Confined Space Incident Reconstruction

The Future Depends on Understanding the Past

By Neil McManus and Assed N. Haddad

The written record is the primary source for acquiring information about confined space incidents. These records contain supposedly factual information, including location, date, time, victim's age and gender, and a narrative summary. The narrative summary can provide additional specific and interpretive information. Interpretive information requires the application of skill and broad-spectrum knowledge about the circumstances of work. Thus, such information necessarily receives the lowest level of confidence.

With care in the manner of performing this inquiry, this information can provide the basis for identifying trends in these events. Also, working on statistical and stochastic data is an important means of transforming data into information, information into knowledge and knowledge into action.

History Repeats, Documents Lack Detail

Incident summaries posted on the OSHA and NIOSH websites share themes identifiable from the historic record. They also show that incidents with similar progression continue to occur despite concerted attention on prevention through regulation. Jorge Agustín Nicolás Ruiz de Santayana y Borrás (best known as George Santayana) said, "Those who cannot remember the past are condemned to repeat it." Historic records are an indispensable resource of knowledge that provide the basis for understanding work conditions and motivation for behaviors and actions that lead to incidents that occur in the present and ultimately the future. In fact, the past is the only such resource.

However, those who study these records must understand their intrinsic limitations due to factors such as coherence, organization and completeness. This reality is true for all seekers of information and knowledge from the past, be they historians, paleontologists, paleobotanists, archaeologists or geologists. As readers of publications produced by these practitioners soon realize, findings from the past are open to interpretation. Sometimes

IN BRIEF
- **Incident reconstruction based on narrative summaries is the primary resource for performing research on confined space entry injuries and fatalities.**
- **Formal, guided inquiry can increase the amount of information extracted from these summaries, but the process requires broad-spectrum knowledge and experience regarding the circumstances of work.**
- **This approach is an important means for transforming data into information, information into knowledge and knowledge into action.**

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Confined space incidents are rare, yet they are often highly consequential, in some cases involving as many as five or six fatalities. Their occurrence is difficult to predict and expensive to prevent.

the interpretation is accurate, sometimes partially correct, and other times completely incorrect, as demonstrated over time. A particular finding often gives rise to multiple interpretations and occasionally generates acrimonious debate about the validity of a specific interpretation.

To gain information, a researcher must deconstruct incidents to identify and characterize fundamental elements, compare those elements against similar elements identified in other cases, then reconstruct incidents to create a descriptive model. This model forms the basis for action by regulators, educators, trainers and hands-on safety practitioners. Without a functional descriptive model, these endeavors cannot occur with the level of knowledge and confidence needed to define what will be most effective.

Incident deconstruction and reconstruction are subject to the same issues and challenges as other efforts that seek truth from records of the past. They depend on the information provided for inquiry. In the case of confined spaces, the source of much of what is known is the information contained in summaries that explain what occurred. These records typically include information submitted by employers, investigative reports produced by regulators, media coverage and in-depth reports created by dedicated investigation teams.

The quantity, quality and completeness of information in these records and the number and availability of pertinent records affect a researcher's ability to deconstruct incidents, analyze fundamental elements and reconstruct to create a descriptive model. Therefore, the process of creating records suitable for use in future inquiries encompasses elements of both art and science, with the artistic element being the anticipation that information collected will be essential for future inquiry.

The specifics of information needed for future inquiry are not intuitive. However, without formal guidance about what details should be captured, with the view that this will generate the greatest amount of information for the effort expended, the ability to create records that anticipate future demand is left to considerable chance.

Complete information is needed to establish the specifics of a particular situation. Too little information limits the researcher's ability to identify and quantify the underlying elements needed for analysis and reconstruction. Too much information can obscure the fundamental elements needed to create a descriptive model.

Fragmented information also limits the ability to understand and explain the past. Investigators sometimes can expand on knowledge by using details initially perceived to be unimportant. This likely applies to research into confined space incidents. Although these incidents produce both nonfatal and fatal outcomes, most of the distant historic information derives from fatality investigations because of greater regulatory emphasis on such cases and the inability to capture and process information in a cost-effective manner.

Nonfatal incidents range in severity from those involving only property damage to those involving only worker injuries. The outcomes range from trivial to severe. Defining the point at which the requirement to investigate and submit information to regulators involves a complex decision logic. It also encompasses the recipient's need to assess information that is retrievable both individually and collectively from these situations. While information retrieval is technically possible, the logistics are costly and the value of the information is questionable. Reinforcing this point, Ernst Mach said in 1905 that "knowledge and error flow from the same mental sources, only success can tell the one from the other" (as cited in Reason, 1990).

In circumstances involving major incidents, the regulatory authority usually assigns specialists knowledgeable and experienced in such inquiry to investigate. Some countries support third-party investigative organizations that can provide independent views of the situation. For example, in the U.S., agencies such as National Transportation Safety Board, CSB and Nuclear Regulatory Commission produce reports that contain considerable detail about incidents occurring within their areas of jurisdiction.

The Historic Record of Confined Space Incidents

Confined space incidents are rare, yet they are often highly consequential, in some cases involving as many as five or six fatalities. Their occurrence is difficult to predict and expensive to prevent (McManus, 1999). Publicly available historic information exists primarily as a result of fatal incident investigations and concerted collection and publication of records by agencies such as NIOSH, OSHA and MSHA. These reports are the main resources for researchers seeking to understand and address the factors involved in these events.

The dangers posed by confined spaces are well known. Thackrah (1831) writes that the Romans knew that work performed in sewers was among the most dangerous. NIOSH (1979) acknowledges this reality in references published in "Criteria for a Recommended Standard: Working in Confined Spaces." The term *confined space* and its recognition value predate this document by many years. Some jurisdictions imposed regulatory requirements concerning work in confined spaces dating to at least the 1960s and likely earlier.

MSHA (1988; 1994), NIOSH (1994) and OSHA (1982a, 1982b, 1983, 1985, 1988, 1990) published a series of reports on incidents that occurred in work spaces meeting regulatory definitions for confined spaces. Almost all contain individual incident summaries from which one can extract additional information. Table 1 briefly summarizes these documents and others available for research.

Generally, the summaries contain quantitative data such as date, time and location, and a narrative that describes the event. The narrative typically consists of at least one paragraph of descriptive information and sometimes one or more pages of such information.

For a brief time, BLS issued annual reports on confined space incidents in industry (Meyer, 2003, 2004a, 2004b). The data published were detailed and provide considerable potential for in-depth investigation.

NIOSH (1994) created the Fatality Assessment and Control Evaluation (FACE) program to investigate incidents in four areas: falls from elevations, contact with electrical energy, confined space entry and machine-related injury. This program enables detailed and consistent investigation of incident circumstances by a dedicated team.

On-scene investigators are able to control the questions posed to witnesses and sometimes victim(s). *A posteriori* investigators have only the information found in the written record, which often lacks the detail needed to conduct in-depth queries. The quality of information provided depends on the investigator's knowledge and skill, and the flexibility permitted by the form used to record it. In the past, the size of the boxes available for storing information likely also constrained the amount collected. Furthermore, instrumentation used to assess atmospheric conditions was primitive compared to what is available today.

The Internet has created an opportunity to revo-

Table 1

Information Sources on Fatal Incidents in Confined Spaces

Activity/focus	Source	Comments
Fires, explosions involving liquids and gases	OSHA, 1982a	Individual summaries of 50 fatal incidents involving 76 fatal injuries; some occurred in confined spaces
Maintenance, servicing of machinery	OSHA, 1982b	Individual summaries of 83 fatal incidents involving 83 fatal injuries; some occurred in confined spaces
Grain handling	OSHA, 1983	Individual summaries of 105 fatal incidents involving 126 fatal injuries; some occurred in confined spaces
Grain handling and storage	Riedel & Field, 2010	Review of 800 suffocation and entrapment incidents between 1970 and 2010
Atmospheric hazards	OSHA, 1985	Individual summaries of 122 incidents involving 173 fatal injuries
	NIOSH, 1994	Individual summaries of 70 incidents involving 109 fatal injuries
Welding, cutting	OSHA, 1988	217 fatal incidents involving 262 fatal injuries reviewed, individual summaries of 164 fatal incidents involving 190 fatal injuries provided for review; some occurred in confined spaces
Shipbuilding, ship repair	OSHA, 1990	Individual summaries of 151 fatal incidents involving 176 fatal injuries; some occurred in confined spaces
Confined spaces	NIOSH, 1994	Individual summaries of 70 incidents, some involved sources of hazardous energy
	Meyer, 2004a	Summary of causative factors by year from 1992 to 2001; some incidents involved sources of hazardous energy
	Meyer, 2004b	Summary of causative factors by year from 1997 to 2001; some incidents involved sources of hazardous energy
Mining	MSHA, 1988	Individual summaries of 38 fatal incidents involving 44 fatalities; some occurred in confined spaces

lutionize provision of information about confined space incidents. For example, OSHA (2014) hosts an online database that contains incident summaries current to 1 year prior to the date of the inquiry. A user enters search terms, including the keywords *confined space* and obtains a list of incidents that occurred within the dates of reference and other defining terms.

This database can provide considerable information and enable one to extract additional detail. This detail forms the basis for further understanding the circumstances involved in individual incidents and for identifying trends. Again, the quality of this analysis depends on the detail and completeness of available summaries.

These records provide ample evidence to support the contention that history repeats itself and that lessons that need to be learned are not being learned. While prevention occurs at the site level, guidance in the manner of performing work safely occurs at the level of educators and trainers, and requirements for the performance of work at the level of regulators. The actions of these groups must reflect the knowledge gained from incident analysis.

OSHA (2014) Form 170 is the document used to record incident information. The content provided in this form, therefore, determines the content available for future research. Examination of incident summaries provided online by OSHA (**www.osha.gov/pls/imis/accidentsearch.html**) reveals that information provided is highly variable from one summary to another. Therefore, effort expended up front to standardize report completeness and content thoroughness likely would provide considerable future benefit for understanding these events and addressing the issues that they pose. NIOSH also posts its FACE reports online (**www.cdc.gov/niosh/face**).

MSHA, NIOSH and OSHA provide a plethora of case summaries, yet they lack clarity and detail. The FACE reports provide considerable detail about a small number of cases.

Independent groups have also gathered information about confined space incidents. For example, the Agricultural Safety and Health Program at Purdue University maintains a database of incidents involving facilities that store and handle agricultural crops. The database contains information from formal investigations performed by

Figure 1

Hierarchy-Based System for Extracting Information From Incident Summaries

Primary			Secondary			Tertiary		
Quantitative	***Qualitative***	***Intuitive***	***Quantitative***	***Qualitative***	***Intuitive***	***Quantitative***	***Qualitative***	***Intuitive***
Date			Month					Possible weather
			Day					Workers on site
Time				Shift				Workers on site
								Visibility
			Incident/ hour					Severity
			Victims/ incident					Severity
Age					Knowledge base			
Type of incident								
Technical cause								
Incident					Agent or condition			
Initiator								
Onset				Pre-exist or work condition				Mechanism of action
				Rate of onset				Severity of hazard
Operation				Process			Substance and other hazards	
				Volume				Confinement
Structure				Process			Substance and other hazards	
				Volume				Confinement
Volume								Confinement
Contents							Substance	
	Visual condition				Presence of hazard			
	Olfactory condition				Presence of hazard			
Reason for entry								
Nature of work					Routine vs. unusual			
Task				Substance and other hazards				
				Process			Substance and other hazards	
Nature of activity				Usual/unusual				
Occupation of entrant				Process			Substance and other hazards	
Entrant qualified for task					Yes, no, possible			
Prepare					Failure to prepare?			
Test					Failure to test?			
Ventilate					Failure to control?			
PPE					Failure to protect?			
Rescue attempt								
Rescue success								
Occupation of rescuer					Social aspects			
Rescue fatalities			Severity of action					

regulators, police and coroners' juries, as well as less formal sources such as newspaper articles and other media reports (Beaver & Field, 2007; Kingman, Field & Maier, 2001; Riedel & Field, 2011).

The greatest limitation of this database is its incompleteness relative to the global picture that existed during the period. The agencies that compiled these reports acknowledge these limitations, especially the fact that not all fatal confined space incidents that occurred during the period of interest are included. In other words, the documents underestimate the number of fatal incidents and fatalities. This potentially skews the understanding about the relative importance of specific hazardous conditions in incident causation.

It also leaves open the question of whether the observations and conclusions derived from this information reflect the truth of the situation as far as was demonstrable. The latter statement has considerable implication where the information provided acquires stature beyond what is justifiable and forms the basis for regulatory action. However, the data are the data, and these documents comprise the universe of what is available for further investigation.

To further complicate things, regulators normally do not consider excavations, trenches and ditches to be confined spaces. These work spaces share the geometric characteristics used to define confined spaces in many jurisdictions and under certain circumstances, the hazardous conditions found in them are the same as those found in other work spaces labeled as confined spaces. These include entrapment of exhaust gases from the engines of portable and mobile equipment, vapors from volatile and flammable solvents introduced into the space, and seepage of gases, vapors and liquids from the surrounding soil.

Furthermore, engulfment, which is the primary concern about trenches and excavations, also occurs in structures such as silos, bins and hoppers that are clearly recognized as confined spaces. Engulfment is engulfment, regardless of semantics about location and type of material. Ultimately, this approach creates a conflict in determining to which classification a particular work space belongs (McManus, 2009). It also means that few construction incidents are attributed to confined spaces (S. Schneider, personal communication, 2013).

Reviewing Incident Reports

The process of extracting information from summaries of confined space incidents is iterative, and it encompasses quantitative, qualitative and intuitive elements. The process resembles a spiral that enlarges with each revolution around the point of origin as more information accumulates.

The inquiry progresses by linking data readily obtainable from the incident summaries and moves from quantitative through qualitative to intuitive elements. With each degradation in information quality, confidence decreases. The envelope formed by the outer limit of accumulated information defines the extent of knowledge that can be derived from the information contained in and beyond the summaries. The quality and thoroughness of the questions posed define the limits of what is retrievable.

Figure 1 provides a means of organizing research. It contains three levels of inquiry: primary, secondary and tertiary; a quaternary level is also possible. The incident summary is the primary source. Within each level, the information can be quantitative, qualitative or intuitive. Links between parameters contained in the same level or between levels form the basis for deriving more information.

Quantitative information found in these resources can give rise during incident deconstruction to quantitative, qualitative or intuitive information on the next lower level. Qualitative information can give rise to qualitative or intuitive information on the next lower level. Information creation at the qualitative and especially the intuitive level depends on the researcher's knowledge and experience, which limit the extent of the outer boundary achievable in exploring incident summaries.

To start, one documents the quantitative and qualitative information provided in the incident summaries, with the easiest data to capture being date and time, and victim's age, gender, job title and occupation. Date enables the researcher to ascertain additional quantitative information including day of the week and season of the year, and weather conditions (e.g., temperature, rain, snow). Time allows one to infer potential issues with visibility (daylight vs. darkness) and work shift (day, evening, night, weekend). In addition, the narrative may include quantitative information about structures, processes, and machines and equipment involved. Such information provides the basis for determining volume, content/contaminants and internal structure.

Work activity described in the narrative provides a cross-check against job title and occupation. This information also helps the researcher determine hierarchical and social relationships involving victims and survivors. In addition, the narrative describes the nature of the situation and flow of events preceding the incident and sometimes after it.

Results & Discussion

The direction of inquiry reflects the researcher's interest and focus, which may not match those of another researcher. This difference is one reason that ongoing availability of the distant and present historic record for future use is essential.

For example, regulators and members of consensus standards committees (e.g., ANSI/ASSE Z117.1, Confined Spaces) are interested in actions and decision making that reflect deficiency in management systems. Regulators use this information as the basis for creating, increasing or enforcing regulatory requirements. Educators and trainers must learn about the elements and the narrative that form the descriptive model. This information is especially critical in situations in which the general progression of events is shown to be predictable. Practitioners involved in incident prevention at the hands-on level where harm actually occurs are

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Table 2

Organizational System Deficiencies & Confined Spaces

Factor	Deficiency
Management	
Policy	•Absent or poorly explained
Organization for work flow	•Absence of preparation and accountability •Absence of active involvement in operational activity •Failure to utilize operational experience
Supervision	
Work planning	•Absent or inadequate or inappropriate for entry and work, emergency response and rescue
Anticipation and recognition skills	•Failure to recognize the potential for occurrence and changes in hazardous conditions
Procedures prepared for the work	•Absent or inadequate or inappropriate to the situation
Training provided to workers	•Absent or inappropriate or inadequate to the situation
Entry and work activity	
Preparation for entry and work	•Necessary equipment absent or inappropriate to the task
Testing	•Absent or inappropriate to the conditions •Equipment not calibrated or serviced
Ventilation	•Absence of ventilation or inappropriate use
Other activity	•Failure or refusal to follow organizational policy and procedures •Impulsive decision making and action •Defeat of safety devices

likely to be most interested in how hazardous conditions develop and how workers respond to them.

The authors of the NIOSH (1979) and OSHA (1982a, 1982b, 1983, 1985, 1988, 1990) reports comment that these incidents resulted from organizational and procedural deficiencies. Table 2 summarizes factors mentioned in the reports that enhanced the potential for onset or exacerbated the severity of these events (McManus, 1999). The information in Table 3 is the same as or similar to that derived from incident investigation in other types of work spaces. That is, this information reveals nothing unique to work spaces meeting the generally accepted definition of confined spaces. Thus, this direction of inquiry adds nothing to the discussion about incident causation and prevention.

McManus (1999) documents information extractable from MSHA (1988, 1994), NIOSH (1994), and OSHA (1982a, 1982b, 1983, 1985, 1988, 1990) reports. The first criterion in his analysis was to ensure that the incidents occurred in work spaces that met the accepted definition prevalent at the time for a *confined space.* The next criterion was to ensure that the information provided was satisfactorily comprehensive for inclusion. The inclusion of only a selection of incidents rather than the entire group in OSHA's 1988 report on welding and cutting was reported as a limitation.

Table 3 summarizes information presented in McManus (1999) by type of hazardous atmospheric condition, which had not been considered previously. This approach allows for side-by-side comparison to identify and assess relationships between causal factors. As readers can see, considerable similarities exist in parameters assessed during exposure to oxygen-deficient and toxic atmospheric conditions. Fires and explosions differ considerably from oxygen deficiency and toxic atmospheres. Incidents of this type are generally abrupt and produce property damage and destruction, and severe traumatic injury.

Table 4 (p. 58) provides information concerning incidents that occurred during exposure to nonatmospheric hazardous conditions that can occur in confined spaces. Such conditions cover a broad spectrum, which is to be expected, given that the hazardous conditions act on different parts of the body by different mechanisms. As a result, factors common to different types of incidents are less likely to exist in these situations.

The common thread is the routine or normal nature of the work. As shown in Tables 3 and 4, the activities associated with these incidents were within victims' normal experience. The incidents also occurred during daytime work hours, during much of the year versus specific periods, and in situations in which hostile weather conditions were not a factor.

The most perplexing finding from the review of these summaries was that safety managers and workers described as "safety conscious" were among the victims (entrants, would-be rescuers) (McManus, 1999). Presumably, these individuals would have more knowledge about the risks intrinsic to confined spaces than other workers. This label produces an expectation of prudence among these employees, including implementation of protective measures before entering the space and beginning to work.

Further research provides a possible resolution to this question and indicates that the situation is more complicated than might first appear. Analysis in McManus (2012) suggests that tasks and work conditions are parallel, independent and mutually exclusive realities in workplaces and work spaces. The existence of these realities and the absence of interaction between them are crucial to understanding incident causation and occurrence.

One cannot focus simultaneously on task and conditions when performing work. Rather, one can focus on one or the other at any point in time. That is, a person can focus on either a task or conditions, but not both in a particular moment in time. This is known as inattention blindness. According to transportation literature (Curry, 2002; Moore & Moore, 2001; NSC, 2010), inattention blindness describes the situation in which a driver can look straight through the windshield in the travel direction and fail to comprehend the significance of the situation ahead. Drivers impaired in this way look at objects but fail to see them.

Applied to confined spaces, this concept argues for use of continuous reading, alarming instruments during work involving exposure to atmospheric hazards (McManus, 2009). Such an approach acknowledges the inability to focus attention to the display of an instrument with no alarm during situations in which atmospheric conditions may deteriorate to a level that can cause harm.

Working with historical information always involves a look backward to a particular period in time. In the case of confined spaces, this period covers many years. However, the incompleteness of the historic record may distort the understanding of event dynamics and causes. At the time of most of the incidents summarized in the MSHA, NIOSH and OSHA reports (covering the mid-1970s to the mid-1980s), engulfment was the major cause of these events in spaces that meet the geometric requirements of confined spaces. This prompted regulatory efforts to address this problem. With the attention given to preventing collapse of the walls of trenches and excavations, this may no longer be the case.

More current compilations of individual fatal incident records involving confined spaces are not available in published sources. The absence of information concerning confined space fatalities that continue to occur limits the ability to identify and investigate trends, including the relative importance of different hazardous conditions. This also hinders the efforts of regulators and safety groups to minimize the occurrence and impact of these events.

Data available in the historic record indicate that confined space incidents continue to be rare events (Meyer, 2003, 2004a, 2004b). Their occurrence is not readily predictable, and their prevention is difficult. Indeed, Meyer (2004a, 2004b) suggests that implementation of OSHA's standard (in 1993) and follow-up enforcement in the U.S. have had limited impact on incidents that occur in these work spaces. Comparison of the incident summaries in OSHA's database with those in the articles involving atmospheric hazards indicates that incidents with similar causation continue to occur. Progression of these incidents is readily describable in a predictive model (NIOSH, 1994, 2014; OSHA, 1983, 2014). This especially appears to be the case in incidents that involve atmospheric hazards.

Table 3

Incident Data: Confined Spaces With Hazardous Atmospheres

Element	Oxygen deficiency	Toxic atmosphere	Fires/explosions
No. of incidents	46	54	44
When condition developed	Prior to entry (76%)	Prior to entry (84%)	During work activity (48%)
Most likely cause	Unknown, N_2, process gas, fuel gas, welding gas	H_2S, CO, Cl-solvent vapor, fuel vapor	Solvent vapor, fuel vapor, welding gas, natural gas
Most likely time	Afternoon	Afternoon	Morning
Most likely day	Tuesday or Wednesday	Monday to Friday	Monday to Friday
Most likely month	April to July	April to July	September to February
Median volume	20 m^3	10 m^3	50 m^3
Condition pre-entry	Clean (56%)	Contents (62%)	Clean (68%)
Odor pre-entry	None (81%)	Yes (69%)	Yes (57%)
Rapid acting	< 10 minutes (98%)	< 10 minutes (73%)	N/A
Work activity	Normal (64%)	Normal (62%)	Normal (87%)
Test pre-entry	None (100%)	None (94%)	None (100%)
Test after entry	None (100%)	None (94%)	None (100%)
Ventilate pre-entry	None (94%)	None (94%)	None (100%)
Ventilate after entry	None (94%)	None (94%)	None (100%)
Age of entrant	20 to 39 (61%)	20 to 39 (69%)	20 to 39 (61%)
Occupation	Broad spectrum	Broad spectrum	Broad spectrum
Rescue attempt	72% of incidents	76% of incidents	---
Death of entrant	97% of incidents	88% of incidents	---
Death of rescuers	50% of incidents	44% of incidents	---
Persistence after incident	Yes (100%)	Yes (100%)	N/A

Note. *% = percent of incidents*

Oxygen-deficient and toxic atmospheric conditions generally preceded entry, whereas fires and explosions were equally likely to occur during occupancy. The same agent can cause all three hazardous atmospheric conditions. When the agent caused oxygen deficiency or a toxic atmosphere, the effect occurred rapidly in a high percentage of situations. These incidents occurred during tasks deemed to be normal work activity to the victims. The data highlight the ongoing importance of testing and ventilation as protective safety measures during this work.

Rescue Attempts

Cases in which several people die during rescue attempts continue to occur. Each of these events is isolated in time and location, yet recurrence over time reveals a predictable sequence of events. One common thread is the selfless effort to assist persons in distress (McManus, 1999; Muncy, 2013). This situation also may reflect the changing nature of work and work situations, and highlights how difficult it is to communicate the risks of rescue to those with the greatest need to know.

In many cases, a specialty contractor provides confined space entry services. This contractor must assess and manage the risks associated with the work to be performed. The worst-case situation is that the smallest provider or the provider employing the least skilled, knowledgeable or literate workers can encounter the greatest risks. This situation considerably magnifies or focuses the risks onto a small number of service providers. The net result is that these employers, through lack of resources, are unable to address the risks of the work that they perform and are, therefore, predisposed to experience serious, potentially fatal incidents.

To address such situations, OSHA implemented its multiemployer policy. This policy classifies employers on a work site according to the level of influence, power and control that they exercise over activities that occur on the site. Influence, power and control determine the scope of duties and responsibilities imposed on each employer and the reasonable care that they are responsible for providing to ensure the safety of their workers.

•The *controlling employer* has general supervisory authority over the work site and the power to correct safety and health hazards or to require others to correct them. This control is established by contract or the exercise of control on the work site.

•An employer who causes a hazardous condition that violates an OSHA regulation is a *creating employer.* This employer is citable even if the workers exposed to the hazard work for other contractors.

•An employer whose own employees are exposed to the hazard is an *exposing employer.*

•An employer on the same work site responsible for correcting a hazard is a *correcting employer.* A correcting employer must take reasonable measures to prevent and discover hazardous conditions and to meet its obligations to correct them.

This structure functions best when all employers approach their obligations with equal commitment and adequate resources for achieving and maintaining them. In practice, however, considerable imbalance exists in both commitment and resources, and conflict dictated through the economics of survival in a competitive environment is inevitable.

Furthermore, a detailed study of incident summaries is needed to develop a descriptive model to identify and understand the underlying motivational elements common to these events. It would also be helpful to link the geometrically defined location of the incident (the confined space) with the incident's technical cause. These causes are no different from causes of other workplace incidents. Thus, the database programming must enable isolation of confined space incidents that share a common cause from incidents that occur in other work spaces.

Also, more resources are needed to educate employers and workers about the risks inherent in improvised rescue attempts, and about strategies for helping workers in distress without adding the risk of unprepared individuals entering the space. These resources should be available in the languages spoken on work sites to maximize their ongoing effectiveness.

Table 4

Incident Data: Confined Spaces With Nonatmospheric Hazards

Element	Engulfment	Entanglement	Electrocution	Process
No. of incidents	114	40	17	11
When condition developed	Prior to entry (43%)	During work activity (63%)	During work activity (59%)	Prior to entry (100%)
Most likely time	Morning	Morning	Morning	Morning
Most likely day	Monday to Thursday	Monday, Thursday, Friday	Monday, Friday	Wednesday, Thursday
Most likely month	March to September	July to March	March to August	March to August
Structure	Bins, chutes	Pits, mechanical equipment	Tanks, containers, vaults	Rooms, vaults
Work activity	Routine (50%)	Normal (60%)	Normal (94%)	Normal (73%)
Tasks	Start flow, clean out, improve flow	Clean, repair, inspect	Welding, cleaning	Repair (27%), inspect (27%), install (18%), adjust (18%)
Condition at entry	Contents not flowing (67%)	Not operating (63%)	Existing energized circuits (53%)	Existing energized circuits (100%)
Immediate cause	Bridge collapse (43%), flow induction (35%)	Unexpected activation (63%), existing movement (35%)	Existing energized circuit (29%), ineffective isolation (47%)	Equipment failure (100%)
Occupation	Laborer, equipment operator	Laborer, trades person	Welder, laborer, electrician	Maintenance, laborer
Rescue attempt	22% of incidents	0% of incidents	12% of incidents	14% of incidents
Death of initial entrant	100% of incidents	100% of incidents	100% of incidents	100% of incidents
Death of rescuers	0% of incidents	0% of incidents	0% of incidents	0% of incidents
Postincident persistence of the hazardous condition	Yes	No	Yes	Yes

Note. *% = percent of incidents*

Conclusion

This article began with the premise that failure to learn from the past contributes to the future occurrence of similar incidents. In the case of confined spaces, we must ask whether the preventive measures have succeeded in this endeavor. Where they have not prevented recurrence, we must determine why to suggest corrective measures.

Black swan is a term often used to describe rare events (Taleb, 2007). A black swan is a highly improbable event with three principal characteristics: unpredictability, massive impact, and an explanation created afterward that makes it appear less random and more predictable than it was. For an event to be a black swan, it need not just be rare; it also must be unexpected and lie outside the realm of possibilities. The historic record provides the means to determine the applicability of this concept to confined space incidents.

The concern then turns to determining whether such incidents are *gray swans* (Taleb, 2007). Gray swans are rare events that are amenable to modeling. Comparison of current records on the OSHA website with those available from the past indicates that the same incidents do recur. The descriptive model created from reconstruction following deconstruction and analysis of past events provides a predictive narrative of what occurs in some situations. The fact that past records describe events that are occurring now highlights the value of this history.

This concurrence argues for careful compilation of incident records as resources for present and future inquiry. Failure to determine, then to create and implement guidance about the level of detail expected in incident investigation documents will continue to limit the information that can be derived from each tragedy and incorporated in preventive measures. **PS**

References

ANSI/ASSE. (2009). Safety requirements for confined spaces (ANSI/ASSE Z117.1-2009). Des Plaines, IL: Author.

Beaver, R.L. & Field, W.E. (2007). Summary of documented fatalities in livestock manure storage and handling facilities: 1975-2004. *Journal of Agromedicine, 12,* 3-23.

Curry, D.G. (2002, March). In-vehicle cell phones: Fatal distraction? *Professional Safety, 47*(3), 28-33.

Kingman, D.M., Field, W.E. & Maier, D.E. (2001). Summary of fatal entrapments in on-farm grain storage bins, 1966-1998. *Journal of Agricultural Safety and Health, 7,* 169-184.

McManus, N. (1999). *Safety and health in confined spaces.* Boca Raton, FL: Lewis Publishers/CRC Press.

McManus, N. (2009, June). Confined space: A paradigm that has outlived its usefulness. Presentation at the American Industrial Hygiene Conference and Exposition, Toronto, Ontario.

McManus, T.N. (2012). *Management of hazardous energy: Deactivation, de-energization, isolation and lockout.* Boca Raton, FL: CRC Press, Taylor and Francis Group.

Muncy, C. (2013,). The 60% statistic. *The Synergist, 24*(2), 24-26.

Meyer, S. (2003, Nov.). Fatal occupational injuries involving confined spaces, 1997-2001. *Occupational Health and Safety, 72*(11), 58-64.

Meyer, S. (2004a). Fatal occupational injuries to workers in a confined space, 1992-2001. Printout of data from BLS database. Washington, DC: BLS.

Meyer, S. (2004b). Confined spaces: Fatal occupational injuries involving confined spaces to all workers by selected characteristics, 1997-2001. Printout of data from BLS database. Washington, DC: BLS.

Moore, L.R. & Moore, G.S. (2001, June). The impact of cell phones on driver safety. *Professional Safety, 46*(6), 30-32.

MSHA. (1988). Think "quicksand": Accidents around bins, hoppers and stockpiles, slide and accident abstract program. Arlington, VA: Author, National Mine Health and Safety Academy.

MSHA. (1994). Hazard information alert: Confined space fatalities—57 since 1980. Washington, DC: Author.

NIOSH. (1979). *Criteria for a recommended standard: Working in confined paces* (NIOSH Publication No. 80-106). Cincinnati, OH: Author.

NIOSH. (1994). *Worker deaths in confined spaces* (NIOSH Publication No. 94-103). Cincinnati, OH: Author.

NIOSH. (2014). Fatality assessment and control evaluation (FACE) program. Retrieved from **www.cdc.gov/niosh/face**

NSC. (2010). Understanding the distracted brain. Retrieved from **www.distracteddriving.nsc.org**

OSHA. (1982a). Selected occupational fatalities related to fire and/or explosion in confined work spaces as found in OSHA fatality/catastrophe investigations. Washington, DC: Author.

OSHA. (1982b). Selected occupational fatalities related to lockout/tagout problems as found in reports of OSHA fatality/catastrophe investigations. Washington, DC: Author.

OSHA. (1983). Selected occupational fatalities related to grain handling as found in reports of OSHA fatality/catastrophe investigations. Washington, DC: Author.

OSHA. (1985). Selected occupational fatalities related to toxic and asphyxiating atmospheres in confined work spaces as found in reports of OSHA fatality/catastrophe investigations. Washington, DC: Author.

OSHA. (1988). Selected occupational fatalities related to welding and cutting as found in reports of OSHA fatality/catastrophe investigations. Washington, DC: Author.

OSHA. (1990). Selected occupational fatalities related to shipbuilding and repairing as found in reports of OSHA fatality/catastrophe investigations. Washington, DC: Author.

OSHA. (1993, Jan. 14). Permit-required confined spaces for general industry: Final rule. *Federal Register, 58*(9), 4462-4563.

OSHA. (1999). Multi-employer citation policy (CPL 2-0.124). Washington, DC: Author.

OSHA. (2014). Fatality and catastrophe investigation summaries. Retrieved from **www.osha.gov/pls/imis/accidentsearch.html**

Reason, J. (1990). *Human error.* New York, NY: Cambridge University Press.

Riedel, S.M. & Field, W.E. (2011). Summary of over 800 grain storage and handling-related entrapments and suffocations documented in the U.S. between 1970 and 2010. Presentation at XXX-IV CIOST-CIGR V Conference, Vienna, Austria.

Santayana, G. (1980). *The life of reason.* New York, NY: Dover Publications.

Taleb, N.N. (2007). *The black swan: The impact of the highly improbable.* New York, NY: Random House.

Thackrah, C.T. (1831). *The effects of principal arts, trades and professions, and of civic states and habits of living, on health and longevity.* Philadelphia, PA: Henry Porter.

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