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Routine Flaring Analysis and Flare Gas Recovery Design and Implementation

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1. ABSTRACT

Routine flaring is one of the major sources of energy loss and environmental concern in oil refineries. This study presents an integrated approach for routine flaring analysis, source reduction, and flare gas recovery implementation at Tabriz Oil Refining Company. The methodology included monitoring flare gas flowrate and composition, correcting measured flowrates based on gas composition, inspecting 492 points in the flare network, identifying avoidable flaring sources, and evaluating the performance of the implemented recovery unit. The stable routine flaring rate was estimated at approximately 2.8–2.9 t/h, and 23 points were found to have a significant contribution to routine flaring. Corrective actions, including leakage reduction, operational adjustments, and elimination or limitation of unnecessary side streams, reduced routine flaring by about 700–800 kg/h. The remaining recoverable gas was treated in a flare gas recovery unit consisting of liquid separation, two-stage liquid ring compression, interstage cooling, amine absorption, and delivery to the fuel gas network. The average operating flowrate of recovered gas delivered to the fuel gas network was about 1050 Nm^3/h. The energy value ratio of recovered gas to natural gas was estimated at 1.49. The project provided an estimated net operating benefit of 0.76 million USD/year, a simple payback period of 5.5–6 years, and gross avoided CO_2 emissions of about 27,000 t/year.

Keywords: Flare System; Flare Gas Recovery; Emission Reduction; Refinery Fuel Gas; Liquid-Ring Compressor.

2. INTRODUCTION

Routine flaring in petroleum refineries represents a continuous loss of valuable hydrocarbon resources and contributes to environmental emissions. Although flare systems are essential safety facilities, the continuous release and combustion of recoverable gases under normal operating conditions should be minimized through source reduction and recovery strategies. Previous studies have investigated flare gas recovery from different perspectives, including operational improvement, recovery to the fuel gas system, power generation, ejector-based recovery, compressor-based recovery, and techno-economic evaluation. However, many studies remain limited to simulation or conceptual assessment and do not fully connect flare network investigation, source reduction, technology selection, actual implementation, and operating performance data.

The present study addresses this gap by combining field monitoring of the flare network, identification and correction of avoidable flaring sources, process design considerations, and evaluation of an implemented flare gas recovery unit. The study emphasizes that the capacity and technology of a flare gas recovery unit should be selected only after reducing avoidable flaring at the source. This approach prevents oversizing of recovery equipment and supports safer and more economical operation.

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3. MATERIALS AND METHODS

The study was carried out in several consecutive steps. First, the flare network was reviewed to identify the main flare headers, old and new unit connections, and major gas transfer routes to the flare stack. Then, flowrate and gas composition data were collected from selected monitoring points. Since flare gas composition is variable, measured flowrates were corrected based on gas composition to obtain more reliable estimates.

In the next step, 492 points in the flare network, including control valves, safety valves, manual valves, bypass lines, and side streams, were inspected. The purpose was to distinguish unavoidable routine flaring from avoidable sources such as internal leakage, improper valve position, unnecessary open routes, and operational malfunctions. Among these points, 23 were identified as having significant effects on routine flaring.

After source reduction, the remaining recoverable gas flow was used as the basis for evaluating recovery options. The selected flare gas recovery configuration consisted of liquid separation, two-stage liquid ring compression, interstage cooling and separation, final separation, amine absorption, and transfer of treated gas to the refinery fuel gas network. The performance of the implemented unit was evaluated using operating data, heat and material balance information, and economic and environmental indicators.

4. RESULTS AND DISCUSSION

The field investigation showed that stable routine flaring before corrective actions was approximately 2.8–2.9 t/h. The inspection of the flare network confirmed that not all routine flaring originated from unavoidable process requirements. A portion of the flow was related to avoidable sources, including valve leakage, unnecessary open bypasses, improper control conditions, and limited but continuous side streams. Corrective actions reduced routine flaring by about 700–800 kg/h.

The remaining recoverable gas was processed in the implemented flare gas recovery unit. The unit was designed to receive low-pressure flare gas, separate entrained liquids, compress the gas in two stages using liquid ring compressors, remove condensed liquids after compression, treat acid gases through amine absorption, and deliver the recovered gas to the fuel gas network. The average operating flowrate of recovered gas delivered to the fuel gas network during the selected monitoring period was about 1050 Nm^3/h.

The comparison of recovery options showed that direct delivery to the fuel gas network was the most suitable route for this refinery because it enabled continuous energy recovery without requiring a new major consumer. Ejector-based systems were not selected due to the need for a stable high-pressure motive fluid. Although steam-driven ejectors can allow water separation through downstream condensation, the refinery did not have additional steam generation capacity beyond existing operating conditions. Therefore, a compressor-based solution was preferred. Among compression technologies, liquid ring compressors were selected due to low suction pressure, wet gas conditions, variable gas composition, and operational flexibility.

The economic evaluation indicated that the recovered gas had an energy value approximately 1.49 times that of natural gas on a molar heating value basis. Considering recovered gas value, separated hydrocarbon liquid value, power consumption, cooling water, and maintenance cost, the net operating benefit was estimated at about 0.76 million USD/year. The simple payback period was estimated at approximately 5.5–6 years. From an environmental viewpoint, gross avoided CO_2 emissions due to natural gas displacement were estimated at about 27,000 t/year.

5. CONCLUSION

This study demonstrated that effective flare gas recovery should begin with source reduction in the flare network. Corrective actions reduced routine flaring by about 700–800 kg/h before recovery unit evaluation. The implemented unit recovered about 1050 Nm^3/h of gas on average and delivered it to the refinery fuel gas network. The project provided measurable energy, economic, and environmental benefits and showed that technology selection for flare gas recovery must be based on actual site-specific data.

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