-reporting system. After the loss, the investigation report recommends that operators get additional training in using the reporting system and that the need to always report problems be emphasized. Nobody looks at why the operators did not use the system. Often, it is because the system is difficult to use, the reports go into a black hole and seemingly are ignored (or at least the person writing the report gets no feedback it even has been read, let alone acted upon), and the fastest and easiest way to handle a detected potential problem is to try to deal with it directly or to ignore it, assuming it was a one-time occurrence. Without fixing the error-reporting system itself, not much headway is made by retraining the operators in how to use it, particularly where they know how to use it but ignored it for other reasons.

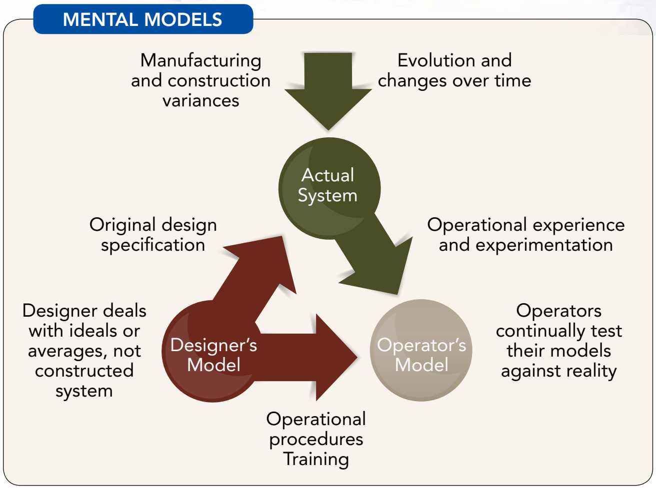


Figure 1. Designers and operators necessarily view systems differently.

Another common human error cited in investigation reports is that the operators did not follow the written procedures. Operators often do not follow procedures for very good reasons. An effective type of industrial action for operators who are not allowed to strike, like air traffic controllers in the U.S., is to follow the procedures to the letter. This type of job action can bring the system down to its knees.

Figure 1 shows the relationship between the mental models of the designers and those of the operators. Designers deal with ideals or averages, not with the actual constructed system. The system may differ from the designer's original specification either through manufacturing and construction variances or through evolution and changes over time. The designer also provides the original operational procedures as well as information for basic operator training based on the original design specification. These procedures may be incomplete, e.g., missing some remote but possible conditions or assuming that certain conditions cannot occur. For example, the procedures and simulator training for the operators at Three Mile Island nuclear power plant omitted the conditions that actually occurred in the well-known incident

because the designers assumed that those conditions were impossible.

In contrast, operators must deal with the actual constructed system and the conditions that occur, whether anticipated or not. They use operational experience and experimentation to continually test their mental models of the system against reality and to adjust the procedures as they deem appropriate. They also must cope with production and other pressures such as the desire for efficiency and "lean operations." These concerns may not have been accounted for in the original design.

Procedures, of course, periodically are updated to reflect changing conditions or knowledge. But between updates operators must balance between:

1. Adapting procedures in the face of unanticipated conditions, which may lead to unsafe outcomes if the operators do not have complete knowledge of the existing conditions in the plant or lack knowledge (as at Three Mile Island) of the implications of the plant design. If, in hindsight, they are wrong, operators will be blamed for not following the procedures.
2. Sticking to procedures rigidly when feedback suggests they should be adapted, which may lead to incidents when the procedures are wrong for the particular existing conditions. If, in hindsight, the procedures turn out to be wrong, the operators will be blamed for rigidly following them.

In general, procedures cannot assure safety. No procedures are perfect for all conditions, including unanticipated ones. Safety comes from operators being skillful in judging when and how they apply. Safety does not come from organizations forcing operators to follow procedures but instead from organizations monitoring and understanding the gap between procedures and practice. Examining the reasons why operators may not be following procedures can lead to better procedures and safer systems.

Designers also must provide the feedback necessary for the operators to correctly update their mental models. At BP's Texas City refinery, there were no sensors above the maximum allowed height of the hydrocarbons in the distillation tower. The operators were blamed for not responding in time although they had no way of knowing what was occurring in the tower due to inadequate engineering design.

FOCUSING ON BLAME

Blame is the enemy of safety. "Operator error" is a useless finding in an accident report because it does not provide any information about why that error occurred, which is necessary to avoid a repetition. There are three levels of analysis for an incident or accident:

- What — the events that occurred, for example, a valve failure or an explosion;
- Who and how — the conditions that spurred the events, for example, bad valve design or an operator not noticing something was out of normal bounds; and
- Why — the systemic factors that led to the who and how, for example, production pressures, cost concerns, flaws in the design process, flaws in the reporting process, and so on.

Most accident investigations focus on finding someone or something to blame. The result is a lot of non-learning and a lot of finger pointing because nobody wants to be the focus of the blame process. Usually the person at the lowest rung of the organizational structure (the operator) ends up shouldering the blame. The factors that

explain why the operators acted the way they did never are addressed.

The biggest problem with blame, besides deflecting attention from the most important factors in an accident, is that it creates a culture where people are afraid to report mistakes, hampering accident investigators' ability to get the true story about what happened. One of the reasons commercial aviation is so safe is that blame-free reporting systems have been established that find potential problems before a loss occurs. A safety culture that focuses on blame will never be very effective in preventing accidents.

REFERENCES

1. Leveson, N. G., "Engineering a Safer World: Systems Thinking Applied to Safety," MIT Press, Cambridge, Mass. (2012).
2. Leveson, N. G., "Applying Systems Thinking to Analyze and Learn from Accidents," *Safety Science*, **49** (1), pp. 55–64 (2011).
3. Dekker, S. W. A., "The Field Guide to Understanding Human Error," Ashgate Publishing, Aldershot, U.K. (2006).
4. Dekker, S. W. A., "Just Culture: Balancing Safety and Accountability," 2nd ed., Ashgate Publishing, Farnham, U.K. (2012).

HINDSIGHT BIAS

Hindsight bias permeates almost all accident reports. After an accident, it is easy to see where people went wrong and what they should have done or avoided or to judge them for missing a piece of information that turned out (after the fact) to be critical. It is almost impossible for us to go back and understand how the world appeared to someone who did not already have knowledge of the outcome of the actions or inaction. Hindsight is always twenty-twenty.

For example, in an accident report about a tank overflow of a toxic chemical, the investigators concluded "the available evidence *should have* been sufficient to give the board operator a clear indication that the tank was indeed filling and required immediate attention." One way to evaluate such statements is to examine exactly what information the operator actually had. In this case, the operator had issued a command to close the control valve, the associated feedback on the control board indicated the control valve was closed, and the flow meter showed no flow. In addition, the high-level alarm was off. This alarm had been out of order for several months but the operators involved did not know this and the maintenance department had not fixed it. The alarm that would have detected the presence of the toxic chemical in the air also had not sounded. All the evidence the operators actually had at the time indicated conditions were normal. When questioned about this, the investigators said that the operator "could have trended the data on the console and detected the problem." However, that would have required calling up a special tool. The operator had no reason to do that, especially as he was very busy at the time dealing with and distracted by a potentially dangerous alarm in another part of the plant. Only in hindsight, when the overflow was known, was it reasonable for the investigators to conclude that the operators should have suspected a problem. At the time, the operators acted appropriately.

In the same report, the operators are blamed for not taking prompt enough action when the toxic chemical alarm detected the chemical in

the air and finally sounded. The report concluded that "interviews with personnel did not produce a clear reason why the response to the … alarm took 31 minutes. The only explanation was that there was not a sense of urgency since, in their experience, previous … alarms were attributed to minor releases that did not require a unit evacuation." The surprise here is that the first sentence claims there was no clear reason while the very next sentence provides a very good one. Apparently, the investigators did not like that reason and discarded it. In fact, the alarm went off about once a month and, in the past, had never indicated a real emergency. Instead of issuing an immediate evacuation order (which, if done every month, probably would have resulted in at least a reprimand), the operators went to inspect the area to determine if this was yet another false alarm. Such behavior is normal and, if it had not been a real emergency that time, would have been praised by management.

Hindsight bias is difficult to overcome. However, it is possible to avoid it (and therefore learn more from events) with some conscious effort. The first step is to start the investigation of an incident with the assumption that nobody comes to work with the intention of doing a bad job and causing an accident. The person explaining what happened and why it happened needs to assume that the people involved were doing reasonable things (or at least what they thought was reasonable) given the complexities, dilemmas, tradeoffs and uncertainty surrounding the events. Simply highlighting their mistakes provides no useful information for preventing future accidents.

Hindsight bias can be detected easily in accident reports (and avoided) by looking for judgmental statements such as "they *should have* …," "if they *would only have* …", "they *could have* …" or similar. Note all the instances of these phrases in the examples above from the refinery accident report. Such statements do not explain *why* the people involved did what they did and, therefore, provide no useful information about causation. They only serve to judge people for what, in hindsight, appear to be mistakes but at the time may have been reasonable.

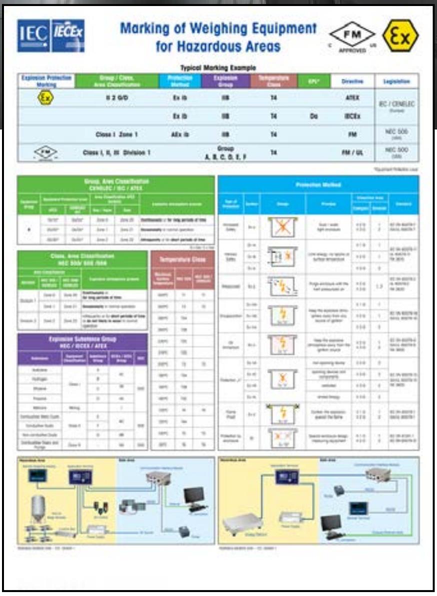
Only when we understand why people behaved the way they did will we start on the road to greatly improving process safety.

ESCAPING THE WHACK-A-MOLE TRAP

Systems are becoming more complex. This complexity is changing the nature of the accidents and losses we are experiencing. This complexity, possible because of the introduction of new technology such as computers, is pushing the limits that human minds and current engineering tools can handle. We are building systems whose behavior cannot be completely anticipated and guarded against by the designers or easily understood by the operators.

Systems thinking is a way to stretch our intellectual limits and make significant improvement in process safety. By simply blaming operators for accidents and not looking at the role played by the encompassing system in why those mistakes occurred, we cannot make significant progress in process safety and will continue playing a never-ending game of whack-a-mole. ●

NANCY LEVESON is professor of aeronautics and astronautics and professor of engineering systems at the Massachusetts Institute of Technology, Cambridge, Mass. **SIDNEY DEKKER** is professor of social science and director of the Safety Science Innovation Lab at Griffith University, Brisbane, Australia. E-mail them at leveson@mit.edu and s.dekker@griffith.edu.au.



Marking of Weighing Equipment for Hazardous Areas

Typical Marking Example

Explosion Protection Marking	Group / Class, Area Classification	Protection Method	Explosion Group	Temperature Class	EPL*	Directive	Legislation
Ex	II 2 G/D	Ex ib	IIB	T4		ATEX	IEC / CENELEC (Europe)
		Ex ib	IIB	T4	Db	IECEx	
	Class I Zone 1	AEx ib	IIB	T4		FM	NEC 505 (USA)
FM	Class I, II, III Division 1		Group A, B, C, D, E, F	T4		FM / UL	NEC 500 (USA)

*Equipment Protection Level

Intrinsically Safe Weighing

Get Your Free Poster Today

METTLER TOLEDO is offering a free simple and easy-to-read poster that provides a comprehensive introduction to hazardous-area classifications, types of protection, and how this information is reflected in the labeling of electrical equipment for hazardous areas.

To receive a free poster, please visit

▸ **www.mt.com/us-hazardous-poster**

METTLER TOLEDO

Understand Intrinsically Safe Weighing Systems

This ignition protection method helps ensure accuracy, safety and compliance in hazardous environments

By Michael Sutton, Product Manager, Hazardous Area Solutions

TWO PRIMARY considerations must be taken into account when choosing the right weighing equipment for hazardous areas: the right classification and the appropriate method of ignition protection. Among several ignition protection methods, the intrinsic safety and flameproof protection methods are similar to the design of weighing equipment for hazardous areas.

Intrinsic safety, however, is one of the safest protection methods. It also completely differs from any other recognized method of protection for certified hazardous areas.

This paper describes the principles of the intrinsic safety protection method, highlights its benefits and gives some examples of possible weighing configurations in hazardous areas. The paper also covers the principles of the flameproof protection methods and its areas of application.

HAZARDOUS AREAS AND THEIR CLASSIFICATIONS

An explosion is the sudden exothermic chemical reaction of a flammable material with oxygen and the simultaneous release of high energy. To eliminate the risk of explosion, one of the three elements of the "Triangle of Fire" (Figure 1) must be removed.

Flammable or explosive materials may be present in the form of gases, vapors, mists or dusts. Each material is present in the production area in the defined concentration and for a certain period of time.

Ignition sources are the sources related to an equipment. These can be hot surfaces, sparks, high energy or intense electromagnetic fields. Equipment suppliers reduce the risk of explosion by eliminating the ignition source and by keeping the system's active ignition energy at the lowest possible level: lower than the minimum ignition energy. The minimum ignition energy is the least amount of energy required to ignite a combustible vapor, gas or dust cloud. The minimum ignition energy is measured in joules.

For example, the explosive "hydrogen-air" mixture can ignite with very low energy input; its minimum ignition energy at atmospheric pressure is about 10–5 joules.

The minimum ignition energy of dusts is in the range of several milijoules up to 100 milijoules.

Businesses conducting collection, transformation and production processes with inflammable substances are obliged to conduct hazardous risk analysis to identify the potentially hazardous

TRIANGLE OF FIRE

Figure 1. Removing one of these three elements can help eliminate the risk of explosion.

HAZARDOUS AREA DEFINITIONS

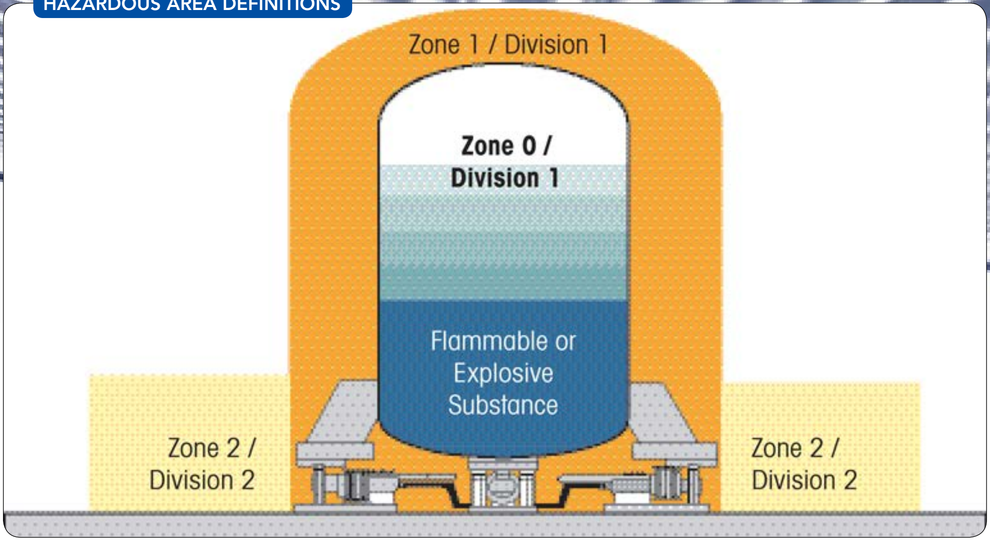


Figure 2. A weighing tank is shown with the distribution and classification of hazardous areas.

areas where dangerous concentrations of explosive mixtures of flammable or explosive materials can occur. Such areas are called “hazardous areas.”

When electrical equipment is used in a location classified as hazardous, it must be appropriately certified and provide the required level of protection. The selection of an appropriate protection method is based on the classification of the hazardous area. That is why it is important to understand area classifications and their differences. Figure 2 shows a weighing tank and the distribution and classification of hazardous areas.

Classification varies throughout the world, but generally, there are two types of classification. Europe has adopted the International Electro Technical Commission (IEC) philosophy referred to as “Zoning.”

Information and specifications for zone classification are defined in the norm IEC EN60079-10 and in national standards. Furthermore, the installation and operation of electrical systems in hazardous locations and the zone classification within the European Community are defined in the ATEX 94/9/EC Directive.

Table 1 shows an overview of the zones, divisions and the allocation of equipment for the relevant hazardous area classification.

HAZARDOUS AREA CLASSIFICATIONS

SUBSTANCE	HAZARDOUS AREA CHARACTERISTICS	HAZARDOUS AREA CLASSIFICATION			EQUIPMENT CATEGORY
		USA NEC500	USA NEC505 / NEC506	ATEX 94/9/EC	
Gases / Vapors	Explosive atmosphere is present continuously	Division 1	Class 1 (NEC505)	Zone 0	1G
	Explosive atmosphere is likely to occur occasionally			Zone 1	2G (1G)
	Explosive atmosphere is likely to occur infrequently or for short periods of time	Division 2		Zone 2	3G (1G and 2G)
Dusts	Explosive atmosphere is present continuously	Division 1	Class 2 (NEC506)	Zone 20	1D
	Explosive atmosphere is likely to occur occasionally			Zone 21	2D (1D)
	Explosive atmosphere is likely to occur infrequently or for short periods of time	Division 2		Zone 22	3D (1D and 2D)

Table 1. An overview of the zones, divisions and allocation of equipment for the relevant hazardous area classification according to Europe and U.S. standards is shown here.

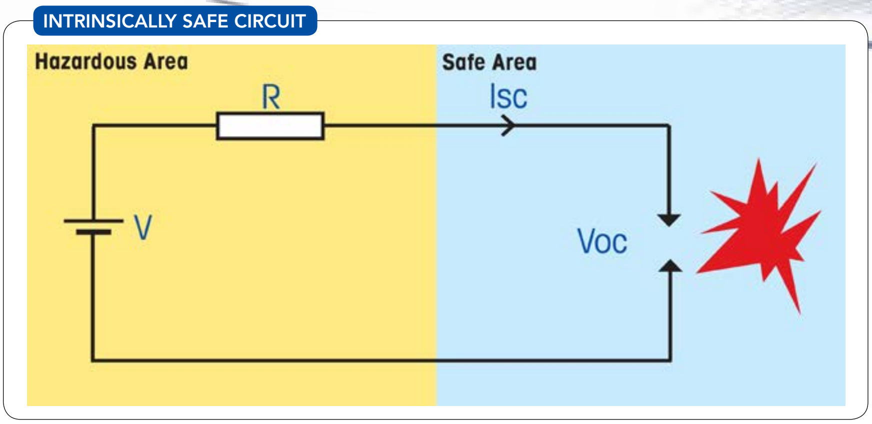

INTRINSICALLY SAFE CIRCUIT

Figure 3. Intrinsically safe electrical equipment is designed to limit the open circuit voltage (Voc) and the short circuit current (Isc) to keep the produced energy at the lowest possible level.

According to the ATEX Directive, hazardous areas are divided into three zones for gases and three zones for dust substances. The classification is defined according to the probability of the presence of an explosive atmosphere. Each zone is corresponding to the particular equipment category.

In North America, areas are classified into classes. Classes are further categorized into Division 1 and Division 2, according to the probability of materials present in a potentially hazardous quantity. Class I (Gases) and Class II (Dust) hazardous areas are divided into subgroups based on the type of flammable gas, vapor or particles present. Class III (Fibers) is not divided into subgroups.

IGNITION PROTECTION METHODS

The basic safety concept is to eliminate the simultaneous existence of the possible ignition sources. The method of protection will likely depend on the degree of safety needed for the type of hazardous location. Besides the degree of safety required for the classified area, other considerations must be made, such as the size of the equipment, its normal function, power requirements, installation costs and flexibility of the protection method for maintenance.

Table 2 shows an overview of the standardized types of protection. It describes the basic principle of each protection method as well as the applicable standard and the classified area.

The protection methods are standardized and the standards vary in different countries. However, the principles of protection are the same regardless of the country. When it comes to designing and developing weighing equipment for hazardous areas, the two methods, intrinsic safety and flameproof, are mainly applied. However, intrinsic safety provides numerous technical and economical advantageous, which makes it the preferred protection method for weighing equipment.

BASIC PRINCIPLES OF INTRINSIC SAFETY

Since it was introduced in non-mining applications, intrinsic safety has evolved to become one of the most commonly used protection methods in process industries. Today, intrinsic safety is one of safest and most advanced methods of ignition protection. It has become the method of choice because, independent from the application, it keeps the entire system safe.

Intrinsically safe technology prevents explosions by ensuring that the energy transferred to a hazardous area is well below the energy required to initiate an explosion. As such, it is restricted to electrical apparatuses and circuits in which the output or consumption of energy is limited. Intrinsically safe systems enable equipment to be used without risk of igniting any flammable gas, dust or fibers that may present in hazardous areas.

INTRINSICALLY SAFE CIRCUIT

An electrical circuit is intrinsically safe when it produces energy below the minimum ignition energy (MIE), which is defined by the appropriate standards.

PROTECTION METHODS

PROTECTION TYPE	MARKING		PRINCIPLE	STANDARD			AREA CLASSIFICATION	
	EU	USA		IEC / EN	USA	CSA	ZONE(S) (ATEX 94/9/EC)	DIVISION (NEC 500)
General Regulation	Ex	AEx	Basis for protection type	60079-0	FM 3600 UL 60079-0	60079		
Intrinsic Safety	Ex ia	AEx ia	Limit energy; no sparks or surface temperature	60079-11	FM 3610 UL 60079-11	60079-11	0, 1 and 2	1 and 2
	Ex ib	AEx ia					1 and 2	
	Ex Ic						2	
Flameproof	Ex d	AEx d	Contain the explosion, quench the flame	60079-1	ISA 60079-1 UL 60079-1	60079-1	1 and 2	1 and 2
Increased Safety	Ex e	AEx e	Dust / water tight enclosure	60079 -7	ISA 60079-7 UL 60079-7	60079-7	1 and 2	1 and 2
Non-Sparking	Ex nA	AEx nA	No sparking device	60079-15	ISA 60079-15 UL 1203	60079-15	2	2
	Ex nC	AEx nC	Sparking devices and components					
	Ex nL	AEx nL	Limited energy; no sparks or hot surfaces					
Encapsulation	Ex m	AEx m	Keep the explosive atmosphere away from any source of ignition	60079-18	ISA 60079-18 UL 60079-18	60079-18	0, 1 and 2	1 and 2
Pressurized	Ex p	AEx p	Purge enclosure with the inert pressurized air	60079-2	FM 3620 UL 60079-2	60079-2	1 and 2	1 and 2
Oil Immersion	Ex o	AEx o	Keep the explosive atmosphere away from the ignition source	60079-6	ISA 60079-6 UL 60079-6	60079-6	1 and 2	1 and 2

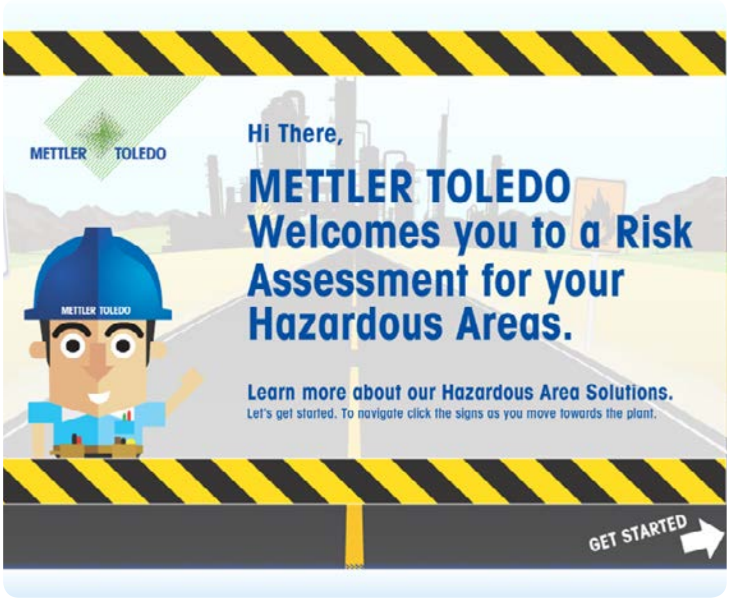
Table 2. This overview of the standardized types of protection describes the basic principle of each protection method, the applicable standard and the classified area.

In Europe, IEC EN60079-11 specifies the construction and testing of intrinsically safe equipment; in the United States, FM3610 does this. Intrinsically safe electrical equipment is designed to limit the open circuit voltage (Voc) and the short circuit current (Isc) to keep the produced energy at the lowest possible level (Figure 3).

It also must be done in such a way that sparks produced when opening, closing or earthing the circuit or produced by any other hot part of the circuit itself would not cause ignition. Intrinsically safe electrical equipment and wiring can be used in Zone1/Division 1 hazardous areas as long as they are approved for the location.

INTRINSICALLY SAFE SYSTEM

An intrinsically safe weighing system is different from a standard weighing system. It combines intrinsically safe elements, associated elements and



INTRINSICALLY SAFE WEIGHING SYSTEM

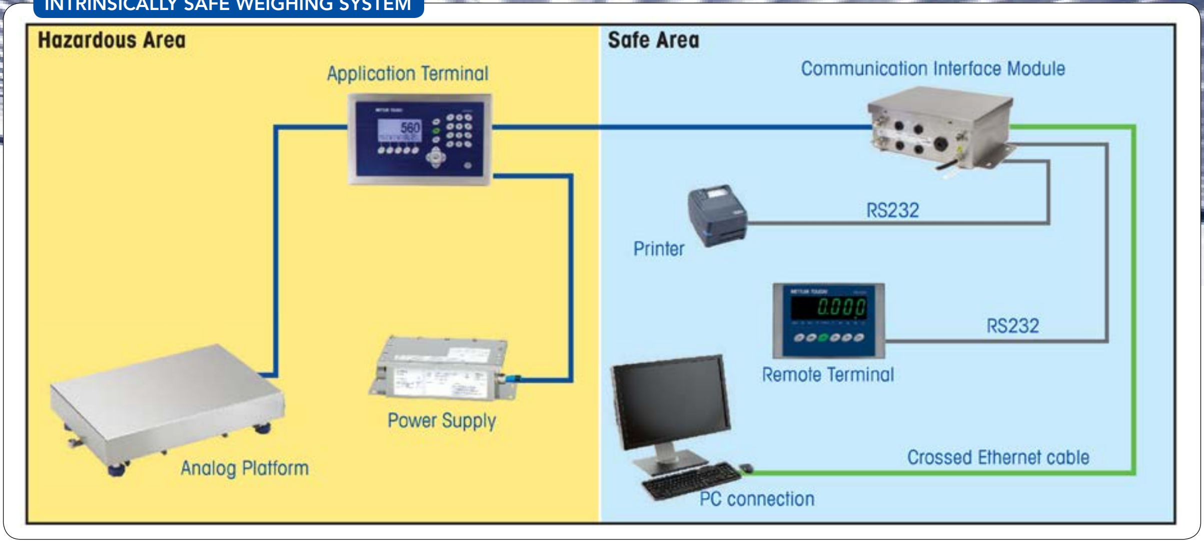


Figure 4. An analog weighing platform and intrinsically safe weighing terminal communicate to standard peripheral instruments, such as PC, through a special barrier.

special approved wiring with standard equipment, which is installed in the non-hazardous safe area. In a hazardous area, all elements of the system must be compatible to form an intrinsically safe system.

Let’s consider an example with an intrinsically safe weighing system. In our example, the intrinsically safe apparatus is an analog weighing platform and intrinsically safe weighing terminal IND560x (Figure 4). The intrinsically safe power supply APS768x serves as the power source for the weighing terminal and is defined as a simple apparatus. Communication to the standard peripheral instruments, such as PC, barcode reader or even remote control terminals, is possible through a special barrier. This is achieved via a communication interface ACM 500, which encompasses both intrinsically safe and non-intrinsically safe electrical circuits.

In an intrinsically safe system, physical barriers are used between the hazardous and safe areas to limit the energy that enters the hazardous area. Intrinsically safe barriers maintain approved levels of voltage and current via power limiting components. They ensure that even under fault conditions, no more than the approved voltage or current enters the hazardous area. This allows standard electrical devices installed in the safe area, such as printers, computers and PLC systems, to be directly linked into a hazardous area.

LEVELS OF CLASSIFICATION AND PROTECTION

Intrinsic safety offers three classification levels, “ia,” “ib” or “ic,” which are based on the safety level and number of faults possible. Each classification attempts to balance the probability of an explosive atmosphere being present against the probability of an ignition occurring.

The level of protection “ia” is a prerequisite for Category 1 equipment and is suitable for use in Zone 0. The level of protection “ib” for Category 2 equipment is suitable for use in Zone 1/Division 1. The level of protection “ic” for Category 3 is suitable for use in Zone 2/Division 2.

The classifications ensure that the equipment is suitable for an appropriate hazardous application. For example, having equipment classified as “EEx ib” means that the equipment is designed containing an intrinsically safe circuit and can be installed in the certified hazardous areas Zone 1/Division 1. Moreover, the “ib” classification indicates that one fault is possible.

Equipment classified as “[EEx ib]” or “EEx [ib]” is defined as an associated electrical apparatus and contains both intrinsically safe and non-intrinsically safe circuits. The square brackets indicate that the associated electrical apparatus contains an intrinsically safe electric circuit, which may be introduced into Zone 1/Division 1. In the first case, “[EEx ib],” the equipment must be installed in the safe area. In the case of “EEx [ib],” the equipment can be installed in both Zone 1/Division 1 hazardous areas and in the safe area.

However, it is also possible for different parts of the system to have different levels of protection. Table 3 presents different protection levels, the numbers of faults possible and the appropriate hazardous area.

INTRINSICALLY SAFE PROTECTION LEVELS

PROTECTION LEVEL	ai	ib	ic
Hazardous Area	Zone 0, 1, 2 / Division 1	Zone 1, 2 / Division 1	Zone 2 / Division 2
Faults possible	2	1	Normal operation

Table 3. Different parts of the system can have different levels of protection.

INTRINSIC SAFETY BENEFITS

One of its greatest benefits is that intrinsic safety enables equipment maintenance within hazardous areas without the need to interrupt the power supply and to obtain a gas clearance certificate, which is necessary with open flameproof equipment. This especially applies to instrumentation because fault finding on de-energized equipment is more complex and time consuming.

Intrinsically safe technology provides a flexible and modular solution to most industrial applications within hazardous areas. It is possible to communicate with the multiple components through specially designed communication elements.

Intrinsically safe equipment and their components, such as cables and cable glands, are relatively inexpensive. Therefore, the installation costs and costs of maintenance and inspection when using intrinsically safe equipment are significantly lower compared to flameproof equipment.

In addition, it is the only technique that limits power output. With intrinsically safe equipment, no sparks or increasing temperature in the electrical circuit can ignite the surrounding atmosphere.

Moreover, the technology is globally accepted by the international certification bodies IECEx, as well as most of the local legislations, such as ATEX in Europe, FM in the United States as well as NEPSI in China, GOST-R in Russia, KTL in Korea and INMETRO in Brazil.

Intrinsically safe equipment generally satisfies all dust and gas legislative requirements and it can essentially be used for every industrial application.

Finally, intrinsic safety offers the best level of safety and accuracy in all hazardous areas. The technology offers the maximum level of precision. Using the advanced hybrid design and a high-precision electromagnetic force compensation with up to 32,000 approved calibration points, the weighing system delivers highly accurate and reliable results. It is safer and less prone to accidental errors than other protection methods and it ensures high uptime in the case of an incident, unlike the flameproof solution.

ADDITIONAL REFERENCES

IEC EN 60079-0: Explosive Atmospheres – Part 0: Equipment – General Requirements

IEC EN 60079-10-1: Explosive Atmospheres – Part 10-1: Classification of Areas – Explosive Gas Atmosphere

IEC EN 60079-11: Explosive Atmospheres – Part 11: Equipment protection by intrinsic safety “i”, 5th Edition

ATEX Directive 94/9/EC: Guidelines on Application, Europe Commision, Fourth Edition, 2012

National Electrical Code, Article 500, NFPA 70, 2011, Delmar: Nacional Electric Code

National Electrical Code, Article 505, NFPA 70, 2011, Delmar: Nacional Electric Code

METTLER TOLEDO Hazardous On-Demand Webinar Basic, www.mt.com/ind-haz-basics

METTLER TOLEDO Hazardous On-Demand Webinar Advanced, www.mt.com/ind-haz-advanced

METTLER TOLEDO Hazardous Catalog, www.mt.com/ind-hazcat

METTLER TOLEDO IND560x Product Brochure, www.mt.com/ind560x

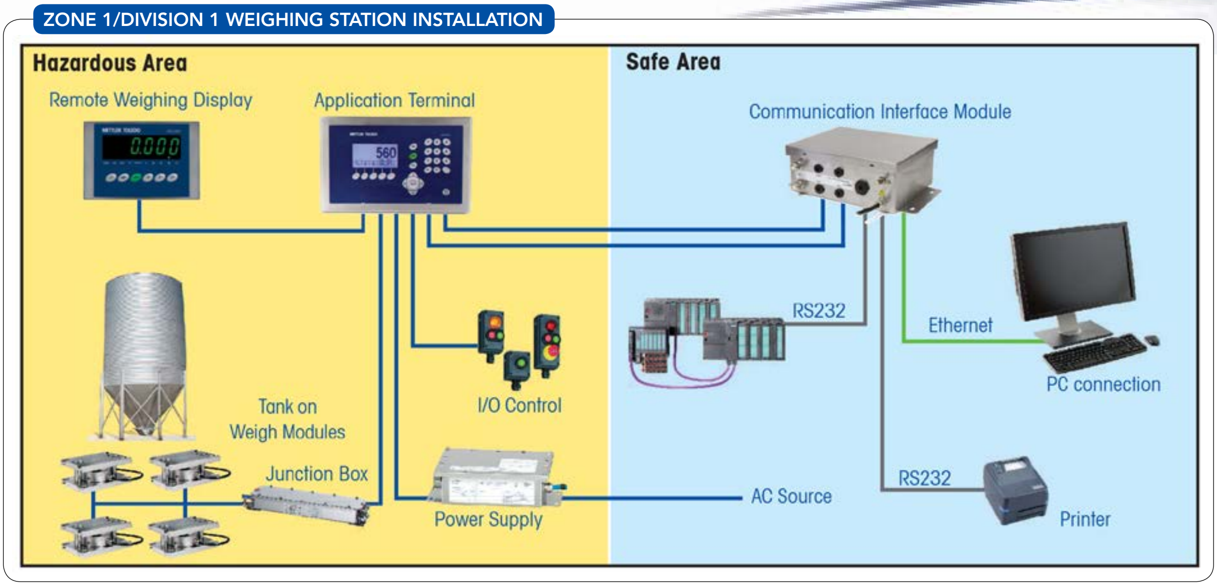

ZONE 1/DIVISION 1 WEIGHING STATION INSTALLATION

Figure 5. Communication in the safe area allows users to interface with the PC, printers or network to a PLC through an intrinsically safe fieldbus, Ethernet or serial RS 232/422/485.

INTRINSICALLY SAFE WEIGHING CONFIGURATIONS

Many hazardous weighing applications exist in the industrial value chain. As many industrial processes incorporate aggressive chemical agents, scales in industrial environments must withstand not only harsh conditions and corrosion, but also must have an inherently safe design to withstand explosive and flammable substances.

Also, the requirements for many weighing applications in which intrinsically safe weighing systems can be applied are very different. Among them are train and truck scales, tank weighing, formulation and recipe applications, filling and dispensing applications, conventional floor and bench scales and control of weighing terminals.

The requirements for weighing systems vary not only by industry and process conducted, but they also vary by level of accuracy required and application-specific needs. Their means of connection to peripheral devices and fieldbus and network connections also varies.

Figure 5 shows a possible hazardous area installation. METTLER TOLEDO's intrinsically safe weighing terminal, IND560x, communicates with intrinsically safe digital high-precision platforms, such as Kx-T4 or intrinsically safe analog load cells, forming an intrinsically safe circuit. The intrinsically safe power supply is an associated part of the intrinsically safe circuit, which serves as a power source for several METTLER TOLEDO intrinsically safe weighing terminals. Communication in the safe area allows users to interface with the PC, printers or network to a PLC through an intrinsically safe fieldbus, Ethernet or serial RS 232/422/485.

A comprehensive range of modular intrinsically safe components can be flexibly combined to work together in an intrinsically safe system and in all types of hazardous areas. That ensures not only an efficient and risk-free weighing process, but also simple installation and maintenance as well as technical documentation registration to meet the company's safety requirements.

FLAMEPROOF – BASIC PRINCIPLE

The flameproof protection method is based on the explosion-containment concept and is in ac-

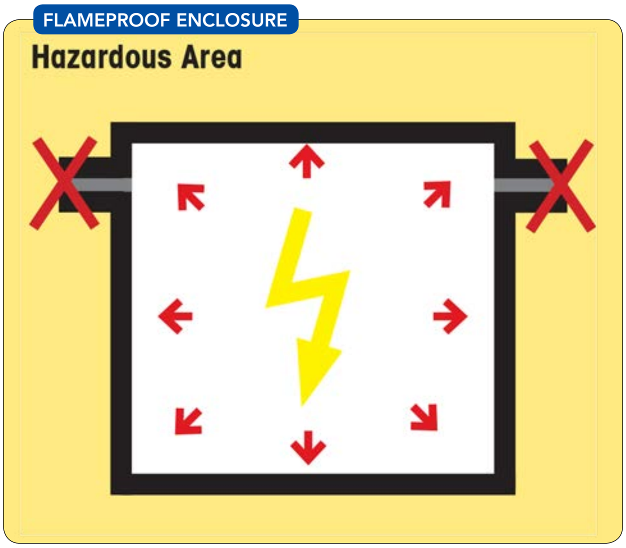


Figure 6.

cordance with IEC EN60079-1 classified as “Ex d.” This concept relies on equipment and wiring enclosures to prevent an internal ignition from escaping to the surrounding atmosphere. In other words, the explosion is allowed to take place, but it must remain confined in the enclosure that is designed to resist the excess pressure the internal explosion causes (Figure 6).

The theory supporting this method is that the resultant gas jet coming from the enclosure is cooled rapidly through the enclosure’s heat conduction and the expansion of the gas. The hot gas is then diluted in the colder external atmosphere. That is only possible if the enclosure openings or interstices have sufficiently small and well-controlled dimensions.

A flameproof system is generally considered somewhat simpler to design than an intrinsically safe system as it doesn’t require completely new equipment design. However, it is generally more expensive to install because of the high cost of running field wiring inside a conduit, which must be sealed between the safe and hazardous areas. It is also often physically larger and much heavier than an intrinsically safe solution.

Flameproof equipment is also more difficult and time consuming to maintain because either the area must be known to be non-hazardous or the equipment must have the energy drained before covers can be removed. Hot permits are required to perform maintenance work on these systems.

Further, when covers are re-installed, extra care must be taken that fasteners are precisely torqued to specified values.

SUMMARY

Several options exist when it comes to ignition protection in hazardous environments. Installing intrinsically safe weighing equipment is the safest method, providing at the same time high accuracy and reliability weighing results. It safely facilitates activities in the hazardous area and is low maintenance. In the case of incidents, the intrinsically safe equipment can be serviced without halting production, and it eliminates heat and sparks in the production area.

METTLER TOLEDO focuses on development of intrinsically safe weighing systems. Intrinsically safe weighing solutions provide the user with the highest level of accuracy, safety, broad functionality, and low installation and maintenance costs. A wide range of high precision and analog weighing platforms ensures high speed and high accurate weighing results in applications, such as filling or dosing. Weighing modules and control terminals and the flexibility of interface communication provide full scope of functionality and enables flexible and modular solution setup in both the hazardous area and in the safe area.

Global acceptance by IECEx, ATEX, FM and relevant local certification bodies provide additional security to the user.