On April 26, 2018, an explosion and subsequent fire (Figure 2) occurred at the Superior Refinery Company LLC refinery in Superior, Wisconsin (“Husky Superior Refinery”). 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, 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 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. 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...
reactor of hydrocarbons and the regenerated catalyst and spent cata-
lyst 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 eval-
uation 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.
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, the primary absorber and sponge absorber

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.

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 emerg-
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.

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.