END-TO-END EMISSIONS

John Soderstrom and Doug Allen, Zeeco Inc., USA, examine the end-to-end emissions reduction solutions available to the oil and gas industry.

End-to-end emissions include both fugitive and intended emissions, and both pose a safety and environmental hazard.[1] If fugitive emissions cannot be eliminated through equipment maintenance, they may become intended emissions through burning them in a flare or eliminating them through the use of flare gas or vapour recovery. Reducing an organisation's end-to-end emissions footprint helps meet permitting requirements and provides a cleaner, safer global environment. For today's global operating companies, end-to-end emissions solutions should use more efficient flares. A comprehensive look at emissions reduction should also include a review of a variety of technologies for reduction of intended emissions.

When processing combustible gases, a flare provides a necessary, safe means of disposal for gas releases. Instead of an accidental, and dangerous, gas release into the atmosphere, potential release sources are collected and routed to a flare, where the gases are ignited and destroyed through controlled combustion in a designed-for-purpose system. While the fire visible from a flare may be alarming, the products of combustion – carbon dioxide (CO_2) and water – are better than a raw gas release.

Once all logical steps have been taken to reduce sources of emissions, from locating and remediating fugitive tank vapours and vent lines on instruments to addressing ageing or failing assets, the potential economic benefit of recovering a highly valuable product cannot be ignored.

FGR systems

In recent years, some refinery owners and operators have recovered the gas in their flare networks in lieu

Table 1. With FGR/liquid seal/vapour recovery (elimination of purge gas)

Flare system	Single 60 in. high capacity steam tip		Staged multipoint ground flare		Two 48 in. VariJet flares	
Number of pilots	4		15		6	
Annual purge gas consumption (Nm^3/y)	0		0		0	
Annual emissions (kg/y)	NO_X	CO_2	NO_X	CO_2	NO_X	CO_2
Pilots	70	119 846	263	449 424	105	179 770
Purge	0	0	0	0	0	0
Steam generation	1074	1 832 630	0	0	0	0
Total annual continuous emissions (kg/y)	1145	1 952 476	263	449 424	105	179 770

Table 2. Flare type comparison

Flare system	Single 60 in. high capacity steam tip		Staged multipoint ground flare		Two 48 in. VariJet flares	
Number of pilots	4		15		6	
Annual purge gas consumption (Nm^3/y)	652 412		73 924		53 038	
Annual emissions (kg/y)	NO_X	CO_2	NO_X	CO_2	NO_X	CO_2
Pilots	70	119 846	263	449 424	105	179 770
Purge	751	1 281 435	85	145 199	61	104 174
Steam generation	1074	1 832 630	0	0	0	0
Total annual continuous emissions (kg/y)	1896	3 233 911	349	594 623	166	283 944

of flaring. Flare gas recovery (FGR) offers real and tangible benefits, including the following:

- Recovered flare gas can be reused in process heater burners and boiler burners.
- Reducing the amount of natural gas purchased by the facility.
- Extending the life of the flare system.
- Lowering greenhouse gas emissions from a facility.

Although the concept of FGR appears simple, it is a critical package directly connected to the flare and the two should be viewed as a single system. The improper design of a compressor, recycle system, or liquid seal drum may result in air being pulled back into the flare header through the flare tip. This can produce an explosive mixture in the flare or flare header, resulting in a flashback and equipment damage.

Liquid seal or staging valve

To divert the gases from the flare stack to the FGR, a liquid seal or staging valve (with a buckling pin bypass device) is normally required. These isolate the flare system from the flare header and divert normal flows to the FGR. At times when the gas flowrate exceeds the FGR system capacity, the device opens (the water seal is broken or the valve opens) to provide a safe relief path to the flare. Liquid seal drums also provide flashback protection for the flare system, since the flare tip provides an open source for air infiltration and the flare pilot provides an ignition source. In FGR systems and traditional flare systems alike, if the equipment downstream of the liquid seal is designed properly, a liquid seal drum can be used to eliminate the continuous purge rate required for flares and the associated continuous emissions (Table 1).

Flaring

In general, flare application design engineers want to minimise the size and diameter of the flare while combusting the gas. Using the smallest applicable diameter converts the potential energy of the gas (pressure) into kinetic energy (velocity). Increased pressure to the flare means the flow area can be smaller, delivering a higher exit velocity, more erect flame, quicker air inspiration, and less sweep gas – all contributing to lower emissions. The smallest possible tip with a high destruction efficiency lowers capital costs and extends equipment lifespan, due to less destructive flame impingement vs a larger diameter flare tip. Large, single point flares also require a higher continuous purge gas flow to prevent air ingress and potential flashback. Minimising or eliminating the need for a continuous purge rate, by utilising smaller flare diameters, staged systems, or variable area designs, will significantly reduce flare system emissions (Table 2).

Benefit of high pressure and staged flare designs

The segmentation, or gradual increase in staged operation, of staged flare designs make such flares multi-functional and deliver inherent operational benefits. Some benefits include design variability, high turndown capacity, low purge rates, and long equipment service life. Zeeco® Variable Jet (VariJet or VJ) flare tips capitalise on high exit velocities and effective air-fuel mixing, driven by high gas-to-air surface area ratios to operate smokelessly and meet emissions requirements. Each arm of the VJ tip incorporates a self-actuated variable exit area assembly that opens when triggered by internal pressure to ensure operation at consistently high exit velocities over a wide range of flow rates. By maintaining operation at a high exit velocity and allowing the variable pressure of the fuel coming into the flare to determine the number of tips needed, the flare does not require additional assist media to operate smokelessly, resulting in the elimination of assist steam production emissions.[2]

To mitigate the risk of combustible mixtures in an open flare line, a continuous 'purge flow' of nitrogen or fuel gas is often maintained through the flare header.

This continuous flow prevents backflow of oxygen into the system. Because most stages are closed until required for an emergency relief scenario, constant purge is unnecessary on closed stages. Therefore, a staged system minimises the amount of continuous purge flow required, lowering the purge utility costs and the flare system's continuous emissions (Table 1).

Pilots and high pressure ballistic ignition

Reliable flare pilots and ignition systems are critical components to maintain safety and emission standards by ensuring flare gases are ignited and destroyed. Hurricane-proof pilots, such as the Zeeco® high stability, low flow (HSLF) pilot, high pressure ballistic pellet ignition systems and state-of-the-art flare monitoring systems help minimise flare emissions challenges. High pressure ballistic ignition systems, where permissible, offer a safe, reliable, and more flexible 'on-demand' ignition solution that minimises emissions, reduces fuel costs, and operates effectively under challenging weather conditions.

Ballistic ignition systems

The company's high pressure ballistic ignition system can be used in conjunction with, or in place of, traditional flare pilots (Table 3) utilising a compressed nitrogen launching system mounted at grade or on-deck to propel zirconium-filled pellets through a guide tube to the flare tip. Upon exiting at high velocity, the pellets impact a striker plate, showering the flare tip exit with sparks and igniting the flare gas stream. Because the high pressure pellets require a minimum impact velocity for ignition, they will not detonate if dropped during loading or fragment collecting. To reduce maintenance and provide reliable spark, all electronics and movable parts are mounted in the launching cabinet.

Table 3. With high pressure ballistic ignition

Flare system	Single 60 in. high capacity steam tip		Staged multipoint ground flare		Two 48 in. VariJet flares	
Number of pilots	0		0		0	
Annual purge gas consumption (Nm^3/y)	652 412		73 924		53 038	
Annual emissions (kg/y)	NO_X	CO_2	NO_X	CO_2	NO_X	CO_2
Pilots	0	0	0	0	0	0
Purge	751	1 281 435	85	145 199	61	104 174
Steam generation	1074	1 832 630	0	0	0	0
Total annual continuous emissions (kg/y)	1826	3 114 064	85	145 199	61	104 174

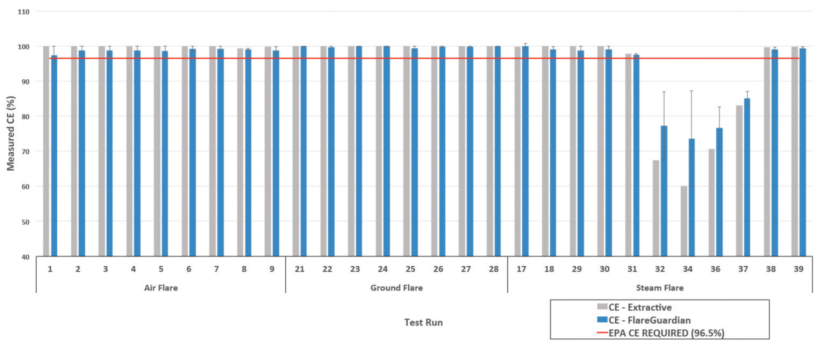

Figure 1. Comparison of extractive sampling combustion efficiency data vs FlareGuardian™ measurements and US EPA CE requirements.

Flare monitoring and optimisation

Unlike other emission sources, combustion in an industrial flare occurs in open air, so it does not allow for a practical method to directly monitor post-combustion flare gases. Current combustion efficiency (CE) flare monitoring methods include the extractive method (directly sampling post-combustion flare gases), open path fourier transform infrared spectroscopy (FTIR), and the use of surrogate parameters (e.g. heating value, exit velocity). Monitoring flare performance using open path FTIR and extractive methods is impractical for continuous monitoring, as confirmed by the US Environmental Protection Agency (EPA) in the recent refinery rule documentation,[2] while the monitoring of indirect parameters is inadequate, complex, and costly.

Plant operators are provided with controls to optimise flare operation by adding supplemental fuel or adjusting the steam-to-vent gas or fuel-to-air ratios. However, actual flare emissions and CE are typically estimated after the fact based on input streams, combustion equations, and indirect measurements, such as the speciation of the waste stream sent to the flare.[3]

A new flare CE measurement and monitoring technology that can directly, autonomously, and continuously monitor flare performance in real time, has recently been developed and validated through a series of large scale tests.[4] This new method has been developed into the FlareGuardian™ brand multi-spectral infrared (IR) imager (Figure 1).

Because of the complexity inherent in indirect methods, and potential time lag in current instrumentation, some users set a constant minimum flow of enrichment fuel to ensure CE compliance, which increases the overall flare emissions. Time lag can lead to under or over steaming a flare, causing increased emissions. By installing and using a multi-spectral IR imager, the enrichment fuel and steam can be more precisely controlled, reducing overall emissions.

Vapour recovery

Throughout the whole process, hydrocarbons are transported and stored multiple times. Each time the

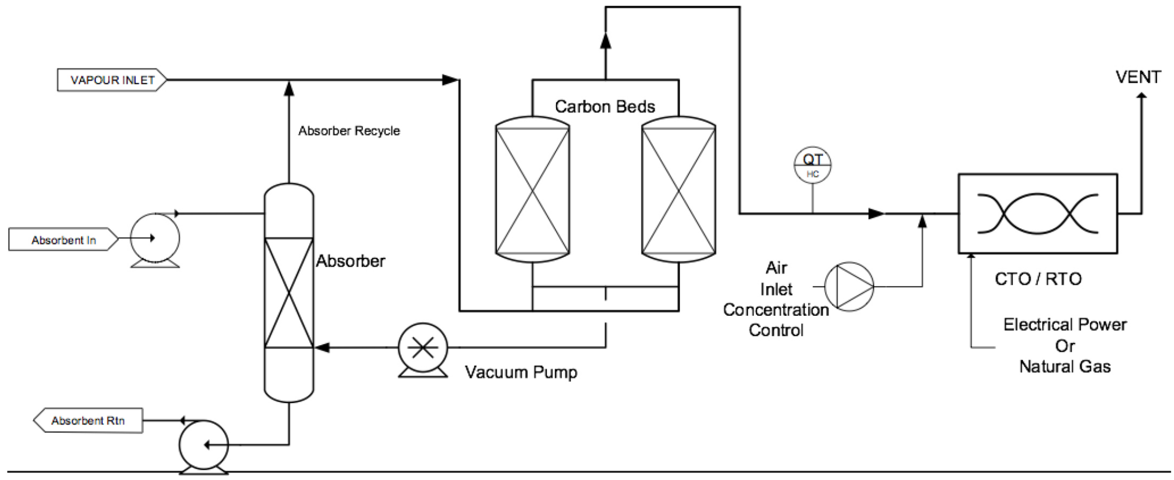

Figure 2. Typical activated carbon adsorption system.

Table 4. With FGR/liquid seal/vapour recovery and high pressure ballistic ignition

Flare system	Single 60 in. high capacity steam tip		Staged multipoint ground flare		Two 48 in. VariJet flares	
Number of pilots	0		0		0	
Annual purge gas consumption (Nm^3/y)	0		0		0	
Annual emissions (kg/y)	NO_x	CO_2	NO_x	CO_2	NO_x	CO_2
Pilots	0	0	0	0	0	0
Purge	0	0	0	0	0	0
Steam generation	1074	1 832 630	0	0	0	0
Total annual continuous emissions (kg/y)	1074	1 832 630	0	0	0	0

feedstock/intermediate/finished product is moved, or even when idle in storage, changes in temperature and pressure will generate vapours. Combustion and environmental control companies can design cost effective methods to handle these vapours by recovering all (or a portion) of the hydrocarbons as a liquid that can be returned as a valuable product, instead of lost as a fugitive or intended emission. Options include one or two-stage vapour recovery units (VRUs), combination vapour recovery flare packages, and combination vapour recovery thermal oxidiser units, determined by the level of emissions reduction required.

Although there are several alternative vapour recovery technologies available, activated carbon adsorption VRUs are often seen as the best available technology[5] for most applications (Figure 2). These systems provide operators with maximum flexibility because they handle an extensive range of products and feature a wide turndown ratio capability, from 0 to 100% of the design flow and inlet concentrations. An additional benefit of vapour recovery is that there is no production of thermal NO_x in the process.

Combination vapour recovery/flare packages allow producers to recover heavier gases as a liquid, and safely flare lighter hydrocarbons such as methane. Combination vapour recovery thermal oxidiser systems require two stages; the first stage is an activated carbon VRU, followed by a second-stage oxidiser of either catalytic thermal oxidiser or regenerative thermal oxidiser design. The two-stage approach can meet the obligation that volatile organic compound (VOC) emissions be recovered, often a requirement of the emissions control permit, whilst meeting stringent overall emissions limits through the second-stage oxidation of what would otherwise be vented from the VRU.

Conclusion

End-to-end emissions reduction is a requirement for global operating companies and there are many options available to help reach the goal. Improving controls and operating philosophies for existing equipment should be the first action taken, but as equipment ages and needs replacement, or as facilities expand, newer and lower emissions technologies should be considered (Table 4). Companies working toward an end goal of total emissions elimination during normal operating and maintenance scenarios have an array of technology options to assist.

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