New Direct Flame Monitoring Technology to Help Operators Comply with Increasingly Stringent Flaring Regulations

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Future Emissions Regulation

- Ethylene processes new emissions standards for flares expected to be similar to Refinery Sector Rule new emissions standards under NESHAP Subpart CC (40CFR § 63.670)
  - Most significant changes:
    - Continuous monitoring required
    - Change from vent gas NHV to CZNHV
    - Data point required every 15 minutes
  - VISR technology is expected to be written into the rule as an acceptable means of meeting the requirements
Presentation Outline

- Introduction to VISR
- Benefits of FlareGuardian™
- Validation of the VISR method
- Capabilities
Introduction to VISR

- The term “VISR” is used for both:
  - The Method – Video Imaging Spectro-Radiometry
  - The Device – Video Imaging Spectro-Radiometer

- FlareGuardian™ is a VISR based product produced by Zeeco, Inc. for flare monitoring
Introduction to VISR

- VISR is a multi-spectral imager. It directly measures relative concentrations of combustion product, carbon dioxide (CO2), and unburned hydrocarbon (HC) in the flame, and calculates flare combustion efficiency (CE) in real time.

- Directly measuring CE eliminates the uncertainty of using surrogate parameters such as Combustion Zone Net Heating Value (NHVCZ) and tip velocity.
Introduction to VISR

VISR is different from other direct flare measurement methods

- Extractive
- PFTIR
- VISR

**Extractive Sampling**
- Point measurement
- Not suitable for routine monitoring

**VISR**
- 3-D measurement (3-D flame is reduced to a 2-D image)
- Suitable for autonomous monitoring or short-term study

**PFTIR**
- Path measurement (the path is reduced to a point)
- Not suitable for routine monitoring
FlareGuardian™
Monitoring Flare Performance with Video Imaging Spectro-Radiometer (VISR)
Benefits of VISR Technology

- Provides real-time combustion efficiency, smoke index, flame stability, flame footprint, heat release, and pilot status.
- Autonomous data collection (DCS or PLC) for optimized flare performance.
- Simplify monitoring, reporting, and compliance activities.
- Remote mounted, non-contact monitoring. Don’t have to shut down to install.
- More accurate results versus indirect monitoring.
Benefits of VISR Technology

▪ Eliminates need for monitoring surrogate parameters. If any of the 12-15 devices for monitoring goes down the plant is in non-compliance.

▪ Short measurement cycle enables quick response and minimizes cost for supplemental fuel, steam, or air.

▪ Industrial closed loop interface allows for flare operation and control based on direct combustion efficiency and smoke index values in real-time.

▪ Easy installation and maintenance and no calibrations.

▪ Eliminates need for visual verification of smokeless performance.
Validation of the VISR Method

- Validated using extractive method
  - 28 test runs were compared
  - Average difference was 0.50% in CE
  - The difference was smaller (-0.30% in CE) when CE was > 80%
Extractive Sampling vs. FlareGuardian™

- CE - Extractive
- CE - FlareGuardian
- EPA CE REQUIRED (96.5%)
For More Details

- U.S. patent No. 9,258,495 issued on Feb. 9, 2016.

- Validation test results can be found in *Journal of Air and Waste Management Association*, January issue of 2016, pp. 76-86.

- The development of VISR was partially funded by U.S. EPA thru its SBIR Phase I and Phase II awards.
VISR Capabilities

- Remotely, continuously, and autonomously monitor the following flare performance metrics:
  - **Combustion Efficiency (CE):** 0 - 100%
  - **Smoke Index (SI):** 0 - 10 for the level of smoke
  - **Flame Stability (FS):** 0 - 100% (0=extremely unstable flame; 100=extremely stable flame)
  - **Flame Footprint (FF):** flame cross section area perpendicular to VISR line of sight; expressed as sq. ft.
  - **Heat Release (HR):** Amount of heat released by flare in the mid-wave infrared (MWIR) region, expressed as Btu/min

- Default time resolution: 1-sec, 1-min, and 15-min average

- The data can be sent to DCS or PLC for display or closed-loop control of flare.
What Can You See Through the Lens of VISR?

- **Case 1: Good Combustion Condition**
- **Case 2: Smoke Condition**
- **Case 3: Over Steaming**
Setup

Visible Image

VISR Image

Color in image:
Green: Hydrocarbon
Red: CO2
Bluish/white: Carbon particles or hot solid objects
Case 1: Good Combustion

CE measured by VISR: 99.8%

Ground truth: CE measured by extractive sampling: 99.9% w/ SD of 0.4%
Case 1: See Progression of Combustion

A parcel of fuel gas is combusted in about 0.47 sec. (14 frames)

Color in images:
Green: Hydrocarbon
Red: CO2

Frame 166
Frame 167...
Frame 170...
Frame 173...
Frame 176...
Frame 179
Frame 180
Case 2: Smoke Condition

SI = 3.15, indicating smoke
Case 3: Over Steaming

CE measured by VISR: 56.6%

Ground truth: CE measured by extractive sampling: 62.0% w/ SD of 19.2%
Study of Case 3 (Over Steaming) Frame-By-Frame

- What is happening when flare is pulsing…

Another puff gets ignited and burns. The cycle repeats.

Color in the images
Green: Hydrocarbon
Red: CO2
Bluish/white: Carbon particles or hot solid object

One puff burns and fades away before combustion is completed

0.033 sec.
Study of Case 3 (Over Steaming) Frame-By-Frame

- Poor combustion

Color in the images
Green: Hydrocarbon
Red: CO2
Bluish/white: Carbon particles or hot solid object

Significant amount of unburned hydrocarbon (green color). Too cold to continue combustion.
Detecting Pilot Flame

- Pilot flames are readily identifiable

Color in the images
- Green: Hydrocarbon
- Red: CO2
- Bluish/white: Carbon particles or hot solid object

- Blue portion: metal pilot hood
- Red portion: pilot flame

- Monitor presence of pilot flame - EPA rule 40 CFR §63.670 (b)
- It’s based on pilot flame, not temp.
- Remote monitoring – easy to maintain
Summary of VISR Capabilities

- For flare monitoring (dashboard)
  - CE (Combustion Efficiency)
  - SI (Smoke Index)
  - FS (Flame Stability)
  - FF (Flare Footprint)
    - can provide flame length
  - HR (Heat Release)
    - Potentially estimate mass rate
  - Monitor pilot flame

- For flare studies, same dashboard as above, plus:
  - Ability to look into flare with unprecedented spatial and temporal resolution
  - Tool for design/research (validating CFD modeling)
  - Troubleshooting of existing flare

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<tr>
<th>Expected Flaring Rule</th>
<th>Can VISR Cover It?</th>
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<tr>
<td>Presence of pilot flame</td>
<td>Yes</td>
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<tr>
<td>No visible emission</td>
<td>Yes</td>
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<tr>
<td>Requirements designed to ensure sufficient CE through surrogate parameters</td>
<td>Yes</td>
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Questions?