

Monitoring of in-process explosive/hazardous material during shift break – learnings from incidents

by

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Abstract

Often in-process explosive/hazardous materials are not being monitored during shift break. This article is trying to list the common in-process monitoring and isolation methods for explosive/hazardous materials during shift break and proposes a few more methods especially in the emulsion explosive manufacturing context. In the first part, the authors also list the monitoring and isolation safety defenses available during operation for a comparison with risk controls during shift break. Some of the hazardous scenarios considered are chemical contamination causing violent reaction during shift break, the heat from a hot spot generated during routine operation but in-between process or shift break no longer being dissipated by transference to a mass explosive/hazardous material, accidental activation of pumps or failure to shut down during shift break, and overheating from an electrical heating system. Some common prevention and mitigation risk controls are being discussed together with proposed new risk controls (perhaps not commonly considered).

Background

In-process explosive and hazardous material includes material or goods that are partially completed and are somewhere in the manufacturing process but not yet ready for sale. Monitoring of in-process explosive/hazardous material during shift break is important as many safety devices usually will be switched off-line and perhaps the plant's power may be shut down during a shift break. Also in some cases, large amounts of in-process explosive and other hazardous material may be left inside the pipelines or equipment during a shift break in order to continue the production process promptly after the shift break has ended. The authors of this article wish to explore other means of monitoring and isolating in-process explosive/hazardous material during a shift break.

In-process explosive and other hazardous material monitoring/isolation during plant operation

Explosive raw materials and other hazardous materials are usually transferred through raw material storage bin/silos to mixing module, hoppers, pumps, cartridging and packing machines to final product storage during an explosive manufacturing process. In term of process safety, many in-line alarm trips and sensors are usually installed, as described in the table 1 below, for the purpose of monitoring and isolation during plant operation:

Item	Equipment	Purpose	Hazardous condition	Suitable Alarm, Trips and Sensors, other safety devices
1	Raw material preparation and holding storage	Storing and preparing explosive raw material as solution.	a. Overfill spillage b. overheat	a. high level alarm and trip sensor b. steam pressure reducing valve/temperature alarm and trip sensor c. pressure relief valve/breathing outlet, burst disc d. load cell/low level alarm trip sensor
2	Pumps (progressive cavity, lobe pump, gear pump, centrifugal pump)	Dosing/Transferring raw material	a. dead heading b. overheat c. dry running	a. high pressure alarm and trip sensor, valve contact limit switch, burst disc b. high temperature alarm and trip sensor c. low pressure alarm and trip sensor, no flow alarm and trip sensor
3	Mixing skid/blender /CR mixer/jet mixer/stir pot static mixer	Mixing, blending, emulsifying	a. overfill spillage b. friction	a. high and low level alarm and trip sensors b. RPM limit c. valve/temperature alarm and trip sensor, high/low pressure sensor, no flow sensor, burst disc
4	Intermediate product holding storage (e.g. hot & cold hoppers)	Transit, batching	a. overfill spillage b. dead heading c. dry running	a. high level alarm and trip sensor b. high pressure alarm and trip sensor, valve contact limit switch, burst disc c. low pressure alarm and trip sensor, no flow alarm and trip sensor
5	Heat exchanger	Cooling down emulsion explosives	dead heading	high pressure alarm and trip sensor, valve contact limit switch, burst disc
6	Cartridge machine/packaging	Final product packaging	a. dead heading b. overheats c. interlocking with pumps	a. high pressure alarm and trip sensor, valve contact limit switch, burst disc b. high temperature alarm and trip sensor c. low level alarm and trip, low pressure alarm and trip, no flow alarm and trip

Table 1: In-process monitoring, alarm, relief, and trip safety devices during plant operation

With all these safety devices safeguarding the explosive manufacturing process, there are many layers of protection in terms of process safety management for in-process goods and raw material.

But what happens when in-process material is left in pipes, bins, hoppers, pumps, mixers during breaks with respect to monitoring?

Often, when the process is stopped, trip and safety devices can remain in idle mode or are shut off as it is believed that there is no energy entry on the material. The result is that in-process material is not controlled.

There have been incidents in the past where explosive material had started to decompose when exposed to excessive heating (in dead spots or due to an unrecognized failure of the heating system), when a decomposition that had started while a product line had been in operation, but the created heat from was no longer dissipated when production was stopped and created a fire with subsequent explosion (e.g. BME packaged plant incident), or when explosive material had been left and solidified before the next shift started and was then exposed to friction or overheating (Sierra booster incident).

Our organization experienced an incident where an explosion occurred in a packaged emulsion plant during lunch break (Austin Powder Malaysia, SAFEX incident notice 20-04). The 38 years old, semi batch process plant (constructed in 1983) had been stopped for lunch break with in-process material remaining in hoppers, pumps and pipes when an explosion occurred almost an hour later. All process equipment had been deenergized and the PLC control was not monitoring sensor signals during the stopped operation. There was also no CCTV to visually monitor the inside of the production room and no smoke or heat detection (e.g. infrared camera) were in place. In addition, the building was not secured and had no access control. No one observed any smoke in the sky from the process building prior to the incident. All these circumstances complicated the root cause analysis and also prevented an early indication of an initial event that subsequently resulted in an explosion.

After a review of learnings from this and other incidents and the common plant setup in the explosive industry, the author wishes to explore possible methods to monitor in-process explosive/hazardous material during (shift) breaks, particularly in the emulsion explosive plant context.

Item	Hazardous scenarios to be considered	Common safety defenses in place	Proposed in-process explosives/hazardous material monitoring and isolation methods
1	Contamination of emulsion explosive with chemicals and causes explosion/toxic gas release incident in-	a) prevention -segregate incompatible chemicals with proper labelling or locked in a separate location to prevent accidental incompatible mixture	a) prevention - Nil b) mitigation

	process or during shift break	<ul style="list-style-type: none"> -CCTV that serves as deterrent in case of sabotage - isolation and control access of the plant during shift break <p>b) mitigation</p> <ul style="list-style-type: none"> -reduce the quantity of incompatible materials available on site 	<ul style="list-style-type: none"> - detection of known gas released (e.g. CO, NO_x) after mixing of incompatible material with alarm (to give an early alarm and evacuation consideration) and trip sensor (on equipment that will need to be running during shift break)
2	Failure of pumps' joint/mixer pin caused by foreign object or lack of maintenance creating a hot spot in between production or during shift break, resulting in accelerated decomposition and explosion when heat is no longer dissipated by moving material	<p>a) prevention</p> <ul style="list-style-type: none"> -mesh screen to prevent foreign object -predictive/preventive maintenance <p>b)mitigation</p> <ul style="list-style-type: none"> -operators report unusual sounds and stop work 	<p>a) prevention</p> <ul style="list-style-type: none"> - Nil <p>b) mitigation</p> <ul style="list-style-type: none"> -hot spot detection alarm and isolation method during shift break -do not shut down the safety devices during shift break or install hardwire standalone alarm and trip panel for continuous monitoring/tripping functionality even during shift break and connected to plant-wide alarm for evacuation purpose with early detection. Access to this safety devices system should be controlled and supported by UPS (uninterrupted power supply) battery. -reduce the explosive quantity contained in process piping, hoppers, mixers, blenders during shift break
3	Accidental activation of pumps/failure to shut off the pump during shift break	<p>a) prevention</p> <ul style="list-style-type: none"> - key lock or password control for power, PLC (only authorized personnel) and safety devices -low- and high-pressure alarm and trip, high temperature alarm and trip -prevent access to the explosive plant during shift break and also CCTV <p>b) mitigation</p> <ul style="list-style-type: none"> -minimize product explosive inventory in the pump or production area 	<p>a) prevention</p> <ul style="list-style-type: none"> -assigned supervisor during shift break to monitor and ensure proper shutdown and no activity during shift break (can be done remotely in some cases) -shutting down of KP machine also shutting down of all critical process equipment and pumps -fail-safe 3-way actuator valve to prevent deadheading in case of accidental activation <p>b) mitigation</p> <ul style="list-style-type: none"> -Nil
4	Overheating from electrical heating system	<p>a) prevention</p> <ul style="list-style-type: none"> -inherent safety design whereby not possible for overheating with decomposition temperature from supply (eg. hot water system instead of pressurized steam whenever possible) -temperature alarm and trip sensor <p>b) mitigation</p>	<p>a) prevention</p> <ul style="list-style-type: none"> -Nil <p>b) mitigation</p> <ul style="list-style-type: none"> -Nil

		-smoke detection and alarm system for evacuation	
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Table 2: Common and proposed in-process explosives/hazardous material monitoring and isolation methods

Conclusion

It is worth to explore further on the monitoring and isolating method for in-process explosive and hazardous material in an explosive plant setup during a shift break as there are often few options in place to reduce the fire and explosion risk in this area. LOPA (Layer of Protection Analysis) and CHAZOP (Control Hazard and Operability Study) review are essential to be implemented to cover the design phase of the plant even for non-operation during shift breaks or in the event of a network security breach if the system is capable to be controlled remotely such as SCADA (supervisory control and data acquisition) system. Controlled access and standalone redundant safety devices for critical equipment would be the gold standard for explosive manufacturing plant with appropriate training for operators and supervisors. Implementation of Management of Change and restricting bypassing safety devices are also paramount to maintain the risk controls in place as the plant is growing in capacity or operating during its lifetime. Critical active safety devices should never be deactivated during any plant stoppage other than full shutdown or under PTW.