flare prevention/minimization assessment

Chevron Richmond Refinery
December 31, 2024

Contents

Tables

Figures

Executive Summary

The Chevron Richmond Refinery operates under stringent federal, state, and local regulations, including those from the Bay Area Air Quality Management District (Air District) related to flaring activity, to protect public health and the environment. Safety flares are the most visible component of the refinery's overall safety system and are used to burn any excess gases when relieving pressure during the refining process and ensuring they are not released directly into the atmosphere.[1]

As part of a 2024 settlement agreement between Chevron and the Air District, Chevron committed to certain actions aimed at reducing emissions and enhancing transparency about flaring events. This Flare Prevention/ Minimization Assessment report presents a comprehensive analysis of the primary cause and contributing factors of reportable flaring events from February 2018 through May 2024. The review identified hydrogen (H2) infrastructure reliability and electrical infrastructure reliability as key areas of focus to improve flaring performance.

The analysis showed flaring events caused by H2 infrastructure reliability were more frequent during the initial part of the 2018 commissioning of a new, more efficient hydrogen production plant and decreased in frequency since due to several targeted efforts being implemented. Electrical infrastructure reliability causes were found to be relatively infrequent but were identified as critical areas for the refinery to consider improvements. Other causes of flaring analyzed in this assessment were categorized as singular occurrences where the root causes and contributing factors were adequately addressed with corrective actions and preventative measures following the specific event.

In the last two years, Chevron has invested over $20 million to reduce flaring events refinery-wide. New infrastructure improvement project recommendations, requiring an additional $12-$15 million investment to execute, have been identified in this assessment as having the potential to further improve H2 and electrical infrastructure reliability issues and minimize flaring. Detailed evaluations of the recommendations will be conducted before implementation. Separately, Chevron will continue other efforts to reduce flaring through improved monitoring and sampling, as well as additional operator training.

The Richmond Refinery has a proud legacy of providing the energy the region depends on for more than 120 years. Chevron is committed to continuous improvement and advancing ways to bring affordable, reliable, and ever cleaner energy to our community.

[1] For more information on flaring visit: https://richmond.chevron.com/environment/air-quality-and-flaring

1 Introduction and Background

Chevron operates a petroleum refining facility located in the City of Richmond and within the San Francisco Bay Area Air Basin that is regulated by the Air District (the "Richmond Refinery").

The Richmond Refinery works with over 36 federal, state, and local regulatory agencies to protect public health and the environment. The health and safety of our community, our workforce and the environment are our highest priorities, and we are committed to advancing ways to reduce emissions from our operations. Since the implementation of our Modernization Project, which included the commissioning of a new Hydrogen Plant, particulate matter emissions facility-wide have been reduced by over 36 percent.

Flaring minimization has been, and continues to be, a focus area at the Richmond Refinery. Chevron has dedicated significant resources and capital investments to reduce flaring from our operations. In 2023 and 2024, the Richmond Refinery invested over $20 million to address flaring. Additionally, the Richmond Refinery is implementing various improvements to our flare monitoring and sampling systems, formalizing an operator training program related to flare reduction, and increasing community engagement and education about flaring.

Chevron has performed a comprehensive assessment of all Air District Rule 12-12 reportable flaring events that have occurred at the Richmond Refinery beginning with implementation of the Modernization Project in February 2018 and ending in May 2024. This Flare Prevention/Minimization Assessment for the Richmond Refinery is provided pursuant to the requirements of Attachment A, Section 4 of the Rule 6-5 Settlement Agreement, which was entered into as of February 12, 2024, by and between Chevron U.S.A. Inc. ("Chevron") and the Air District. This detailed written report includes (i) an analysis of the primary cause and contributing factors of each flaring event and actions that could have been taken to prevent or minimize the event; and (ii) recommendations for potential projects that may prevent or minimize the recurrence of such events.

2 Scope of Review

Data were gathered from 48 Flare Causal Reports covering 114 flaring events from February 2018 through May 2024 that were submitted to the Air District. Flare Causal Reports are required by Air District Rule 12-12 and contain the dates of flaring events, root causes, contributing factors, and preventative measures. This information is also documented in the Richmond Refinery's Flare Minimization Plan, which is updated and submitted to the Air District on an annual basis.

The primary cause and contributing factors of each flaring event and actions that could have been taken to prevent or minimize the event were evaluated to (1) identify the failed equipment or process that caused the event and (2) understand the frequency of occurrences related to the equipment or process. Based on this flaring incident analysis, each equipment failure was reviewed to identify:

1. the specific equipment type,
2. the failure mode, (i.e., the specific way in which equipment, or a process can fail to perform its designed function), and

3. the failure mechanism, (i.e., the processes or physical conditions that lead to a failure mode of equipment).

Through this methodology, primary areas requiring attention and improvement were identified to enhance equipment reliability and inform potential strategies to mitigate these issues and reduce the likelihood of future flaring events.

3 Results and Findings

As summarized in Figure 1, the review of reportable flaring events identified hydrogen (H2) infrastructure reliability and electrical infrastructure reliability as the two areas with the highest related causes of flaring. Other causes of flaring analyzed in this assessment were categorized as singular occurrences where the root causes and contributing factors were adequately addressed with corrective actions and preventative measures following the specific event.

A summary of findings on failed equipment, failure mode, and failure mechanism for all flaring events analyzed is included in Appendix A.

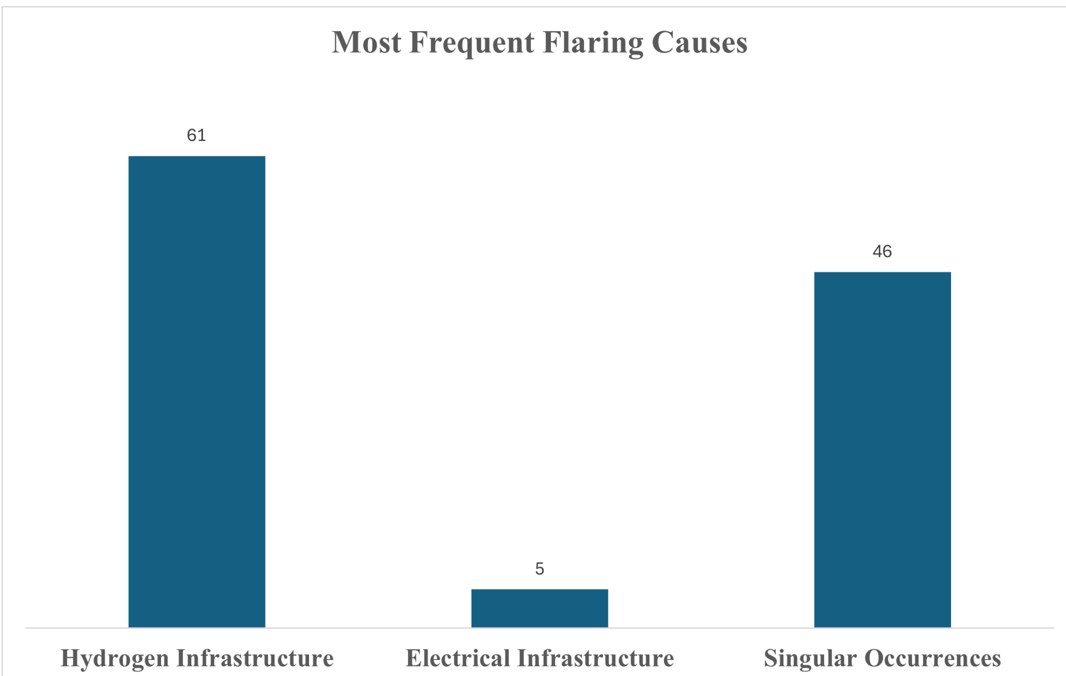

Figure 1: The most frequent flaring causes (February 2018 – May 2024)

3.1 Key Focus Areas

Hydrogen supply and electrical power are integral to the reliable operation of the refinery. These areas of the refinery's infrastructure have already become an area of focus in recent years related to the Richmond Refinery's efforts to minimize flaring. This analysis further reinforces concentrating on these focus areas to develop and implement more effective strategies and solutions to minimize flaring and contribute to more reliable and efficient operation.

3.1.1 Hydrogen Infrastructure

The reliability of H2 infrastructure stands out as the most common cause of flaring during the review period. Importantly, the hydrogen plant has a dedicated flare and the normal start-up and shutdown processes for the hydrogen plant requires flaring to occur, in part to comply with the Air District's Rule 13-5 which limits methane emissions from hydrogen plants.

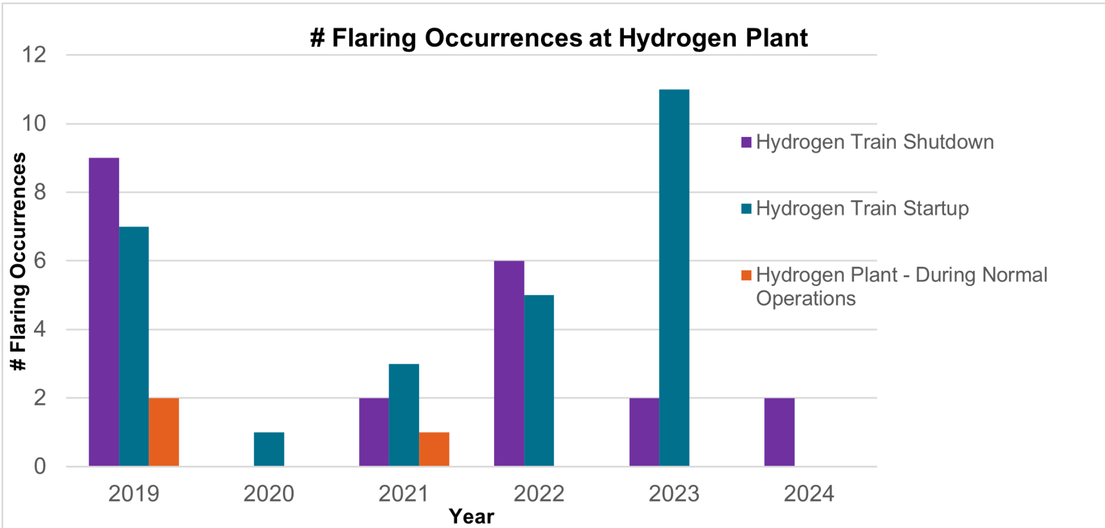

Figure 2: Reportable flaring incidents at H2 Plant (2/2018 – 5/2024).

As outlined in Figure 2, most reportable flaring events at the H2 flare were primarily attributed to the startup and shutdown activities of the H2 trains, with only three flaring events occurring while the H2 plant was in normal operation. However, H2 infrastructure reliability issues caused the H2 plant to have an increased rate of unplanned shutdowns (and subsequent start-ups) during the review period, with the highest frequency during the initial commissioning years of the H2 plant. The annual frequency of reportable flaring events caused by H2 plant shutdowns resulting from equipment failures has been decreasing since the installation of the H2 plant (see Figure 3). This improvement trend aligns with the Richmond Refinery's H2 infrastructure reliability improvement project initiatives outlined in Section 4.

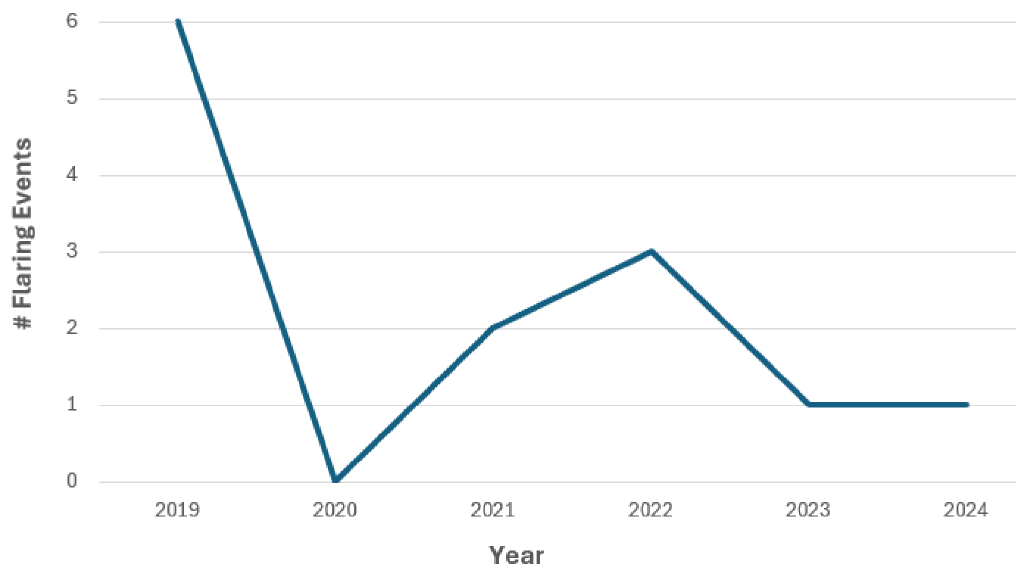

Figure 3: Flaring events from hydrogen plant shutdown caused by equipment failure (as opposed to planned shutdowns)

3.1.2 Electrical infrastructure

The second most frequent failure cause for flaring is the reliability of electrical infrastructure, with an average of one occurrence per year. While the number of events related to electrical infrastructure reliability is low, the consistent and reliable supply of electrical energy is a critical focus area for the Richmond Refinery.

The electrical infrastructure root causes reviewed in this analysis are mainly due to electrical systems becoming unreliable and electrical system design issues. These electrical failures could lead to unexpected equipment failures and subsequent flaring. In response to each flaring incident, corrective actions and preventative measures were developed to avert recurring failures and enhance the overall reliability of the Refinery's electrical infrastructure. Lessons learned from past flaring events related to power outages were analyzed, leading to the development of both short-term and long-term measures designed to minimize the risk of future power outages.

These measures are intended to support the continuous and reliable operation of the Refinery's electrical systems, thereby reducing the likelihood of flaring events caused by electrical failures. A continued focus on addressing these issues could involve an assessment of the electrical infrastructure and identifying and rectifying faulty components to enhance reliability.

4 Actions and projects implemented to prevent or minimize flaring

Over the past several years, the Richmond Refinery has been actively engaged in various projects to enhance reliability of the facility's H2 and electrical infrastructures. These initiatives are driven by various assessments of the H2 Plant system and electrical system as well as the lessons learned from the past flaring events that were caused by reliability issues. The Richmond Refinery conducted root cause investigations of these flaring incidents and identified areas for improvement.

Table 1 contains actions taken and projects that were implemented in 2023 and 2024 to improve H2 infrastructure and electrical reliability to minimize and prevent flaring. Chevron's investment of $20-$25 million to identify and complete these projects demonstrates our commitment to operational excellence and our focus on minimizing future flaring events at the Richmond Refinery.

Table 1: Actions and projects implemented in 2023 and 2024 to help reduce flaring ($20 to $25 million invested)

Causal Factor	Action / Project	Description
H2 Infrastructure Reliability	Upgrade Train 2 ID Damper	H2 Train 2 furnace dampers had sticking issues that resulted in process upsets. The pneumatic actuators were slower to respond to draft disturbances than electrical actuators, which contributed to the furnace tripping. Upgrading the ID dampers can reduce plant upsets and trips.
H2 Infrastructure Reliability	Upgrade Steam Flow Transmitter Design	Feed steam orifice meters were susceptible to plugging from ammonia bicarbonate salts which resulted in unreliable steam readings. Loss of steam readings caused five train trips. Richmond Refinery upgraded both trains to a sealed capillary design to prevent plugging.
H2 Infrastructure Reliability	Simplify Emergency Trip Philosophy - Final Logic Change	A redundant trip logic switch caused a double trip of both hydrogen trains. Removing the redundant logic switch decreased the time and volume of flaring during a hydrogen trip without impacting safety.
H2 Infrastructure Reliability	Booster Suction Pressure Override	Richmond Refinery implemented a suction pressure override control so that spillbacks will not close on loss of H2 trains, causing damage to booster cylinder valves. Improved booster reliability can decrease flaring events going forward.
H2 Infrastructure Reliability	Simplify Train 1&2 Safety Instrumented Systems (SIS) and Distributed Control System (DCS) Logic	Thirteen trip functions were removed or simplified in Hydrogen Train 1 and Train 2 to prevent H2 train trips.
H2 Infrastructure Reliability	Train 1&2 SIS and DCS Logic Simplifications and Instrument Upgrades	Richmond Refinery implemented instrumentation changes and upgrades to prevent nuisance H2 Plant trips, including added redundant instruments to allow for segregation of DCS and SIS instruments; added redundant DCS instruments for improved control; modified draft transmitter design to reduce noise; upgraded thermowells to mitigate vibration risk; and upgraded to gold plated transmitter.
H2 Infrastructure Reliability	Upgrade Train 1 ID and FD Dampers and Train 2 FD Damper	Actuators on furnace dampers were upgraded to prevent sticking and seizing. This can reduce furnace trips at the H2 Plant and can reduce plant upsets and trips.
H2 Infrastructure Reliability	Critical Control Valve Upgrades	Fourteen control valves received logic and hardware simplifications to nuisance valve closures to help reduce H2 Plant trips.
H2 Infrastructure Reliability	MK Relay Upgrade	The exciter relays for MK compressors were identified with insufficient coil lock protection, which can cause trips of one compressor during the startup of another compressor. This project added coil locks to the exciter relays and replaced the motor relays with an improved technology that

Causal Factor	Action / Project	Description
		allows for event reporting to improve troubleshooting of trips.
H2 Infrastructure Reliability	Add steam heat tracing to flow transmitters	The steam tracing kept the steam flow meters above the temperature where formation of ammonium bicarbonate salts will plug the system, which led to trips on the SIS and DCS systems. Reduced tripping of the SIS and DCS should decrease flaring at the H2 Plant during shutdown and startup.
Electrical Infrastructure Reliability	Install Fast Transfer on Buses	The fast transfer switch will keep the 4.16 kV and 480V Bus online if the 4.16 kV Bus loses its power supply.
Electrical Infrastructure Reliability	Upgrade systems to High Resistance Ground	The existing electrical systems at the H2 Plant were low resistance grounded systems that required ground faults be removed from the system immediately due to limited but damaging ground fault currents associated with power failure. Upgrading to a high resistance ground allowed the medium voltage system to alarm for a ground fault rather than trip to isolate the fault, thereby improving process continuity.

5 Potential Future Projects

In addition to completed projects in Table 1, the Richmond Refinery is recommending the following projects to ensure a more dependable refinery system, thereby enhancing overall facility reliability and efficiency. An evaluation of the requirements and resources will be conducted to determine the feasibility of the recommendations below. These potential projects are estimated to require an additional $12-$15 million total investment, if all are implemented.

5.1 H2 infrastructure reliability

The flaring assessment identified that H2 infrastructure reliability was the most frequent cause of flaring. The following are recommendations for projects that Chevron can implement to further improve the reliability of our H2 infrastructure.

5.1.1 Establish H2 Plant reliability focus team

An H2 Plant Reliability Focus Team would identify critical areas to enhance system reliability. By focusing on reliability, potential issues can be identified and addressed before they escalate, thereby improving the system’s overall performance and efficiency. A Focus Team would provide more dedicated resources and promote continuous improvement by implementing best practices and discovering innovative solutions with the objective of improving reliability at the H2 Plant and overall H2 infrastructure.

5.1.2 Eliminate Bus 1 transformers arc flash hazard risk

A fault of these transformers could result in damage and an unplanned trip of a hydrogen train due to arc flash hazard. One potential improvement would be to install a new overcurrent relay with harmonic blocking capability at the transformer primary to respond to faults at the transformer secondary and re-feed the 480V motor control center transformer from associated H2 Plant switchgear. This project could also install new arc flash protection at the motor control center main incoming section that is wired to trip the contactor. If undertaken, this project could reduce the likelihood of the H2 Plant tripping due to electrical faults and arc flash.

5.1.3 Pressure Swing Absorber valve preventative maintenance program

Hydrogen train trips can be caused by Pressure Swing Absorber (PSA) valve failures. Implementation of a preventative maintenance program for the PSA valves can reduce hydrogen train trips. As part of this program, Chevron could take a single bed pair down and rebuild or replace twelve switching valves on the bed pair.

5.1.4 Modify control circuits on pump motors

A tripped control circuit associated with pump motors can cause a shutdown of the H2 Plant. In the trip circuit, the anti-pump relay is used both in the control circuit interposing relay and directly to the motor control circuit. When the interposing relay fluctuates, the direct signal to the control circuit will trip the motor. To improve reliability of the H2 Plant, upgrading undervoltage relays and modifying the control wiring would remove redundant logic from the trip circuit. Implementing this would likely optimize the system's ability to handle voltage dips and avert unnecessary shutdowns of the hydrogen train.

5.2 Electrical Infrastructure Reliability

The flaring assessment identified electrical infrastructure reliability as a primary cause of or contributing factor to flaring. The following are projects that Chevron could potentially implement to improve electrical reliability.

5.2.1 Establish electrical plant reliability focus team

An Electrical Plant Reliability Focus Team would identify critical areas to enhance electrical infrastructure reliability. By focusing on reliability, potential issues can be identified and addressed before they escalate, thereby improving the system's overall performance and efficiency. A Focus Team would provide more dedicated resources and promote continuous improvement by implementing best practices and discovering innovative solutions with the objective of improving the reliability of the overall electrical infrastructure.

5.2.2 Replace Motor Control Center breakers with draw-out type

A fault of the Motor Control Center (MCC) breakers can subsequently lead to a complete loss of power to the MCC and cause a trip of the associated hydrogen train. To enhance reliability of the electrical infrastructure, a project could evaluate an upgrade to the existing MCC breakers to draw-out type breakers that could provide more efficient selective coordination between the main and feeder circuits. If implemented, this project should ensure that only the affected feeder breakers are isolated during a fault, while the remaining MCC continues its operation normally. In general, this implementation would likely improve the reliability of the hydrogen trains and also contribute to efficient and safe operation of Richmond Refinery's electrical infrastructure.

5.2.3 Upgrade transformer relay at H2 Plant

To enhance the reliability and safety of Richmond Refinery's electrical infrastructure, the existing transformer relays would be upgraded to more advanced and reliable models. Implementing this upgrade would provide better protection and monitoring capabilities to reduce electrical faults such as overcurrent, short circuits, and other anomalies. This project could reduce the risk of unexpected shutdowns and equipment failures, thereby improving stability of the electrical infrastructure.

5.2.4 Tone base Direct Transfer Trip for line protection relays

Line 1 & Line 2 connect our main switchyard to 2 & 4 Substations, which provide power to plants in the Hydroprocessing Business Unit. This potential project would upgrade the existing Direct Transfer Trip system, reducing trips that can potentially lead to power loss to 2 & 4 Substations and all subsequent plants, which in turn leads to flaring.

Appendix A: Summary of failed equipment, failure mode, and failure mechanism

Year	Equipment Type	Failure Mode	Failure mechanism	# Occurrences
2018	Compressors	Compressor shutdown due to high thrust position in the steam turbine driver	Entrained liquid (wet steam) passing through steam turbine	1
2018	Valves	Dump valves opened	Tank pressure loss	1
2018	Pumps	Pump tripped on high speed	Frozen governor linkage	1
2019	Hydrogen Train 1	Hydrogen Train 1 commissioning	Hydrogen Train 1 commissioning	1
2019	Hydrogen Train 2	Hydrogen Train 2 commissioning	Hydrogen Train 2 commissioning	1
2019	Compressors	Compressor shutdown due to false indication of low lube oil pressure	Water intrusion to the junction box	1
2019	Compressors	Compressor shutdown on high liquid in KO drums	Level was not reduced quickly enough to prevent from filling beyond shutoff point	1
2019	Compressors	Compressor shutdown due to false indication of high liquid	NH4SH accumulated in level indicator	2
2019	Compressors	Compressors shutdown	Malfunctioned seal oil tank level control valve	1
2019	Compressors	Compressors shutdown on high liquid level	Plugging issues and pump failures caused light cycle oil entered the relief system	1
2019	Valves	Dump valves closed	2 Separate signals triggering valves close but one of them was slower than other	1
2019	Furnaces	Furnace shutdown	Malfunctioned flow regulator	1
2019	Hydrogen Train Startup	Hydrogen Train Startup	Normal startup procedure	1
2019	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Valve/actuator coupling came loose and allowed a PSA tail gas valve to open	1
2019	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Inadvertent isolation of a common pressure tap	1
2019	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Malfunctioned induced draft fan	1
2019	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Malfunctioned quick exhaust valve	2
2019	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Normal shutdown procedure	3
2019	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Stale datapoint during the network switch upgrade	1

Year	Equipment Type	Failure Mode	Failure mechanism	# Occurrences
2019	Hydrogen Train Startup	Hydrogen Train Startup	Normal startup procedure	6
2019	Heat Exchangers	Failed	Plugged	1
2019	Hydrogen Plant	Hydrogen was routed to the vent	Stormy atmospheric conditions	1
2019	Hydrogen Plant	Imbalance between hydrogen production and demand	Hydrogen recycle compressor tripped offline	1
2019	Power outage	Electrical Faults	Stormy atmospheric conditions	2
2019	Pressure Relief Valves	Malfunctioned pressure safety valve	Mechanical failure	1
2019	Pumps	Pumps shutdown	Leak from a level control valve allowed vapor to enter the suction line of the KO drum pump	1
2020	Compressors	Hydrogen feed compressor tripped	Insufficient isolation by the valve	1
2020	Compressors	tripped offline	Fast acting solenoids caused pressure dip	1
2020	Scrubbers	overhead vapor flow into the relief system	Ammonia flow ratio into the emergency scrubber bottoms recirculation system was insufficient	1
2020	Hydrogen Train Startup	Hydrogen Train Startup	Normal startup procedure	1
2020	Limited FGR Capacity	Multiple units started up overwhelmed FGR capacity	A FGR compressor startup was delayed	1
2020	Valves	Faulty pressure control valve	Mechanical failure	1
2020	Pumps	Pumped failed to shutdown	Faulty breaker	1
2020	Steam Production Unit	Steam producing unit tripped	False interpretation of a pull from a pull switch station handle.	1
2020	Substations	Substations tripped	Incorrectly labeled drawing that did not match the circuitry in the field	1
2020	Reactors	Overpressure reactors	insufficient hydrogen recycle gas flow	1
2021	Cogeneration Units	Shutdown	Faulty fire alarm pull station	1
2021	Cogeneration Units	Outage	Faulty breaker	1
2021	Columns	Overpressure	Reduction liquid level in gas recovery unit due to faulty valve	1
2021	Compressors	Shutdown	Malfunctioned valves	1
2021	Compressors	Shutdown	Steam controller and positioner connector detached	1
2021	Compressors	Slow down	Faulty pressure transmitter	1
2021	Compressors	tripped offline	Low suction pressure	1
2021	Hydrogen Plant	Imbalance Hydrogen production/demand	Significant drop in hydrogen gas demand	1

Year	Equipment Type	Failure Mode	Failure mechanism	# Occurrences
2021	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Insufficient control logic	1
2021	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Normal shutdown procedure	1
2021	Hydrogen Train Startup	Hydrogen Train Startup	Normal startup procedure	3
2021	Heat Exchangers	Insufficient Water Wash Procedure	Insufficient process monitoring/indication	1
2021	Hydrotreater Exchanger	Leak	Flange leak	1
2021	Pumps	Seal leak	Lack of sufficient seal flush	1
2021	Separators	Runaway pressure	Faulty level indicator	1
2021	Substations	Failed electrical transmission system	Contaminated insulator	1
2021	Pressure Alarms	Insufficient	Insufficient time to respond	1
2021	Utility Boilers	Shutdown	Significant change in fuel gas compositions	1
2021	Control Logic	Failure	Faulty flow indicators	1
2022	Compressors	Malfunctioned	Mechanical Failure	1
2022	Compressors	Shutdown	Blocked oil filter	1
2022	Compressors	Shutdown	Knockout drum liquid accumulation	2
2022	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Insufficient combustion air flow rate to the draft fans	1
2022	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Malfunctioned compressor valves	1
2022	Hydrogen Train Shutdown	Hydrogen Train Shutdown	Normal shutdown procedure	4
2022	Hydrogen Train Startup	Hydrogen Train Startup	Normal startup procedure	5
2022	Heat Exchangers	Failed	Tube leak	1
2022	Knock Out Drums	Liquid accumulation	Malfunctioned/inoperative level instrumentation	1
2022	Valves	Failure	Defective manufacturing	1
2022	Pressure Swing Adsorption	Shutdown	Planned Shutdown	1
2022	Pumps	Shutdown	Sludge and sediment accumulation	1
2022	SIS Logic	Failure	Insufficient SIS logic design	1

Year	Equipment Type	Failure Mode	Failure mechanism	# Occurrences
2022	Startup Procedures	Insufficient	Insufficient procedure	1
2022	Valves	Malfunctioned	Failed valve positioner	1
2023	Compressors	Shutdown	Failed internal/malfunctioned orbit valves	1
2023	Compressors	Shutdown	Faulty electrical wiring	1
2023	Compressors	Shutdown	Residual brine in the boiler feed water system causing compressor to reduce speed	1
2023	Hydrogen Train Shutdown	Shutdown	Normal shutdown procedure	2
2023	Hydrogen Train Startup	Startup	Normal startup procedure	11
2023	Knock Out Drums	High liquid accumulation	Malfunctioned level indicator	1
2023	Pumps	Failure	Defective pump governor's drive coupling materials	1
2023	Substations	Power Outage	Faulty electrical equipment	1
2024	Compressors	Shutdown	Elevated temperatures on the compressor valves	1
2024	Compressors	Shutdown	High liquid in knockout drums due to malfunctioned level indicator	1
2024	Hydrogen Train Shutdown	Shutdown	Normal shutdown procedure	2
2024	Human Error	Lack of understanding of operations	Communication	1