



U.S. Chemical Safety and Hazardous Investigation Board

Organic Peroxide Decomposition, Release, and Fire at Arkema Crosby Following Hurricane Harvey Flooding

Fact Sheet

Arkema's flood plans met the 100-year and 500-year flood elevation, but not Harvey-level flooding.

The CSB found that the Arkema Crosby plant had written plans in place to account for known flood risks based upon over 50 years of operational knowledge at the facility. Even though much of the facility was built before any part of the site was designated to be in a FEMA flood zone, the CSB found that the Crosby facility met the current FEMA 100 year flood elevation, and that implementation of Arkema's product handling guidelines, updated in 2016, met the current FEMA 500 year flood elevations.

The CSB report makes the following key observations and conclusions:

1. *The Crosby plant met the current FEMA 100 year flood elevation*

"[T]he Crosby facility appears to have had sufficient safeguards in place to prevent loss of refrigeration in the Low Temperature Warehouses for a 100-year flooding event." *Report, Paragraph 31*

"[T]he Crosby facility appears to have had sufficient safeguards in place to prevent loss of refrigeration in the Low Temperature Warehouses for a 100-year flooding event." *Report, Paragraph 172*

"Although the flooding associated with Hurricane Harvey exceeded the design capability of Arkema's safeguards, the CSB investigation concluded that Arkema's safeguards could likely provide adequate protection for a 100-year flooding event." *Report, Paragraph 350*

2. *When implementing its flood plans, the Crosby plant met the current FEMA 500 year flood elevation*

"At the 500-year flood level, if the refrigerated trailers had been loaded and placed in the laydown area, as attempted during Harvey, the organic peroxide contents would have likely maintained sufficient cooling to prevent a decomposition incident." *Report, Paragraph 171*

“During Hurricane Harvey, the flood water at Adlong Ditch reached about 54.5 feet. The elevation at the laydown area is 52 feet and the fuel tank for the refrigerated trailer is 3 feet 5 inches above the ground. If all refrigerated trailers had been placed in the laydown area, they would likely not have lost refrigeration if workers could have stayed onsite to monitor them.” *Report, Paragraph 171, footnote a*

3. The Crosby plant had written plans and detailed procedures that addressed flooding, and the plant implemented those plans.

“Arkema’s procedures detail actions to take in response to a variety of scenarios that might elevate the temperature in one of the Low Temperature Warehouses. Identified actions include:

- Expediting maintenance for refrigeration equipment issues;
- Relocating the organic peroxide products to another Low Temperature Warehouse;
- Starting up the emergency generators to supply backup electrical power;
- Using liquid nitrogen as an alternative source of refrigeration; and
- Moving the organic peroxide products to refrigerated truck trailers.”
- *Report, Paragraph 52*

“Anticipating that Hurricane Harvey would make landfall the next day (Friday, August 25, 2017), personnel at the Arkema Crosby facility began to prepare for the storm. The Arkema Crosby facility had a hurricane plan detailing how the site planned to protect workers and property before, during, and after a hurricane. The team assigned to implement the plan started meeting at the beginning of the hurricane season (June 1) and monitored storms forming in, or moving into, the Gulf of Mexico.” *Report, Paragraph 63*

“Although the CSB investigation found no single flood design basis for the Arkema Crosby facility, the site’s hurricane plan, emergency plan, process hazard analysis (PHA), worst-case scenarios, and written statements issued by Arkema in relation to the Hurricane Harvey flooding all show how the facility viewed its susceptibility to flooding. This viewpoint is expressed by Arkema’s post-incident statements, which are consistent with those made by Arkema employees to CSB investigators—the site had a history of flooding, and about two feet of water is the most employees recall onsite before the Hurricane Harvey flooding.” *Report, Paragraph 166*

A. HURRICANE PREPAREDNESS PLAN

“The Arkema Crosby facility had a written hurricane preparedness plan that detailed how the site planned to protect workers and property before, during, and after a hurricane.” *Report, Paragraph 5*

“Among other storm preparations, the Arkema Crosby Hurricane Preparedness Plan includes the following items to address flooding:

- Fill storage tanks, where practical to prevent them from floating;
- Fill dumpsters with water to prevent them from floating;
- Acquire an off-road forklift, with large tractor-style tires that is capable of moving through a couple of feet of floodwater;
- Obtain a flat-bottom boat, capable of operating in shallow water; and
- Stock waders as part of the personal protective raingear.” *Report, Paragraph 167*

B. EMERGENCY RESPONSE PLAN

“The Arkema Crosby’s Emergency Response Plan discusses many potential emergency situations including:

- Organic peroxide decomposition;
- Loss of electrical power; and
- Severe weather events such as flooding.” *Report, Paragraph 168*

“The flooding and high-water section of the Emergency Response Plan does not consider the amount of flooding as seen during Hurricane Harvey. Arkema wrote its emergency plan with an unstated emphasis on a lower level of floodwater. The Emergency Response Plan says:

Care shall be taken to be sure water is kept out of equipment, shops, control rooms, offices, etc. These areas are to be checked during severe rainstorms to prevent damage or personal injuries. Non-essential personnel are to be released when appropriate. The following items must be checked during heavy rains:

- Monitor levels in all secondary tank containments.
- Open storm water containment gates as needed.
- Secure all containers and equipment as necessary.
- Monitor levels in sanitary sumps.” - *Report, Paragraph 169*

C. STORAGE BUILDING SAFETY GUIDELINES

“The policy was updated in 2016 to direct workers to move organic peroxide products to refrigerated trailers if the backup generators failed to operate upon loss of power to the Low Temperature Warehouses. The liquid nitrogen system was to be used in the event that there was “no other alternative available.” *Report, Paragraph 171*

“At the 500-year flood level, if the refrigerated trailers had been loaded and placed in the laydown area, as attempted during Harvey, the organic peroxide contents would have likely maintained sufficient cooling to prevent a decomposition incident.” *Report, Paragraph 171*

“During Hurricane Harvey, the flood water at Adlong Ditch reached about 54.5 feet. The elevation at the laydown area is 52 feet and the fuel tank for the refrigerated trailer is 3 feet 5 inches above the ground. If all refrigerated trailers had been placed in the laydown area, they would likely not have lost refrigeration if workers could have stayed onsite to monitor them.” - *Report, Paragraph 171, footnote a*

D. PROCESS HAZARD ANALYSIS

“Had the Arkema PHA assessed flooding, the limited industry guidance on flooding would likely have been insufficient to provide specific or sufficiently conservative level of action to protect against the hazards posed by the flooding during Hurricane Harvey. Even without this assessment, however, the Crosby facility appears to have had sufficient safeguards in place to prevent loss of refrigeration in the Low Temperature Warehouses for a 100-year flooding event.” *Report, Paragraph 172*

“At the time the Low Temperature Warehouse PHA was performed, corporate PHA requirements did not mandate that all PHA teams consider flooding scenarios. In 2014, Arkema modified its corporate PHA policy to require its PHA teams to identify and evaluate natural hazards such as flooding.” *Report, Paragraph 327*

E. FM GLOBAL

“Although FM Global identified the flooding risk at the Arkema Crosby facility, the FM Global report did not make any recommendations to Arkema to address its flood hazards. Furthermore, FM Global was satisfied with the changes that Arkema made based on their report. It should be noted that the FM Global report pointed out multiple issues at the Crosby facility and the facility addressed many of the issues.” *Report, Paragraph 165*

4. The Crosby plant implemented multiple backup systems to address a loss of power emergency.

“Arkema had multiple safety systems in place to ensure that organic peroxide products were kept cold and would not reach their SADTs. In Arkema’s process hazard analysis (PHA), the PHA team members identified the following layers of protection: redundant refrigeration systems in the Low Temperature Warehouses; emergency generators to provide power in case a Low Temperature Warehouse lost power; liquid nitrogen for alternative cooling; and refrigerated trailers to store organic peroxide temporarily.” - *Report, Paragraph 29*

“Each Low Temperature Warehouse is equipped with at least two refrigeration systems, with one serving as a backup. Because refrigeration is needed to maintain some of Arkema’s organic peroxide below the self-accelerating decomposition temperature, the company’s procedures stress the importance of taking prompt action when refrigeration equipment problems arise.” - *Report, Paragraph 51*

“Seven diesel-powered emergency generators supply a backup source of electricity to buildings and equipment at the Arkema Crosby facility (Figure 5). Two of the seven emergency generators provide backup power to Arkema’s Low Temperature Warehouses.” - *Report, Paragraph 53*

“The Arkema Crosby facility uses a liquid nitrogen system to deliver a backup source of emergency cooling for its Low Temperature Warehouses. If a significant refrigeration problem occurs, such as loss of power and backup power, workers can connect short hoses and then open valves to inject liquid nitrogen into any one of the organic peroxide Low Temperature Warehouses to supply a source of refrigeration that is independent of electricity. Each of the Low Temperature Warehouses is equipped with dedicated piping for liquid nitrogen.” *Report, Paragraph 54*

“As a final backup for scenarios causing elevated temperature in one of the Low Temperature Warehouses, organic peroxide products can be relocated to one or more portable refrigerated truck trailers. Arkema uses these refrigerated trailers primarily for shipping organic peroxide products to customers; however, Arkema procedures allow the use of these trailers in emergency situations or while making repairs to Low Temperature Warehouse refrigeration systems.” - *Report, Paragraph 55*

“The fuel tank for these refrigerated trailers is located under the container that powers the refrigeration unit. With a full tank, the refrigerated trailers can normally maintain appropriate cold conditions for more than a week.” - *Report, Paragraph 55*