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Valero

Valero Benicia Refinery
March 23, 2019 FGS Stack CO Exceedance Root Cause Analysis
Report Completion Date: July 12, 2019

I. OVERVIEW

On the afternoon of March 23, 2019, Flue Gas Scrubber ("FGS") carbon monoxide ("CO") increased above 1,000 ppm ("Incident"). Valero Benicia Refinery ("Valero" or "Refinery") promptly shutdown the Fluid Coker; however, this did not resolve the elevated FGS Stack CO. Multiple processing units, including the Pipestill Unit, were shut down on March 24, 2019.

After the Pipestill Unit was shut down, the Refinery conducted inspections to assess the mechanical integrity of the equipment. Inspections on the Fluid Coker Unit revealed no mechanical damage of concern, but inspections on the Atmospheric Pipestill Furnace ("F-105") identified furnace tube bulging and leaks. Material failure analysis testing conducted by an external expert identified high temperature creep as the cause of the F-105 tube damage.

Valero promptly convened an Investigation Team to identify the cause of the Incident. The Investigation Team subsequently determined that the furnace tubes were exposed to elevated temperatures with low- to no-flow conditions during a non-routine Pipestill Unit restart in November 2018, creating an opportunity for coke to form inside of the tubes. The coke inside the tubes led to increased tube temperatures during normal operation, which in turn led to accelerated creep damage.

II. RESPONSE ACTIONS

Consistent with the Company's commitment to transparency, Valero made required and courtesy notifications to relevant agencies in connection with the Incident.

Valero also retained a third-party consultancy to conduct air monitoring in the surrounding community. The results of this monitoring were within normal urban levels and below action levels. Valero's fence line monitoring system, which is approved by the Bay Area Air Quality Management District, was operational throughout the event. As a precaution, the City of Benicia on March 23, 2019 issued a community warning for sensitive individuals with respiratory issues to limit time outdoors. The City lifted this warning later that same day. There were no injuries in connection with the Incident.

Based on the Investigation Team's conclusions and recommendations, Valero implemented several improvements prior to restarting the Refinery to help safeguard against recurrence.

III. INVESTIGATION METHOD AND TEAM

On March 23, 2019, Valero convened a team to investigate the root cause of the Incident using a causal analysis method consistent with applicable state and federal regulations and the Refinery's Incident Investigation Reporting Procedures. The Investigation Team included Refinery personnel with expertise in Process Safety, Operations, Maintenance, Inspection, and other pertinent areas. The team also consulted with third-party and Valero technical experts. The team reviewed various materials in connection with the investigation into the Incident, including, but not limited to: process data, electronic shift logs, air monitoring data, the Pipestill Unit Process Hazard Analysis, third-party expert testing results, sample analyses, equipment specifications, and other information.

IV. PROCESS OVERVIEW

Process units relevant to the Incident include the Fluid Catalytic Cracker ("FCCU"), the Fluid Coker, the Pipestill furnaces, and the FGS. To summarize the process flow at a high level, CO gas from the Fluid Coker and FCCU are mixed and enter the Pipestill furnaces, F-105 and F-106 (Vacuum Pipestill Furnace) where the CO gas is incinerated. The flue gases from these furnaces contain air pollutants that require emissions control consistent with state and federal environmental requirements. Accordingly, the flue gas from the Pipestill furnaces flows to Selective Catalytic Reactors to reduce nitrogen oxides. The flue gas then flows through a Waste Heat Boiler to produce steam and cool the gas. Flue gas then flows through a series of scrubbers to remove particulate matter and sulfur oxides before exiting the FGS Stack.

V. CAUSAL ANALYSIS

A. Initiating Event

In November 2018, a low- to no-flow condition in the F-105 tubes occurred during a restart after an unplanned shutdown without full unit de-inventory of the Pipestill Unit. Specifically, during the restart on November 3, 2018, a safety valve on the Crude Preheat Train ("SV-107") lifted, allowing crude oil flow to bypass F-105. When this condition was discovered, SV-107 was immediately replaced with its spare. The Pipestill Unit startup was completed on November 4, 2018, with no further issues. It was not appreciated at the time, however, that the crude oil bypass of F-105 exposed the furnace tubes to elevated temperatures with low- to no-flow, creating an opportunity for coke to form inside of the tubes. Following the November 2018 restart, SV-107 was inspected and tested by a third-party expert. The expert confirmed during off-site testing and inspection that no damage occurred to SV-107 and that the valve did lift and reseat within code tolerances.

In reviewing prior data relating to the November 2018 restart, the Investigation Team determined that a hydraulic surge event during restart likely caused SV-107 to lift. SV-107 is a pilot operated valve with a remote sensing line that relies on process pressure to drive full reseating of the valve. Since the hydraulic surge event took place over a very short time period, it is possible that the process pressure directly after this event was insufficient to reseat the valve.

B. March 2019 Event Analysis

In early March 2019, the FGS Stack began experiencing relatively minor CO fluctuations while the Fluid Coker was experiencing burner level instability. Because Fluid Coker instability can lead to elevated coke fines in the flue gas through carryover, such instability was considered to be a cause of the increase in FGS Stack CO during that timeframe. Operational moves on F-105 were made in response to the elevated CO, which appeared successful in directionally reducing the FGS Stack CO; however, these moves resulted in furnace tube metal temperature ("TMT") increases that can directionally accelerate the furnace tube creep life consumption rate.

On March 23, 2019, the Refinery experienced another sudden increase of FGS Stack CO. In response to this development, the Fluid Coker was immediately shut down. This did not directionally improve the FGS Stack CO, indicating that the Fluid Coker was not the primary contributor. When the Pipestill Unit was shut down a few hours later (when feed was ceased), the FGS Stack CO reduced. This supports the conclusion that furnace tube leaks led to the incomplete combustion of crude and subsequent elevated FGS Stack CO.

Post-shutdown inspection data showed that F-105 "D" and "E" pass tube leaks are attributable to excessive creep damage. Inspection data also showed "C" pass experienced leaks; however, process data trended by the Investigation Team indicates that unlike passes "D" and "E," "C" pass normalized flow did not drop significantly after the start-up in November 2018. Therefore, it is possible that "C" pass was not the first pass to leak, but could have subsequently leaked as a collateral effect of the initial leaks found in "D" and "E" passes.

VI. Findings and Recommendations

The March 2019 FGS Stack CO exceedance was the result of F-105 tube failures. The damage mechanism for the F-105 tube failures was high temperature creep. This damage mechanism was verified through third-party metallurgical analysis of the furnace tubes. The creep was caused by operating at TMTs above normal. The high TMTs were caused by the insulating effect of coke inside of the tubes. The coke was formed due to low- to no-flow condition in the tubes during a start-up in November 2018. This low- to no-flow condition was caused by SV-107 internally lifting and diverting flow around F-105.

The Investigation Team developed the findings, interim recommendations (implemented before the May 2019 restart), and final recommendations, below, in connection with the investigation into the Incident. Some of these recommendations may not be directly related to the root causes of the Incident, but are considered beneficial to enhanced operation of F-105.

March 23, 2019 FGS Stack CO Exceedance: Findings and Recommendations			
Ref.	Finding	HCA Recommendation	Target Date
1	From November 2018 to March 2019, F-105 tubes experienced accelerated creep, which was not timely identified and mitigated, leading to the tubes' subsequent failure and FGS Stack CO exceedances in March 2019	Procedural: Implement enhanced Process Engineering Monitoring for F-105 and F-106 furnace operations for possible flow restrictions	Implemented on May 5, 2019
2a	Localized coke build-up in the F-105 tubes was not effectively detected by existing temperature indicators	Active: While detection of localized coking is a common industry challenge, consider enhancing temperature monitoring in additional areas of F-105: • Restore 24 TMTs on tubes on West end of F-105 box • Add 24 TMTs on tubes on East end of F-105 box	Implemented from April 25-26, 2019, prior to May 2019 startup
2b	F-105 tube leak was not rapidly discerned	Active: To aid in furnace monitoring, operations restored CO and O2 analyzer functionality	Implemented from April 25-26, 2019, prior to May 2019 startup
3	The Pipestill Unit Consequence of Deviation ("COD") table did not include effective guidance on the time limit for operation of F-105 in start-up, low flow conditions	Procedural: Review and revise COD table to provide additional guidance regarding consequences of deviating from normal operating limits during start-up, low flow conditions	Implementation due date: October 1, 2019
4	SV-107 may not have reseated immediately, which allowed for an extended diversion of flow from F-105	Active: Material build-up in the pilot system can adversely affect the ability of the valve to reseat. Evaluate optimal size of sensing line for SV-107 to minimize potential for material build-up in the pilot system	Implementation due date: October 1, 2019
		Procedural: Update, as appropriate, Pipestill procedure(s) to reduce likelihood of flow diversion from F-105	Implemented before May 2019 restart