Chemical Plant Safety

Applying the Tools of the Trade to a New Risk

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After the events of September 11, make sure your plant's safety plan accounts for acts of terrorism and sabotage.

For years, those employed in the chemical industry have known that the safe operation of chemical plants is essential to the industry's continued ability to survive. The human, political and financial costs of having accidents are just too high for the chemical industry to not exhibit excellence in their efforts to operate plants in safe and environmentally responsible ways. Almost without exception, it has succeeded.

Each year the chemical industry and airline manufacturers vie for the distinction of best-employee-safety record *(1)*. The chemical industry has an outstanding record in both transportation safety and the safe operations of its processes. As with most other industries, once it was recognized how much of an impact the chemical industry was having on the environment, it began working to turn that performance around. That effort has resulted in a dramatic and steady decline in releases and waste produced from chemical sites. For example, the National Institute for Chemical Studies (NICS) stated in its executive summary of the West Virginia Scorecard Toxic Release Inventory by Manufacturing Sector that "The chemical industry has eliminated the most local releases with a drop of 22.3 million pounds" *(2)*.

When we have had problems, they have served to reinforce the importance of diligence in operating ever-safer sites. Process incidents such as those at Flixborough *(3)*, Seveso *(4)*, Bhopal *(5)* and most recently Toulouse *(6)* cannot and should not go unheeded (*CEP*, Jan. 2002, pp. 44–45). Over the years, the chemical industry has spent tremendous resources (intellectual, human and financial) on learning and applying tools and techniques to make our plants ever safer. Some of the tools we have developed have been described and chronicled in the works of AIChE's Center for Chemical Process Safety (CCPS, Box) *(7)*.

As an industry, extreme care has been taken to identify, analyze and control hazards of all types at our sites. The industry thought it had most of the major incident types thoroughly covered — that is, until Sept. 11, 2001.

As I (Patrick) stood watching the unthinkable unfold on one of the few televisions in our plant, I looked out the window of our office building and wondered what we would do if one of the terrorists were headed for us. My answer frightened me. All we could have done was watch, and then react, just as the people in New York, District of Columbia and Pennsylvania had done. We don't have anti-aircraft weapons or fighter jets to protect our plant. And, if they could get to targets like the Pentagon, what hope did we have? I can't help but think I was only one of literally millions of people thinking the same thing at the same time that day.

After the initial sense of helplessness faded, we considered just what would happen if terrorists picked our site for their next target. We found that all of the work we have done to prevent traditional types of accidents in our plant would also serve us well if the initiator of the incident were a terrorist or saboteur. When we accounted for these more-clandestine aggressive initiating causes in place of the potential causes we have typically considered, we realized that our reactions to many potential criminal efforts would be the same as for less sinister initators. These actions have not only been the result of committed professionals, industry initiatives and companies that truly want to be good corporate citizens, but also regulators, community partners and activists that hold the industry to a minimum standard none should fall below.

Some terrorist-proof measures are already in place

To illustrate these points, consider the examples of what would happen if a terrorist or saboteur attempted to break a bottom valve off of a tank of hazardous chemicals, or tried to start a fire, or tried to mix incompatible material in a process, or any number of other actions that they might think would cause a serious chemical plant accident:

• In most cases involving large volumes of highly hazardous chemicals, excess flow valves are in place that would stop a rapid flow of the chemicals.

• Processes and storage have been segregated, separated or protected to limit large volumes or events where one action could trigger multiple consequences.

• Where highly hazardous chemicals are involved, processes have fixed protection, as well as trained emergency response teams that could handle the incident.

• Anyone trying to cause a major incident would have to know enough about our processes to know what to mix and in what quantities, how to get it into the process, how to get past site security, and then how to avoid being seen by our operators who rove the units watching for process abnormalities 24 h/d. These operators have been trained to notice something as subtle as a different sound in a pump, so a strange package or person in the unit should certainly stand out. After Sept. 11, everyone is at a continuous heightened level of attention to these details, seems with no hesitancy to react or sound an alarm when something is amiss.

• Hazardous contamination scenarios have been considered in safety reviews. Appropriate reaction control or inhibiting systems are in place to interrupt runaway reactions if cooling and pressure relief are not considered adequate.

• Control systems are designed to detect heat or pressure of a chemical reaction and to control that reaction.

• Most highly hazardous chemical processes are designed so that they can be put under negative pressure and the contents contained, and then destroyed, neutralized or sent to a safe holding area.

• These same measures are in place to receive chemicals from relief systems if they are activated.

• If, for some reason, terrorists were able to overcome

Other Sources of Information on Security and Terrorism

- October 2001 Site Security Guidelines for the U.S. Chemical Industry ACC, Chlorine Institute and SOCMA
- Relevant CCPS books (www.aiche.org/pubcat):
  1. Plant Guidelines for Technical Management of Chemical Process Safety
  2. Guidelines for Hazard Evaluation Procedures, 2nd edition, with Worked Examples
  3. Guidelines for Chemical Process Quantitative Risk Analysis, 2nd edition
  4. Tools for Making Acute Risk Decisions
  5. Layer of Protection Analysis
  6. Guidelines for Consequence Analysis of Chemical Releases
  7. Inherently Safer Chemical Processes
  8. Guidelines for Safe Storage and Handling of Reactive Materials
  9. Guidelines for Safe Storage and Handling of High Toxic Hazard Materials
  10. Guidelines for Safe Warehousing of Chemicals
  11. Guidelines for Chemical Transportation Risk Analysis
  12. Guidelines for Process Safety in Outsourced Manufacturing Operations
  13. Contractor and Client Relations to Assure Process Safety
  14. Guidelines for Technical Planning for On-Site Emergencies
- NFPA Hazardous Material Guide
- U.S. Coast Guard — Security Risk Assessment Survey
- U.S. Military 130th Security Forces Squadron — Domestic Terrorism & Fundamentals of International Terrorism
- U.S. Postal Service
- F.B.I. (local office)
- State police and other state agencies — Local Homeland Security Dept.
- Chemical Hazards of the Workplace — Proctor and Hughes, 4th ed., Toxicological Concepts, Nick H. Proctor, PhD.
- Emergency Response to Terrorism, 1st ed.; Joint partnership of the Federal Emergency Management Agency , U.S. Fire Administration, National Fire Academy and the U.S. Dept. of Justice Office of Justice Programs
- State of West Virginia Chem-Bio Handbook: West Virginia Office of Emergency Services; Building 1, Room EB–80, 1900 Kanawha Blvd, E. Charleston WV 25303-0360; Phone: (304) 558–5380; Fax: (304) 344–4538
- 2000 Emergency Response Guidebook: U.S. Department of Transportation, Research and Special Programs Administrations
- National Institute for Occupational Safety and Health: Pocket Guide to Chemical Hazards DHHS (NIOSH) Publication 85-114
- Chemical Hazards Response Information System (CHRIS), http:// www chris manual.com

Date: 01-15-01 Site: XYZ Chemical Unit: ABC Production Train Node: Raw Materials Storage Revision: 9	Deviations List	Drawing 123456-01A1 Main Equipment: Field Storage Tank T-101	Page 98

Equipment or line	Deviation	Causes	Final event - Effects & Consequences	S	IP	R	Detection - Action	N	FP	FR	RS
T-101 Storage Tank	Contamination	Inadvertent – Contaminant accidentally added Sabotage – Contaminant intentionally added	Violent reaction leading to high pressure and temperature & toxic gas formation. Rupture of Tank due to runaway exothermic reaction. Would result in fatalities, environmental impact, legal implications, damage to company image, and financial losses.	C	2	1	Pressure relief valve plus bursting disc (adequately sized?) Blow down through vent system to Flare (not capable of preventing tank rupture) Daily analysis for contaminant content of all material fed to Storage Tank and on Storage Tank contents itself	? 0 0	2	1	001

Figure 1. Sample of a HAZOP deviation table.

all of these systems, long-standing efforts to work with communities surrounding the site would activate and initiate community responses, such as evacuation or shelter-in-place *(8)*, limiting the impact of terrorist actions.

These are only a few of the more obvious examples of what were already in place well before Sept. 11. Most of the problems outsiders or ill-willed insiders could do to cause a serious chemical accident had been considered with different initiators. They had been considered in original designs of chemical processes, previous accident investigations, regulations, and process hazard analyses (PHAs) conducted and revalidated over the years. Redundant and robust systems to prevent or react to these scenarios were already in place.

Problems such as high and low temperatures or pressures, abnormal contents, higher or lower than normal flows, fire exposures, and virtually every other process variable designers could think of or the industry had learned over the years were considered. "What-if" questions were asked and answered. Checklists were constructed from years of learning from operating processes and experiences gained from thorough accident investigations. The procedures were applied to ensure that virtually nothing was overlooked when considering additional safeguards. Furthermore, PHAs are revalidated every five years to keep up with new information, lessons learned, and methods to continuously improve on previous work.

However, it was also found that, for the most part, terrorism and sabotage had not been specifically considered as initiating events for process incidents, especially on a scale as was seen on Sept. 11. Even though a number of controls are in place, there is still a concern that something might have been missed. What would be found if the questions "What-if" a terrorist attack was waged on our site or "What-if" we had an employee or visitor who was a member of a terrorist group that wanted to cause problems at the site? Are chemical processes adequately protected against terrorism or sabotage? Hadn't Bhopal, Sept. 11 and now Toulouse awakened most of the world to the possibility of terrorism or internal sabotage? These questions need to be answered.

When considering these questions, think of them with the same degree of diligence given to the other variables that have been reviewed for years. To gain necessary perspectives, consult with internal security professionals, their peers and external security agencies. Involve them in the review early so their opinions and information can be fully considered in reviews related to their expertise on securing site perimeters, controlling access by outsiders into the plant, and establishing procedures or guidelines that all can accept.

Your review will undoubtedly identify security actions that need to be taken immediately. Some of those had been identified prior to Sept. 11, but due to the U.S. strength and our sense of security as a nation, we had grown lax in this area. We should learn from the experiences of other nations that we can ill afford to let our guard down again.

Some of the site-security-related actions to be taken may include:

- improve fencing
- install lights in areas where it is dark and that might be easy access points
- add remote cameras where frequent patrols are impractical
- take steps to limit the number of suppliers coming on site
- for those suppliers that do enter the site, be sure their drivers are who they say they are and check their employers
- reduce the number of contractors onsite and take steps to verify that those who remain have been checked out
- tighten control on caterers and janitorial service providers working in your plant
- set policies and train people handling mail to know what to watch for and what to do if they discover suspicious mail
- work more closely with local and state law enforcement groups
- make sure you have good communication lines with the FBI and Coast Guard.

These are a few of the actions recommended by security experts. Take these and other actions recommended by

Risk Sheet n° 001								
Ref. Doc.: P&ID # 1234567		Rev. n°: 0		Date: 01-31-01			D.Sheet 6	
Plant	XYZ Chemical		**Facility**		ABC Production Train			
Section	Raw Materials Storage		**Equipment**		**STORAGE TANK T-101**			
Undesirable Event	**Release of toxic gases resulting in on and off-site fatalities.**							
Cause(s) necessary for the event	1 – Inadvertent or deliberate addition of a contaminant to Tank T-101 containing reactive material – remote possibility.							P
Scenario leading from the causes to the event and to its consequences								
Inadvertent or deliberate (sabotage) addition of a contaminant to Tank T-101, which contains reactive material. Violent reaction results leading to the formation of the toxic gases. Rapid pressure build-up ruptures tank releasing toxic decomposition gases and remaining tank contents. *SEVERITY TO:* People: Catastrophic — Injuries/fatalities on and off-site from exposure to toxic gases. *Environment:* Low — Release will exceed reportable quantities. No off-site environmental impact. *Image:* Catastrophic — Negative international media coverage that affects the company's reputation. *Legal:* High — Interruption or withdrawal of an operating permit. Potential for court case. *Financial:* Catastrophic — Losses >$40 million due to injuries, property damage, liability, business interruption, and potential fines.								
Consequences of the event	People	Envir.	Image	Legal	Finance	Severity	Probability	Potential Risk
	C	L	C	H	C	**C**	**2**	**1**
Means of prevention: limit the probability of the event								**N**
Site security (physical barriers, security patrols, contractor & delivery driver picture ID's required)								0.5
Personnel background checks for employees								0.5
Access to storage area is restricted								0.5
No source of contaminant in area (need to connect several lengths of hose)								1.0
Pressure relief valve sized to prevent tank rupture for water contamination scenario								1.0
Refrigeration of tanks to slow reaction with water								1.0
Vented through scrubber and flare system to destroy toxic gases								1.0
All valved fittings locked with SOP for removal								1.0
Employees trained to respond to reactive tank								0.5
Means of protection: limit the severity of the consequences								
Underground storage tank limits release.								
Event with means of prevention and/or protection								
Residual Scenario	People	Envir.	Image	Legal	Finance	Severity	Probability	Residual Risk
	H	L	H	M	H	**H**	**4**	**3**
Present at risk assessment Assessed by							Ref RS_001-010.doc Printed 12-07-01	

Figure 2. Sample risk sheet completed for a reactive chemical.

these professionals.

But don't stop there. In the chemical industry, when something represents a significant risk, one or even two layers of protection are not enough *(9)*. Consider what else needs to be done. Use the same tools we have used for years. The even-more-real threat of terrorism or sabotage has to be added to the list of variables we need to consider in our process hazard reviews. Considering these variables in retrospect, you will find that the well-thought-out tools and processes that have been used for less sinister variables continue to work best. When a system is designed on sound theory and accumulated experience, it just works, regardless of what hazard is being considered.

Good systems and analytical tools work well and give the results needed, but there is no single answer for even very similar questions across different processes, sites or companies. To try to provide something useful for the many varied processes and company cultures that read this paper, it is best to provide examples of how to use standard chemical industry tools to consider the hazard of terrorism or sabotage at our sites. The remainder of this paper is intended to provide examples of how to do just that.

Identify additional hazards presented by terrorism or sabotage

The first objective should be to identify the vulnerable areas at a site or in transportation of hazardous chemicals. This can be done using traditional process safety tools and techniques *(10)*.

Simply add terrorism and sabotage to your HAZOP keyword list and consider the "target value" from a terrorist's perspective, difficulty in initiating the event, and the barriers in place to prevent the various steps necessary to reach the end result from occurring. Consider the results of this HAZOP team dialogue just as you would other keyword discussion, such as "High Temperature," "Low Flow," "Loss of Vacuum" and whatever other keywords your system happens to use.

To consider "target value" examine the following:

• Impact — If a terrorist successfully attacks a process, what would be the impact?

• Accessibility — How difficult would it be for them to achieve a successful attack?

• Hysteria value — Does this process have any special hysteria factor that would increase its target value (*i.e.*, biohazard, radioactivity, dioxin, etc.)?

• Usefulness as a weapon — Are the chemicals, isolated intermediates or raw materials, products that, if stolen, could be used as terrorist weapons? How much would they need? How difficult would it be to steal or transport if stolen?

• Essential supply — Would the loss of a particular process seriously impact the nation's infrastructure? Is it produced in adequate quantities elsewhere to meet demands if this process was lost?

Include specific lines on a checklist to consider terrorism and sabotage. And ask the question "What-if a terrorist group wanted to attack a particular element of the process?" or "What-if a disgruntled employee or one with ties to a terrorist/extremist group wanted to cause damage at a certain point?"

If you are using failure-mode and effect analysis, fault tree or any other system, the same adjustments can be made to include these considerations. Figure 1 is a sample of a HAZOP deviation table considering these questions.

Analyze the adequacy of control measures in place and necessary additions

The second objective should be to analyze the control measures that are in place and their effectiveness. Consider what other measures are needed, and then take actions to improve existing ones and put new needed ones in place. Many different methods can be used to complete this step. One example is the Risk Sheet. Figure 2 is a sample Risk Sheet completed for a reactive chemical.

An additional note regarding to documentation of any terrorism or sabotage issues should be considered. Many law enforcement agencies, security groups and legal departments would prefer that dialogue and documentation on these variables not be included with routine PHA work. Their reason for concern is this work could provide too much information on how a site prepares to prevent actions by, and react to, terrorists and saboteurs. In the final analysis, each company should determine how it wants to deal with these issues. Consider the effect on the quality of the review, if the review team were limited and did not include the standard complement of technical specialist, operators and maintenance representatives. Also consider the added level of complexity to the filing and retrieval of important information if the results were kept separate from other files. There would also be a question as to whether or not conducting the analysis and not sharing the information with affected employees for the sake of security would meet the intent of OSHA's Process Safety Management (PSM) regulations. The arguments for restricting access and inclusion are both compelling.

Another way to analyze a specific scenario is to treat it as if the event or the initiating action has happened and then apply an appropriate incident analysis tool *(11)*. In Figure 3, the causal-tree method is used.

Considering the same reactive chemical scenario described above, the following has been developed as a partial example of how to apply to this traditional tool to this non-traditional hazard.

The unwanted end result would be contamination of the storage tank. Then, the tree would be built either in the traditional fashion of identifying all of the facts related to the potential incident or simply using the logic of "Necessary" and "Sufficient" to fill in each branch, the latter being more efficient, but requiring a deeper understanding of the process.

From the construction of the diagram, weaknesses in the protection of Tank T-101 from terrorist or sabotage attack could be identified and addressed. For example, thinking through the tree might trigger the site to implement the following actions:

• reinforce its general security

• add cameras and lighting to remote spots

• limit contractors and deliveries.

• require all bulk shippers to provide a list of driver names and photo identification for all truck drivers, matching the two prior to granting access

• establish a plan to react to terrorists crashing gates.

• review backgrounds of all new employees and those hired within the last five years

• inspect all incoming rail cars to confirm that no one has hidden on board the car and that there are no unusual packages

• train operators to watch for unknown individuals or suspicious items on their rounds

• relocate small-package pick-up and delivery to outside the secure perimeter, if onsite delivery is allowed

• review potential attack modes and protection of barge docks and coordinate efforts with the Coast Guard team patrolling the waterfront

• install additional physical barriers in front of sensitive process areas

• review precautions put in place due to hazards identified in routine PHA work; be sure they are adequate for sabotage or terrorist scale scenarios, and that they are in place and operational

• add specific training for the site and mutual-aid-emergency response squads for what they should do for different scenarios. The lessons of the World Trade Center have taught us the error of responding too soon, and too near, when terrorists are involved. We need to identify when to intervene and when to hold back until it is safe for response teams to attack the problem.

These and numerous other direct actions can be

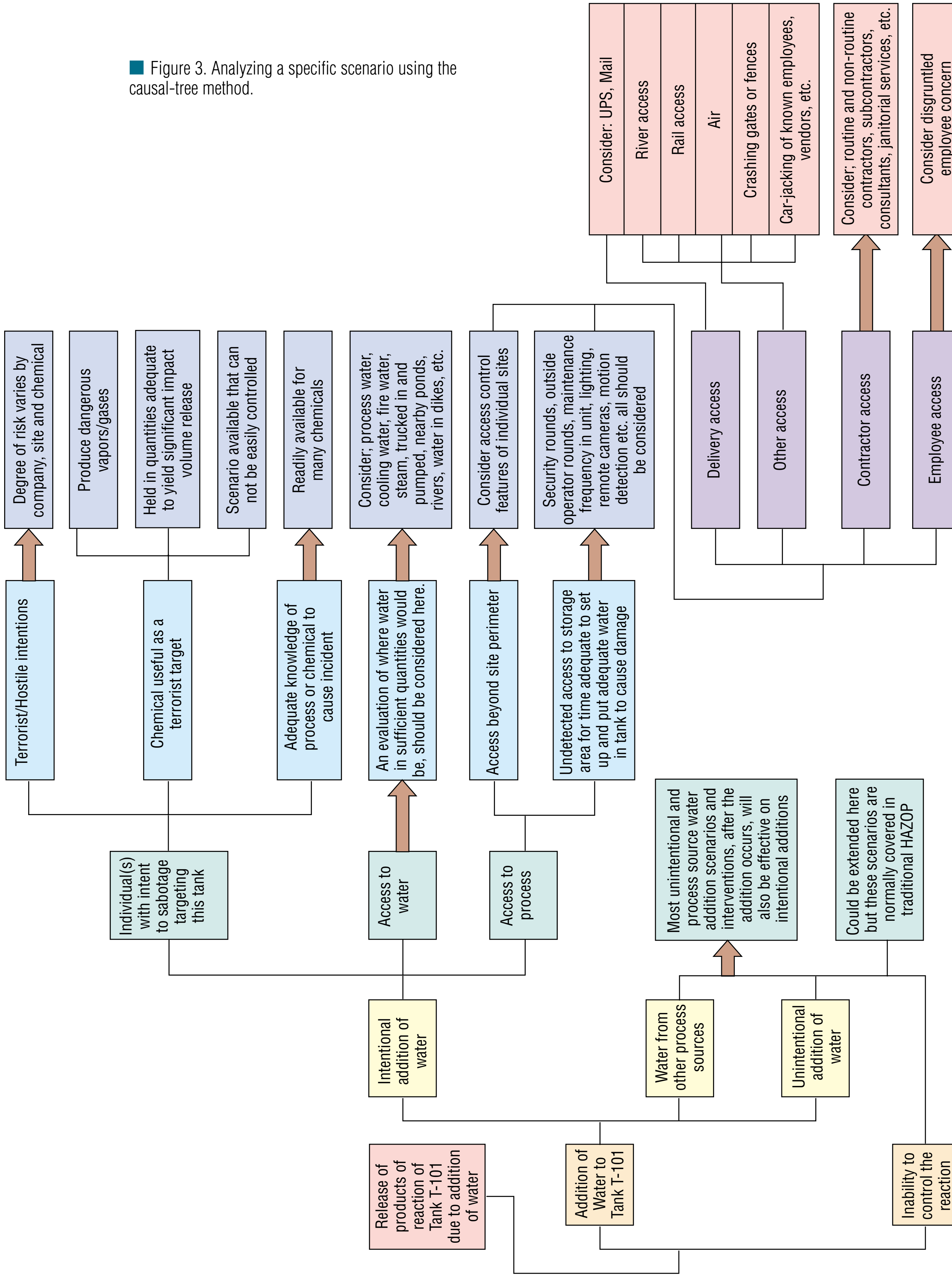

Figure 3. Analyzing a specific scenario using the causal-tree method.

taken. Good analysis of the potential attacks a site might be vulnerable to helps to quickly direct the resources to the areas most needed.

Controlling the additional hazards presented by terrorism and sabotage

Unlike most other hazards, secrecy in how to deal with threats of terrorism and sabotage should be considered an important layer of protection. Not showing information in this case is a deterrent. Those wishing to inflict harm on our nation or companies will be less anxious to do so if they are not confident their acts will succeed. If measures are in place that would thwart those actions, it is important that terrorists do not know what they are.

The other major difference in considering these hazards is that, for the first time, an intelligent initiating cause needs to be considered. Pressure, temperature, flow and chemistry are complex issues, but not intelligent. Once the hazard has been identified, it can be controlled. With terrorism or sabotage, we must be ever-vigilant in watching what is being tried around the world and incorporating what is learned into our own control schemes. If a control prevented an incident today, the next time an attempt is made, the terrorists will have learned their lesson and adjusted their plan.

We have to take a lesson from those brave souls on the Sept. 11 flight that went down in Pennsylvania. When they learned what the terrorists had in mind, they acted and kept them from accomplishing their primary goal. Today, more than ever before, it is important that we maintain open lines of communication among industry peers to learn and improve our ability to control consequences of terrorist acts. As of this writing, we still do not know much of the true cause of the accident those few days after Sept. 11 in Toulouse, France. Regardless of the cause of this, it is as important that we learn from these incidents. The result of these terrorist acts cannot be the closing off of communication about accidents and important lessons from them.

Remember, most controls for the consequences of terrorist-initiated chemical process incidents will be the same as controls for the same hazard caused by any other non-terrorist initiator. Treat them as such. Put the proper barriers and layers of protection in place to control what they might cause. The chemical industry has learned from, and professionally responded to, the other tragic lessons learned. This case of terrorists attacking U.S. buildings and innocent citizens of the world is no different. CEP

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