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The Benefits of Procedural PHAs

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Abstract

Procedural PHAs are a valuable tool for examining operating procedures and can be completed either while writing or updating a procedure. Historically, 70% of major accidents have occurred during non-routine operations. Using a Procedural PHA to review the appropriate course of action for those operations can help identify potential hazards and suitable safeguards, thus preventing or lessening incidents.
In this presentation we teach how and why to use Procedural PHAs. Procedure heavy processes like loading/unloading, start-up/shutdown, complex valve configurations, by-pass of independent functions and batch processes benefit from using this approach.

We share how Procedural PHAs are an excellent tool for non-standard operations and show ways this approach can help you identify improvements for your procedural heavy processes to provide a more in-depth look at what could go wrong.

Keywords: Procedural PHA, PHA, Managing Process Safety for Non-Routine Operations

1 Introduction

A Procedural PHA applies a HAZOP or What-If style technique to the steps in a procedure to identify hazards and ways to mitigate the hazards. Performing a PHA of the written steps of a procedure can be used to identify critical steps that may have been missed during development of the procedure as well as uncover areas that may lack clarity or necessary details which may cause potential hazards during the use of the procedure.

There have been twenty incidents over the past twenty years where OSHA and/or CSB investigations specifically noted issues with procedures as contributing factors to the incident. A table of those incidents is provided in Appendix A. Of those twenty incidents, 85% were attributed to unloading, batch processes and non-routine operations (start-up/shutdown/maintenance) with 65% during non-routine operations showing a need to examine procedures systematically to uncover issues.

2 Regulatory Requirements

From an OSHA, EPA and RAGAGEP perspective, sites are required to review all modes of operation including non-steady state. Often these modes of operation are best covered through a review of the procedures.

OSHA documents, including citations, internal PVQ audit guidance documents, and NEP inspection guidance reference the need to review procedures for hazards.

Local requirements may also apply, for example the guidance documents for Contra Costa County Health Services Industrial Safety Orders in California include reference to performing Procedural PHAs.

3 What is a Procedural PHA

- Procedural PHA applies a HAZOP or What-If technique to the steps in a procedure to identify hazards and ways to mitigate the hazards.

Procedural PHAs are done similarly to the way a regular PHA is done. You break down the procedure into smaller pieces and analyze them using guidewords. The steps within the procedure may also be grouped together based on parameters, much like pieces of equipment would be grouped in a PHA for equipment or reviewed separately.

Like in a regular PHA, it is not always clear where to break down the steps. Additionally, it may not be appropriate to create different nodes. Some procedures can be evaluated as one node, each step or phase change being a “what it” and analyzing them using the different deviations. Other procedures may be so complicated that different steps or phases become different nodes. The point is, like a standard process hazards analysis, the complexity of the procedure will determine the path you take.

However, trying to generically capture procedural related causes during a standard PHA by simply stating “failure during start-up” for example, can lead to failure to identify potential consequences that could occur and safeguards. Therefore, conducting a procedural PHA can drive a more precise cause-consequence pairing and thus ensure correct safeguards exist and/or good recommendations are made to cover the risk gap.

Using a Procedural PHA approach can identify critical steps and unique hazards that may occur if the procedure is not understood or followed. The purpose is to identify and evaluate those accident scenarios that may result during utilization of the procedure and ensure appropriate safeguards are in place.

4 Why use a Procedural PHA

First, it is a better fit than standard PHA/LOPA for identifying causes associated with a procedure. The more procedure specific cause-consequence pairing ensures correct safeguards exist for the scenarios and identifies risk gaps to be addressed.

When identifying human factors related causes associated with a procedure many of the safeguards would not be independent of the cause (ie. human failure to complete a step according to the procedure), thus invalid. So, then the real question becomes is the procedure robust enough to mitigate risk associated with its execution. Procedural PHAs can identify potential pitfalls inherent to the procedure.

It addresses concerns with procedures that may include:

Is the procedure robust enough?

Are steps in correct order?

Is the wording specific enough?

Is additional verification needed**?**

All of these things can be identified during a procedural PHA.

5 How to set up a Procedural PHA

There are a couple of ways to set up a procedural PHA depending on the complexity, the length, and the desired outcome.

If it is a relatively short or simple procedure, you may choose to list each deviation, then review every relevant step within that deviation, identifying consequences as you go.

Deviation	Causes	Consequences
1. Does not complete step	1. Miss step1 in 5030.2 procedure	1. Potential decreased vacuum in seal pot
	2. Miss step 6 in 5030.2 procedure	1. Potential decreased vacuum in seal pot. Not a consequence of interest
	3. Miss step 12 in 5030.2 procedure	1. Potential high level in the absorber column may lead to carry over. [redacted]
	4. Miss step 13 in 5030.2 procedure	1. Potential to run DI water tank dried. [redacted]
	5. Miss step 16 in 5030.2 procedure	1. Potential pump damage. [redacted]
2. Does more than the required step	1. NA	
3. Less is performed in a quantitative sense. (80 lbs added instead of 100 lbs.)	1. Step 20 in 5030.2 procedure	1. Less than 63" added to column may lead to loss of level on start up, resulting in loss of suction in pump. [redacted]
	2. Step 22 in 5030.2 procedure	1. Less than 60% opened may lead to backing up the abosorber
	3. Step 25 in 5030.2 procedure	1. Potential loss of cooling water in HP plant leading to high temperature. [redacted]

Alternatively, you may begin by breaking down the procedure into smaller pieces to analyze using guidewords/ "What-if" questions. The procedure steps become nodes or system/sub-systems and design intent is the content of the step to be performed. It is acceptable to group 2 or 3 steps together that have the same parameters, much like pieces of equipment would be grouped in equipment based PHA.

Nodes
1. Rail Switching Logistics
2. Locomotive Start up
3. Locomotive Switch Railcars
4. Locomotive Shutdown
5. Rail Safety Policy

Node 1 [redacted] Prepn - Sulfuric Acid from T-60 to T-24 [redacted]

Node 2 [redacted] Prepn - Sulfuric Acid dilution (Water Softener & T-24)
Node 3 [redacted] Prepn - Isobutylene addition from T-71 to T-24 (Reactn) [redacted]

Node 4 [redacted] Prepn - Reaction finishing (Agitation) (T-24)
Node 5 [redacted] Prepn - Vacuum removal of unreacted isobutylene (T-24 & TO)
Node 6 [redacted] Prepn - [redacted] cooling and hold-up (T-24)

The complexity of the process will determine the best approach.

Essentially the same concept goes into analyzing a procedure as does a process, however, you use different guide words. Guidewords (for HAZOP)/questions (What-If) are applied to identify possible failures in following the procedure that could result in possible hazards or releases by skipping steps or inadvertently performing a step inaccurately.

Guidewords/questions are also used to identify procedural deficiencies or incompleteness. The deviations are different and are related to steps in a procedure. Some may be the same that you are used to seeing. Below is a table of some of the common deviations used in procedural PHAs.

Common guidewords/questions	
Missed step	Steps completed out of order
Valve opened too far/not far enough	Valving configuration/complexity
Valve locations	Temperatures
Rate of change / temperatures	Too much heat/Not enough heat
Rate of change / time	Too much time/Too little time
“Cooking” time required	Too much mixing/Not enough mixing
Wrong material	Wrong concentration of material

Changes in parameters are good places to separate steps. It is important to take note of things like:

- temperatures, (“cooking”) time required,
- ramping up/down times/temperatures,
- valves that are too far apart for one person to manage in the time required,
- valving line-ups that are too complex to manage in the time allotted when grouping.

<u>Discuss how you intend to address Risk Ranking!</u>

Risk Ranking can sometimes present a challenge due to the potential lack of independence between cause and safeguards, especially if you are using a LOPA like process for crediting safeguards. If this is the case, there is a tendency for teams to want to provide engineered solutions which then can create different and unintended consequences. So, it is imperative to discuss with management how you should address risk ranking if you know that you may fall short of enough independent safeguards. Some companies allow more leniency in utilizing human based safeguards when completing a Procedural PHA, and some choose to conduct Human Factor based studies for high-risk activities and address accordingly. Just be sure to have clarity on what is appropriate for the site, as many sites do not yet have guidance on conducting a procedural PHA.

5.1 Two Approaches for Recommendations

There are two basic approaches that can be used to document any changes needed to improve the procedure.

<u>Approach 1: Generate a recommendation list to update the procedure (like in a standard PHA recommendation list)</u>

Using this approach the team identifies the changes, additions, deletions that are recommended, (along with the reason why) in the PHA worksheets using the Recommendations column to capture cautions, hazards, recommended tools, etc. For example:

Update Procedure #XX to include a step to open valve XY before step 32

<u>Approach 2: The outcome is the actual procedure</u>

For a new procedure in a new process, you can use the recommendation column of the PHA worksheets to create and modify the procedure as you go.

For a new procedure in a "cloned" process, you can track changes or modifications to the procedure in the recommendations column as well as have a team member red-line a copy, much like drawings would be red-lined during a PHA if an error was found.

6 Four Key Applications of Procedural PHAs

There are 4 primary areas that benefit from conducting a procedural PHA, those include:

1. Batch processes
2. Heavily procedural driven processes, such as unloading/loading procedures
3. Manual/Complex valve configurations

4. High hazard activities with high active failure potential (i.e. Start up, Shutdown procedures)

Each application will be discussed in more detail below.”

6.1 Batch Processes

Batch process can be reviewed by procedure or by equipment. When done by procedure, you may often cover the same piece of equipment several times. The benefit of that is that you identify the correct consequences/safeguard combinations based on the phase of the operation. If you complete a batch process by equipment, it may be easier to overlook a consequence or necessary safeguard.

Looking at it from a procedural aspect, a natural place to group steps are based on stages of the batch process.

Additionally, batch process steps can be computer or human driven, so it is important to understand which part is which.

For example, when you have a completely computer-generated batch process, the questions become,

“What if a valve sticks open (or closed) during X phase?

Alternatively, if the process is fully human driven, the questions may be,

“What if Valve A is opened in place of Valve B?” or

“What if temperature is ramped up too quickly?”

Then, if the process is partially human driven, i.e., the operator adds A material at step Y, then you have questions like,

“What if too much (little) material is added?”

“Can the material be added at the wrong point of the process?”

6.2 Human Heavy Processes: Loading/Unloading

Historically, there have been several incidents and near misses during loading & unloading processes. Loading/Unloading presents whole set of different hazards than “normal” procedural PHA because there is often 3rd party involvement. As such there are several pieces of information to look for before even beginning.

The list below is some of the common things to consider when reviewing loading/unloading.

1. Does the site use a single trucking company for delivery or several?
2. Does the trucking company have its own safeguards?

   Are they a requirement per DOT, and/or a requirement as part of their contract?

Can they be counted by the site for credit? (Usually not)

3. How many steps and people are involved in placing & receiving an order of material?

   Think about the purchasing process, Bill of Lading, weighing the truck, etc. These may become part of a safeguard identifying multiple people involved.

4. Is the material to be loaded/unloaded in a classified area? How is the area classification maintained?

5. How is the truck secured? Who secures it?

6. Is the truck driver involved in the loading/unloading?

   If not, where do they remain during the process? a safeguard identifying multiple people involved

There are several other elements involved in looking at loading/unloading which are often covered in the procedure and therefore the PHA. The items listed above are just SOME of the things that may be overlooked.

During a PHA for loading/unloading, depending on the process, you may use both standard deviations and procedure-based deviations.

Deviations	Guide Word	Parameter
1. Wrong/ Missed Sequence	Other than	Sequence
2. Low/No Flow	Low/No	Flow
3. More/High Flow	More	Flow
4. Not enough Time	Less	Time
5. Too much Time	More	Time
6. Reverse/ Misdirected Flow	Reverse/Misdirected	Flow

6.3 Manual/Complex Valve Configurations

Many times, you will come across a series of complex valving configurations, such as a set of parallel dryers that have a regeneration mode. When they are operated manually or partially manually, they can lead to errors during the valve switching. Many sites been moving toward automating these valve sequences, however, not all.

When looking at a system like this, it is possible to set up two nodes (my preference). One node for "normal operation" and a second for "regeneration" and assume one direction.

Then, a valve that is closed in normal operation and open as part of the regeneration phase can be reviewed as a "failed open" or "inadvertently left open" valve under the reverse flow or misdirected flow deviation and vice versa.

Another area of complexity that can be overlooked for valve configurations is when two valves must be (de)activated simultaneously, or nearly so, and they are too far apart for one operator to operate without calling out another person. This is something that a procedural PHA can identify.

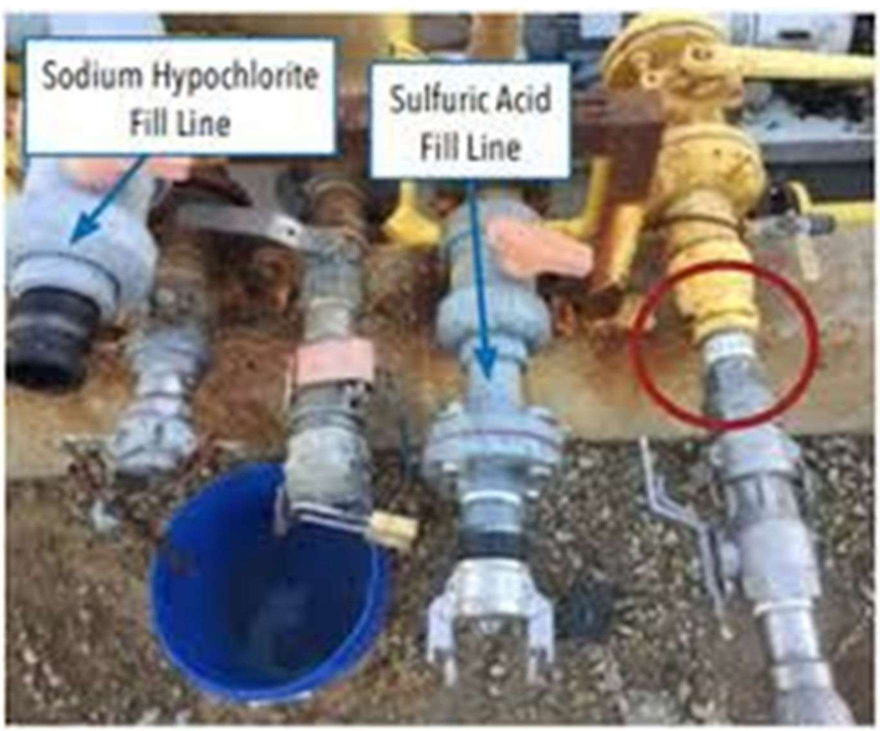
Example: A refinery startup procedure called for opening two manual valves. The challenges were that they had to be opened within a short amount of time, they were about a mile apart and there was a potential for a train to go between them . While conducting a procedural PHA, this was identified as a concern and they added a requirement for a second person to be involved in that portion of the startup.

Another valve configuration that can be a problem is loading/unloading ports and the potential complexities involved.

Example from a CSB case study: Oct 2016, there was a massive release of toxic chlorine gas into the atmosphere at MGPI facilities in Kansas where they produce food alcohol. It was due to a chemical reaction between sodium hypochlorite (bleach) with sulphuric acid. This reaction was never part of the intended process. It was due to a delivery operator unloading the sulphuric acid into the bleach tank due to wrong connection to the inlet ports of the various filling lines.

The filling ports were placed close together, included incompatible chemicals and were not clearly labelled. The facility relied on the plant supervisor to identify the correct port and to unlock the port. Unfortunately, in this incident both the sulfuric acid port and the sodium hypochlorite ports were unlocked at the same time.

This highlights the importance of reviewing procedures to identify and eliminate high risks when possible.



6.4 High Hazard Activities: Start-up/Shut-down/Recycle/Hot Stand-by

Start-up and shut-down activities account for a large portion of incidents in industry, yet they are often not well documented in standard PHAs. There may be a deviation for startup/shutdown, or better yet, it may be its own node. Unfortunately, unless the procedure itself is systematically reviewed, hazards may be overlooked.

Some of the challenges in these activities is that safeguards are placed in bypass or automatic valves set to manual to facilitate these activities.

Additionally, these activities may only occur occasionally. For example, start-up from a cold state may only happen every 3-5 years. During that period, changes may have been made in the field that could impact the activity and/or changes in the process that might present new hazards.

While the MOC process is designed to mitigate those concerns, taking a holistic view of the procedure with all current changes BEFORE using it is best practice.

Example: A client made changes to their shut-down process, deciding to complete a steam purge prior to shutting down. They had done this at other locations, but not this one. They decided to complete a procedural PHA starting with the procedure from another site. We took that procedure and updated it, given the configuration of the site I was working with and made changes as we went. When I left, they had a new procedure.

7 Conclusion

Procedural PHAs are a valuable tool for examining operating procedures and can be completed either while writing or updating a procedure. History has shown us that 70% of major accidents occur during non-routine operations. Thus, using a Procedural PHA to review the appropriate course of action for those operations can help identify potential hazards as well as the suitable safeguards, thus preventing or lessening incidents.

7 References

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3 Handbook of Loss Prevention Engineering, 2 Volume Set, Joel M. Haight (Editor), ISBN: 978-3-527-32995-3 April 2013

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Appendix A

US Incidents Related to Procedures over the past 20 years (2003-2023)

Incidents Related to Procedures			
When	Where	What Happened	Ref.
September 2022	BP Toledo Refinery Toledo, OH	As workers attempted to correct rising liquid levels in a fuel gas mix drum, a flammable vapor cloud formed, ignited and then triggered an explosion, resulting in fatalities. Naphtha was released when flow control valves were opened in an attempt to regulate an overfill occurring in upstream process equipment. The opened valve allowed the flammable liquid to enter the refinery's fuel gas system. OSHA inspectors identified training deficiencies related to procedures, as well as insufficient emergency shutdown procedures as contributing factors. OSHA Area Director: "This tragedy is a reminder of why employers must consistently reevaluate those procedures for accuracy and ensure workers are properly trained to respond in dangerous situations."	1
October 2021	MGPI Processing, Atchison, KS	Gas cloud of chlorine/other compounds released due to incorrect hose connection during delivery due to poor labelling. The mixture of the two chemicals, sulfuric acid and sodium hypochlorite, produced a cloud containing chlorine and other compounds. The cloud impacted workers onsite and members of the public in the surrounding community. The investigation noted errors & inconsistencies in the unloading procedure was known issue. (see also Process Safety Beacon "Wrong material + Wrong tank = Trouble", May 2023)	2,3
July 2021	Daikin America Inc Decatur, AL	Three chemical operators were exposed to toxic fluorocarbon and other hazardous chemicals that resulted in the workers suffering respiratory failure with two fatalities and one injury. The exposure occurred while the workers were conducting maintenance activities requiring a processing line break, a nitrogen purge, and atmospheric venting of equipment, resulting in the release of toxic fluorocarbons and other hazardous chemicals. The investigation revealed that the company failed to institute critical safe work practices required under OSHA's Process Safety Management standard and ensure workers used appropriate respiratory protection and personal protective equipment. The OSHA notice cites: "the	1

		employer did not develop and implement written operating procedures that provided clear instructions for safely conducting activities involved in each covered process consistent with the process safety information that addressed health and safety considerations, such as precautions necessary to prevent exposure, including engineering controls, administrative controls, and personal protective equipment The employer also failed to perform air monitoring to assess chemical exposures, provide written procedures that clearly identify the required level of respiratory protection, and communicate to workers the hazards associated with the chemicals."	
July 2021	LyondellBasell LaPorte, TX	A release of 100,000 pounds of acetic acid during a maintenance event at the LyondellBasell facility in La Porte, TX, resulted in fatal release of acetic acid & methyl iodide mixture with 30 personnel being transported to medical facilities for evaluation and/or treatment. CSB investigation noted the turnover crew did not have written procedures for the work being conducted.	2
November 2020	Wacker Polysilicon Charleston, TN	Seven workers were exposed to a release of hydrochloric acid during a maintenance activity at the facility. One of the workers was fatally injured, and three other workers sustained serious injuries. The final report noted written procedures as a key issue, specifically: "Wacker did not have a written procedure to execute the torquing task and instead relied on the piping manufacturer's equipment manual to communicate the torque requirements to the contractors. The manual, however, did not include the torque requirements for the bolts that were over-torqued. The resulting lack of clarity of the differing torque requirements led to the inadvertent over-torquing of the flange bolts on live operating equipment, the equipment fracture, and the release of HCL"	2
January 2020	Materion Advanced Materials Group Inc. Buffalo, NY	At 2:20 p.m. on January 22, 2020, an employee was adding dextrose to a heated vessel containing caustic, water and silver nitrate. The employee added the dextrose too quickly causing an exothermic reaction which resulted in the solution erupting & the employee incurring burns.	1

November 2019	TPC Group LLC LaPorte, TX	The incident occurred when a piping section ruptured, releasing highly flammable butadiene that quickly ignited. The resulting pressure wave destroyed parts of the facility and injured two TPC employees and a security contractor. The investigation identified that a temporary dead leg was created in piping containing 98% butadiene that resulted in popcorn polymer forming. The CSB investigation identified that the dead leg procedure did not identify all temporary dead legs in the unit which may have contributed to the incident. OSHA cited the company for failing to develop and implement procedures for emergency shutdown, and inspect and test process vessel and piping components.	1,2
May 2019	AB Specialty Silicones Waukegan, IL	Four employees suffered fatal injuries in an explosion and fire at the plant. Operators at the facility in Waukegan, Illinois were performing a batch operation that involved manually adding and mixing chemicals in a tank inside the production building. During the operation, an operator pumped an incorrect chemical into the tank, which was incompatible with another chemical that was added to the tank. The incorrect, incompatible chemical was stored in an identical drum to one of the correct chemicals, the only differentiating markings being small labels on the drums, and bung caps. After the incompatible chemicals were mixed, the tank contents underwent a chemical reaction, causing a process upset in which the tank contents foamed and overflowed from the tank's top opening. A fog also formed. The CSB determined that the process upset produced hydrogen gas, which released inside the manufacturing facility's production building. Soon after the hydrogen gas release started, it ignited, causing a massive explosion and fire. Company was cited by OSHA for failure to ensure that electrical equipment and installations in the production area of the plant complied with OSHA electrical standards, and were approved for hazardous locations. The company also used forklifts powered by liquid propane to transport volatile flammable liquids, and operated these forklifts in areas where employees handled and processed volatile flammable liquids and gases, creating the potential for ignition. The CSB report also notes: "AB Specialty developed a double initial procedure practice in 2014 in an effort to prevent employees from	1,2

		charging the wrong materials to batch processes, which was proceduralized in 2019. The occurrence of the May 3 incident indicates that AB Specialty's double initial procedure program did not prevent a wrong material from being added to the tank".	
October 2018	Superior Refining Company LLC Superior, Wisconsin	An explosion and subsequent fire occurred during a planned maintenance event, the incident report notes that the unit shutdown procedure did not provide clear instructions for safely conducting activities consistent with the PSI. CSB also noted that "Ensuring the mechanical integrity of critical equipment used during the refinery shutdown operation could have prevented this incident"	1,2
May 2018	Kuraray America Pasadena ,TX	An ethylene release caught on fire, injuring 23 workers. At the time of the incident, 266 employees and contract workers were onsite. The incident occurred during a chemical reactor system startup following a scheduled maintenance shutdown (turnaround). High-pressure conditions developed inside the reactor and activated the reactor's emergency pressure-relief system, discharging flammable ethylene vapor into ambient air in an area where a number of contractors were working. These workers were performing various tasks that were not essential to the startup of the reactor, including welding, which likely ignited the ethylene vapor cloud, causing the fire. There were several safety issues noted in the CSB report including that Kuraray management supplied its operations team with nightly operating instructions that conflicted with the company's written operating procedures and resulted in unmanaged changes during the reactor startup.	2
November 2016	ExxonMobil Baton Rouge, LA	An isobutane release and fire seriously injured four workers in the sulfuric acid alkylation unit at the ExxonMobil Refinery in Baton Rouge, Louisiana. During removal of an inoperable gearbox1 on a plug valve, the operator performing this activity removed critical bolts securing the pressure-retaining component of the valve known as the top-cap. When the operator then attempted to open the plug valve with a pipe wrench, the valve came apart and released isobutane into the unit, forming a flammable vapor cloud. The isobutane reached an ignition source within 30 seconds of the release, causing a fire and severely burning four	2

		workers who were unable to exit the vapor cloud before it ignited. CSB noted a key lesson learned is to establish detailed and accurate written procedures and provide training to ensure workers can perform all anticipated job tasks safely.	
February 2015	ExxonMobil Torrance, CA	An explosion occurred in the ExxonMobil Torrance, California refinery's Electrostatic Precipitator (ESP), a pollution control device in the fluid catalytic cracking (FCC) unit that removes catalyst particles using charged plates that produce sparks—potential ignition sources—during normal operation. The incident occurred when ExxonMobil was attempting to isolate equipment for maintenance while the unit was in an idled mode of operation; preparations for the maintenance activity caused a pressure deviation that allowed hydrocarbons to backflow through the process and ignite in the ESP. The site re-used a procedure developed for a similar maintenance operation in 2012 that allowed deviation from typical refinery safety requirements. They did not, however, perform a sufficient hazard analysis to determine if the unit conditions specified in the 2012 procedure were valid for the 2015 operation. The safeguards specified in the 2012 procedure were not sufficient for the 2015 operation, and they failed to prevent hydrocarbons from backflowing through the process and into the ESP;	2
June 2013	William Olefins Geismar, La	A catastrophic equipment rupture, explosion, and fire at the plant resulted in two fatalities. The incident occurred during nonroutine operational activities that introduced heat to a type of heat exchanger called a "reboiler" which was offline, creating an overpressure event while the vessel was isolated from its pressure relief device. The introduced heat increased the temperature of the liquid propane mixture confined within the reboiler shell, resulting in a dramatic pressure rise within the vessel due to liquid thermal expansion. The reboiler shell catastrophically ruptured, causing a boiling liquid expanding vapor explosion (BLEVE) and fire. Weaknesses in the site PSM program included deficiencies in implementing Management of Change (MOC), Pre-Startup Safety Review (PSSR), and Process Hazard Analysis (PHA) programs. In addition, the	2

		company did not perform a hazard analysis or develop a procedure for the operational activities conducted on the day of the incident.	
August 2008	Bayer Crop Science, Institute, WV	On August 28, 2008, at about 10:35 p.m., a runaway chemical reaction occurred inside a 4,500 gallon pressure vessel known as a residue treater, causing the vessel to explode violently in the methomyl unit at the facility. Highly flammable solvent sprayed from the vessel and immediately ignited, causing an intense fire that burned for more than 4 hours, with 2 fatalities and 8 injuries. The incident occurred during the restart of the methomyl unit after an extended outage to upgrade the control system and replace the original residue treater vessel. The methomyl control system upgrade required a revision to the SOP to incorporate the changes needed to operate the methomyl unit with the new Siemens system, and to reformat the SOP to a computerized document. However, at the time of the incident the SOP revision remained incomplete; the operators were using an unapproved SOP. The review and approval record of the working copy in use at the time of the incident was unsigned. A watermark on each page read "draft in review 11/13/07".	2
March 2005	BP Texas City Refinery Texas City, TX	A series of explosions occurred at the BP Texas City refinery during the restarting of a hydrocarbon isomerization unit. Fifteen workers killed and 180 others were injured. The explosions occurred when a distillation tower flooded with hydrocarbons and was over-pressurized, causing a geyser-like release from the vent stack. One finding in the CSB report noted that the Start Up Procedure lacked sufficient instructions. The Baker report also noted issues with procedures.	2,4
January 2005	Acetylene Service Company Perth Amboy, NJ	On January 25, 2005, a gas explosion killed three workers at the Acetylene Service Company plant in Perth Amboy, NJ. The blast originated in a wooden shed located near six large storage tanks that received liquid waste from the plant's acetylene generating system. The plant produces, repackages, and distributes acetylene used in welding. One of several recommendations in the CSB Safety Bulletin on the incident is to maintain up-to-date operating procedures and checklists for the entire operating process.	

April 2004	Formosa Illiopolis, IL	Five workers were fatally injured and two others were seriously injured when an explosion occurred in a polyvinyl chloride (PVC) production unit at Formosa Plastics in Illiopolis, Illinois, east of Springfield. The explosion followed a release of highly flammable vinyl chloride, which ignited. CSB determined that this incident occurred when an operator drained a full, heated, and pressurized PVC reactor. The CSB believes that the operator cleaning a nearby reactor likely opened the bottom valve on an operating reactor, releasing its highly flammable contents. The explosion forced a community evacuation and lighted fires that burned for several days at the plant. The CSB determined that facility emergency procedures for evacuation were ambiguous and also found that the company did not have comprehensive written standards managing interlocks at its PVC facilities contributing to the incident.	2
November 2003	DPC Enterprises Glendale, AZ	On November 17, 2003, there was a release of chlorine gas from the DPC Enterprises chlorine repackaging facility in Glendale, Arizona, near Phoenix. Fourteen people, including ten police officers, required treatment for chlorine exposure. The release occurred when chlorine vapors from a rail car unloading operation escaped from a system designed to recapture the material, known as a scrubber. Owing to the exhaustion of absorbent chemicals in the scrubber, chlorine gas was released. The incident investigation noted issues with written procedures as a root cause of the incident.	2
July 2003	Honeywell Baton Rouge, LA	There were three incidents within 30 days at the site. On July 20, 2003, there was a release of chlorine gas from the Honeywell refrigerant manufacturing plant in Baton Rouge, Louisiana. The accident resulted in the hospitalization of four plant workers and required residents within a half-mile radius to shelter in their homes. On July 29, 2003, a worker was fatally injured by exposure to antimony pentachloride when a gas cylinder released its contents to the atmosphere. On August 13, 2003, two plant workers were exposed to hydrofluoric acid, and one was hospitalized. The CSB investigation listed several issues with SOPs as a contributing factor. It also noted that nonroutine situations were not always recognized and reviewed to ensure that work could	2

		proceed safely.	
April 2003	DDWilliamson Louisville, KY	On the morning of April 11, 2003, one worker was killed at the D.D. Williamson food additive plant in Louisville, Kentucky, when a process vessel became overpressurized and failed catastrophically. The failure caused a release of aqueous ammonia as well as extensive damage to the plant, which manufactures caramel coloring. As one of three root causes, the CSB investigation determined that the site did not have adequate operating procedures or adequate training programs to ensure that operators were aware of the risks and trained to respond appropriately.	2

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