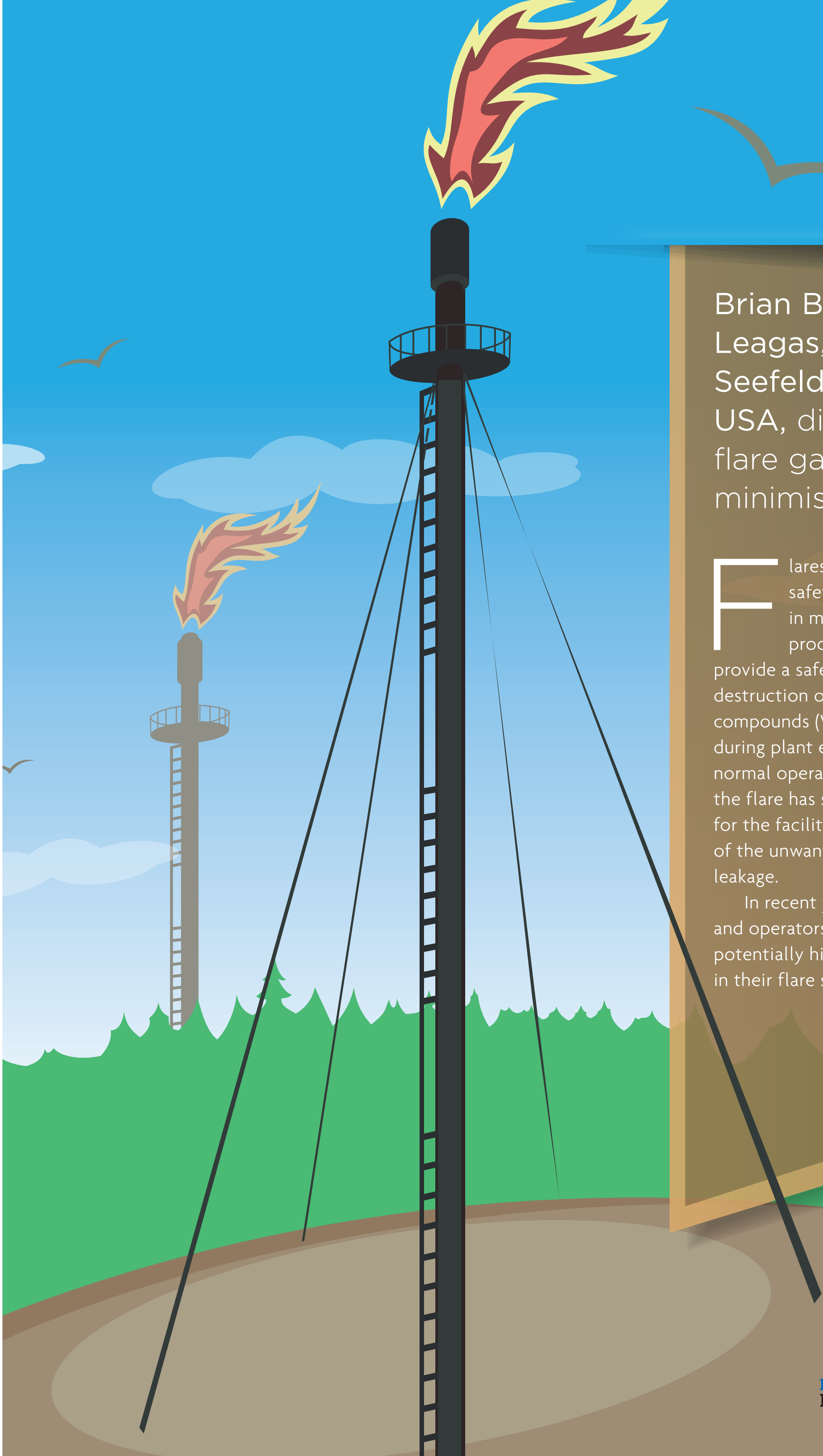
PRACTICAL FLARE GAS RECOVERY



Brian Blackwell, Trevor Leagas, and Greg Seefeldt, Zeeco, Inc., USA, discuss practical flare gas recovery for minimisation of flaring.

Flares play a critical role as a safety device in refineries, and in most oil and gas producing or processing facilities. Flares provide a safe, effective means for the destruction of volatile organic compounds (VOCs) and other gases during plant emergencies, upsets, and normal operating conditions. Historically, the flare has served as the vapour 'sewer' for the facility, collecting and burning all of the unwanted gases and system leakage.

In recent years some refinery owners and operators decided to recover the potentially high heat value gases existing in their flare systems due to normal

Figure 1. Example with a Zeeco flare gas recovery system.

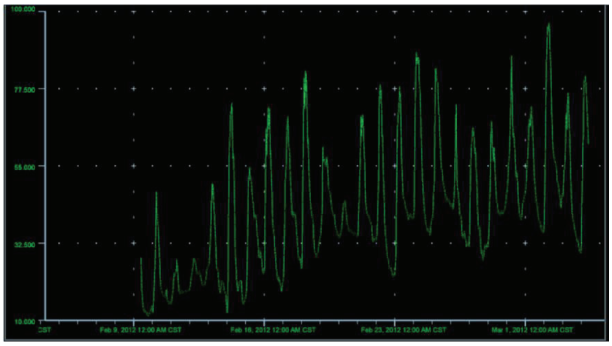


Figure 2. Flow meter output.

operations in lieu of flaring. Flare gas recovery (FGR) offers some real and tangible benefits:

- Recovered flare gas can be reused in plant process heater burners and boiler burners.
- Reduces the amount of natural gas purchased by the facility.
- Less purchased gas can lead to a fairly short return on investment for the cost of the flare gas recovery system.
- If the flare tip is an assist type, employing flare gas recovery reduces the consumption of steam or air while increasing the life of the flare tip.

FGR provides intangible benefits, as well. Reducing the amount of flaring overall reduces the visibility of the flare, improving public perceptions of the facility.

Flaring in the US is addressed by the Environmental Protection Agency (EPA) in Section 111 of the Clean Air Act of 1970, which authorised the EPA to develop technology based standards that apply to specific categories of stationary sources. These standards are referred to as New Source Performance Standards (NSPS) and are found in 40 CFR Part 60. Subpart J and Subpart Ja of the NSPS deal specifically with petroleum refineries. While NSPS Subpart Ja (40 CFR 60; §60.100a-§60.109a) has a much broader application than just the reduction or elimination of routine, or non-emergency, flaring, the standard does directly address reducing routine flaring overall.

Three applicability triggers in NSPS Subpart Ja are directly related to flare systems: construction, modification, and reconstruction.

Construction is the erection of a new flare on or after June 24, 2008. Construction is, of course, any new flare built in a refinery.

Reconstruction is defined in the NSPS General Practices §60.15(b) as having occurred when the current day capital cost of all flare related capital projects over any two year period is greater than 50% of the current day capital cost to totally replace the flare with a comparable new flare.

Modification of a flare, for the purposes of meeting Subpart Ja, commences (1) when a project that includes any new piping from a refinery process unit, including ancillary equipment, or a fuel gas system is physically connected to the flare (e.g., for direct emergency relief or some form of continuous or intermittent venting); or (2) when a flare is physically altered to increase the flow capacity of the flare. However, only a few specific exceptions exist to the 'new connections' passage to the flare rule, and refinery operators should familiarise themselves with the ruling or seek expert assistance.

Basically, if a refinery has constructed a new flare, reconstructed a flare, or modified its existing flare system since June 2008, NSPS Subpart Ja will apply to that flare.

- New or reconstructed flares must comply with all portions of Subpart Ja upon startup of the flare.
- Modified flares must comply as follows:
  - 162 ppmv H_2S (three hour rolling average) limit at startup of the flare with exceptions allowed as follows: (1) modified flares not previously subject to the H_2S limit in 40 CFR 60 Subpart J; (2) modified flares with monitoring alternative as defined in Subpart Ja; or (3) flares complying with Subpart J as specified in a consent decree. In these cases the flare will need to comply with the 162 ppmv requirement by November 13, 2015.
  - Compliance with all other portions of Subpart Ja by November 13, 2015.
  - The 162 ppmv H_2S limit does not apply to the combustion in the flare of process upset gases.

Subpart Ja also contains specific design, equipment, work practice, or operation standards that apply to any owner or operator of an affected flare. §60.103a states that each owner or operator who operates a flare subject to this subpart shall develop and implement a written flare management plan no later than November 11, 2015 or upon startup of the modified flare, whichever is later. Requirements for continuous flow monitoring, H_2S concentration monitoring and total reduced sulfur monitoring for any affected flare, whether constructed, reconstructed or modified, are also a part of the rule. The continuous monitoring requirements in Subpart Ja present both a cost to refineries as well as potential cost savings over time. Once refinery operators can quantify the amount of gas being burned in the flare on a regular basis, they can identify cost effective flare gas minimisation or recovery projects to improve operational profitability by capturing high energy value gas. The H_2S and total reduced sulfur continuous monitoring is included for environmental reasons to reduce the occurrences of exceeding the 162 ppm H_2S in a three hour rolling average, or 500 lb of SO_2 emitted in a 24 hour period.

While enforcement lies at the discretion of the regulator, (and penalties for failing to comply with the provisions of NSPS Subpart Ja are still not clear), the EPA's 'Enforcement Alert, EPA 325-F-012-002' was sent out in August 2012 announcing that penalties under the Clean Air Act for violations of US federal requirements can result in fines of as much as US$37 500/d per violation.

Figure 3. ZEECO deep liquid seal drums.

Likely outcomes of flaring regulations

While flaring and emissions control regulations vary worldwide, they are in general becoming more and more stringent. Even operators in areas not yet required to have flare mitigation plans or flare gas recovery options in place can benefit from the economic, environmental, and public perception benefits of reducing routine flaring through a flare gas recovery system. In the US, the potential for costly fines or even plant shutdowns makes investigating this option a far better short term time investment with the November 2015 compliance date looming. Other economic and intangible benefits for installing flare gas recovery include reduction in purchased gas for the refinery, reduced utility consumption by the flare, extension of the life of the flare tip, reduced noise produced by the flare during normal operations, reduced visibility of the flare by neighbours, and improved perception of the facility within the community.

Step by step system design

Feasibility study

In most situations, the initial step to introduce flare gas recovery is the completion of a feasibility study. This study should include an extended period of flare gas flow metering to help identify the true flow rates of gas to be recovered. Zeeco recommends a monitoring minimum time of three weeks, although engineers prefer to evaluate months' or even years' worth of flow data, if available.

Flow metering of the gas to be recovered is just one part of the study. Consideration should also be given to the type of technology that will be utilised; comparing the technology's suitability in respect to the inlet and outlet conditions of the system; and assessing the economics of each technology and flexibility in operation.

Once the flow metering data and other technical considerations are addressed, the supplier and end user should then discuss the technology options and the selection of a flow rate suitable for the technology and the refinery. Due diligence upfront should prevent systems from being oversized, resulting in a poor return on investment.

If the end user can make available the cost of fuel gas, utilities, and other critical information, the feasibility study also can predict the likely payback time and other cost benefits.

Once the feasibility study is completed and the project costs are identified, the end user should then determine any changes that need to be made to the flare's current operation. As part of this, consider where possible maintenance or upgrades should be applied to reduce the flare load created by each item of plant:

- Block and bleed valve sealing.
- Header sweep gas flow rates.
- Installation of flare purge reduction devices to reduce continuous purge rate.
- Replacement of leaking pressure safety valves (PSVs) that relieve to the flare header.
- Replacement of leaking control valves that relieve to the flare header.

Once these considerations have been addressed and the flaring reduced as much as possible without affecting the refinery's operation, the study can be reassessed and recovery rates can be adjusted as necessary.

Flare management plan

In addition to completing the feasibility study and making upgrades to equipment that feeds into the flare system on a day to day basis (i.e., non-emergency release), the end user should review its flaring management policies. This review should include an assessment of which flares are used for which service, and how they could be used more efficiently or upgraded to accommodate a change in flow or different gases. Zeeco's extensive experience in flare system design and supply allows its engineering team to provide assistance to end users in development of their flare management plans.

Deep liquid seal systems

Ensuring a consistent system back pressure is crucial when installing a FGR unit. Zeeco recommends the application of a deep seal drum to achieve this. Zeeco's deep seal drums were developed after years of extensive research and development to offer an advanced design that improves FGR efficiency and ensures the flare operates without pulsation or surging, issues that are common with standard liquid seal drums.

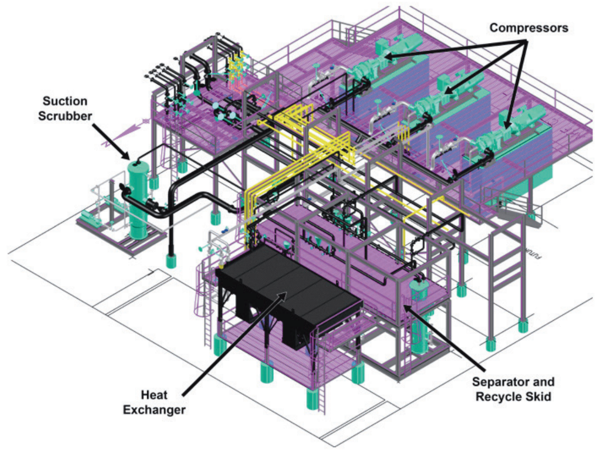


Figure 4. 3D model of a ZEECO flare gas recovery system.

In addition to increasing the efficiency of the FGR operation, these deep seal drums provide a higher level of safety in the overall system design. Should the turndown control on the FGR system malfunction, the compressors could potentially begin pulling a vacuum on the flare header. A deeper seal drum will allow a greater amount of vacuum to be pulled before the seal is broken and air can enter through the flare tip (causing an explosion hazard). A deeper seal drum therefore provides a longer amount of time for the turndown issue to be fixed or the system to be shut down before any safety hazards occur.

FGR design

Following the completion of the feasibility study and/or identification of the design recovery flows of flare gases, the following information also will be needed before the FGR design can be completed:

- Inlet flare header pressure.
- Inlet gas temperature.
- Required recovered gas outlet pressure.
- Required gas outlet temperature.
- Technology preference.
- Available cooling water supplies.
- Site space availability.
- Range of gas compositions.
- Utility availability.
- Required system turndown.
- Location of FGR within the refinery and distance to the takeoff point from the flare header.

Once this information has been obtained, the FGR system will be custom designed and tailored to the process application. Depending on the system requirements, a number of technologies may be available, each with its own merits and limitations. The following offers a brief summary of the most common technologies for FGR systems:

Sliding vane compressors

Sliding vane compressors are simple machines that do not follow any API standard. They can operate with a variable speed drive unit and can, therefore, offer high efficiency. Sliding vane compressors can be offered with a built in 3:1 turndown.

The maximum outlet pressure of sliding vane compressors is approximately 150 psig and the heat of compression is passed into the gas, so gas after cooling is required.

The advantages of sliding vane compressors lie in their efficiency (65 - 75%) and the resulting low power usage and flexibility in operation. Disadvantages include their materials of construction being ductile iron and an inability to meet stringent standards.

Liquid ring compressors

These have become the industry standard for FGR systems. They are good for discharge pressures up to approximately 150 psig but their efficiency is not as good as other technologies with them working at approximately 25 - 30% at full load.

These compressors work by mixing gas with liquid (normally water) and, therefore, require a separation vessel post compression.

These compressors have the advantage of being able to accept some liquids and particulates in the gas, plus they operate at relatively low speeds and have low maintenance demands.

Oil flooded screw compressors

These compressors can reach discharge pressures well above 150 psig and higher efficiencies than liquid ring compressors (60 - 80%). An internal slide valve is used to turn the compressor capacity down.

The main disadvantage is that oil contacts the process gas and will eventually become contaminated. The frequency of required oil changes is dependent on process conditions.

Dry screw compressors

These compressors can reach discharge pressures well above 150 psig; however, since there is not any oil in the compression cycle to remove heat, all of the heat is transferred to the compressed gas. This high heat of compression results in the need for multiple stages of compression with intercooling. Variable frequency drives (VFDs) are used to turn them down to approximately 75% capacity. Oil contamination is not a concern, since there is not any oil in the compression cycle.

The main disadvantages are the high noise levels due to the high speed of operation (> 8000 RPM), the need for multiple stages with intercooling, and the high compressor cost.

Reciprocating compressors

Reciprocating compressors are typically not preferred for FGR applications, primarily due to their high maintenance requirements (as a result of the many moving parts). However, reciprocating compressors have the advantage of creating a high pressure ratio in a single stage and can supply recovered gas to a pressure of > 300 psig. The more modern, lower maintenance machines should be applied if the choice is made to use a reciprocating compressor. They also tend to be lower cost than the screw compressor technologies and site operators/technicians tend to be more familiar with working on recips than other compressor technologies.

Eductors/ejectors

If a refinery has a high pressure motive force available (which can be gas, water or steam), the application of an eductor or ejector can be considered. An eductor offers an excellent low cost solution. The criteria for using an eductor system is significantly different than for a regular flare gas recovery package, but should be considered as an option or a partial system option during the feasibility stage. The main drawback of eductors is the large amount of motive force (i.e., utility requirements) needed.

Required ancillary equipment for FGR

The ancillaries needed for operating a FGR system depend on the technology choice. For any compressor technology where a service liquid (water, oil, etc.) is mixed with the gas, the liquid then needs to be separated and recycled, which requires a separator vessel. The service liquid collects the heat from compression, and as such needs to be cooled. This can be completed by shell and tube or plate and frame heat exchangers, assuming the end user has a cooling source available or by using a stand alone air cooled heat exchanger.

Depending on the compressor technology used, the gas inlet requirements may alter. For example, the gas must be clean and dry for the screw compressors and the sliding vane compressors but this is not as critical for the liquid ring units. In some cases a suction scrubber may be necessary to remove liquids or particulate before the gas enters the compressor.

The ancillaries required downstream of the compressors will be determined by the refinery's requirements in respect to the recovered gas. Dry screw, sliding vane, and reciprocating compressors pass the heat of compression into the gas and, as such, the recovered gas will need to be cooled after the compressor discharge. For the liquid ring technology and flooded screw compressors, most of the heat is passed into the service liquid and, therefore, only the service liquid needs to be cooled before being recycled back into the system.

All FGR units will require a control system. This can be via a stand alone programmable logic controller (PLC), or alternatively, the system control can be accommodated within the site distributed control system (DCS).

Some end users prefer that FGR systems be supplied preassembled as single skid units. Within reason this can be achieved on smaller FGR systems. However, for larger systems the units are supplied in many pieces to be stick built on site, or as several larger modules that are tied together at the site.

Case study

Zeeco had the opportunity to provide multiple stages of support for several FGR systems for a European refinery. This project started with verification of the original feasibility study, FGR design and engineering, flare system modification, and supply and commissioning of the FGR system.

The end user's requirements for the project were to reduce H_2S flaring at the refinery to satisfy local regulators and to conserve fuel to help ensure the long term financial viability of the plant. The end user operated two separate flare systems located in different areas of the refinery. The project:

- Determined during the feasibility stage that two separate 'packaged' flare gas recovery units were the preferred solution.
- Discovered that the recovered gases on both systems contained large concentrations of H_2S (> 50% in some cases), so a downstream H_2S scrubbing system was utilised to clean the gases for reuse in the plant.
- Modified both existing flare liquid seal drums to provide approximately 0.5 psig of suction pressure at the FGR inlet. Control of the FGR systems was from stand alone PLCs.
- Designed both FGR systems based on a similar design using a common engineering concept, and supplied them as single skid units ready to 'plug and play' as required.
- Both units used liquid ring compressor technology, and the systems were supplied with a 100% recycle lines for operational flexibility.
- Installed and commissioned the flare gas recovery systems in March 2014, and both FGR systems have run smoothly since.
- Calculated an original payback period for continual operation of the systems of approximately 14 months. However, the actual normal gas flow rate during refinery operation is higher than expected, which will likely shorten the payback period.

The end user is experiencing the following benefits from its FGR systems:

- Reduced H_2S flaring.
- Improved visual image on the plant.
- Reduced smoking of the flare, since the normal flow rates in the utility flare are now recovered.
- Compliance with local regulatory requirements.
- Reduction in the amount of purchased fuel gas in the plant, since recovered gas is used.
- Expected increase in the longevity of flare tips.

Conclusion

Subpart Ja regulations will continue to impact the US refining industry for the next several years, and similarly tightening regulations will affect flaring worldwide. While some refineries already have implemented the necessary changes to comply with these regulations, other facilities are farther behind and run the risk of non-compliance. Zeeco continues to encounter end user confusion in the industry about the necessary changes needed at each facility and recommends choosing an experienced flare and flare gas recovery expert to best understand the impact regulations have at each facility.