Steam Report

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COMMONWEALTH OF PENNSYLVANIA
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EXECUTIVE SUMMARY

This Steam Report is prepared by Shell Chemical Appalachia LLC ("Shell")in compliance with its May 24, 2023 Consent Order and Agreement ("COA") with the Pennsylvania Department of Environmental Protection ("PaDEP") to demonstrate that the Shell Polymers Monaca ("SPM" or the "Site") steam system will, during unforeseen upset conditions, deliver an adequate amount of steam in a timely manner to the Elevated Flare to promote combustion and operate in a condition that is consistent with the Plan Approval. A multi-disciplinary technical team was formed and commissioned to perform a root-cause analysis and dynamic simulation study to address this issue.

A high-fidelity dynamic model of the integrated steam system was built to help (a) analyse the root cause(s) of the steam inadequacy issues, and (b) formulate measures that will reduce the likelihood of a recurrence of visible emissions at the Elevated Flare.

The model was validated/benchmarked against past upsets and flaring events at SPM and then used to predict future steam system response during upset scenarios not yet experienced at the Site. As of July 7, 2023, Shell completed the development, validation, and benchmarking of the model.

The team conducted a series of deep-dive sessions where multiple operating and upset scenarios were simulated against different unit configurations to fully understand system behavior and constraints. After running different failure modes and simulating previous flaring events, the team identified the Steam Let-down stations as the primary bottleneck and the root cause of the issue. The underperformance of the Steam Turbo Generator (STG) and the potential loss of STG Extraction steam were also identified as threats to delivering adequate steam to the Elevated Flare.

The model was used to help the team formulate, test, and evaluate system modifications that will ensure the delivery of sufficient steam to the flare during a flaring event. The proposed system modifications include (1) de-bottlenecking the let-down stations, (2) enhancing the performance of the STG Inlet and Extraction Pressure controls, and (3) automatically curtailing steam to the Deaerators on a loss of STG Extraction steam to the LP (Low Pressure) steam header.

With the completion of the implementation of these modifications/enhancements to the SPM Steam System, for any future plant upsets where the flaring rates are within the design smokeless capacity of the flare system, Shell expects that the recurrence of Elevated Flare visible emissions (smoking) will be mitigated, and any future visible emissions should not exceed the allowable limits specified in Shell's Plan Approval as approved by PaDEP.

1. INTRODUCTION / PROBLEM STATEMENT

An issue has been previously identified with the SPM Steam System's apparent inability to deliver an adequate amount of steam to the elevated flare to prevent limited visible emissions ("smoking") during unforeseen upset conditions.

A task force was strategically formed and commissioned to perform a root-cause analysis (RCA) and a dynamic simulation study to address this problem. The team consisted of Shell Technical Staff from various disciplines, Site Operations personnel, and 3rd party (Wood) Pennsylvania-Licensed Professional Engineer and Flow Assurance Engineer.

The RCA and dynamic study involved the development and use of a high-fidelity dynamic model of SPM's integrated steam system to evaluate the ability for the medium pressure steam system to supply adequate steam to the Elevated Flare during flaring events caused by unit upset conditions.

Over the last several months, the team carried out a series of "deep-dive" sessions where multiple operating and upset scenarios were simulated against different unit configurations to fully understand system behavior, constraints, and weaknesses. The model was used to help the team formulate, test, and evaluate system modifications that will ensure the delivery of sufficient steam to the flare during a flaring event.

This report summarizes the outcome of this study.

2. MODELING APPROACH / STRATEGY

The strategy adopted by Shell to solve the problem involved the use of a high-fidelity, first-principles dynamic model of the steam system and was executed through the following steps:

2.1 Model Development / Update

A rigorous dynamic model of the integrated steam system was developed using UniSim Design® simulation software. (Note: UniSim Design is a Honeywell software product that is widely used in industry for Process Design, Simulation, & Engineering.) The model was built with a very high level of detail that incorporated all available system data including (but not limited to) PFDs (Process Flow Diagrams), P&IDs (Piping & Instrumentation Diagrams), H&MB (Heat & Material Balance), Equipment & Instrument Data Sheets, Piping Isometrics, Process Control Narratives, etc. This strategy ensured that modelling assumptions are kept to a minimum and a true dynamic digital twin of the steam system was created.

2.2 Model Validation (Steady state & Dynamic)

The model was validated against actual operating data by linking the model to the plant historical data to reproduce previous plant upsets that led to flaring. The model-predicted responses were benchmarked against the actual recorded plant behavior and the model was fine-tuned iteratively until a reasonable match between the model predictions and reality was achieved.

2.3 Dynamic Scenarios / Root Cause Analysis

Various upset scenarios that could lead to flaring at the Elevated Flare were simulated and analysed using the dynamic model. System bottlenecks and underperformance issues that prevent the delivery of adequate steam to the flare tips were identified. The model was further used to identify opportunities to enhance the robustness, reliability, and availability of the steam system by testing the response to upset.

2.4 Problem Solution / Mitigation

System modifications and enhancements were proposed and tested using the model by (a) re-configuring the model with the proposed changes in place, (b) running the modified model against various upset conditions/flaring events, and (c) verifying that proposed mitigation options effectively enable the system to deliver sufficient steam to the flare tips when required.

3. FINDINGS/RESULTS (ROOT-CAUSE ANALYSIS)

The following areas of concern were identified that can impact the ability of the system to deliver sufficient steam in a timely manner to the Elevated Flare to promote combustion and operate in a condition that consistently complies with the Plan Approval.

3.1 SHP (Super High Pressure) – HP (High Pressure) LD (Let-down) Station

The dynamic analysis has confirmed that this LD station, as originally designed and installed, is a bottleneck that limits the delivery of steam to the Elevated Flare. In the original configuration, there are two parallel LD valves with Desuperheaters but only one is in service with the other reserved as a cold spare.

Also, in the as-built design, there is a threat to steam availability if the Desuperheater Temperature Control system shuts off the LD valves on high steam temperature.

3.2 HP-MP (Medium Pressure) LD Station

This LD station has been identified as another bottleneck to steam delivery to the Elevated Flare as originally designed and installed. Like the SHP-LP LD station, the original installation included two parallel LD valves with desuperheaters with only one valve normally in service and the other valve used as a spare.

3.3 STG (Steam Turbogenerator) Performance

To meet the transient steam demand to the flare, the load on the STGs needs to be adjusted in a timely manner. Underperformance of the STGs due to issues with the mechanical components (valves) and internal controls (Inlet Pressure Limiters and Extraction Controls) will impact the ability of the system to deliver adequate steam to the flare when needed.

3.4 Loss of STG Extraction

In some situations, as the system automatically cuts back on the STG load (power) when there is a need to send steam to the flare, the STG load could go into an operating mode where the extraction steam to the LP (Low Pressure) header is lost. When the LP steam demand cannot be met by the STG extraction, the system starts pulling steam via the SHP-HP and HP-LP LD stations. The SHP-HP LD station becomes a bottleneck again when there is a demand for steam to the flare.

3.5 Others (For Enhanced System Robustness / Reliability / Availability)

The model was further used to assess and evaluate the steam system holistically to identify and make comprehensive system-wide adjustments to the control system and the operating philosophy to bolster efficiency, robustness, reliability, and availability. Several enhancements were identified such as improved controller tuning, addition of feedforward and override control schemes, and optimum operating modes for the GTGs (Gas Turbo Generators) and HRSGs (Heat Recovery Steam Generators). While these control improvements are not required for smokeless flaring, they boost the overall robustness, reliability, and operability of the integrated steam system.

4. SOLUTIONS

The following mitigation options have been proposed, tested, and evaluated using the dynamic model. Various upset conditions that could lead to a flaring event have been simulated to verify the adequacy of the proposed solutions and to gauge the overall robustness of the Steam System.

4.1 SHP-HP LD Station: Debottleneck

Status: Complete – Implemented in field and in operation

The SHP-HP LD station has been de-bottlenecked by reconfiguring the system to utilize both LD valves via a "split-range" control strategy. This effectively doubles the let-down capacity of the SHP-HP LD station.

The threat of losing HP and MP steam due to high temperature has been mitigated by reconfiguring the temperature control system to ensure that the temperature excursion is minimized to where the trip logic is less likely to be triggered.

4.2 HP-MP LD Station: Debottleneck

Status: Complete – Implemented in field and in operation

Like the SHP-HP LD station, the HP-MP LD station has been de-bottlenecked by reconfiguring the system to utilize both LD valves via a "split-range" control strategy. This effectively doubles the let-down capacity of the HP-MP LD station.

4.3 STG Performance: Enhance Inlet & Extraction Pressure controls

Status: Complete – Implemented in field and in operation

All identified mechanical and control issues that adversely affected the performance of the STGs have been resolved. Proposed STG control modifications leverage the speed of response of the STG to sudden changes in pressure and steam demand. These enhancements to the STG Inlet and Extraction Pressure controls that were implemented boosted the performance of the STGs. The STG is the most effective "handle" that can be manipulated to robustly manage transient steam demands.

The overall pressure control system for the steam system has been analysed and optimized to complement the STG controls, thereby ensuring that steam will always be delivered to the flare when needed regardless of the number of STGs that are online. The appropriate setpoints and tuning parameters for the various controllers have been set for robust operation.

4.4 Loss of STG Extraction: Mitigate by Curtailing Pegging Steam

Status: Operations guidance issued; control changes planned

When the system drifts into this abnormal/crippled operating regime, the problem can still be mitigated by temporarily cutting back on the "Pegging Steam" (i.e., LP steam to the Deaerators) to "re-direct" the steam to the flare instead. The control system will be modified to accomplish this automatically. Prior to automation, operators are advised to perform this step manually as soon as STG extraction steam is lost during a flaring event.

5. FINAL REMARKS / CONCLUSION

The required system modifications described in Sec 4.1 to 4.3 have been implemented. The LD Stations have been de-bottlenecked by putting the spare valves in service, and the STG controls have been enhanced. The implementation of the control system change specified in Sec 4.4 will be initiated shortly (July 2023) and the operators have been provided the appropriate operational guidance to mitigate the loss of STG extraction steam during a flaring event.

Thus, since the implementation of proposed modifications and enhancements to the SPM Steam System have been completed, for any future plant upsets where the flaring rates are within the design smokeless capacity, it is expected that the recurrence of elevated flare visible emissions will be significantly minimized (if not eliminated) and any future visible emissions (smoking) should not exceed the allowable limits as specified in Shell's permit as approved by PaDEP.