NEW DIRECT FLAME MONITORING TECHNOLOGY TO HELP OPERATORS COMPLY WITH INCREASINGLY STRINGENT FLARING REGULATIONS

Scot Smith, P.E
Zeeco, Inc.
Broken Arrow, Oklahoma, USA

J. Matt Miskelly

ABSTRACT

Known shortcomings of current flare monitoring methods plus new EPA standards drove the need to develop a new direct flare combustion efficiency (CE) measurement and monitoring method – a technology that directly, autonomously, and continuously monitors flare performance in real time. This patented method, known as VISR, or Video Imaging Spectro-Radiometry, utilizes a multi-spectral infrared (IR) imager to simultaneously measure the relative concentrations of combustion products, carbon dioxide (CO_2), and unburned hydrocarbons (HC) at the pixel level. Directly monitoring flare CE eliminates inaccuracies associated with the current practice of monitoring indirect parameters (heating value, velocity, etc.). Because VISR devices can operate autonomously, no aiming or manual data reduction is required. Remote measurement removes the need for contact with corrosive process streams, making VISR devices less costly to maintain and operate over time. This paper will discuss the VISR technology and how it can be used to generate continuous, real-time data on CE and smoke, allowing operators to optimize flare performance in real time.

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Introduction

The changing government regulations imposed on refineries, gas processing facilities, petrochemical manufacturers, and OEM vendors demand constant adaptation to meet requirements. Across the globe, facilities are scrutinized for their emissions contributions to our global environment and are soon to be held to even more stringent standards. Since its inception, the United States Environmental Protection Agency (EPA) has been actively involved in various flare system enforcement initiatives to reduce the emissions from flares. Some examples of industrial flares can be seen below in Figures 1 & 2.

Figure 1 – Example of Air Assisted Flare

Figure 2 – Example of Sonic Process Flare

In December 2015, the EPA imposed well-defined flaring regulations regarding emissions in the new Refinery Risk and Technology Review (RTR) Rule. To comply with this updated regulation, flare performance is required to be monitored by strict, defined parameters that currently can only be determined using indirect measurement methods or labor-intensive extractive sampling techniques.

Recent testing has shown that the latest EPA methodology for monitoring combustion efficiency (CE) by way of calculating the combustion zone net heating value (CZNHV) varies greatly and invites questions regarding the efficacy of this method. Also, of the few other measurement methods known to measure CE as required to comply with new regulations, none have been credited with being timely, effective in cost or results, or easy to operate and manage. For example, extractive sampling techniques are effective and accurate, but require tremendous effort and labor to produce results. Measuring surrogate parameters (indirect monitoring) requires substantial financial investment in specialized components to ensure compliance (gas chromatographs, BTU analyzers, ultrasonic flowmeters, etc.). Consequently, results do not produce a direct measurement of a flare's performance or any real-time data. A method that will comply with the EPA's newest regulations and optimize flare performance requires a more long-term, simplified, and accurate solution. In this paper, we will discuss how the implementation of new technology utilized in Zeeco's FlareGuardian™ (formerly known as FlareSentry) monitoring system can generate real-time continuous monitoring to meet this demand and satisfy compliance with ease.

VISR Technology

Other technology exists to directly monitor flare systems, but most cannot produce results to verify regulation compliance. Those technologies can have tremendous shortcomings as well; for instance, while the use of infrared (IR) flame or pilot monitors can provide imagery capable of determining the presence of a flame, no flare performance or efficiency measurements can be derived with these devices. When “Passive Fourier Transform IR” methods (PFTIR) are employed, they can provide data to comply with regulations but are limited to a single line of sight approximate to wind direction for a flaring event and must be continuously manned and adjusted to monitor CE. With the use of patented Video Imaging Spectro-Radiometry (VISR) technology, achieving real-time measurement of flare efficiency and hydrocarbon (HC) /combustion product emissions is simplified. VISR technology provides a direct flare CE measurement while simultaneously minimizing the chance of calculation errors common to indirect measurement technologies. VISR’s multi-spectral imaging system utilizes a specialized micro-lens array and bandpass filtering systems to generate CE and performance information in real time. This capability utilized in conjunction with complex flame behavior algorithms, permits VISR devices to convert the filtered signals identifying chemical species and combustion products into data images to deliver detailed, accurate measurements of a flare’s performance. Figures 3a-3d below illustrate the capabilities of VISR to produce filter-specific imaging to achieve this function.

Figure 3a – Image of smokeless flaring

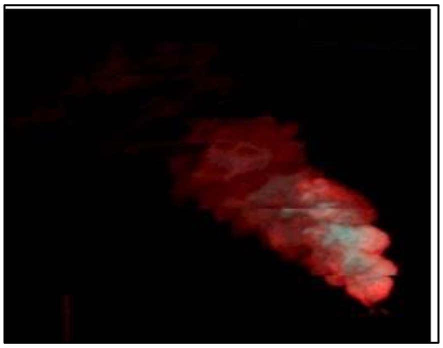

Figure 3b – VISR Image of smokeless flare

Figure 3c – Example of Smoking Flare System

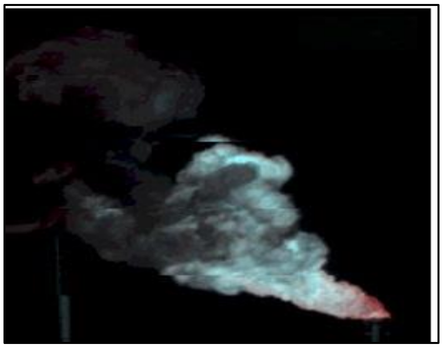

Figure 3d – VISR reported image of smoking flare

VISR's capabilities to recognize chemical species in distinct wavelength spectrums (CO_2, CO, HC, etc.) at the pixel level produces comparative measurements within the flame envelope. Over a measurement frequency of 30 Hertz (Hz), VISR reports in one (1) second averaged intervals of flare performance and other parameters (smoke production, flame surface area, etc.). Environmental effects such as ultraviolet (UV) and infrared (IR) interference from sunlight in the field of view have essentially no effect on the measurement capabilities of a VISR system. In addition, rain and fog do not prevent this technology from obtaining accurate measurements, ensuring consistent data and performance of the device over various conditions.

FlareGuardian™

To take full advantage of the advancements made by VISR technology, Zeeco has produced a VISR-based product called FlareGuardian to meet the demand for an efficient, accurate, and compliant direct flare monitoring system. An illustration of the testing setup of a Zeeco FlareGuardian unit can be seen in Fig. 4.

Figure 4 – Zeeco FlareGuardian monitoring system in use during validation testing

Table 1 below shows the high-level requirements of the RTR rule in relation to industrial flaring. Because the legislation does not clearly define the methodologies to verify compliance, CE measurement via direct monitoring devices such as FlareGuardian will eliminate many of the hardships faced by companies otherwise forced to employ and substantiate measurement via "alternative options."

EPA Rule 40 CFR, Part 63	Compliance Requirements	Covered by FlareGuardian?
§ 63.670 (b)	Presence of Pilot Flame	✓
§ 63.670 (c)	No Visible Emissions	✓
§ 63.670 (d)	The three requirements are design to ensure sufficient CE through surrogate parameters	✓
§ 63.670 (e)		
§ 63.670 (f)		

Table 1 – Comparative Table showing EPA requirements and VISR

As illustrated, FlareGuardian offers the capability to meet all requirements and ensure compliance while avoiding costly measurement techniques and reducing the time required to adjust in the field – consequently improving flare efficiency. Table 2 explains the full benefits of employing Zeeco's FlareGuardian flare monitoring system:

FlareGuardian Benefits and Design Aspects
-Provides real-time combustion efficiency, smoke index, flame stability, flame footprint, heat release, and pilot status for a complete picture of flare performance
-Autonomous data collection (PLC or DCS) for optimized flare performance
-Simplifies monitoring, reporting, and compliance activities
-Patented technology
-Remote mounted, non-contact monitoring
-More accurate results versus indirect monitoring
-Eliminates the need for monitoring surrogate parameters
-Smoke index (SI) assist in achieving incipient smoke conditions day and night
-Short measurement cycle enables quick response and minimizes cost for supplemental fuel, steam, or air
-Industrial interface allows for closed loop flare operation and control based on direct combustion efficiency and smoke index values

Table 2 – Design Features and Benefits of Zeeco FlareGuardian monitoring system

-Easy installation and maintenance, uninterrupted production processes, and no calibrations

Direct measurement for flame CE avoids exposing equipment to corrosive process streams and prevents the use of expensive, unreliable solutions for data collection. An autonomous solution allows for independent monitoring and adjustment to flaring conditions, minimizing the use of operator intervention. VISR devices such as FlareGuardian hold the potential to directly, autonomously, and continuously monitor flare performance in real time. Thus, this data is readily available to review and execute critical adjustment decisions (i.e. adjustments in supplemental fuel, steam, or air) for flaring scenarios to maintain compliance and meet federal and local regulation criteria. Once online, FlareGuardian begins to report directly to the user system performance parameters in a dashboard structured report for ease of interpretation. Filtered imagery of the flame, real-time calculation, and report of CE, indications of smoking, and other parameters can be viewed without an operator needing to attend the flare itself.

In the next section, we will review and discuss the validation of the FlareGuardian device against current approved EPA methods of flaring efficacy, thereby demonstrating that the use of VISR technology can generate unparalleled data quality and further optimize performance of flaring systems in real time.

Testing and Validation

Extensive testing and validation has occurred at Zeeco's testing facility to determine the feasibility of the FlareGuardian system. In November 2014, full scale experimentation was conducted near Tulsa, Oklahoma at Zeeco, Inc.'s testing facility. An example of the testing setup can be seen in Figure 5.

Figure 5 - Example of testing Setup for FlareGuardian Validation

A total of 39 test points was observed measuring CE for two separate methods (extractive sampling against FlareGuardian VISR monitoring). Validation was performed on three separate Zeeco, Inc. production flare tips as follows. This selection was made to show the diversity of measurement capabilities using FlareGuardian:

➢ Zeeco Model QFS, 16”, steam assisted
➢ Zeeco Model AFDS, 10”, air assisted
➢ Zeeco Model MPGF, multi-point sonic flare, pressure assisted

For this experiment, flares were evaluated by FlareGuardian at a distance of 300 feet from the base of each flare stack. DRE and CE were measured to validate the results from the FlareGuardian monitor against that derived by extractive sampling. Using the methods consistent with the standard EPA methods for stack testing, a sampling hood was suspended over the flare using a crane setup as depicted in Figure 5. Gas samples were transported back to a stable trailer monitoring facility on site and continuously analyzed for presence of combustion products (carbon dioxide and carbon monoxide), oxygen content, and unburned hydrocarbons.

Results

The results of the testing performed by Zeeco, Inc. are shown graphically in Figure 6. The average CE difference between the two methods for all reported tests was 0.50%. Measurement of CE between extractive sampling and FlareGuardian were highly consistent, varying only in regions where poor combustion efficiency was achieved. The full data set with all measured parameters can be found in Appendix 1.

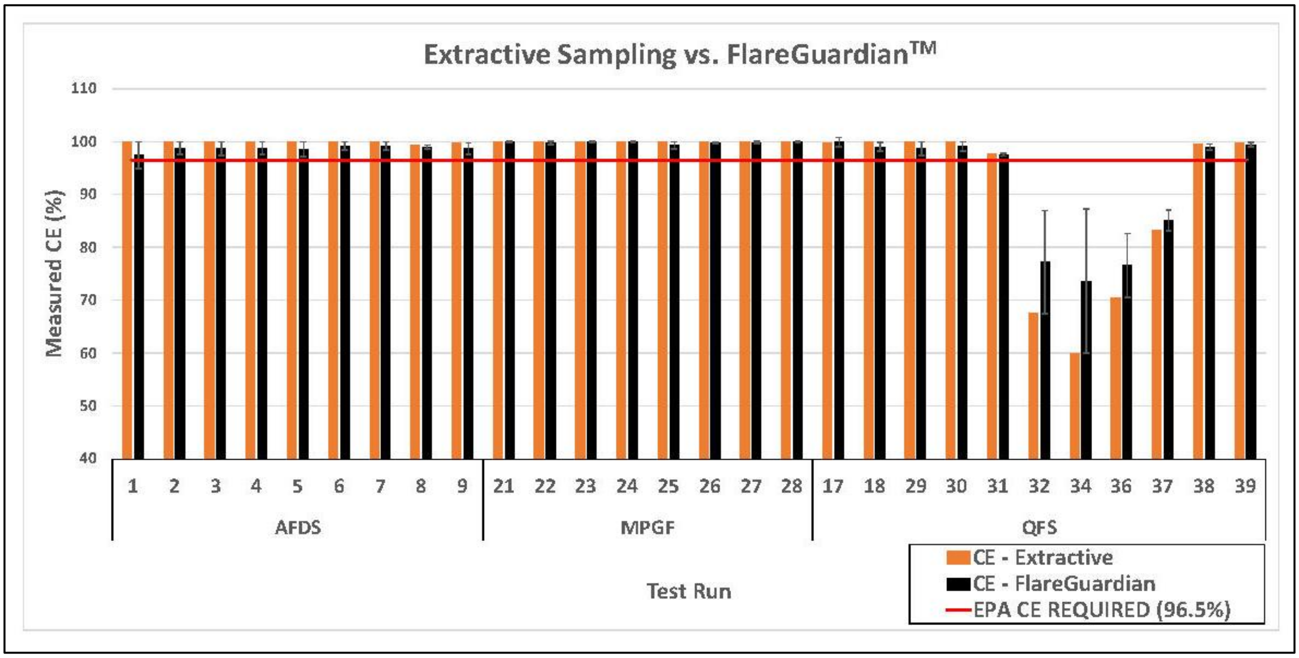

Figure 6 – Flare CE Validation of FlareGuardian vs. Extractive Sampling Method

Based on the individual percent difference against the extractive method reference, the data suggests that FlareGuardian holds a more conservative calculation basis for calculating CE. As federal regulations for compliant CE exist at 96.5%, even in accounting for a conservative calculation, the difference between extractive sampling and VISR are minimal. Based on the data, it can be inferred that excellent repeatability and accuracy exists between FlareGuardian and extractive sampling, thus promoting the use of VISR in flaring applications moving forward.

Discussion

Current measurement methods possess certain pitfalls, such as high capital cost, extensive servicing of all components, constant re-calibration of devices, exposure to corrosive process conditions, and higher labor investment to ensure compliance with mandated regulations. Also, since the EPA RTR rule is accompanied by time-dependent monitoring constraints, a problem is created when striving to comply while using methods that do not provide real-time results. Surrogate parameter measurement is dependent on multiple process components to report data in a multitude of timeframes, which can create prohibitive delays in obtaining results for relative flaring performance. During this composite time delay, flaring process conditions could change dramatically and possibly negate any compliance corrective action, a problem which is not experienced by the real-time data reporting provided with VISR devices. FlareGuardian simplifies monitoring and reduces the involvement of plant operators to ensure compliance and flare efficacy. Currently, the EPA RTR rule has been derived to govern flaring applications in the US refining industry. With the compliance deadline approaching in the near future, refineries will be required by law to meet these evaluation parameters regardless of the technology employed. More extensive coverage of operations will be in the line of sight for future regulation, such as chemical plants, midstream operations, and further upstream exploration and production efforts. As these regulations progress, so should the technology behind remaining compliant, such as developments like the VISR-based FlareGuardian system.

Conclusions

Available data supports that the use of VISR technology has been validated and will soon emerge not only in the industry but also with regulatory agencies as the best available technology for flare monitoring. VISR-based products such as FlareGuardian will enable operators to reduce flaring emissions, improve flare performance, and troubleshoot flaring systems, giving them a means to control CE and optimize performance in real time.

Appendix

No.	(A)	(B)	(C)	(D)	(E)	(F)	CE – EX	CE – FS	CE % Diff	SI	(G)
1	AFDS	Propane (100%)	7994	33.29	-	259	99.94	97.40	-2.54	2.85	21.13
2	AFDS	Propane (100%)	7994	33.29	-	259	99.99	98.80	-1.19	2.46	19.45
3	AFDS	Propane (100%)	7994	33.29	-	259	99.98	98.70	-1.28	4.58	19.37
4	AFDS	Propane (100%)	6670	39.89	-	221	99.99	98.80	-1.19	2.87	17.63
5	AFDS	Propane (100%)	6670	39.89	-	221	99.97	98.60	-1.37	2.70	18.84
6	AFDS	Propane (100%)	5278	50.42	-	178	99.97	99.20	-0.77	2.66	19.83
7	AFDS	Propane (100%)	5278	50.42	-	178	99.95	99.20	-0.75	2.50	20.03
8	AFDS	Propane (100%)	3063	86.87	-	107	99.33	99.00	-0.33	0.72	20.53
9	AFDS	Propane (100%)	3063	86.87	-	107	99.77	98.70	-1.07	1.44	18.94
17	QFS	Propylene (100%)	4910	-	0.48	1031	99.86	99.90	-0.86	3.99	19.93
18	QFS	Propylene (100%)	4910	-	0.48	1031	99.90	99.00	-0.80	2.24	19.98
21	MPGF	Propane (100%)	5079	-	-	-	100.00	99.90	-0.10	0.24	18.77
22	MPGF	Propane (100%)	5079	-	-	-	100.00	99.70	-0.30	0.27	18.07
23	MPGF	Propylene (100%)	4952	-	-	-	100.00	99.90	-0.10	1.41	17.92
24	MPGF	Propylene (100%)	4952	-	-	-	100.00	99.90	-0.10	1.36	17.38
25	MPGF	Propane/N_2 (50/50)	2448	-	-	-	99.97	99.30	-0.67	0.23	19.48

26	MPGF	Propane/N_2 (50/50)	2448	-	-	-	99.99	99.80	-0.19	0.35	18.19
27	MPGF	Natural Gas (100%)	3300	-	-	-	100.00	99.80	-0.20	0.26	17.03
28	MPGF	Natural Gas (100%)	3300	-	-	-	100.00	99.90	-0.10	0.32	15.76
29	QFS	Propane (100%)	4640	-	0.52	1035	99.99	98.70	-1.29	0.56	19.91
30	QFS	Propane (100%)	4640	-	0.52	1035	99.97	99.10	-0.87	0.70	17.60
31	QFS	Propane (100%)	1879	-	1.25	571	97.75	97.50	-0.25	0.46	19.90
32	QFS	Propane (100%)	1879	-	1.25	571	67.48	77.20	9.72	0.83	20.24
34	QFS	Propane (100%)	1537	-	1.53	489	59.99	73.60	13.61	0.17	19.94
36	QFS	Propane (100%)	1537	-	1.53	489	70.57	76.60	6.03	0.15	18.75
37	QFS	Propane (100%)	1537	-	1.53	489	83.15	85.10	1.95	0.21	18.38
38	QFS	Propane (100%)	3328	-	0.71	850	99.67	99.01	-0.57	0.40	17.38
39	QFS	Propane (100%)	3328	-	0.71	850	99.82	99.40	-0.42	0.46	18.86

Average CE difference between the two methods – all 28 tests: 0.50%
Number of tests with oxygen <19.5% (indication for good extraction): 18
Average CE difference between the two methods – 18 tests with oxygen <19.5%: -0.10%

Where,

(A) = Flare Tip Type (AIR, MPGF, or STEAM)

(B) = Fuel Type Used and Composition

(C) = Fuel Flow Rate, In LB/HR

(D) = Stoichiometric Air Percentage (SA %)

(E) = Steam-to-HC Ratio (lb_{steam}/lb_{HC})

(F) = Combustion Zone Net Heating Value (CZNHV, BTU/FT^3)

(G) = Average O_2 in extracted sample (%)