

Solutions for Minimizing the Impact of Subpart Ja for Flare Systems

As Presented at AFPM Environmental Conference, 2014

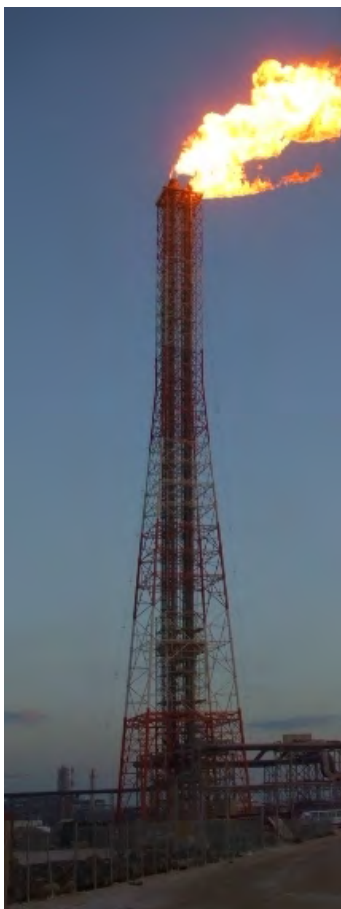
Authors:

Brian Blackwell, Zeeco, Inc.

Trevor Leagas, Zeeco, Inc.

Greg Seefeldt, PE, Manager, Vapor Control, Zeeco, Inc.

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



Typical Flare System

In recent years some refinery owners and operators decided to recover the potentially high heat-value gas existing in their flare systems due to normal operations, in lieu of burning the gas in

the flare. Flare gas recovery, they determined, offered some real and tangible benefits. Recovered flare gas could be re-used in plant process heater burners and boiler burners, which in turn reduced the amount of natural gas purchased by the facility. Purchasing less gas provided a fairly short return on investment for the cost of the flare gas recovery system. If the flare tip happened to be an assist-type, employing flare gas recovery also reduced the consumption of steam or air while increasing the life of the flare tip by reducing the amount of gas being continuously burned by the flare. Flare gas recovery provided some intangible benefits, as well. By reducing the amount of gas in the flare, the visibility of the flare itself was minimized, improving public perceptions of the facility.

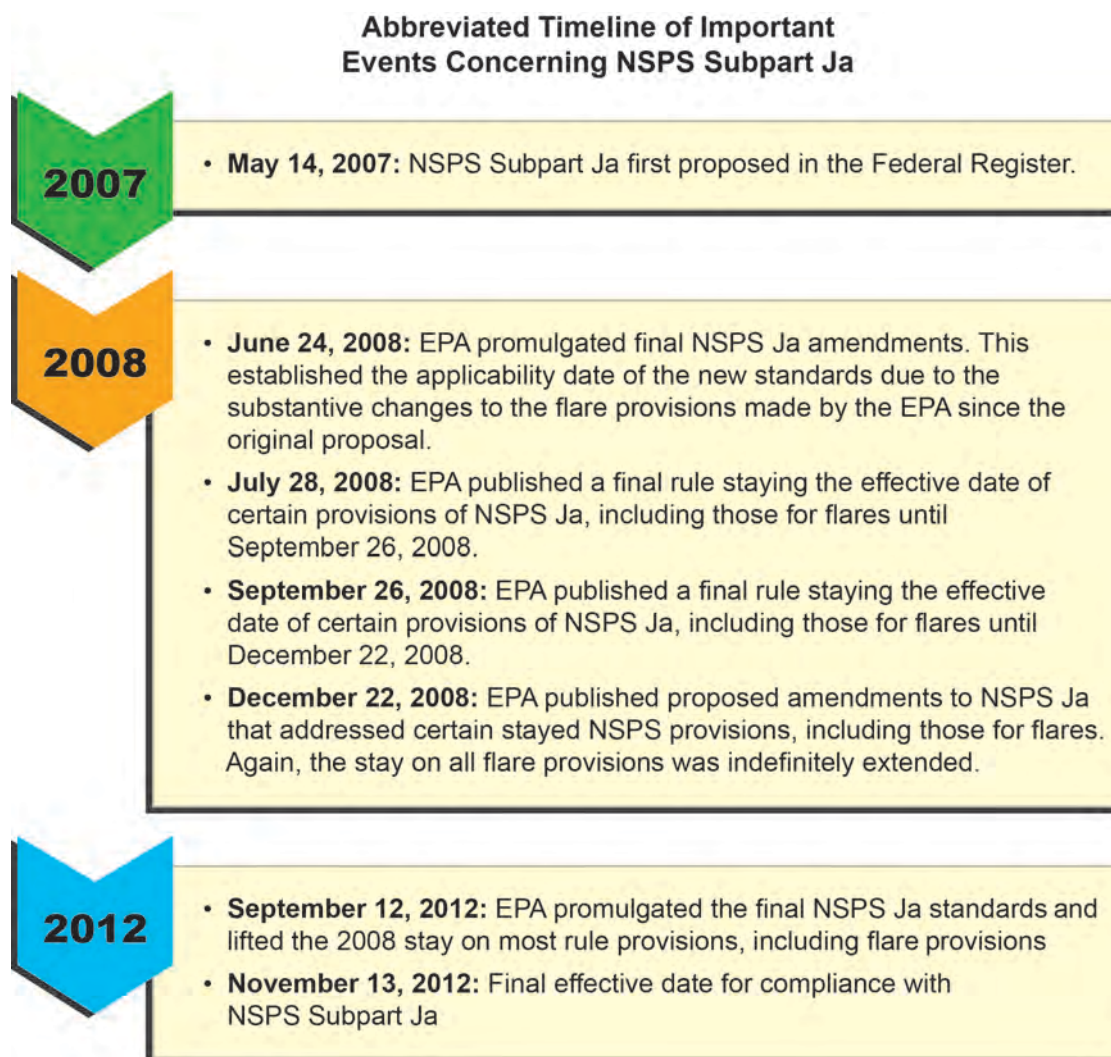


ZEECO® Flare Gas Recovery System

Flare consent decrees originated in the year 2000 with the National Petroleum Refinery Initiative. Consent decrees are formalized negotiations between the EPA and state environmental agencies, the DOJ and private corporations. There were 31 settlements with U.S. Companies representing more than 77% of U.S. petroleum refining capacity. (EPA-HQ-OAR-2007-0011, p. 27188) The consent decrees cover 107 refineries in 32 states and territories, with most decrees referencing the flaring of acid gas and the need to reduce the production of SO₂ to decrease production of acid rain.

Section 111 of the Clean Air Act of 1970 authorized 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. The NSPS applies to new, modified and reconstructed affected facilities in specific source categories, such as manufacturers of glass, cement, rubber tires and wool fiberglass. Subpart J and Subpart Ja of the NSPS deal specifically with petroleum refineries. The previous paragraph concerning the consent decrees is included here, because according to the proposed rule document issued in the

Federal Register in May 2007, the consent decrees were one of four sources for information to develop the proposed standards for new petroleum refining process units. While NSPS Subpart Ja (40 CFR 60; §60.100a-§60.109a) has a much broader application than just the reduction or elimination of “routine” flaring, the standard does directly address this.



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. The exemptions are as follows:

- Connections made to install monitoring systems to the flare.
- Connections made to install a flare gas recovery system or connections made to upgrade or enhance components of a flare gas recovery system (e.g., addition of compressors or recycle lines).
- Connections made to replace or upgrade existing pressure relief or safety valves. However, this is strictly limited to a new pressure relief or safety valve with a set point opening pressure – no lower – and an internal diameter no greater than the existing equipment being replaced or upgraded.
- Connections made for flare gas sulfur removal.
- Connections made to install back-up (redundant) equipment associated with the flare (such as a back-up compressor) that does not increase the capacity of the flare.
- Replacing any piping or moving an existing connection from a refinery process unit to a new location in the same flare, provided the new pipe diameter is less than or equal to the diameter of the pipe/connection being replaced/moved.
- Connections that interconnect two or more flares.

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 H₂S (three-hour rolling average) limit at startup of the flare with exceptions allowed as follows: (1) modified flares not previously subject to the H₂S 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 within three years (i.e., November 13, 2015).
 - The 162 ppmv H₂S limit does not apply to the combustion in the flare of process upset gases.

Subpart Ja requirements for flares can be split in two major areas: documentation/reporting requirements and monitoring hardware.



DOCUMENTATION AND REPORTING REQUIREMENTS

Subpart Ja 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. The flare management plan must list all refinery process units, ancillary equipment, and fuel gas systems connected to the flare for each affected flare. The plan must include an assessment of whether discharges to affected flares from these process units, ancillary equipment, and fuel gas systems can be minimized. The flare minimization assessment must (at a minimum) consider elimination of process gas discharge to the flare through:

- process operating changes or gas recovery at the source, or
- installation of flare gas recovery system, or
- minimization of sweep gas flow rates by installation of deep liquid seals in the flare headers.

The flare management plan also must provide a description of each affected flare. This should include an evaluation of the baseline gas flow rate to the flare, and procedures to minimize or eliminate discharge to the flare during planned startups and shutdowns. The plan must describe procedures to reduce flaring in case of fuel gas imbalance (i.e., excess fuel gas for the refinery's energy needs). If the affected flare is equipped with a flare gas recovery system, the flare management plan must also include procedures to minimize the frequency and duration of flare gas recovery system outages, and to minimize the volume of gas flared during such outages.

Each owner or operator of an affected flare shall perform a root-cause analysis and corrective action plan any time SO₂ emissions exceed 500 lb in any 24-hour period. Root-cause analysis and corrective action must also be performed for any flaring event in excess of 500,000 SCFD above the baseline flow in any 24-hour period. The root-cause analysis report and the corrective action plan must be submitted within 45 days of the triggering event.

MONITORING HARDWARE

Subpart Ja also contains requirements for continuous flow monitoring, H₂S concentration monitoring and Total Reduced Sulfur monitoring for any affected flare, whether constructed, reconstructed or modified. The rule provides monitoring alternatives for certain flares. Flares that qualify for monitoring alternatives include any affected flare that includes a liquid seal and can be classified as an emergency flare or secondary flare (less than 4 flaring events per year), or a flare equipped with a flare gas recovery system that is designed, sized and operated to capture all normal flows. The alternative monitoring method does not require installation of continuous flow monitoring, H₂S concentration monitoring, or Total Reduced Sulfur monitoring as long as flare header pressure (i.e., pressure transmitter) and liquid seal level monitoring (i.e., level transmitter) are both provided. Pressure transmitters and level transmitters are typically much less expensive to purchase and install than other continuous online analyzers required by the rule.

The continuous monitoring requirements in Subpart Ja present both a cost to refineries as well as potential cost savings over time. In the proposed rule document published in May 2007, the EPA references a 1998 rule instituted by the South Coast Air Quality Management District requiring refineries to measure the flow rate and hydrocarbon content of gases sent to the flare, which required cost expenditures to install the necessary equipment. The rule did not set emissions limits. However, it still led to the reduction in flaring. Once they could quantify the amount of gas being burned in the flare on a regular basis, refinery operators identified cost-effective flare gas minimization or recovery projects to improve operational profitability by capturing high energy-value gas. In other words, the cost of continuous flow monitoring led to fuel gas savings in the end for many facilities. The H₂S and Total Reduced Sulfur continuous monitoring is included for environmental reasons to reduce exceedances of the 162 ppm H₂S in a three-hour rolling average, or 500 lbs of SO₂ 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 nonetheless sent out in August 2012, announcing that penalties under the Clean Air Act for violations of federal requirements can result in as much as \$37,500 per violation, per day.

LIKELY OUTCOMES OF SUBPART Ja

Once the flare management plan is completed and the monitoring equipment is installed, some refineries may discover that they are exceeding the allowable H₂S limits. It may be possible to reduce the H₂S limits by installing desulfurization equipment upstream; however, this may not be cost-effective or not sufficient to lower the H₂S to allowable limits in all cases. If these situations arise, the most effective approach may be to install a flare gas recovery system. The potential for costly fines or even plant shutdowns makes investigating this option a far better time investment with the November 2015 compliance date looming in the near distance.

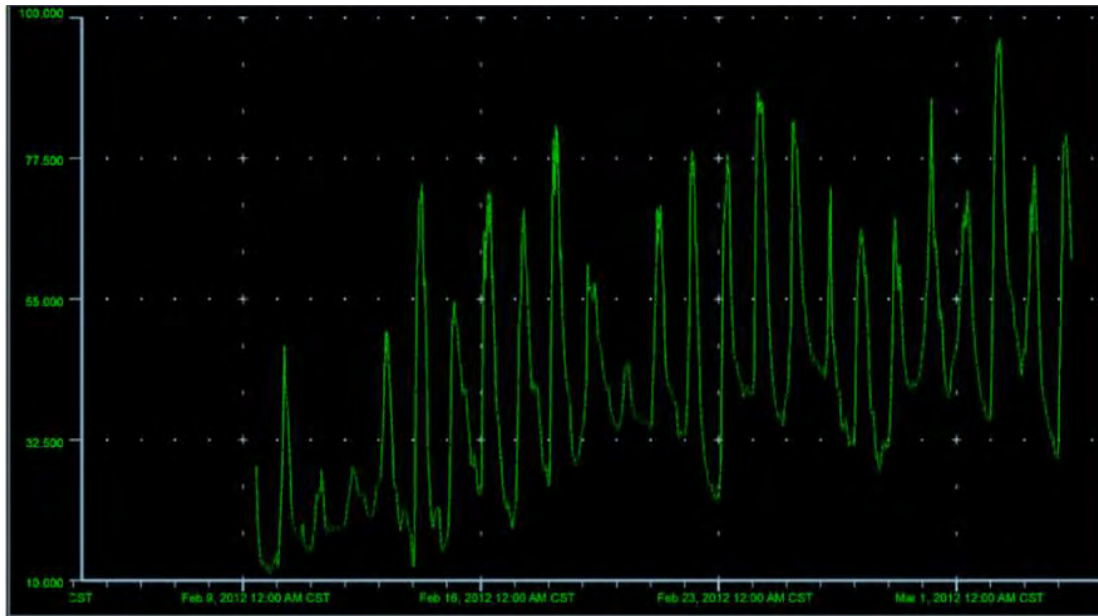
Flare gas recovery, while not specifically required to meet the NSPS Ja requirements, is an economically viable solution to help owners and operators of affected flares meet the mandated requirements. A deep liquid seal, or some other back pressure control device, is necessary for the safe operation of a flare gas recovery system. As mentioned earlier, with the installation of flare gas recovery the owner or operator can use alternative monitoring methods. This eliminates the mandate for continuous online flow and sulfur measurements. A flare gas recovery system is an end of the line flare gas minimization apparatus. It may be more cost-effective to install flare gas recovery than to re-route fuel gas-producing process units out of the flare and to new users.

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 neighbors, and improved perception of the facility within the community.

Zeeco custom-designs and installs the precise size FGR system for each refinery application; this approach is critical to ensure accurate performance and long system life. One reason for our precision engineering is that, although flare gas recovery systems provide major economic and environmental value to refineries, they can also command high power if oversized. Zeeco believes that each refinery should be evaluated first by our engineering experts to determine a realistic and reasonable flow rate for flare gas recovery.

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 our preference would be evaluating months' or even years' worth of flow data, if available.



Flow Meter Output

Flow metering of the gas to be recovered is but one part of the study. Consideration should also be given to the type of technology that will be utilized; 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 PSV's 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 re-assessed 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. Given Zeeco's extensive history in flare system design and supply, our engineering team can provide assistance to end users in development of their flare management plans.

Deep Liquid Seal Systems: Modifications to Improve Flare Gas Recovery Economics

Ensuring a reasonable system back pressure is crucial when installing a Flare Gas Recovery 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. Zeeco also can provide existing systems with a new drum, or in some cases, retrofit another manufacturer's drum to accommodate our seal internals.

In addition to increasing the efficiency of the FGR operation, Zeeco's deep seal drum provides a higher level of safety in the overall system design. Should the turndown control on the Flare Gas Recovery 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). This provides a longer amount of time for the turndown issue to be fixed or the system shut down before any safety hazards occur.



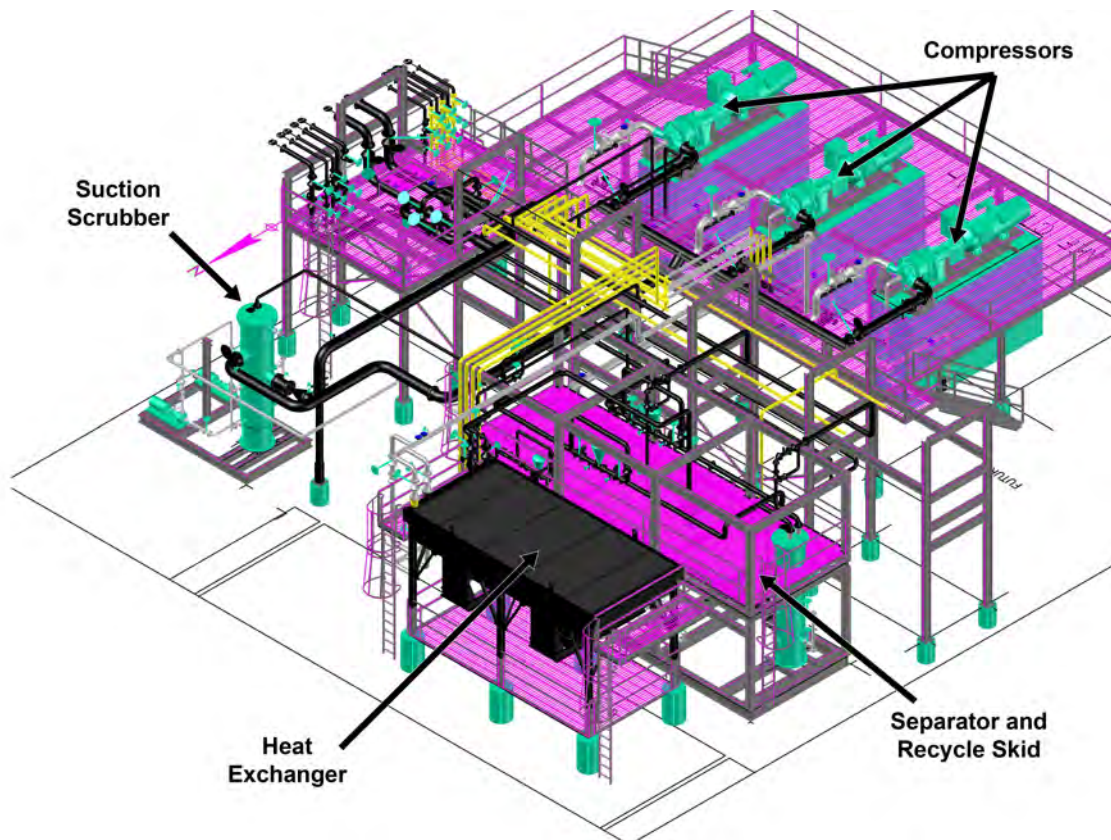
ZEECO Deep Liquid Seal Drums

FGR Design

Following the completion of the feasibility study and / or identification of the design recovery flows of flare gas, 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 technology for Flare Gas Recovery systems:



3D Model of a ZEECO Flare Gas Recovery System

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 ~ 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 to 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 Flare Gas Recovery systems. They are good for discharge pressures up to around 150 psig but their efficiency isn't as good as other technologies with them working at around 25 to 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 particles 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 to 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. VFD's 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 (>8,000 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 recip 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 Flare Gas Recovery 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 Flare Gas Recovery units will require a control system. This can be via a stand-alone PLC, or alternatively, the system control can be accommodated within the site.

Some end-users prefer that FGR systems be supplied pre-assembled as single skid units. Within reason this can be achieved on smaller Flare Gas Recovery 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 Flare Gas Recovery systems for a major European refinery. This project included 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 twofold:

- (1) Reduce H₂S flaring at the refinery to satisfy local regulators
- (2) 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. It was determined during the feasibility stage that two separate "packaged" flare gas recovery units were the preferred solution.

The recovered gas on both systems contained large concentrations of H₂S (>50% in some cases), so a downstream H₂S scrubbing system was utilized to clean the gases for re-use in the plant.

Both existing flare liquid seal drums were modified to provide approximately 0.5 psig of suction pressure at the FGR inlet. Control of the FGR systems was from stand-alone PLCs.

Both Flare Gas Recovery systems were based on the similar design using a common engineering concept, and both were supplied as single skid units ready to "plug and play" as required. Liquid ring compressor technology was used on both FGRs, and the systems were supplied with a 100% recycle lines for operational flexibility.

The flare gas recovery systems were installed and commissioned in March 2014, and have run smoothly since then.

The original calculated payback for continual operation of the systems is 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 H₂S flaring
- Improved visual image on the plant
- Reduced "smoking" flaring, 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.
- Longer term benefits will be longevity of flare tips



Flare Gas Recovery Systems



Conclusions

Subpart Ja regulations will continue to impact the U.S. refining industry for the next several years. While some refineries already have implemented the necessary changes to comply with these regulations, other facilities are farther behind and run the risk of incompliance when the final November 2015 date is reached. Although these regulations may not be as complicated as other EPA regulations, Zeeco continues to experience end-user confusion in the industry about the necessary changes needed at each facility. Zeeco's recommendation is to always choose an experienced flare and flare gas recovery expert to best understand the impact these regulations will have at each facility.



The information contained in this paper reflects Zeeco, Inc.'s opinions and interpretations of Environmental Protection Agency regulations; accordingly, information in this paper is not promised or guaranteed to be correct or complete, and should not be considered an indication of future results. Zeeco, Inc. expressly disclaims all liability in respect to actions taken or not taken based on any or all the contents of this paper.