TAKING CONTROL

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Emissions from industrial flares have been under increased scrutiny from the US Environmental Protection Agency (EPA) as well as many states over the last five years. During this time, the EPA has determined that over-assisting a flare – the addition of excessive steam or air at the flare tip – can significantly reduce destruction removal efficiency (DRE) and increase emissions compared to what was previously considered.

Since the 1980s, regulations regarding the operating requirements for flares were contained in 40 CFR 60.18 and 40 CFR 63.11 (herein referred to as either 60.18, 63.11, or Subpart A). These regulations set out requirements regarding the presence of a pilot flame, a limit on visible emissions, limits on the exit velocity, and minimum net heating values in the vent gas (NHV_{vg}). These regulations did not contain requirements regarding the amount of assist gas that could be added to a

Figure 1. Combustion controls and industrial flare compliance continue to be challenging.

flare. Typically, assist gas was controlled to minimise visible emissions of the flare and were not generally considered from a DRE perspective.

Through various industrial flare tests, it was determined that in order to ensure sufficient DRE, the amount of assist gas needed to be accounted for in conjunction with the amount and quality of the vent gas being flared. These concepts took shape through the EPA Office of Air Quality Planning and Standards (OAQPS) document, 'Parameters of a Properly Operated Flare', as well as a number of consent decrees (CDs) or other enforcement actions. These documents laid out the concept of considering the net heating value in the combustion zone (NHV_{cz}) in order to demonstrate sufficient DRE.

The concept of NHV_{cz} was then incorporated into regulations with the publication of changes to the Refinery Sector Rule (RSR), which incorporated the flare requirements into 40 CFR 63 Subpart CC, referred to as the 'Maximum Achievable Control Technology Subpart CC' (MACT CC). MACT CC applied to flares controlling regulated material from refineries.

With a compliance date of 30 January 2019, refineries are working to determine what is necessary from not only a monitoring aspect, but also a control perspective. This focus on controls is a change in paradigm from monitoring and emissions reporting requirements to a monitoring and control requirement. While the new regulations were added to the rules of the refining sector, these changes are also expected to influence regulations for the chemical sector in its upcoming revisions. Thus, these concepts are critical not only for refineries, but for chemical facilities too.

Monitoring

Monitoring flares has stayed relatively consistent from the requirements that were first put forward by the early flare-related CDs. The monitoring falls into four categories: vent gas flow rate, assist gas flow rate, supplement gas flow rate, and vent gas composition/NHV. The monitoring of these parameters forms a basis for calculating the NHV_{cz} and determining if sufficient DRE has been achieved. While there are techniques for directly determining the combustion efficiency (CE) of a flare (such as passive fourier transform infrared [PFTIR]), those techniques have not been utilised for continuous long-term operation of a refinery flare. Therefore, compliance with the MACT CC requirements will be a calculated value, based on the monitoring.

Flow monitoring for the vent gas was installed on many flares due to various requirements, with one of the largest drivers being the New Source Performance Standard (NSPS), Subpart Ja, regulation, which was finalised for the refinery sector in 2012. Flares subject to NSPS Ja were required to install a flow monitor on the vent gas header, unless an exemption in the regulation was utilised. Through compliance with NSPS Ja and the publishing of the revisions to MACT CC, the requirements for the vent gas flow monitors were made consistently accurate. The accuracy requirements for the various monitoring devices can be found in Table 13 of MACT CC.[1]

Assist gas (typically steam or air) flow monitoring did not have a regulatory requirement until MACT CC. While many refinery flares have been equipped with flow meters, not all of the flow meter technologies installed meet the requirements of the regulation. The two key items for consideration are the accuracy (found in Table 13) and the range of the monitor. The accuracy needs to meet the values listed in Table 13 for the normal range of flows. However, the term 'normal range' was not defined in the regulation, which has caused some debate as to its meaning.

The requirements for a continuous parameter monitoring system (CPMS, 40 CFR 63.671) note that "the span of the CPMS sensor and analyser must encompass the full range of of all expected values." The use of the words 'full' and 'all' indicate that the flow monitor used must be able to read from the minimum to maximum values. For many applications, this would not be a cause for concern. But, when taking assist steam into consideration, the minimum flow rate is typically less than 1000 lb/hr, with a maximum flow rate potential in the tens to over one hundred thousand lb/hr. This wide dynamic range, paired with the accuracy requirements, can lead to many flares requiring an upgrade to the technology utilised for steam flow measurement.

The regulatory requirement for supplemental gas flow monitoring depends on the location of the supplemental gas injection relative to the vent gas flow meter. If installed downstream of the vent gas flow meter, the supplemental gas addition will need a dedicated flow monitor and will need to meet the accuracy requirements in Table 13 for a vent gas flow meter (supplemental gas is defined as part of vent gas). If installed upstream of the vent gas flow meter, a supplemental gas flow meter is not a regulatory requirement. However, monitoring this flow rate can have benefits from a flare control perspective.

Monitoring the composition/NHV of the vent gas can be accomplished through a variety of analytical techniques. Early CDs required the use of gas chromatography (GC) for this monitoring. Additionally, many refineries installed GCs for sulfur monitoring required by NSPS Ja and installed GCs that were also capable of speciating the hydrocarbons for NHV_{vg} determination. Based on comments in the preambles to the RSR, it appears that the EPA structured portions of the regulation to accommodate the continued used of GCs. One significant change from the early flare CDs was the shift from a 3 hr rolling average NHV_{cz} used for compliance to a

15 min. block for NHV_{cz} compliance under MACT CC. This compression of the compliance timeframe has caused many refineries to consider technologies that have a faster response time than the typical 7 – 15 min. response time of a GC, in order to assist with speed or readings for the associated control element of the rule.

Two primary technologies being considered are a calorimeter or mass spectrometer. While the calorimeter measures the NHV_{vg} directly, the mass spectrometer speciates the components to calculate the NHV_{vg} using known NHVs of each constituent. Manufacturers of both of these analysers indicate a NHV_{vg} value can be determined on an approximately 1 min. basis. The accuracy requirements for these calorimeters are included in Table 13.[1]

One concept incorporated into MACT CC surrounds the NHV value utilised for hydrogen. If the amount of hydrogen is specifically measured, a value of 1212 Btu/ft^3 can be utilised for hydrogen in lieu of the typical value of 274 Btu/ft^3. These values are listed in Table 12 of the regulation.[1] With a compliance point of 270 Btu/ft^3 for the NHV_{cz}, the use of the elevated value could be beneficial for a refinery with significant amounts of hydrogen in the vent gas. Typically, a GC or mass spectrometer will provide this value through their speciation. Meanwhile, a calorimeter would need to include a separate analytical technique to provide this value. In consideration of this allowance, some calorimeter manufacturers have begun including this hydrogen measurement option.

Quality control methods for the various analytical techniques vary as the requirements for a calorimeter are based on the manufacturer's recommendations. The requirements for a GC are listed as following the applicable performance specifications, with some modification. Quality control experiences and methods are changing for a number of sites based on the requirements to meet the GC procedures. In turn, calibration and/or validation reference gas standards needed for QC compliance can vary widely depending on the analyser type utilised and its intended function.

For instance, a GC used as the primary monitoring device would most commonly utilise a few calibration standard cylinders utilising 6 – 12 hydrocarbon components. In some cases, a GC is only used to provide a measure of hydrogen content for use with a calorimeter in order to take advantage of the 1212 Btu/ft^3 adjustment allowed by the rule. Similarly, the quantity of reference gas stand needed for support of a mass spec will vary depending on the composition of the flare stream. Also, the desirability of using mass spec analytical data as a system troubleshooting aid could prompt addition of standards for components normally only seen in trace amounts.

In cases where hydrogen speciation is incorporated, design of calibration gas mixtures along with the use of Table 12 normalised certificates of analysis has helped enhance both troubleshooting and reporting consistency.

Controlling NHV_{cz}

MACT CC now requires the flare to demonstrate a minimum NHV_{cz} of 270 Btu/ft^3 when combusting regulated material for more than 15 min. Once regulated material is sent to the flare for more than 15 min., the flare needs to comply with the limit for all of the 15 min. blocks that the regulated material sent to the flare. While the analytical technique is not specified in the regulation, the short compliance window for the NHV_{cz} (15 min.) has the potential to drive monitoring decisions that best ensure an ability to be in control of the flare while minimising the amount of supplemental fuel needed to achieve 270 Btu/ft^3. Preliminary modelling of various flaring scenarios has shown a general trend – the faster the response time of the vent gas composition/NHV monitor, the less supplemental fuel that is required for control.

Complying with the minimum NHV_{cz} is not expected to be a significant issue in most refinery flaring events, resulting from upset conditions due to the high hydrocarbon content of the vent gas. Three areas of the most potential concern surround:

- Maintenance events where purge gas streams containing a high concentration of nitrogen or steam ('inerts') are sent to the flare, dropping NHV below the 270 Btu threshold.
- Low flow events where over-assisting is a concern.
- Flaring events that begin in the later portions of a 15 min. block with minimal time to adequately supply the required amount of supplement gas.

Maintenance events that send significant amounts of inert gases to the flare have issues with regards to speed and magnitude. If the inerts are sent to the flare quickly, the control system needs to be robust enough to add a significant amount of supplemental fuel quickly to the flare. Additionally, if the total quantity is large, the overall amount of supplemental fuel will also be large. This will require refineries to evaluate various scenarios to determine if supplemental gas lines are adequately sized and that the fuel system has the overall capacity to meet requirements.

Low flow events need to be evaluated for interaction with the required minimum amount of assist gas, which needs to be sent to the flare on a continuous basis. Often at low flow conditions, the minimum amount of assist gas being sent to the flare will depress the NHV_{cz} and a gas with high Btus may need to be supplemented when sent to the flare at a low rate.

When an event begins in the last few minutes of the 15 min. block and extends into the next block, all blocks need to be in compliance. Therefore, the block with only a few minutes of regulated material flow will need to show compliance. Depending on the amount of assist gas sent to the flare and the NHV_{vg} of the material, a large amount of supplemental fuel may be required. These types of scenarios require a robust system with fast monitoring and controls.

Supplemental fuel gas alternatives

When assessing the addition of supplemental fuel gas, selecting the best methods requires consideration of several factors, including:

- Selection of the most effective fuel gas based on NHV and consequent flow and volume requirements.
- Availability of fuel gas at sufficient volumes.
- Accessibility of the fuel gas source for connection to the flare stream.
- Capital costs associated with connecting fuel gas sources to the flare.

Examples of wake up moments could include:

- Natural gas, propane or other supplemental fuel gas is available and plentiful, but the capital cost of running lines to meet high flow requirements is unexpectedly high.
- Insufficient fuel capacity could require the slowdown of depressurising events that could extend turnaround schedules and increase downtime costs significantly.
- Air or steam assist flow impacts NHV during low flow venting situations.

These scenarios can result in considerable capital cost and/or extended downtime for major maintenance events with high associated direct opportunity costs. One potential solution for meeting Btu requirements is the use of external fuel gas supplies. These are available as bulk, trailer-mounted or other systems, and can be integrated with flow or analyser devices to provide direct feed control of the supplemental fuel gas. These systems also provide the option of using gases, such as propane, which are clean burning and provide approximately twice the NHV of natural gas or hydrogen. This added heating value increases the logistical feasibility for use of these external solutions, which require half the flow rate and half the total gas consumption that would be required for natural gas or hydrogen, either of which can also be provided through supplemental external sources.

External supplemental fuel gas systems utilising direct integrated control based on flow, calorimetric or other analytical data can provide added assurance of maintaining compliance while minimising costs due to over-feeding.

Conclusion

New regulations are driving the need for refineries and certain chemical operations to monitor and control the operation of their flares to ensure sufficient DRE. There are many choices for the various monitoring points, each with benefits and drawbacks that need to be evaluated against the specific operating scenarios anticipated for the flare. While the points of monitoring and control are similar for flares, each flare system is unique and experiences different scenarios that will require detailed evaluation.

Expected monitoring and control challenges include monitor speed, response time of the control system, and the availability of sufficient amounts of supplemental gas. Moreover, MACT CC removed the startup, shutdown and malfunction exemption, which has increased the number of scenarios that need to show compliance with a standard.

The MACT CC regulation has provided a new challenge for refiners. The environmental monitors discussed are no longer only required for quantifying emissions – they are now required to cause operational changes to the flare.

Reference

1. '40 CFR Parts 60 and 63: Petroleum Refinery Sector Risk and Technology Review and New Source Performance Standards; Final Rule', US EPA, Vol. 80, No. 230, pp. 95 – 97, (December 2015), https://www.gpo.gov/fdsys/pkg/FR-2015-12-01/pdf/2015-26486.pdf