Caught in the Storm: Extreme Weather Hazards in the Chemical Enterprise

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Board Member & Interim Executive Authority

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#ACSOrlando
@Kulinowski
@chemsafetyboard
Vision:
A nation safe from chemical disasters.

Mission:
Drive chemical safety change through independent investigations to protect people and the environment.
ITC Fire – March 2019
Arkema Inc. Chemical Fire (August 2017)
Organic Peroxides

<table>
<thead>
<tr>
<th>Peroxides</th>
<th>Peroxydicarbonates</th>
<th>Dialkyl Peroxides</th>
<th>Diacyl Peroxides</th>
<th>Hydroperoxides</th>
<th>Peroxyketals</th>
<th>Ketone Peroxides</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-OOC-R</td>
<td>Luperox P (t-Butyl perbenzoate)</td>
<td>Luperox 223-M75S (Di-2-ethylhexyl peroxydicarbonate)</td>
<td>Luperox 101 2,5-dimethyl-2,5-bis (1-Butyl-peroxy) hexane</td>
<td>Luperox LP (Lauroyl peroxide)</td>
<td>Luperox DDM-9 (MEKP Solution in Plasticizer - 9% Active Oxygen)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Luperox 26 (t-Butyl peroctoate)</td>
<td>Luperox 225-M60S (Di-sec-Butyl peroxydicarbonate)</td>
<td>Luperox DC (Dicumyl peroxide)</td>
<td>Luperox A98 (Benzyl peroxide)</td>
<td>Luperox 231 (1,1-Di-t-Butyl peroxy 3,3,5-trimethyl cyclohexane)</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Luperox 10M75 (t-Butyl peroxypivalate)</td>
<td>Luperox 225-M60S (Di-sec-Butyl peroxydicarbonate)</td>
<td>Luperox DC (Dicumyl peroxide)</td>
<td>Luperox CL90 (Cumene hydroperoxide)</td>
<td>Luperox 331M80 1,1-Di (t-Butyl peroxy) cyclohexane</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Luperox 11M75 (t-Butyl peroxyvalerate)</td>
<td>Luperox 225-M60S (Di-sec-Butyl peroxydicarbonate)</td>
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<td>Luperox CL90 (Cumene hydroperoxide)</td>
<td>Luperox 331M80 1,1-Di (t-Butyl peroxy) cyclohexane</td>
<td></td>
</tr>
</tbody>
</table>

Note: Luperox DDM-9, DHD-9, DDM-30, and Delta X-9 will change to Luperox and drop * during 2001. Formulations will not change.

Organic Peroxides – Their Safe Handling and Use. Arkema
Self-Accelerating Decomposition Temperature (SADT)

Organic Peroxides – Their Safe Handling and Use. –Arkema

https://youtu.be/98jOeCr06Xs
Types of Organic Peroxides

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Heating may cause a detonation or deflagration (explosion)</td>
</tr>
<tr>
<td>B</td>
<td>Heating may cause a thermal explosion or fire</td>
</tr>
<tr>
<td>C-F</td>
<td>Heating may cause a fire</td>
</tr>
</tbody>
</table>

49 CFR § 173.128 - Class 5, Division 5.2 - Definitions and types.
# Refrigerated Organic Peroxide Inventory and Properties

<table>
<thead>
<tr>
<th>Luperox™</th>
<th>Peroxide Chemical Family</th>
<th>Maximum Storage Temperature (°F)</th>
<th>SADT (°F)</th>
<th>Hazard Category (Type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Peroxyester</td>
<td>14</td>
<td>70</td>
<td>D</td>
</tr>
<tr>
<td>10M75</td>
<td>Peroxyester</td>
<td>14</td>
<td>81</td>
<td>D</td>
</tr>
<tr>
<td>11M45</td>
<td>Peroxyester</td>
<td>32</td>
<td>113</td>
<td>D</td>
</tr>
<tr>
<td>11M75</td>
<td>Peroxyester</td>
<td>32</td>
<td>84</td>
<td>C</td>
</tr>
<tr>
<td>188M75</td>
<td>Peroxyester</td>
<td>5</td>
<td>59</td>
<td>D</td>
</tr>
<tr>
<td>221</td>
<td>Peroxydicarbonate</td>
<td>-9</td>
<td>23</td>
<td>C</td>
</tr>
<tr>
<td>233M75S</td>
<td>Peroxydicarbonate</td>
<td>14</td>
<td>68</td>
<td>D</td>
</tr>
<tr>
<td>223S</td>
<td>Peroxydicarbonate</td>
<td>0</td>
<td>59</td>
<td>C</td>
</tr>
<tr>
<td>223V75</td>
<td>Peroxydicarbonate</td>
<td>14</td>
<td>77</td>
<td>D</td>
</tr>
<tr>
<td>225M60</td>
<td>Peroxydicarbonate</td>
<td>14</td>
<td>50</td>
<td>C</td>
</tr>
<tr>
<td>546M75</td>
<td>Peroxyester</td>
<td>14</td>
<td>77</td>
<td>D</td>
</tr>
<tr>
<td><strong>Total Inventory (Pounds)</strong></td>
<td><strong>367,000</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Organic Peroxides – Their Safe Handling and Use. Arkema
“Certainly, we didn’t anticipate having six feet of water in our plant.”
Arkema President
2001
June – Tropical Storm Allison strikes first on June 5; returns three days later for a second round of storms. Texas Medical Center essentially shut down. North Downtown Houston decimated. Two million people impacted; 22 lives lost. More than 70,000 structures flood. Damages top $5 billion.

“ALLISON: A NAME WE'LL NEVER FORGET”
Memorial Day Flood (2015)

2015

“HIGHEST RAINFALL RECORDED”

Source: Harris County Flood Control District
Tax Day Flood (2016)

2016
April 17-18 – Tax Day Flood. Historic flood over northern and western Harris County results in seven fatalities. Average 12-16 inches of rain in 12 hours countywide; record pool levels in Addicks and Barker reservoirs. Estimated 9,820 structures flood in Harris County.

2016
May 26-27 – Memorial Day Flood. North and northwest Harris County hit with 8–13 inches of rain. Overbank and structural flooding along Spring, Willow, Little Cypress and Cypress creeks, San Jacinto River. More than 400 structures flood in Harris County and more than 500 in the Conroe

“HISTORIC FLOOD”

Source: Harris County Flood Control District
Memorial Day Flood (2016)

Source: Harris County Flood Control District
Houston Floods.
Watershed and Gauge Station

Map of the Cedar Bayou Watershed in Harris County, Texas

Arkema Crosby Facility and the Cedar Bayou Gauge Station 1740

~3 miles

https://www.hcfcd.org/projects-studies/cedar-bayou/
Floodplain Map

http://www.harriscountyfemt.org/
Rainfall Exceeds 500-yr Event

For this region, a 500-year event is:

- 19.3 in / 24 hr
- 20.7 in / 48 hr
- 22.3 in / 96 hr

Harris County Flood Control District, "Gauge Station 1740 Data," 2017
Cedar Bayou Stream Elevation

0.2% (500-yr)
1% (100-yr)
2% (50-yr)
10% (10-yr)

HCFCD, "Gauge Station 1740 Data," 2017
Historical Storm Elevation Data

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/18/1994</td>
<td></td>
<td>56.08'</td>
</tr>
<tr>
<td>5/20/2000</td>
<td></td>
<td>50.08'</td>
</tr>
<tr>
<td>9/13/2008</td>
<td>Ike</td>
<td>53.70'</td>
</tr>
<tr>
<td>10/31/2015</td>
<td></td>
<td>55.10'</td>
</tr>
<tr>
<td>6/4/2016</td>
<td></td>
<td>50.40'</td>
</tr>
<tr>
<td>8/27/2017</td>
<td>Harvey</td>
<td>59.00'</td>
</tr>
</tbody>
</table>

High water mark elevations are approximate.

HCFCD, "Gauge Station 1740 Data," 2017
Flood Insurance Rate Map - 1985

Zone C – Area of Minimal Flooding
Zone A – Areas of 100-year flood

FEMA Flood Map Service Center
Flood Insurance Rate Map - 1996

Zone X – Areas determined to be outside the 500-year floodplain

Zone A – Areas of 100-year flood

FEMA Flood Map Service Center
Flood Insurance Rate Map - 2007
Arkema electric utility supply and organic peroxide low-temperature warehouses now in the 100-year floodplain
Insurer Identified Flood Risk in 2016

- Engineers visited facility, met with plant manager, and produced a report identifying the flood risk
  - Adlong Ditch was source of flooding hazard
  - Site is in both 100-yr and 500-yr floodplains
  - Property damage and business interruption loss estimates computed
- Arkema Crosby facility fell in the bottom quartile of insurer’s risk benchmarking tool, partly due to flood risk
- No recommendations were made but Arkema made some changes in response to the report
Key CSB Findings

- Four different layers of protection had common failure mode (flooding).
- Floodplain information is not required to be used in process hazard analyses.
- More robust industry guidance is needed to help hazardous chemical facilities better prepare for extreme weather events.
- Facilities should not rely on individual employees’ experiences with past events to predict future risk.
Other Significant Releases

Magellan Midstream Galena Park
Tank leak released 11,000 barrels
(461,000 gal) of gasoline. Some
reached a local waterway.

Valero Houston Refinery
Floodwater lifted tank from
foundation, releasing benzene,
other compounds
Superfund Sites Affected by Harvey

San Jacinto River Waste Pits
- Protective cap damaged during flooding, exposing underlying waste
- Dioxin levels >70,000 ng (rec <30 ng)
- Erosion of river bottom under cap by ~12 ft
Flood Risks for Industrial Facilities

- Lift vessels from footings, causing release of contents
- Floating vessels impact other equipment
- Increased drag forces cause piping connections to fail
- Intrusion of water into electrical equipment
- Acceleration of corrosion of safety-critical equipment
CSB Guidance to Industry

• Perform an analysis to determine susceptibility to extreme weather events and other natural disasters
• Apply a conservative risk management approach when evaluating and mitigating the potential effects of extreme scenarios
• Ensure that critical safeguards and equipment are not susceptible to common mode failures
Figure 1. Estimated Flood Damages Due to Unmitigated Climate Change

Estimated flood damages under the Reference scenario in 2050 and 2100 for the IGSM-CAM climate model (millions 2014$). Results are presented for the 18 2-digit hydrologic unit codes (HUCs) of the contiguous U.S. Stippled areas indicate regions where the projected damages are significantly different from the historic period (at a 90% confidence interval).

For more information, visit EPA’s “Climate Change in the United States: Benefits of Global Action” at www.epa.gov/cira.