Factual Update
Published: September 17, 2019
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Table of Contents

Acronyms and Initialisms ....................................................................................................................................................... 4
1.0 Incident Summary ........................................................................................................................................................... 5
2.0 Background ...................................................................................................................................................................... 5
  2.1 KMCO .................................................................................................................................................................................. 5
  2.2 Isobutylene ............................................................................................................................................................................. 5
  2.3 KMCO Isobutylene System ......................................................................................................................................................... 6
3.0 The Incident ..................................................................................................................................................................... 7
4.0 The Y-Strainer ................................................................................................................................................................. 10
5.0 Next Steps ....................................................................................................................................................................... 11
References ............................................................................................................................................................................ 13
Explosion and Fire at KMCO Chemical Facility
Crosby, Texas | Incident Date: April 2, 2019 | No. 2019-02-I-TX

Acronyms and Initialisms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>American Petroleum Institute</td>
</tr>
<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
</tr>
<tr>
<td>CCPS</td>
<td>Center for Chemical Process Safety</td>
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<tr>
<td>CSB</td>
<td>U.S. Chemical Safety and Hazard Investigation Board</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>FNPT</td>
<td>Female National Pipe Thread</td>
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<tr>
<td>LLC</td>
<td>Limited Liability Company</td>
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<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
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<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<tr>
<td>ORG</td>
<td>Owner Resource Group</td>
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<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
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<td>PSM</td>
<td>Process Safety Management</td>
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<tr>
<td>PTFE</td>
<td>Polytetrafluoroethylene</td>
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<tr>
<td>RMP</td>
<td>Risk Management Plan</td>
</tr>
<tr>
<td>SDS</td>
<td>Safety Data Sheet</td>
</tr>
</tbody>
</table>
1.0 Incident Summary

On Tuesday, April 2, 2019, just before 10:46 am, a vapor cloud of isobutylene formed at the KMCO, LLC (“KMCO”) facility in Crosby, Texas after a three-inch gray iron (a type of cast iron) y-strainer, a piping component, failed. Shortly after 10:50 am, the vapor cloud found an ignition source and ignited, causing an explosion. The explosion killed one KMCO worker and seriously burned two others. On the day of the incident, more than 200 KMCO employees, contract workers, and visitors were onsite. The incident injured at least 30 workers—seven KMCO employees and 23 contract workers. A shelter-in-place was issued to community members within one mile of the KMCO facility. The incident interrupted normal business operations at KMCO and resulted in two rounds of employee layoffs, reducing the number of employees at the Crosby facility from more than 180 to less than 50.

2.0 Background

2.1 KMCO

The KMCO facility in Crosby, Texas manufactures specialty chemicals and operates tolling facilities (Figure 1). Tolling is “[a]n arrangement in which a company (which has specialized equipment) processes raw materials or semifinished goods for another company” [8]. KMCO purchased the Crosby plant on July 1, 2012 and has owned and operated the facility since.

2.2 Isobutylene

Isobutylene is a highly flammable, colorless gas, with a sweet gasoline odor. Under certain (temperature and pressure) conditions, isobutylene can be a liquid. Among other things, isobutylene is used in the production of aviation fuel, resins, chemicals, packaging, plastics, and antioxidants for food. Isobutylene is typically transported and stored in a liquefied form, and it is among the gases

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1 The isobutylene storage tank level decreased during the incident, but the amount of isobutylene released is not yet known. KMCO’s computer control system records process data in a proprietary format. The manufacturer of the system helped KMCO secure the process data and to extract the data for the various investigation parties, including the CSB. The CSB received this information on August 23, 2019. The inventory (level) of isobutylene in KMCO’s isobutylene storage tank, before and after the incident, is part of this data. The isobutylene storage tank has two level devices and preliminary evaluation revealed differences that will require further analysis.

2 The Harris County Institute of Forensic Sciences autopsy report shows the KMCO worker died from “sharp force injuries of the right upper extremity with transection of the right brachial artery and vein” resulting from an “accident” [1].

3 KMCO records show seven employee injuries resulting from the incident. Two employees sustained second and third degree burn injuries all over their body, one employee suffered from a blood clot, one employee experienced a lower back strain, and three employees developed respiratory issues.

4 According to a KMCO manager, less than 50 employees remained at the Crosby facility at the end of July 2019.

5 Artie McFerrin founded a company that built the plant at the Crosby site in 1975. In July 2012, the McFerrin family’s company sold the plant to KMCO, LLC.

6 The Center for Chemical Process Safety (CCPS) defines tolling as “[p]roviding manufacturing services for a fee by a contractor (the toller), to a company issuing (letting) a contract for those services. Talled services can include, reaction processes, formulation, blending, mixing or size reduction, separation, agglomeration, packaging/repackaging, and others or a combination of the above [19].”

7 ORG Chemical Holdings owns KMCO. ORG Chemical Holdings also owns the KMTex, LLC (“KMTex”), which operates a facility in Port Arthur, Texas. Similar to KMCO, KMTex is a tolling and specialty chemical manufacturing facility.

8 Isobutylene has a vapor density of 1.94, making it heavier than air. Isobutylene’s lower explosive limit is about 1.8 volume percent and its upper explosive limit is about 9.6 volume percent [22, p. 8].

9 Isobutylene is a gas at atmospheric pressure and typical outdoor air temperatures. Liquefying isobutylene takes increased pressure, significant cooling, or a combination of increased pressure and cooling. At atmospheric pressure, isobutylene will be a liquid if it is colder than its boiling point of 19.6 degrees Fahrenheit. Liquefying isobutylene at 20 degrees Celsius (68 degrees Fahrenheit) requires pressures greater than 2,560 hectopascal (371 pounds per square inch). Liquefying isobutylene requires more pressure at warmer temperatures and less pressure at cooler temperatures.
Explosion and Fire at KMCO Chemical Facility
Crosby, Texas | Incident Date: April 2, 2019 | No. 2019-02-I-TX

referred to as LPG, or liquefied petroleum gas [10]. KMCO received isobutylene shipments as a liquid, stored it as a liquid, and fed the isobutylene to its batch reaction system as a liquid.

2.3 KMCO Isobutylene System

KMCO used isobutylene as a raw material in its batch reaction process (Figure 4) to manufacture sulfurized isobutylene lubrication additive products [11, 12]. On the day of the incident, this reaction system was producing HiTEC® 3315 [11], a lubrication additive [13].

The equipment used to produce sulfurized isobutylene at KMCO includes an isobutylene storage tank (Figure 2) and a batch reactor (Figure 3) [14]. This report is using the “batch” term because KMCO manufactures its sulfurized isobutylene products in batches rather than in a continuous operation.

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10 Other LPG’s include propane, propylene, and butane.
11 Sulfurized isobutylene is an extreme pressure lubrication additive [20, p. 120].
12 KMCO filed a Risk Management Plan (RMP) with the EPA on February 23, 2018 [37]. KMCO included isobutylene in its RMP and the company identified the isobutylene as being a Program Level 3 process [37, p. 33]. KMCO’s RMP submission also clarifies that the isobutylene system is regulated by both the EPA RMP rule and the OSHA Process Safety Management (PSM) standard [37, p. 33].
13 The HiTEC® 3315 safety data sheet refers to sulfurized isobutylene as alkyl polysulfides.
14 KMCO replaced its isobutylene storage and piping system between 2014 and 2015.
Figure 4. shows a simplified schematic of the process used to charge the batch reactor periodically with isobutylene to make sulfurized isobutylene.

There are two pumps in the isobutylene system; an isobutylene circulation pump and an isobutylene charge pump. Operators can only start or stop these pumps from the field. The isobutylene circulation pump circulates isobutylene through more than 1,200 feet of piping, from the storage tank to the sulfurized isobutylene reactor unit and back to the isobutylene storage tank. The isobutylene charge pump then feeds the sulfurized isobutylene reactor when the proper step in the batch reaction procedure calls for adding isobutylene. As shown, the inlet piping to the isobutylene charge pump includes a y-strainer and a flex hose.

In addition to manually operated valves, the isobutylene system has several automatic valves. Of these automatic valves, board operators, working inside the control room, could only control the pressure control valve shown in Figure 4. The automatic ball valves could only be opened or closed by operators in the field.\(^\text{15}\)

3.0 The Incident

On the morning of April 2, 2019, KMCO operations staff was making a batch of sulfurized isobutylene. Before 7:00 am, operators completed the isobutylene charge to the batch reactor that night shift operators started. After completing the isobutylene charge, the unit operator closed several valves on the isobutylene charge pump outlet (discharge) piping to the sulfurized isobutylene reactor.\(^\text{16}\)

Later in the morning, an operator was walking by the sulfurized isobutylene batch reactor when there was a loud “pop” sound followed by a loud whooshing noise similar to “an air hose coming off.”

The operator described seeing a white cloud of vapor hovering near the ground with three to four feet of a wavy, hazy vapor above it, that looked “like a water mirage over hot pavement” or “like if you’re filling up a gas tank and you see the fumes coming out.

\(^{15}\) The automatic ball valve on the inlet (suction) piping to the isobutylene circulation pump was equipped with a fusible link. This design should allow the valve to automatically close under certain fire conditions [30, p. 97]. The April 2, 2019 incident did not expose this valve to fire conditions.

\(^{16}\) A scrubber pump needed repair and the sulfurized isobutylene batch was holding until that maintenance work was completed. While waiting for the maintenance on the scrubber pump, the unit operator performed other tasks, such as helping a coworker connect a railcar for a different process.
In describing the release, a KMCO supervisor said it was like seeing “a two-foot river” of isobutylene vapor “going all the way down the road.”

After identifying the leak as isobutylene, a KMCO operator used the all-call feature on the plant radio system, which allows simultaneous communication on all the KMCO radio channels, to announce: “Attention KMCO, evacuate the reaction area.” Based on KMCO surveillance video, which shows many people suddenly acting with concern and purpose, this radio call to evacuate the reaction area took place at about 10:46 am.

KMCO operators and supervisors then took actions, including:

- Ordering a plant-wide evacuation;
- Turning on fire water monitors;
- Turning off equipment;
- Instructing people using motorized equipment to shut the equipment down and evacuate; and
- Closing vehicle gates near the release to prevent workers from driving into the vapor cloud.

Despite these efforts, the isobutylene vapor cloud exploded. Workers already heading to rally points hurried their evacuation (Figure 5). KMCO surveillance cameras visibly shook just after 10:50 am, capturing the time of the explosion.\(^{18}\)

Emergency responders to the KMCO incident included KMCO’s Emergency Response Team, the Crosby Fire Department, Mutual Aid Mont Belvieu, and Harris County. Harris County responders included the Sheriff’s office and the Harris County Fire Marshal’s Office. KMCO also brought in U.S. Fire to help with the firefighting. The incident triggered a shelter-in-place order for community members within a one-mile radius \(^{19}\).

\[\text{Figure 5. Evacuation. This surveillance camera image shows workers evacuating after the explosion. (Credit: KMCO).}\]

\(^{17}\) An all-call is a call from an individual radio to every radio on the channel and to multiple talk groups. It is used to make important announcements requiring the user’s full attention \(^{23}\).

\(^{18}\) Based on KMCO surveillance video, about four minutes and 29 seconds elapsed between the operator’s radio call and the explosion.

\(^{19}\) Officials lifted the shelter-in-place at 3:15 pm, more than five hours after the explosion.
KMCO conducted a headcount of its employees, contractors, and visitors and found that one KMCO employee, an operator, was missing. Emergency responders recovered the missing operator near the entrance to a building in the plant (“plant building”) that was previously a control room. At 12:07 pm, medical responders evaluated the operator and did not try to resuscitate him. The Harris County Institute of Forensic Sciences autopsy report shows the operator died from “sharp force injuries of the right upper extremity with transection of the right brachial artery and vein” resulting from an “accident” [1].

One of the responders described what the plant building now looked like, saying:

Shrapnel. ... There was nothing left of it. Wires, there was nothing there. There wasn’t a building there anymore (Figure 6, Figure 7, and Figure 8).
4.0 The Y-Strainer

KMCO installed a filtration strainer (y-strainer) on the inlet (suction) piping to the isobutylene charge pump. A typical application for a y-strainer is to remove solid particles from a liquid stream (Figure 9). The three-inch y-strainer had threaded ends, and KMCO added flange-to-threaded connections to allow the y-strainer to connect to the isobutylene piping flanges (Figure 10).

Post-incident, the source of the isobutylene release was identified as the three-inch y-strainer on the inlet (suction) piping to the isobutylene charge pump. The y-strainer was found with a hole, which is roughly 3-inches by 5.5-inches, on its west side (Figure 11). A KMCO operator (who saw the release) confirmed that the location of the hole was consistent with where he saw the isobutylene escaping.

A metal fragment that appears to be consistent with the piece missing from the y-strainer was found on the ground, near the sulfurized isobutylene reactor, and to the west of the y-strainer (Figure 12).

Figure 9. Generic Y-Strainer. This graphic shows a generic depiction of a typical y-strainer application—used to remove solid particles from a liquid stream. (Credit: [13]).

Figure 10. Y-Strainer (East Side). This post-incident photo shows the top and east side of the three-inch y-strainer on the inlet piping to the isobutylene charge pump. The orientation of the y-strainer was such that the straight through flow was headed north. (Credit: CSB).

Figure 11. Y-Strainer. This photo shows west side of the failed y-strainer involved with the April 2, 2019 incident. (Credit: CSB).

Figure 12. Y-Strainer Piece. This photo shows the single piece that likely separated from the failed y-strainer. (Credit: CSB).
The y-strainer involved in the incident appears physically consistent with the standard three-inch gray iron y-strainer KMCO stocks in its warehouse. Using the KMCO warehouse inventory information, the CSB purchased an exemplar y-strainer that also appears physically consistent with the y-strainer involved in the incident (Figure 13).

The supplier’s technical specifications (Figure 14) confirm that the exemplar y-strainer has a gray iron (cast iron) body with an internal stainless-steel strainer. Gray iron is a type of cast iron [14].

5.0 Next Steps
The CSB investigation is ongoing. Investigators will continue developing the incident causal analysis based on evidence collected during the investigation. A final report, consisting of facts, analysis, conclusions, and recommendations will be issued at the completion of the investigation.
Members of the U.S. Chemical Safety and Hazard Investigation Board:

Kristen Kulinowski, Ph.D.
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Manuel Ehrlich
Member

Richard Engler
Member
References


[3] Jose Plata, Jorge Torres and Julio Chavez v. KMCO, LLC and ORG Chemical Holdings.


Explosion and Fire at KMCO Chemical Facility
Crosby, Texas | Incident Date: April 2, 2019 | No. 2019-02-I-TX


