Investigation Update

December 2022

This document provides an update on the CSB investigation of the April 8, 2021, incident at the Yenkin-Majestic OPC Polymers resin plant in Columbus, Ohio.

Incident Summary

On April 8, 2021, at approximately 12:02 a.m., a mixture of flammable naphtha vapors and resin liquid became pressurized and then was released through the manway of an operating kettle at Yenkin-Majestic's OPC Polymers resin plant in Columbus, Ohio. The naphtha vapor spread through the enclosed building and formed a flammable vapor cloud both inside and outside the building. Approximately two minutes later, at 12:04 a.m., the flammable vapor cloud found an ignition source, and an explosion and fire erupted (**Figure 1**). One employee was fatally injured, and eight others were transported to area hospitals for injuries. The blast shook neighboring buildings, and at least one nearby business sustained damage. The resin plant was severely damaged, and Yenkin-Majestic demolished it after the incident.

Figure 1. Resin plant the day after the incident. (Credit: CSB)

Background Information

YENKIN-MAJESTIC

Yenkin-Majestic Paint Corporation ("Yenkin-Majestic" or "YM") is a coatings and paint manufacturer based in Columbus, Ohio. The company was founded in 1920 and moved to its current location in 1954. At the time of the incident, Yenkin-Majestic employed about 180 people and had three divisions: Majic Paints, YM Industrial Coatings, and OPC Polymers [1]. OPC Polymers developed and manufactured resins for the coatings industry [2]. The incident occurred at the resin plant within the Yenkin-Majestic facility.

VM&P NAPHTHA (SOLVENT)

In resin production, a solvent is typically added as a "thinner" to the resin mixture to lower the final product's viscosity, as well as affect its drying and film formation properties [3, pp. 12, 71]. Yenkin-Majestic used varnish maker and painter's naphtha ("VM&P") as the solvent for the resin batch that was in production the day of the incident [4]. VM&P is a petroleum-derived hydrocarbon solvent, also known as hydrotreated light straight run naphtha. According to its safety data sheet, VM&P causes skin irritation and may cause drowsiness or dizziness. VM&P is a highly flammable liquid that boils (vaporizes) between 264 °F and 291 °F. As a vapor, VM&P is about four times heavier than air, meaning that it will accumulate in low or confined areas and spread along the ground.

Yenkin-Majestic stored VM&P and other liquid ingredients in a storage tank farm located outside of the resin building. The company transferred the liquid ingredients into the kettles through piping from the storage tanks in quantities specified in its recipes.

RESIN PRODUCTION PROCESS

OPC Polymers could produce over 120 different products at the resin plant [5]. The resin batch reactions took place inside agitator[a]-stirred reactors, called kettles, that were heated with furnaces or steam. **Figure 2** is a simplified drawing of a furnace-heated kettle. The materials needed for the batches were added to the kettle from the top of the kettle. Liquid ingredients would be added at the top of the kettle through piping routed from storage tanks. Solid ingredients could be dropped into the kettle from a hopper through an opening on the kettle, typically the manway. Operators could also add solid material into the kettle in smaller quantities through the manway as needed.

[a] An agitator, or a mechanical mixer, is a shaft-mounted impeller system that is connected to a drive unit (such as a motor) [6, p. 345].

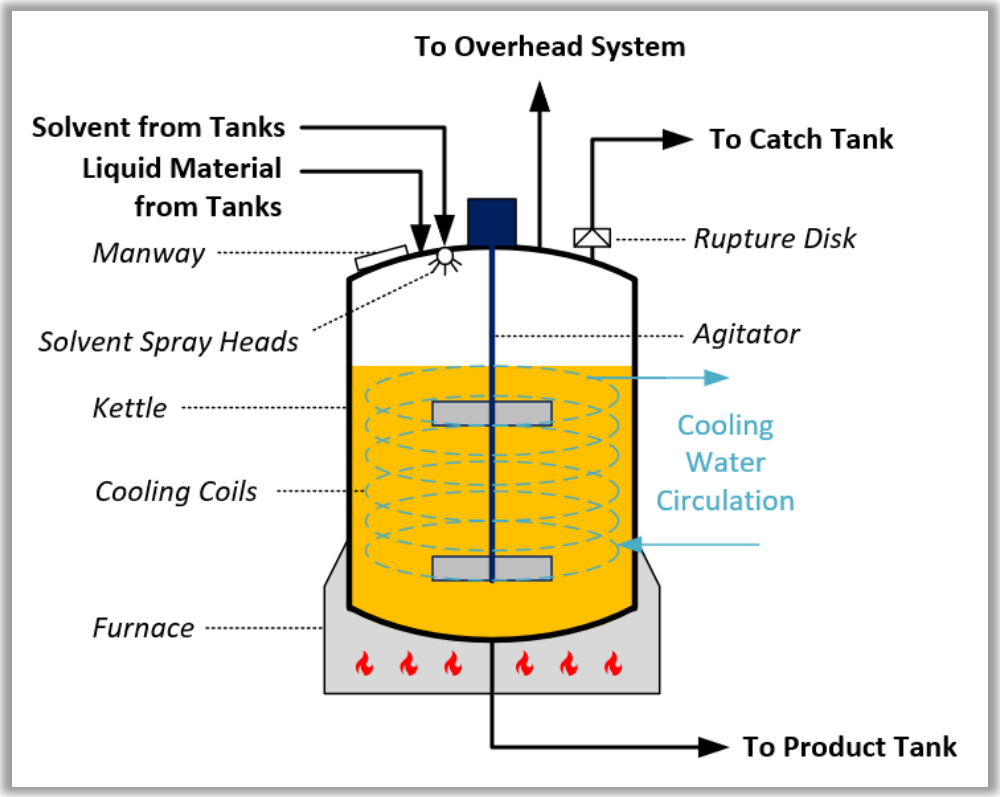

Figure 2. Simplified kettle drawing (not to scale). (Credit: CSB)

Yenkin-Majestic used a proprietary recipe to make each resin product by blending and reacting the various chemicals inside the heated, continually stirred kettles. Towards the end of the reaction, the kettle operators analyzed samples of the kettle's contents every 15-20 minutes to monitor the reaction's progress. After the operator determined that the reaction was completed, based on laboratory sample results, the operator would push a "Batch Done" button at the kettle's control panel. This action would shut down the furnace and begin water circulation through the cooling coils to cool the kettle's contents.

During the cooling step, solvent was also typically added to aid in cooling.[a] The solvent's primary purpose was to bring the resin mixture to a target product specification, and it did not chemically react with the resin. After the kettle contents were cooled down to a target temperature, the resin was transferred to a tank, where it was blended with additional solvent to a final specification. The VM&P solvent is less dense and less viscous than the resin produced in the kettle. According to Yenkin-Majestic's standard operating procedures, proper agitation (or mixing) was required for the resin manufacturing process to mix all ingredients and distribute heat optimally inside the kettle.

Kettle 3 was typically operated at or near atmospheric pressure. The kettle was configured with a high-pressure alarm at 2 pounds per square inch gauge (psig), and an automatic high-pressure trip at 4 psig. If the pressure inside the kettle exceeded 4 psig, the safety interlock[b] was designed to shut down the furnace and turn on

[a] The solvent varied based on the product. On the night of the incident, the cooling solvent added was VM&P.

[b] Safety interlocks take automatic action to achieve or maintain a safe state of the process when a process variable reaches a defined limit [8, p. 217].

cooling water to the coils to reduce the pressure inside the kettle. The Kettle 3 emergency pressure-relief system also included one rupture disk to protect the vessel from high-pressure conditions. In the event of high pressure inside the kettle, the rupture disk would open and direct the pressurized contents of the kettle into the catch tank.

The incident initiated at Kettle 3 during the production of a batch of resin. The batch was in its cooling step, before any material was transferred out of the kettle into another tank.

Resin Plant Layout

The resin plant was a multi-story enclosed building that housed six kettles and other process equipment. The kettles spanned two stories of the resin plant, where the first (ground) floor housed the furnaces that heated the kettles, and the second floor contained the equipment used to control the process. The kettles were enclosed in various rooms. Some of the kettles were set up to be controlled and monitored through a control panel next to the kettle inside the kettle room, while others were controlled from adjacent control rooms. The laboratory, where operators analyzed samples during the batch runs, was on the third floor.

The incident began on the second floor of the resin plant, where a two-phase mixture of flammable VM&P solvent vapors and resin liquid became pressurized and then was released from Kettle 3's manway. **Figure 3** shows the general layout of the second floor, where red circles indicate kettle locations, and other circles indicate auxiliary equipment such as tanks.

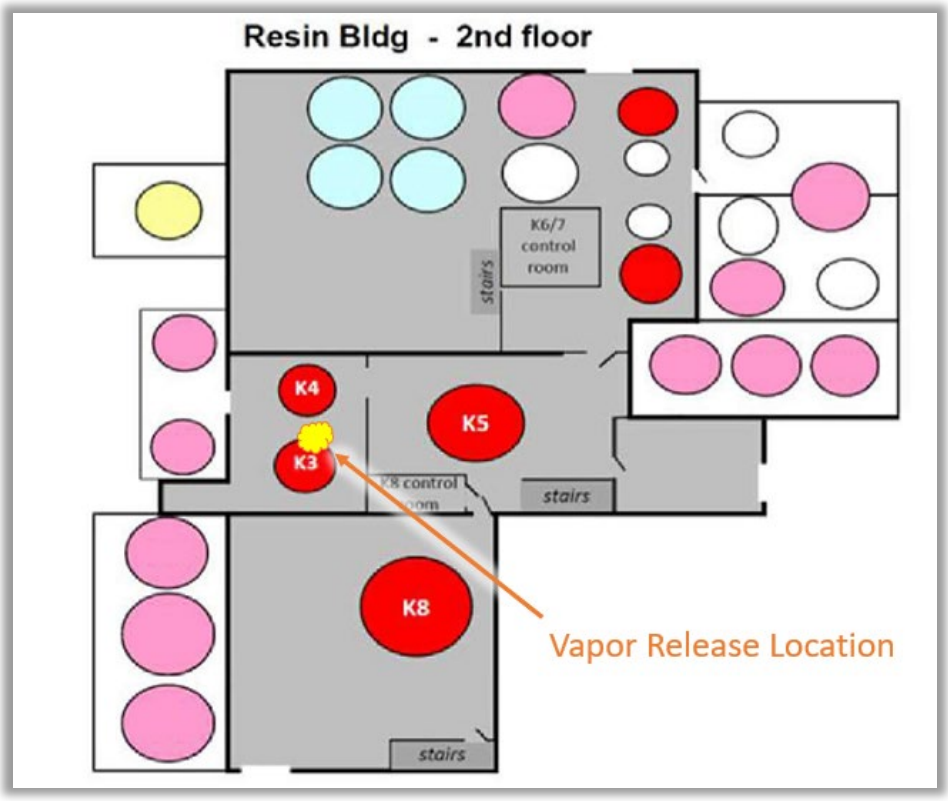

Figure 3. Flammable solvent vapor release location. (Credit: YM with annotations by CSB)

Incident Description

The incident occurred during the night shift when the reaction in Kettle 3 was nearly complete. Fifteen employees were working at the resin plant that night. Employee A, who was responsible for operating Kettle 3 on this night shift,[a] had been analyzing resin samples to monitor the progress of the reaction. Recorded data from the control system and surveillance video footage showed that the agitator shut down at approximately 10:22 p.m. while Employee A was not in the kettle room.[b] Employee A returned a few minutes later, at 10:25 p.m., after processing the final resin sample for this batch. Employee A pushed the control system's "Batch Done" button at approximately 10:33 p.m. to begin cooling the kettle's contents.[c] At this point in the procedure, the Kettle 3 agitator should have been running, but it remained stopped.

At approximately 11:06 p.m., Employee A began adding solvent (VM&P) into the kettle through the four spray heads at the top of the kettle (**Figure 2**). According to the solvent flow totalizer data, about 300 gallons[d] of solvent flowed into the kettle at a steady rate over about 26 minutes, from approximately 11:06 p.m. to 11:32 p.m. Control system records showed that the temperature measured inside the kettle during this time was about 430 °F, while the solvent coming in from the storage tank was approximately 70 °F. Employee A finished adding the solvent to Kettle 3, and he was waiting for the kettle temperature to cool down to less than 325 °F before transferring the resin into the next tank.

Around midnight, about 90 minutes after Employee A pushed the Batch Done button, the kettle temperature was recorded at 424 °F. At this time, Employee A looked into the kettle through the glass window of the manway and noticed for the first time that the agitator was off (not turning). He later told the CSB that he did not know why or when it had turned off; however, knowing that the agitator was supposed to stay on for the duration of a batch, he turned it back on.

When the agitator began mixing the kettle's stagnant layers of hot resin and liquid solvent (VM&P) at 12:02 a.m., the solvent began to vaporize, increasing the pressure inside the kettle from nearly 0 to 4 psig in 15 seconds and triggering the kettle's high-pressure alarm and safety interlock.[e] About two seconds after the high-pressure alarm activated, when the pressure inside the kettle reached approximately 9 psig, a mixture of hot resin liquid and flammable solvent vapor began releasing from the kettle's manway into the enclosed room where the kettle was located. **Figure 4** shows surveillance camera images from the first six seconds of the release from Kettle 3's manway. Within seconds, the entire room filled with white vapor, obscuring visibility. Employee A could smell what he later identified to the CSB as flammable VM&P naphtha inside the room.

[a] The kettle operators were typically qualified for multiple kettles, and were assigned a batch, or kettle, for each shift based on the resin plant's production schedule.

[b] The furnace also shut down at this time, because it was programmed to automatically shut down when the agitator shut down.

[c] The cooling water flow did not start, because it was programmed to activate only while the agitator was running.

[d] Kettle 3 could contain up to almost 3,000 gallons of liquid. Based on the kettle's geometry, 300 gallons of liquid would add approximately 9-10 inches to the liquid level inside the kettle.

[e] The safety interlock was designed to shut down the furnace and turn on cooling water to the coils. Since the furnace was already shut down, only the cooling water was activated by this action.

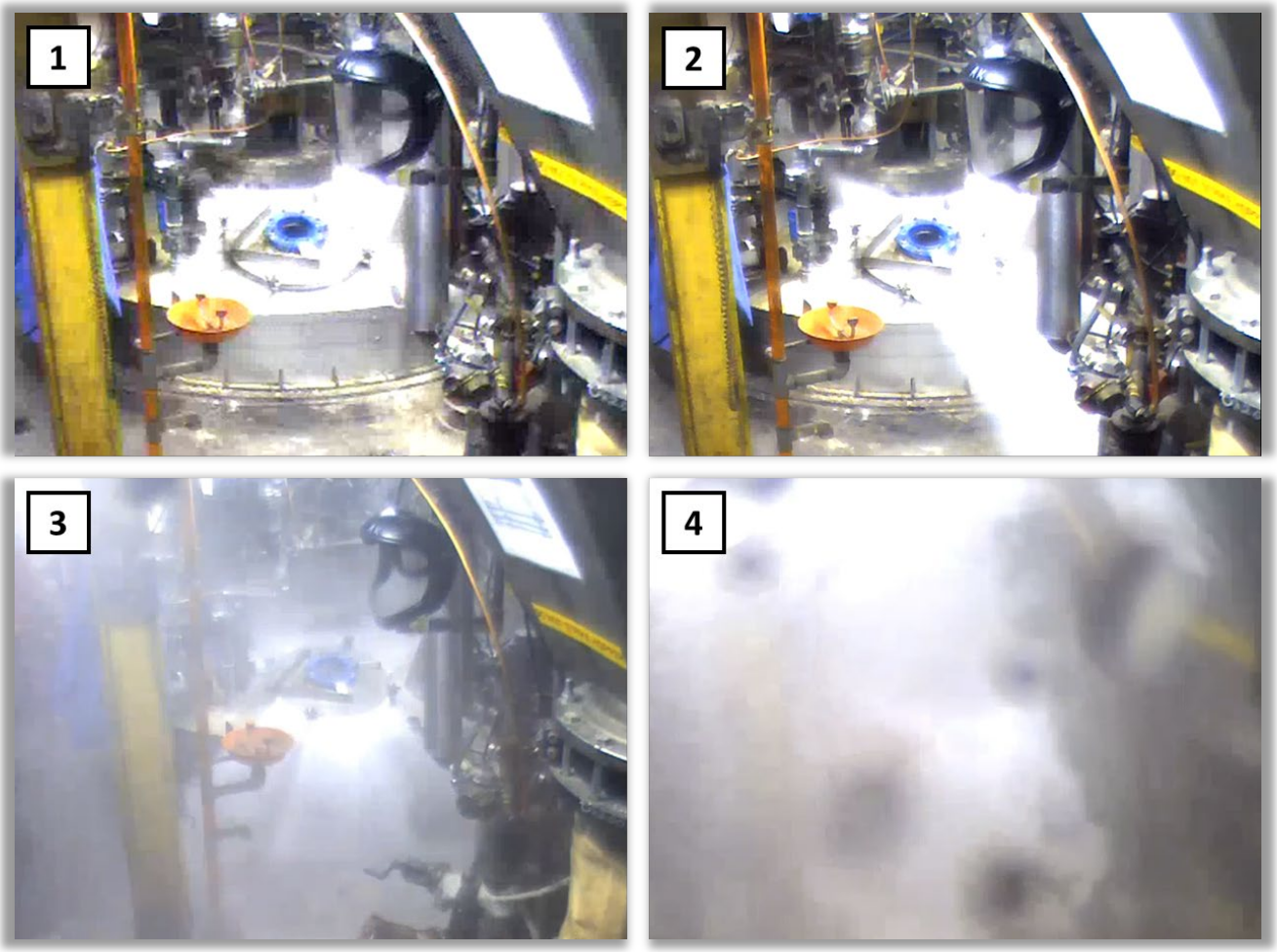

Figure 4. Initial six seconds of the vapor release from Kettle 3. (Credit: Yenkin-Majestic)

Employee A informed the CSB that after the flammable release started, he tried to reverse his actions and turn off the agitator, but he could not see through the white vapor and had difficulty breathing. He had also been sprayed with hot resin during the release. Employee A stated that he tried to hit the emergency-stop button with his eyes closed, but he was not able to reach it. About 20 seconds after the release started, Employee A evacuated from the kettle room.

Employee B, who was in a nearby kettle room, saw Employee A in distress and helped him evacuate from the building. Surveillance cameras show Employees A and B emerging from the resin plant at approximately 12:03:50 a.m., about 80 seconds after the release began, and approximately 30 seconds before the explosion.

The agitator continued stirring the contents of Kettle 3, and the pressure inside the kettle continued to climb until it peaked at 18 psig, according to control system records. Flammable solvent vapor continued leaking from the manway, and over the next minute, the kettle pressure gradually decreased until it was less than 1 psig.

Meanwhile, operators in other areas of the resin plant were unaware of the release. Surveillance cameras recorded a cloud of flammable solvent vapors moving into adjacent operating areas of the plant. Eventually, the flammable vapor cloud began to flow out of the second floor onto the ground level, where it could be seen from

outside of the building. At 12:03:30 a.m., Employee C saw the white vapor from the outside of the building and began running into the resin plant to investigate what he thought was a steam leak.[a] Around this same time, multiple flammable gas detectors inside the furnace room on the first floor started recording an increasing concentration of flammable vapors.[b]

Figure 5 shows the extent of the ground-hugging flammable vapor cloud pouring out of the west side of the resin plant, just before the vapor cloud exploded at 12:04:23 a.m. The arrow points in the direction of the kettle room where the release occurred on the second floor.

Figure 5. Vapor cloud just before the explosion. (Credit: Yenkin-Majestic)

Shortly before the explosion, some employees were using their cell phones to communicate with workers inside the plant, and some employees stated that they personally alerted other employees of the incident. According to witness accounts, no one used the resin plant's intercom communication system to call for an evacuation or otherwise warn workers of the imminent danger. Post-incident, Yenkin-Majestic also confirmed that the fire alarm system had not been activated to evacuate workers prior to the explosion.[c] Employees working at or near the resin plant that night told CSB investigators that they did not hear any alarms or other warnings before the explosion.

The explosion also ignited additional flammable material present at the resin plant, resulting in a large fire, and several of the 15 employees working that night had to evacuate the building by running through the flames. Employees performed a head count and identified three missing people. Firefighters rescued two injured and trapped employees from the collapsed and unstable resin plant. The third missing employee was found fatally

[a] Steam and solvent vapors are typically both white in appearance.

[b] The flammable gas detectors in the furnace room triggered automatic furnace shutdowns and an e-mail notification to the process engineer; however, they were not configured to sound an audible alarm inside the furnace rooms. All four furnaces were shut down at the time of the incident.

[c] According to Yenkin-Majestic's fire emergency and evacuation plan, the fire alarm system starts a general evacuation alarm if a manual pull station is activated, a water-flow is detected, or a smoke detector is set off.

injured and partially covered by rubble inside the second floor of the resin plant several hours later that morning, when the fire department continued the search in daylight using surveillance drones.

Kettle 3 History

In 1961 Yenkin-Majestic hired a contractor to design and build Kettle 3. At the time, the vessel was designed and stamped as a pressure vessel with a maximum allowable working pressure (MAWP) of 40 psig, and registered with the National Board of Boiler & Pressure Vessel Inspectors (NBBI).

Yenkin-Majestic stated that following a major Kettle 3 project in 1997, the manufacturer's original nameplate was removed in an effort to de-rate the kettle and lower its MAWP.[a] Yenkin-Majestic did not have documentation of this change. In 2019, Yenkin-Majestic updated Kettle 3's equipment file with a letter stating that "[...] this vessel should be considered de-rated, operating at atmospheric conditions." Yenkin-Majestic's records showed that at the time of the incident, Kettle 3's maximum operating pressure was 12 psig, with a rupture disk setpoint within a "range" of "13.5 – 15 psig."

In December 2020, Yenkin-Majestic modified Kettle 3 to add a new, custom-designed 20-inch manway on top of the kettle consisting of a nozzle, an operable lid, and a gasket (**Figure 6**). Yenkin-Majestic contracted one company to design, fabricate, and install the manway, and another company to evaluate the nozzle design conditions for a maximum pressure of 16 psig. The flammable release occurred from this new manway.

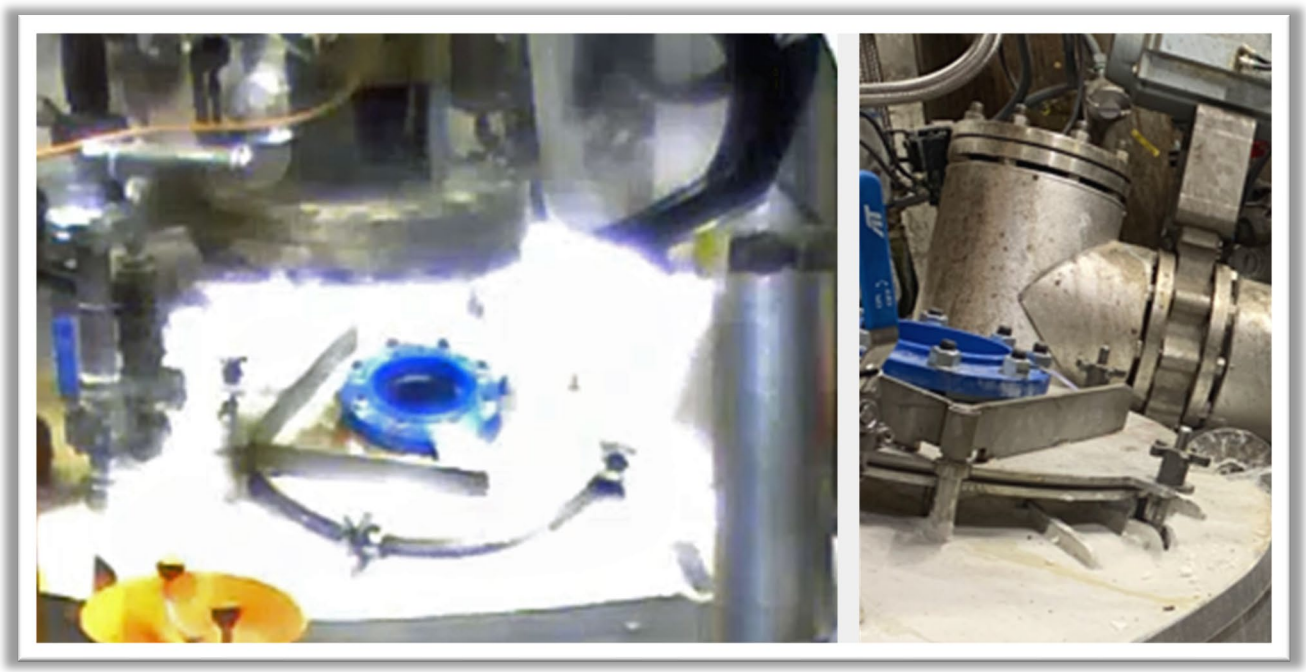

Figure 6. Photos of the new manway before the incident. (Credit: Yenkin-Majestic)

[a] Pressure vessels containing pressures that exceed 15 psig are typically subject to mandatory codes as defined by the international American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code [9].

Path Forward

The CSB is continuing to gather facts and analyze several key areas, including:

- Equipment design;
- Process safety management systems;
- Regulations, industry standards, and guidance; and
- Emergency response to a flammable vapor release.

The investigation is ongoing. Complete findings, analyses, and recommendations, if appropriate, will be detailed in the CSB's final investigation report.

References

[1] Yenkin-Majestic, "Yenkin-Majestic Paint Corporation," [Online]. Available: https://www.yenkin-majestic.com/. [Accessed 29 July 2021].

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[9] The American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section VIII: Rules for Construction of Pressure Vessels, New York, NY, 2021.