FLARE PLAY

Matthew Martin and Dharmik Rathod, ClearSign Technologies, explain how new combustor technologies can help strike a fair balance between meeting stringent emissions regulations and maintaining profitable operations when flaring low pressure permeate gas.

Emissions compliance can be challenging for any operation that must dispose of vent gas. Achieving high destruction efficiency, flame stability, and low NO_x emissions can be even more difficult when the vent gas is supplied at low pressure. An often-overlooked cost-of-compliance when disposing of vent gas is the operational expense of the combustors themselves, as well as the opportunity cost from unimplemented emissions reduction. For even moderately sized operations, the savings could range into the millions of dollars per year when using technology for venting low-pressure permeate gas.

Benefits and challenges of low pressure permeate gas

Reduced permeate gas pressure can be beneficial when separating carbon dioxide and methane from gas mixtures. Membrane separation efficiency can be increased, and compression costs are reduced for biogas upgrading and natural gas conditioning. However, flaring low pressure permeate gas can be challenging, particularly if large amounts of inert components remain in the vent gas. Stable combustion with minimal assist gas can be difficult, destruction efficiency (DE) can be reduced, and NO_x emissions may suffer.

The flaring of vent gas can be necessary when there is no use for the gas or there is an abnormal operating condition. For those with a site-wide emissions cap, the use of continuous vent gas flares can limit the capacity or expansion of other profit-making equipment, particularly when standard emissions factors are used to characterise the performance of the flares.

Table 1 lists the general emissions requirements for flares and Enclosed Combustion Devices (ECDs). In most cases the actual requirements are found on a per-state/province and per-permit basis. It may be appealing to select an elevated flare with a NO_x factor of 0.06 lb/million Btu for ease of implementation but in continuous operation, it could reduce the available NO_x emissions for a site by a factor of 2 - 6 under a yearly cap.

Figure 1. A elevated pipe flare in operation.

Background on flares

Elevated pipe flares

Elevated flares are perhaps the most familiar design – if for no other reason than one can readily see their flames. Figure 1 shows an elevated pipe flare in operation. The flame is easily visible even during the day. Emission of smoke is common when the mixing of vent gas with the atmosphere is not assisted by steam or fan-driven air. In the US, vent gas velocity at the exit of the flare is limited by regulation.[1] This velocity limit is for good reason; it has been proven that the flare flame can lift and extinguish if the vent gas velocity becomes too high. Even before the point of flame extinction the destruction efficiency can begin to reduce, resulting in increased emission of unburned vent gas. Unburned vent gas is increasingly under scrutiny due to regulatory interest in methane emissions and the resulting effect on the environment.

Table 1. General emissions requirements for flares and enclosed combustion devices [1 - 6]

Location	Device type	NO_x limit [3,2]	Destruction efficiency (%)	VOC limit	Methane limit
US (EPA)	Flare	--	98	98% DE	98% DE
US (EPA)	ECD	BACT	95 - 99	≥95% or ≤20 ppmv	>95% DE
California	Flare	0.06 lb/million Btu	98	Varies	--
California	ECD	0.036 - 0.072 lb/million Btu	98 - 99	98% DE	--
Texas	Flare	BACT	98	By permit	98% DE
Texas	ECD	0.06 - 0.10 lb/million Btu	95 - 99	95% DE	95% DE
Colorado	Flare	0.068 lb/million Btu	95	95% DE	95% DE
Colorado	ECD	0.068 lb/million Btu	95	95% DE	95% DE
Canada	Flare	BAET	98	98% DE	--
Canada	ECD	BAET	98	98% DE	--

Ground flares

Ground flares are typically used in petrochemical and gas processing plants. These flares require high vent gas pressure to entrain the necessary air for complete combustion and elimination of smoke. For installations with vent gas delivered to the flare with high pressure and high calorific value they can be an ideal solution. Generally, these flares fail to meet the 40 CFR 60.18 or state-level exit velocity requirements, but in the US can now be permitted with a framework for accelerating the required Alternative Means of Emissions Limitation (AMEL) request. Importantly, it is extremely difficult to continuously measure the NO_x in an open ground flare.

Totally enclosed ground flares

Combustion manufacturers often offer totally enclosed ground flares (TEGF). These flares usually use the ground-level high pressure tips (burners) of a ground flare inside an insulated stack. This arrangement allows for measurement of emissions and is beneficial for destruction efficiency due to the elevated temperature in the combustion zone. Unfortunately, the capacity is limited because the airflow is restricted through the same stack that is used to maintain operating temperature. When properly designed these flares do not smoke under any conditions.

TEGFs can alternatively be called incinerators, combustors, or thermal oxidisers, particularly when not using high pressure flare tips as the burners. The name also often implies various levels of sophistication in the design, or simply how the device is permitted. Regardless, these enclosed combustion devices allow for improved destruction efficiency and verifiable emissions, but often at the expense of NO_x production.

Technology for low pressure vent gas

ClearSign Technologies Corp. has previously introduced enclosed combustor technology that can meet existing emission regulations. Figure 2 shows ClearSign Core equipped enclosed combustors. These combustors do not emit smoke or visible light pollution while in operation and meet any existing permit limit.

Table 2 shows the field performance of a previously installed ClearSign flare. This flare technology is designed for use with higher pressure (10 psi(g) or greater) vent gas, not low pressure permeate vent gas (0.25 psi(g) or less). The company has designed a new model of enclosed combustors to specifically meet this need.

This combustor was designed to have emissions performance that meets any regulatory requirements while also minimising operating cost. This cost optimisation is not limited to the cost of vent gas compression – the combustor is of similar size to conventional technology, the ancillary equipment is the same, and the utilities are minimised.

Table 3 shows a comparison of the operating cost using a 30 million Btu/h conventional technology combustor compared to that with ClearSign's low pressure technology. The costs were calculated with the additional cost of compression that the vent gas is pressurised from 0.25 psi(g) to 20 psi(g). The ancillaries are proportional to common designs, the cost of NO_x is comparable to an Emissions Reduction Credit (ERC) sale in Texas, US at US$100 000/t[7] with a reduction from 0.1 lb/million Btu to 0.01 lb/million Btu, and the emission

Figure 2. A ClearSign Core enclosed combustor. There is no visible light emission or smoke when in operation.

Table 2. Field performance data from previous ClearSign Flare installations

Measure	Value
NO_x (ppm)	1 - 6
CO (ppm)	<4
VOC (ppm)	<3
DE (%)	<99.99

Table 3. Operating cost comparison for conventional enclosed combustor technology compared to a ClearSign Low Pressure installation

Measure	Conventional technology	ClearSign Low Pressure
Additional cost of compression (US$/y)	106 171	--
Cost of ancillaries (US$/y)	5256	3154
Cost of NO_x (US$/y)	236 520	--
Cost of methane (US$/y)	206 329	41 266
Total (US$/y)	554 277	44 419
Five-year total (US$/y)	2 771 383	222 097

of methane is priced with the newly enacted US methane tax of US$900/t.[8] The total one-year savings when using the low pressure technology is US$0.5 million, which is on the order of a complete flare replacement. The five-year total savings sum to over US$2.5 million.

Even when not considering the methane tax or NO_x credits – for locations where these are not available – the US$0.5 million five-year OPEX advantage for replacing technology is significant. Perhaps more impactful, and not included in the table, is the extra earning potential from redirecting the NO_x emissions from a site-wide cap to other equipment that can be profitable, for example, electricity production from turbines or increasing the heater treater unit count. The cost savings and potential for profit are more pronounced when one considers that many sites have more than one flare or enclosed combustor that can be replaced.

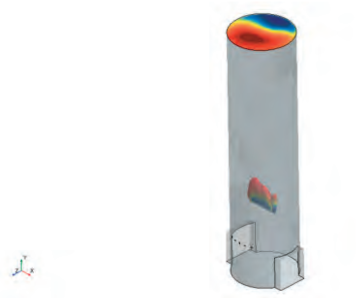

Figure 3. A low pressure ClearSign Core enclosed combustor simulation.

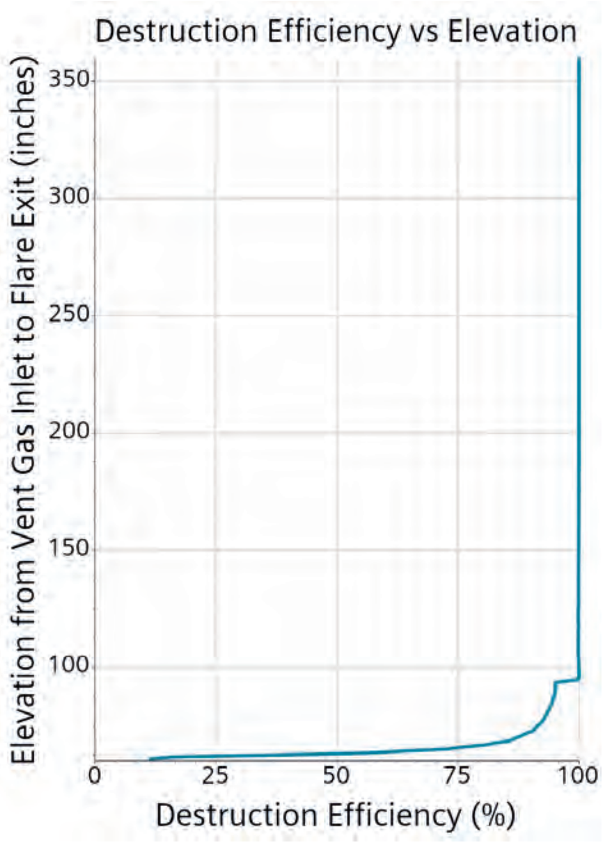

Figure 4. Predicted destruction efficiency from the vent gas inlet to the combustor exit.

Virtual prototyping and risk reduction

The current technology is applicable across a wide variety of vent gas compositions. However, there are special case combustor needs that require further rigour. Examples include vent gas with unusually high concentrations of carbon dioxide, nitrogen, or benzene. For these special cases, computational fluid dynamics (CFD) may be used to virtually test the combustor before construction begins. Compliance risk is reduced by proving the performance by computational means. Figure 3 shows one such simulation result where the flame front is shown well inside the combustor confines while the variation in stack gas is examined at the exit. These simulations have been able to show the stability of vent gas flames using various different burner geometries that is consistent with theory and expectation.

Figure 4 shows the predicted destruction efficiency from the vent gas inlet to the stack outlet from the simulation of a ClearSign Core equipped combustor. The destruction of the vent gas is complete well before the stack exit due to the novel mixing design. Importantly, this mixing does not produce high levels of NO_x while providing a high destruction efficiency. This is done all while maintaining standard, and often regulated, outlet temperatures.

Conclusion

Application of new combustor technology can dramatically reduce the operational cost of vent gas disposal. If unnecessary and uneconomic compression of permeate vent gas can be eliminated, these cost savings can be significant, even without increased emissions regulation. With current and pending emission regulation, the cost of using outdated combustion technology can range into the millions of dollars per year per flare. By using newer and more advanced combustors, permit limits can be easily met while realising significant cost savings. For locations operating under a site-wide cap, the emissions savings can be used to provide increased profitability from increased capacity.

References

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