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CSB U.S. Chemical Safety and Hazard Investigation Board

Factual Investigative Update

April 26, 2018 Husky Superior Refinery Explosion and Fire

Figure 1. *Surveillance Camera Image of the Husky Superior Refinery Explosion. Credit: WDIO ABC News.*

August 2018

On April 26, 2018, an explosion (Figure 1) and subsequent fire (Figure 2) occurred at the Superior Refinery Company LLC refinery in Superior, Wisconsin ("Husky Superior Refinery").[1] The incident occurred in the refinery's Fluid Catalytic Cracking Unit (FCCU). In preparation for the shutdown, the refinery brought in hundreds of contractors and increased operations staffing. The contractors were performing many tasks such as electrical work, preparing for chemical cleaning, building scaffolding, and welding. As a result of the explosion, thirty-six people sought medical attention, including eleven refinery and contract workers who suffered OSHA recordable injuries. In addition, a large portion of Superior,[2] Wisconsin was evacuated.

The explosion occurred around 10:00 am on April 26, 2018, while the refinery was shutting down the FCCU for periodic maintenance and inspection. The explosion occurred during a scheduled break time and many workers who were previously in the unit before the explosion had moved either into blast resistant buildings[3] or away from the process unit before the explosion occurred.

The FCCU uses heat and a small particle-size, solid catalyst to convert high molecular weight hydrocarbons into more valuable, lower molecular weight hydrocarbons.[4] The FCCU has three slide valves, the regenerated catalyst slide valve, spent catalyst slide valve, and a flue gas slide valve to, among other functions, control the flow of catalyst between the reactor (hydrocarbon-side) and the regenerator (air-side) of the FCCU.

The FCCU shutdown began when Husky Superior Refinery workers stopped the hydrocarbon feed to the FCCU at 5:40 am on April 26, 2018. After the feed was stopped, steam was used to clear the FCCU

1 According to a Calumet filing with the U.S. Securities and Exchange Commission, Husky Superior Refining Holding Corp. acquired the Superior Refinery from Calumet (Calumet Refining, LLC) on November 8, 2017, 170 days before the April 26, 2018 incident. The Superior Refinery Company LLC is a wholly-owned subsidiary of Husky Superior Refining Holding Corp.

2 Superior, Wisconsin covers 45 square miles and has a population over 27,000.

3 The CSB's investigation report into the 2005 BP America Refinery Explosion discussed the importance of the use of blast resistant buildings. This report can be found here.

4 The CSB described a FCCU in both its investigation report and its animation of the 2015 explosion at the ExxonMobil refinery in Torrance, California. Among other free online resources, the OSHA Technical Manual provides a description of Petroleum Refining Processes that includes a FCCU discussion in Section IV (F). In addition, some readers may find this API Fluid Catalytic Cracking Unit video to be a helpful overview of a general refinery FCCU process.

Figure 2. *Smoke from the Fire at the Husky Superior Refinery. Credit: WDIO ABC News.*

reactor of hydrocarbons and the regenerated catalyst and spent catalyst slide valves were closed as part of the shutdown procedure.

In all modes of FCCU operation, it is important to prevent air in the regenerator from mixing with hydrocarbons in the reactor and downstream equipment because of the potential for such mixing to create flammable (explosive) hazard conditions within portions of the FCCU. During normal operation this is achieved, in part, by using the slide valves to maintain a catalyst level in both the reactor and regenerator which acts as a barrier.

A differential pressure instrument continually measured the difference in pressure from directly above the spent catalyst slide valve to the regenerator pressure. During the shutdown, a positive differential pressure indicated that the pressure above the spent catalyst slide valve was greater than the regenerator pressure, and that no air was flowing from the regenerator into the reactor.[5] A negative differential pressure, on the other hand, could indicate conditions allowing air to flow from the regenerator through the spent catalyst slide valve and into downstream equipment. This instrumentation, however, would have reported any negative differential pressures as zero because its lower limit was zero, and it was not configured to show negative differential pressures.

The Husky Superior Refinery's FCCU shutdown procedure specified that the unit "may have to have some catalyst in the reactor stripper to hold a seal across the spent [catalyst] slide valve." At times during the shutdown, conditions existed that could have allowed air from the regenerator to flow backwards through the spent catalyst slide valve into the reactor, and into equipment downstream of the reactor which contained flammable hydrocarbons.

Process data indicated that the spent catalyst slide valve was closed about 10 minutes into the shutdown and the reactor catalyst level fell to zero about 30 minutes after operators stopped the feed. Post-incident inspection showed that a catalyst level was not present above the spent catalyst slide valve. Disassembly and evaluation of the spent catalyst slide valve revealed internal wear that could have allowed catalyst flow through the valve even when the valve was in the closed position. The differential pressure across the spent catalyst slide valve was zero for about 10 percent of the time between the beginning of the shutdown at 5:40 am and the incident at about 10:00 am, indicating that air flow from the regenerator into the reactor and downstream equipment was possible.

Iron sulfide deposits can exist inside FCCU equipment. The Husky Superior Refinery's FCCU training manual states that, "The danger of iron sulfide exists in its 'pyrophoric' properties, that is to say,

5 If no catalyst barrier is present above the spent catalyst slide valve, positive differential pressure could indicate conditions allowing hydrocarbon flow into the regenerator and downstream equipment, where air is present.

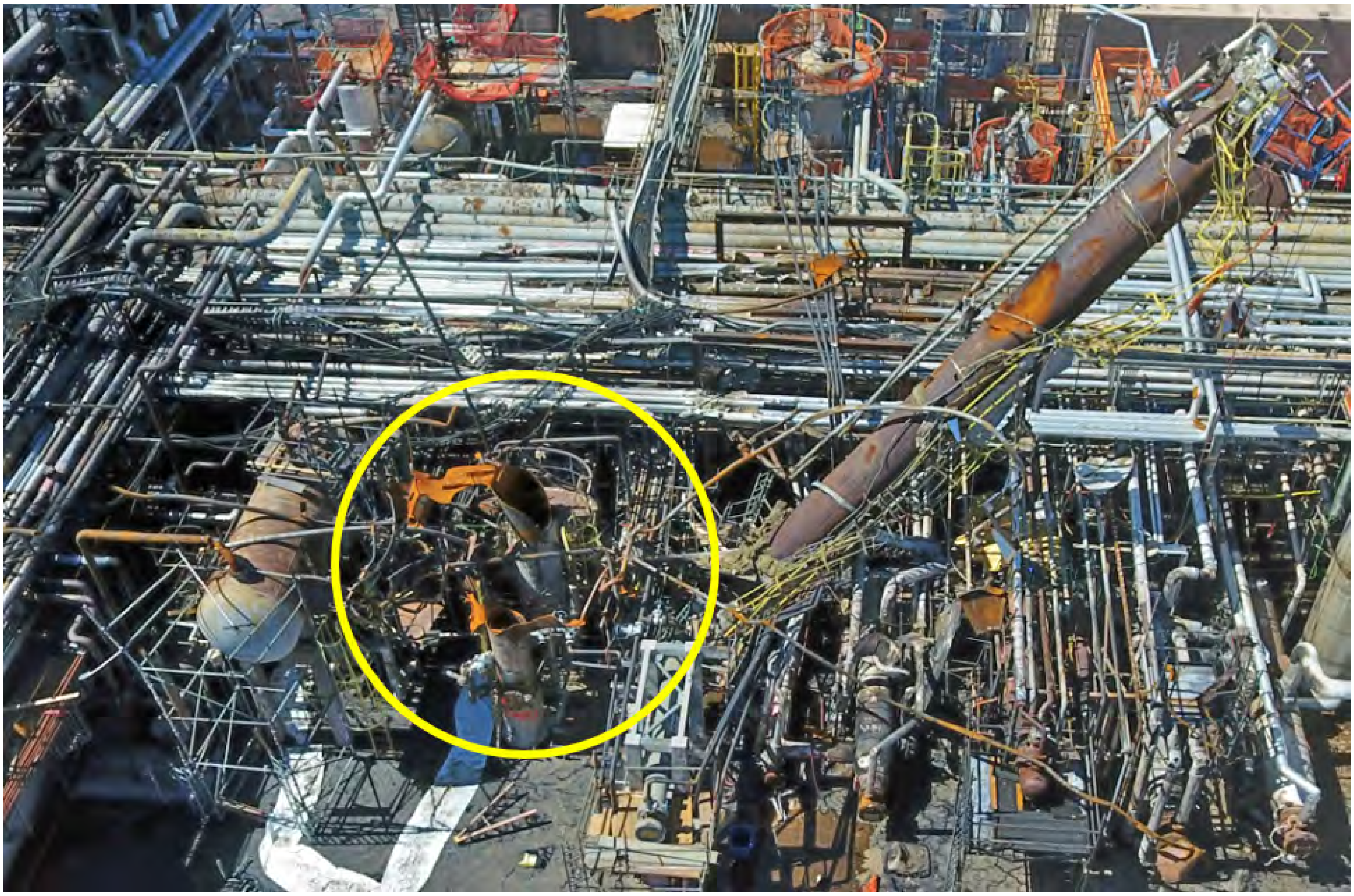

Figure 3. *Two of the Vessels Destroyed in the Explosion at the Husky Superior Refinery (yellow circle). The photo shows that only the bottom portion of the two process vessels remained after the explosion. The remaining portions of the vessels were blown into surrounding units of the refinery. Credit: Husky Superior Refinery.*

it will ignite spontaneously when exposed to air." The Husky Superior Refinery planned to treat its FCCU equipment susceptible to containing iron sulfide with a chemical to mitigate iron sulfide deposits after shutting down the unit. Because these procedures had not been implemented at the time of the explosion, however, iron sulfide deposits were not yet treated and could provide a source of ignition if exposed to air.

Two FCCU vessels,[6] the primary absorber[7] and sponge absorber[8] (Figure 3), were destroyed in the explosion. The primary and sponge absorbers serve to recover heavy hydrocarbons[9] from a gas stream by mixing the gas stream with a liquid stream that absorbs the heavy hydrocarbons.

Debris from the explosion flew about 200 feet, and impacted a large, nearby, aboveground storage tank containing about 50,000 barrels of asphalt, puncturing the side of the steel tank and spilling over 15,000 barrels of hot asphalt into the refinery (Figure 4). This released asphalt ignited about two hours after the explosion, creating a large fire.

A Unified Command was set up to address the situation at the Husky Superior Refinery in accordance with National Incident Management System (NIMS) practice. Operations for the incident command included emergency responders from the Husky Superior Refinery's emer-

6 The two vessels are part of the gas concentration unit, which is a subset of what the Husky Superior Refinery records refer to as the FCCU.

7 The dimensions of the primary absorber were 36 inches (internal diameter) by 69.5 feet tall. The vessel had a maximum allowable working pressure of 250 pounds per square inch at 150 °F. The primary absorber was constructed in 1961 using SA-212-B steel and the vessel was not stress relieved.

8 The dimensions of the sponge absorber were 30 inches (internal diameter) by 48 feet tall. The vessel had a maximum allowable working pressure of 250 pounds per square inch at 150 °F. The sponge absorber was constructed in 1961 using SA-201-A steel and the vessel was not stress relieved.

9 The liquid phase recovers gases heavier than propane from the vapor phase.

Figure 4. *Post-incident photographs of the leaking Asphalt Storage Tank. Debris from the explosion punctured the side wall of the tank creating a large asphalt leak outside of the secondary containment area. Credit: CSB (left) Duluth News Tribune (right).*

gency response team supported by the Superior Fire Department.

Around 12:15 pm the spilled asphalt ignited, creating a large fire spanning multiple units at the refinery. Because this fire risked compromising other process equipment containing hazardous chemicals, the Unified Command issued its first community evacuation notice at 1:00 pm. By 2:41 pm, the evacuation zone consisted of a 3-mile radius around the refinery, and a 10-mile rectangle extending south from the refinery (Figure 5). The evacuation zone size was established to protect the public from the smoke plume and as a precaution in case the refinery's highly toxic hydrofluoric acid equipment was compromised.[10]

Firefighters extinguished the asphalt fire at the refinery by 9:00 pm. The Unified Command then lifted the evacuation zone the next morning at 6:00 am.

The CSB investigation is ongoing. Investigators continue to collect data and evidence from the site. Investigators will develop a root cause analysis of this incident based on evidence collected during the course of the investigation. A final report, including facts, analysis, conclusions, and recommendations will be issued at the conclusion of the investigation.

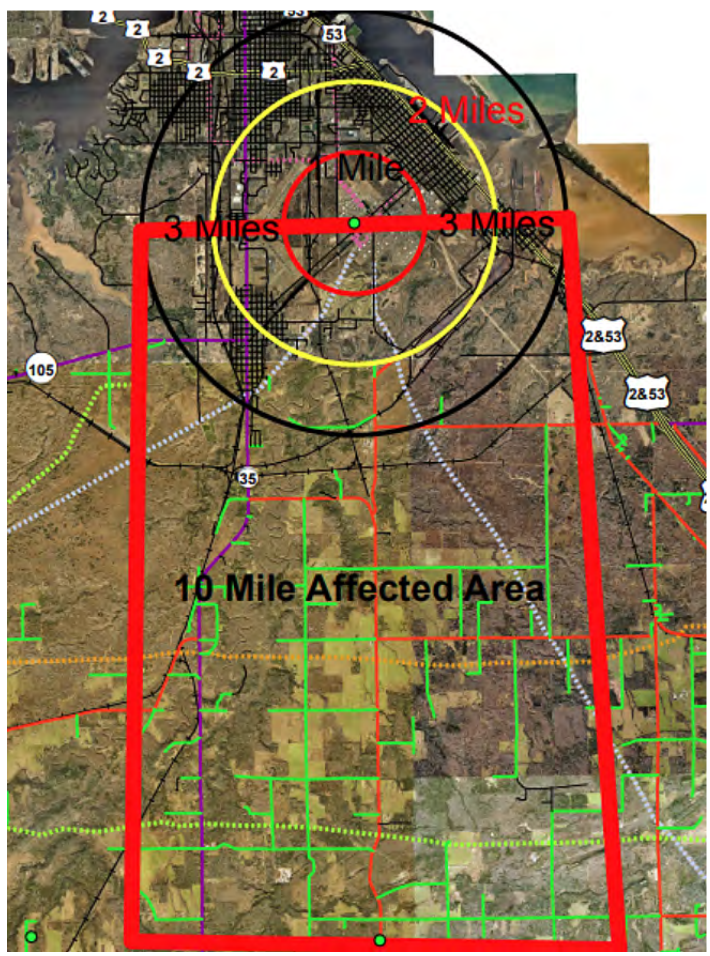

Figure 5. *Evacuation Zone on April 26, 2018. Credit: Douglas County, Wisconsin.*

10 The Husky Superior Refinery uses hydrofluoric acid in its alkylation unit. The hydrofluoric acid storage tank is located about 150 feet from the primary and sponge absorbers that exploded. Neither the hydrofluoric acid tank nor the water curtain equipment surrounding the hydrofluoric acid tank, used to provide water suppression in the event of an acid leak, were impacted by explosion debris.