Environmentally and Economically Beneficial
Flare Gas Recovery Projects in Petrochemical Facilities

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Introduction
Petrochemical operations vent flammable waste gases from process units during normal operations and during process upsets. These waste gases are routed to a Flare System through a piping (flare) header for safe disposal in the flare. The primary function of the flare is to protect the plant, employees, and surrounding environment. However, routine flaring creates trade-off emissions such as nitrogen oxides (NO\textsubscript{x}), sulfur oxides (SO\textsubscript{x}), and Green House Gases (GHG) (CO, and CO\textsubscript{2}). These routine emissions and any released unburned hydrocarbons contribute to the total plant emissions.\textsuperscript{1} It may seem easy to minimize flaring, but isolating the safety release system (flare) from the Petrochemical Facility to allow Flare Gas Recovery (FGR) is a specialized project. This paper will not detail the particulars of an FGR project, as that has been previously explained.\textsuperscript{2} Instead, emphasis is on current legislative developments, FGR environmental benefits, important FGR System components, and FGR economic benefits.

Near Zero Flaring - 40 CFR 60, Subpart Ja
Near Zero Flaring in Petrochemical Facilities is achievable and being enjoyed by many progressive and responsible companies. There have been two drivers for these projects, environmental and economic. The latest US legislative initiative is the pending final promulgation of 40 CFR 60, Subpart Ja. This legislation has been stayed since February 24, 2009. Information obtained in July 2010 indicates this stay will be lifted within 2010.\textsuperscript{3} The legislation will apply to Petroleum Refinery Flares for which construction, reconstruction, or modification commenced after May 14, 2007 (Affected Flare). An Affected Flare’s flow is limited to 250,000 scf per day on a 30 day rolling average.\textsuperscript{4} A summary of the emission limits contained in this legislation is shown in Figure 1.

<table>
<thead>
<tr>
<th>Component</th>
<th>Emission Limits</th>
<th>Rolling Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO\textsubscript{2}</td>
<td>20 ppmv</td>
<td>3 hour</td>
</tr>
<tr>
<td></td>
<td>8 ppmv</td>
<td>365 day</td>
</tr>
<tr>
<td>Fuel Gas H\textsubscript{2}S</td>
<td>162 ppmv</td>
<td>3 hour</td>
</tr>
<tr>
<td></td>
<td>60 ppmv</td>
<td>365 day</td>
</tr>
</tbody>
</table>

Figure 1

In the US, it is anticipated that similar legislation will be applied in the near future to chemical plants and gas treatment facilities to limit sulfur emissions.
Flare Gas Recovery
The concept of flare gas recovery is quite simple; in fact, it is difficult not to see the value of compressing flare gas for use as fuel, feedstock, or product instead of sending it to be burned uselessly in a flare. The basic processes employed in the FGR System are compression and physical separation. Liquid ring compressors [or other appropriate compression technology] perform gas compression and the separation of recovered vapor phase from a mixed liquid is accomplished in a horizontal separator vessel.

![Generalized Flare Gas Recovery Process Schematic](image)

As flare gas flows into the Flare Header, an established hydrostatic head in the Liquid Seal Vessel (LSV) will prevent flare gas from flowing to the flare. This causes a slight increase of pressure in the Flare Gas Header (FGH). When the FGH pressure reaches the gas recovery initialization set point, the compression system will begin to compress the flare gas. The FGR System will start and stop with control signals from the DCS and the gas compressors will stage up or down based on the inlet pressure and recycle control valve position.

The discharge of the compressors will flow into the Service Liquid Separator Vessel where gas and service liquid are disengaged. The compressed
recovered flare gas is delivered to the facility fuel gas distribution system, or provided for another appropriate use.

The compressor service liquid, in this case water, is used in the compressor as a seal between the impeller and the compressor case. The service liquid is separated from the recovered gas stream, cooled, and recirculated to the gas compressor train for reuse.

The gas processing capacity of the FGR System adjusts to maintain a positive pressure on the Flare Header upstream of the LSV. This positive pressure will ensure that air will not be drawn into either the flare system or the FGR System. If the volume of flare gas that is relieved into the flare system exceeds the capacity of the FGR System, the pressure in the flare header will increase until it exceeds the backpressure exerted on the header by the liquid seal. This excess gas volume will pass through the LSV and on to the flare where it will be burned. This will be the case, for example, when there is a rapid increase in flare gas flow due to an emergency release of gas from the plant.

When the flare gas flow is less than or equal to the capacity of the FGR System, the flare gas will be recovered and directed to the refinery fuel gas header, or other appropriate points. During these periods, there will be little or no visible flame at the flare (the flare pilot may be visible). In the event that the flow is less than the FGR System capacity, the FGR System adjusts to a turndown condition. This is accomplished by staging compressors on and off, variable speed drive, internal volume control, and/or by diverting discharged gas back to the suction header through a recycle control valve.

Advantages of Flare Gas Recovery
There are numerous advantages and benefits of Flare Gas Recovery projects including:

Improved Public Relations
The mostly constant burning of gasses in a facility flare troubles many people. Installation of a FGR System can achieve near zero flaring thus eliminating complaints to the facility. After installation, an excellent opportunity exists to advertise the project and increase goodwill in the community by explaining all the project benefits.

Reduced Plant Fuel Gas Consumption or Increased Product Sales
Recovered Flare Gas can be used in the plant fuel system to offset purchased fuel, or in some cases, be used as feedstock into the plant or a process. In the case where a plant is “long” on gas, the recovered gas can be used as fuel in a gas engine driven Flare Gas compressor, or as fuel for an engine or turbine driven electric generator. Producing electricity from the recovered gas can significantly offset the plant’s monthly electricity purchase.
Reduced Green House Gas Emissions from the Facility
Using recovered Flare Gas in the plant fuel system reduces purchased gas and lowers the plant combustion emissions. Before the FGR System is installed, the plant is purchasing a set amount of fuel gas for operations and is generating combustion by-products in the Flare and from the consumed fuel gas. Using the Recovered Flare Gas as fuel reduces the plant’s fuel gas purchase and eliminates the combustion products from burning that previously purchased fuel.

Reduced Flaring Light, Noise and Odor
Continuous flaring can produce combustion noise, flame radiation, and sometimes a foul smell. All these attributes can be irritating to the facility neighbors and cause complaints to the plant management or city officials. An installed FGR System will reduce the routine flaring to Near Zero and eliminate these complaints.

Reduced Steam or Electricity Consumption for the Flare
Most large plant flares require some type of supplemental energy to achieve smokeless flaring. This is typically provided by steam injection or air injection by an electric motor driven blower. This supplemental energy is reduced to bare minimum when the FGR System produces Near Zero Flaring.

Extended Flare Tip Life
An often-overlooked benefit of installing a FGR System is extended flare tip life and reduced periodic replacement costs. The facility flare is designed for the emergency gas release of a plant shutdown and the associated large flame. Continuous flaring of relatively small gas flows results in a much smaller flame, closer to the flare tip and can cause flare tip damage over time. Replacing a flare tip can be expensive, and if not scheduled as part of a plant turn-around, can be disruptive to the plant production.

Compression Technologies
Several compression technologies are available for FGR Systems. Over the last 35 years various companies have used several compressor types including Dry Screw Compressors (DSC), Sliding Vane Compressors (SVC), Reciprocating Compressors (RC), Liquid Ring Compressors (LRC), and Oil Injected (or Oil Flooded) Screw Compressors (FSC) both single and dual screw designs. The chosen compressor technology greatly affects the FGR System initial cost, FGR System physical size, and FGR System operating and maintenance expense. In addition, process suitability must be evaluated when using a water sealed LRC or an oil Flooded Screw Compressor. Figure 3 shows a worldwide summary of compressor technology choices for FGR Systems. Liquid Ring Compressors have been most prevalent in Refinery FGR applications.
Liquid Seal Vessels

Liquid Seal Vessels installed in the flare header are an integral and important component of each Flare Gas Recovery System providing smooth operation and safety by preventing air ingress into the Flare Header and cross contamination when multiple flares are connected to a common FGR installation, and a positive inlet pressure to the FGR Compressor System. The Liquid Seal Vessel (LSV) is a critical equipment item for safe and successful operation of the FGR System. LSVs used in FGR Systems are termed “deep liquid seals” with seal water depth of 30” or more. This provides adequate pressure control range for FGR System operation. It is crucial that the LSV is properly designed and sized to handle the changes in flow and transition safely from the normal flare gas flow rates to any emergency flare gas flow rate. An illustrative example of a LSV and the internal baffles in a deep LSV is shown in Figure 4.
Typically, the LSV is installed downstream of the Knock-Out Vessel that is usually near the base of the flare stack. When properly designed, the LSV provides the following:

1. It prevents the occurrence of “flash back” into the flare system, by preventing the ingress of air (oxygen) into the flare stack and/or piping. **A SAFETY REQUIREMENT.**
2. It provides the necessary back pressure for proper staging and operation of the FGR System compressors. **A PROCESS REQUIREMENT.**
3. It reduces the amount of purge gas required for the flare system by holding a positive pressure on the flare header. With the LSV installed, purge gas can be introduced into the vapor space of the Liquid Seal Drum and not upstream in the process areas. **THIS IS BOTH A SAFETY REQUIREMENT AND AN ECONOMIC BENEFIT.**
4. It allows the flare system to operate smoothly and efficiently when the flare gas flow is greater than the FGR System capacity. Even with an FGR System operating, the flare must be able to safely and efficiently handle any excess flows. A properly designed LSV will allow flaring to occur without surging or “puffing”. **THIS IS A PROCESS, SAFETY, AND ENVIRONMENTAL REQUIREMENT.**
5. A properly designed LSV will promote smooth, efficient operation of the FGRS and the flare operation. During low flare gas flow, the FGR System will have enough back pressure for staging the compressors. During increased flare gas flows, the LSV will provide a smooth transition from the minimum flaring rate to the “break out” flaring rate and then to the maximum or “blow dry” flaring rate. **The Liquid Seal Drum internal design is most critical for providing smooth flaring over the entire range of flare gas flow rates.**

**Flare Gas Recovery Application and Project Payback**
Application of this technology in Petrochemical and Refinery Facility Flares provides good environmental stewardship and conservation of valuable resources with excellent project payback. Project payback is usually less than two years as shown as shown by examples in Figure 5 and Figure 6.
<table>
<thead>
<tr>
<th>Plant</th>
<th>Oil Refinery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Western U.S.</td>
</tr>
<tr>
<td>FGR Design Recovery Flow Rate</td>
<td>4.9 MMSCFD</td>
</tr>
<tr>
<td>FGR Mean Recovery Flow Rate</td>
<td>2.4 MMSCFD (97% of Flare Activity Production)</td>
</tr>
<tr>
<td>Year 1 Operating &amp; Maintenance</td>
<td>182,000 USD</td>
</tr>
<tr>
<td>Year 1 Value of Recovered Gas</td>
<td>3,700,000 USD</td>
</tr>
<tr>
<td>Flare Emissions Reduction</td>
<td>NOx 34.6 Ton/Year</td>
</tr>
<tr>
<td></td>
<td>CO 188 Ton/Year</td>
</tr>
<tr>
<td></td>
<td>HC 71.4 Ton/Year</td>
</tr>
<tr>
<td></td>
<td>SOx 74.8 Ton/Year</td>
</tr>
</tbody>
</table>

**Payback in ~14 months**

*Figure 5*

<table>
<thead>
<tr>
<th>Plant</th>
<th>Large Refinery Process Flare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>To maximize economic nuisance flaring reduction</td>
</tr>
<tr>
<td>Gas Processing Design Flow Rate</td>
<td>17.3 MMSCFD</td>
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<tr>
<td>Gas Processing Mean Flow Rate</td>
<td>15 MMSCFD</td>
</tr>
<tr>
<td>Flaring Reduction</td>
<td>82%</td>
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<tr>
<td>Year 1 Value of Recovered Gas</td>
<td>11,300,000 USD</td>
</tr>
<tr>
<td>Recovered Gas HV</td>
<td>688 BTU/scf (Utilized as Fuel Gas)</td>
</tr>
<tr>
<td>Basis of Economics</td>
<td>Fuel Value $3/MMBTU</td>
</tr>
<tr>
<td></td>
<td>Electric Power $0.062/Kwh</td>
</tr>
</tbody>
</table>

**Payback in ~20 months**

*Figure 6*
Conclusion
Near Zero Flaring in Petrochemical Facilities is achievable and being enjoyed by many progressive and responsible companies. The concept of flare gas recovery is quite simple; in fact, it is difficult not to see the value of compressing flare gas for use as fuel, feedstock, or product instead of sending it to be burned uselessly in a flare. Application of this technology in Petrochemical and Refinery Facility Flares provides good environmental stewardship and conservation of valuable resources with excellent project payback. There are numerous advantages to flare gas recovery including Improved Public Relations, Reduced Plant Fuel Gas Consumption or Increased Product Sales; Reduced Green House Gas Emissions from the Facility; Reduced Flaring Light, Noise and Odor; Reduced Steam Consumption for the Flare; and Extended Flare Tip Life. Several compression technologies are available for Flare Gas Recovery Systems. Liquid Seal Vessels installed in the flare header are an integral and important component of each Flare Gas Recovery System providing smooth operation and safety by preventing air ingress into the Flare Header and cross contamination when multiple flares are connected to a common Flare Gas Recovery installation, and a positive inlet pressure to the Flare Gas Recovery Compressor System. Project payback of total installed cost is usually achieved in two to three years.

References

Author Biography
Roger E. Blanton, P.E. is currently a Sr. Applications Engineer for John Zink Company LLC based in Tulsa, Oklahoma, USA. He is a registered professional engineer working for over 30 years with rotating equipment and petrochemical processes. Blanton holds a BS degree in Mechanical Engineering from the University of Tulsa, and an MBA degree with management emphasis from Oklahoma State University. He has specialized for the last 25 years in technical product design, application, and sales; new product development and introduction; sales and distribution channel management; and international business development. He is a member of the American Society of Mechanical Engineers (ASME), Tau Beta Pi Engineering Honor Society, and past president of the Greater Ozarks International Trade Association. Direct questions and/or comments to him at roger.blanton@johnzink.com.