



The VISR Method for Flare Monitoring

October 2023

Introduction to Providence Photonics

- Established in 2012
- Headquartered in Baton Rouge, Louisiana
- Developing and manufacturing products in the field of optical gas imaging for industrial applications
 - Six patents issued, 4 pending
- Industries served
 - Oil and gas sector
 - Chemical and petrochemical sector
- Partnered with Teledyne/FLIR through Minority Share Investment in 2019



Providence Photonics Product Portfolio

Leak Detection & Quantification



- FLIR QL320
 - For use with FLIR OGI camera
 - Quantifies fugitive emissions



- FLIR ADGiLE Leak Detection
 - Fixed mount OGI based leak detection
 - Emerging product/Q3 2023



- FLIR In-camera quantification
 - Latest generation of FLIR cooled handheld cameras

Flare Measurement or Monitoring



- Mantis
 - Remote measurement of flaring efficiency
 - Utilizes VISR method
 - Continuous or short term
 - Mature product



- Mantis Lite
 - Remote measurement of flaring efficiency
 - Utilizes VISR method
 - Continuous or short term
 - Emerging product/Q4 2023

Providence Field Work



- Flare performance measurement and surveys
 - OGMP 2.0
 - OGCI
 - Methane emissions inventory
 - Regulatory compliance inspections
 - EPA Regions 4, 5 and 6
 - Permitting issues (99 program, Title V)
 - Research/validation of other methods
- Rentals/leases
 - Installations for continuous monitoring

Mantis Field Work by the Numbers

- 🔥 900+ Flare (~85% onshore/15% offshore)
- 🔥 1200+ individual flare measurements
- 🔥 18 Countries in 5 continents
- 🔥 The numbers keep growing



Shell

bp



TOTAL



equinor



Woodside Energy



BAZAN GROUP
OIL REFINERIES LTD



American Petroleum Institute



شركة تنمية نفط عمان
Petroleum Development Oman



Ministry of Environment



WHITING



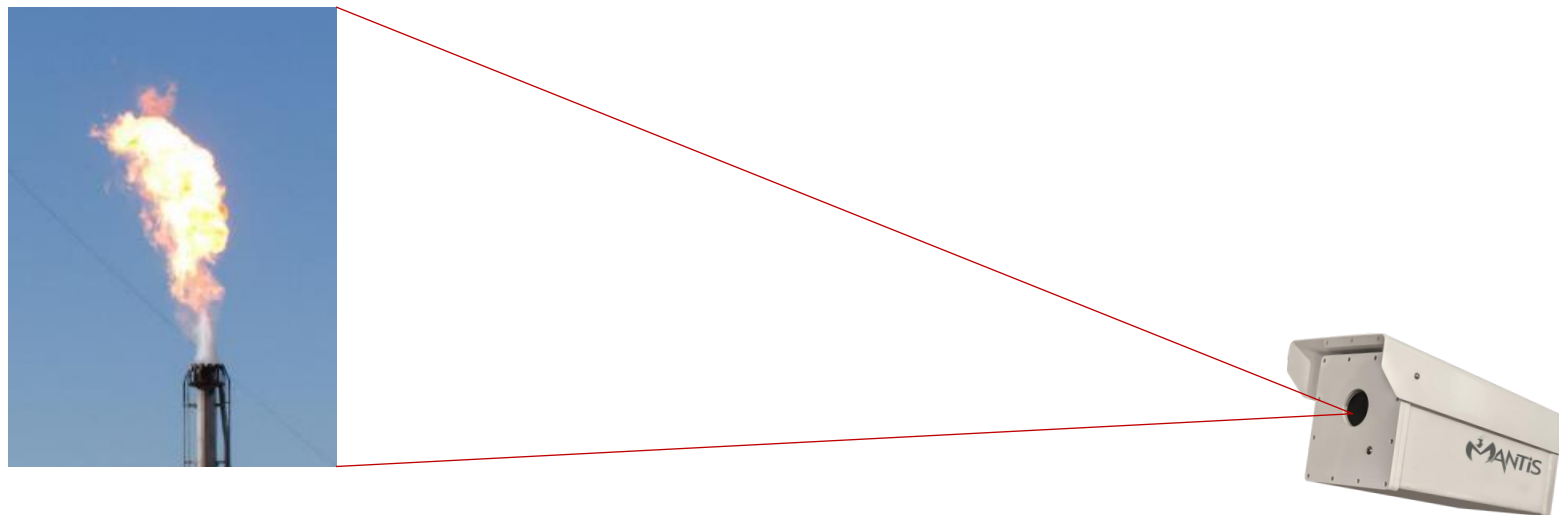
BDI



CREATING A CLEANER ENVIRONMENT™

Introduction to VISR

- 🔥 Video Imaging Spectral Radiometer (VISR) is a multi-spectral IR 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), flare tip velocity, and impact of wind.
- 🔥 VISR was developed with seed funding from U.S. EPA through its SBIR grant.



Mantis Capabilities

- 🔥 ***Directly, remotely, autonomously, and continuously*** 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 to 100% (measure of change in radiance)
 - **Flame Footprint (FF):** flame cross section area perpendicular to VISR line of sight; expressed as sq. ft. or m²
 - **Fractional Heat Release (HR):** Amount of heat released by flare in the mid-wave infrared (MWIR) region, expressed as Btu/min or MMBtu/hr
 - Presence of pilot flame
- 🔥 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
 - Set CE and SI limits to keep flare always in optimal condition, lowering emissions

Mantis Combustion Efficiency Method

- 🔥 **Flare CE** is determined by measuring relative concentrations of CO₂ and HC on the combustion envelope where combustion has ceased
 - Spatially averaged across pixels on the combustion envelope
 - Temporally averaged across all frames captured in 1 second (typically about 30)
 - Data reduction is automatic with no latency



Validation of the VISR Method

- 🔥 Multiple validation tests at Zeeco test facility. Peer reviewed paper published in 2016
- 🔥 Blind test organized by Petroleum Environmental Research Forum (PERF), including ExxonMobil, BP, Chevron, CP Chem, Eastman, Phillips 66, Saudi Aramco, Shell, and administered by John Zink Hamworthy Co.
 - Extractive sampling method was used as the Reference Method
 - 45 test conditions, 70 min each, 2 weeks of testing
 - The VISR method was challenged by varying:
 - Flare operating conditions (different fuel compositions, different flaring rate, optimal, over-assist, under-assist, etc.)
 - Environmental conditions (wind, cloud, sun, rain, fog, day vs. night, etc.)
 - Different distances and orientations relative to flare and wind direction



Results of Validation Tests

- 🔥 **Precision:** Relative Standard Deviation (RSD) from PERF tests range from 0.07% to 2.84% with an average of 0.80%, comparable to the Reference Method (average RSD = 0.88%), and well below the 20% threshold as specified in the EPA Method 301 validation method
- 🔥 **Accuracy:** The mean difference from the Reference Method is only 0.07 expressed as % CE and statistically same as the Reference Method.
- 🔥 **Note:** the Reference Method (i.e., the extractive sampling method) can be used at a R&D testing facility and is not practical for real-world flares. The VISR method is.

How well is your air assisted flare burning?



CE = 98%



CE = 100%

Optimizing your combustion with VISR



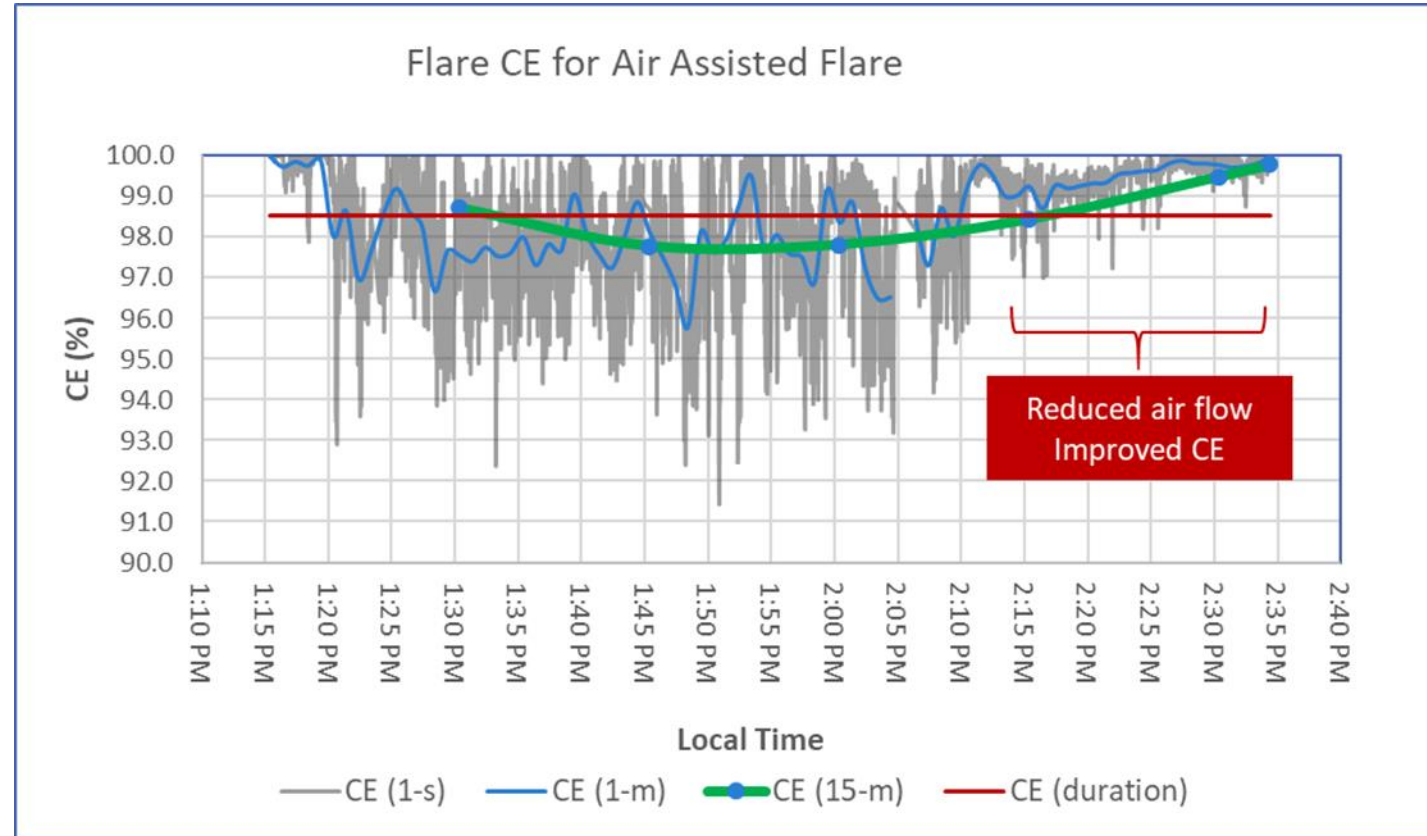
Closed loop control

- VISR data has 1-second resolution and no latency
- Well suited for control



Example using air assisted flare

- Note CE improvement when air flow reduced
- CE improved from 98% to near 100%
- Potential to significantly reduce methane and VOC emissions
- Implications for GHG emissions
- Installed VISR has dual functions:
 - Control/optimize the flare
 - document and quantify emissions reductions



Interesting Findings – Flares ID 6-1 and ID 6-2

Both flares are steam assisted. What about their performance?

Flare ID 6-1



CE = 95%



Flare ID 6-2

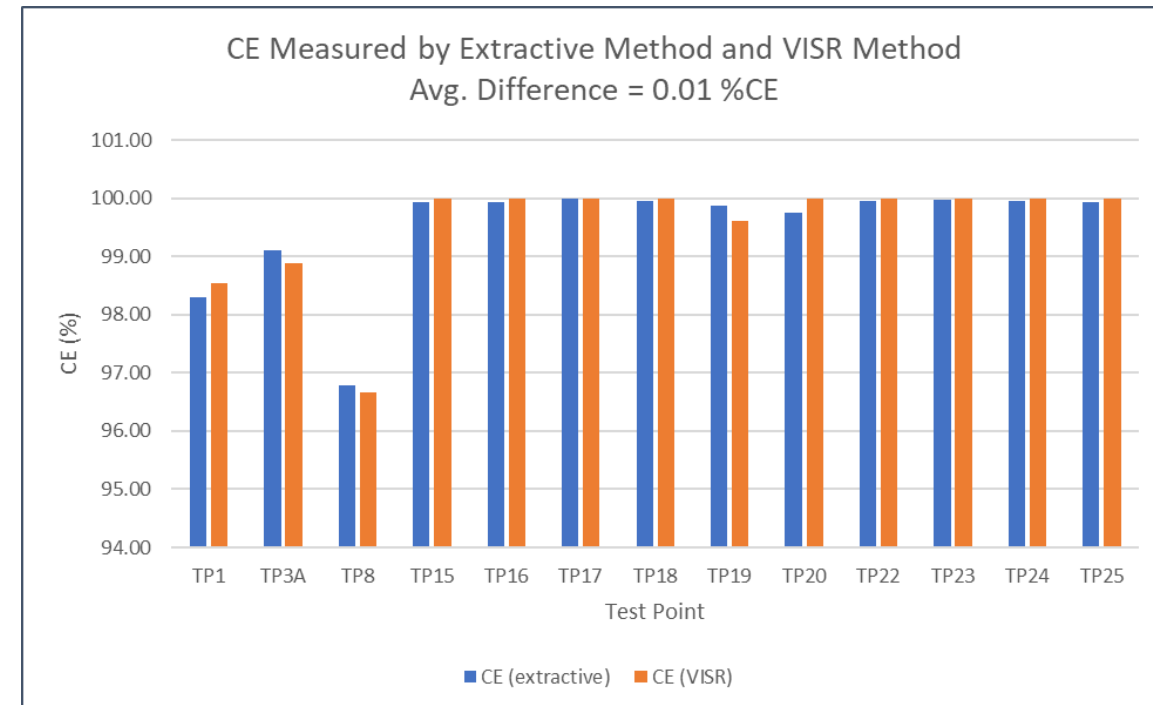


CE = 75%



Using VISR method on enclosed combustion

- 🔥 Mantis was designed to measure efficiency of elevated flares
- 🔥 New capability developed to measure enclosed combustion sources
 - Enclosed ground flares
 - Enclosed Combustion Devices (ECD)
 - Incinerators
 - Compressors
 - Heaters/boilers
 - Engines or any internal combustion with a stack
- 🔥 Validation testing completed
 - Excellent agreement with extractive methods
 - VISR Method limits apply
 - Minimum temperature between 400-500°C



Mantis vs Mantis Lite



Mantis

- Directly measures flare CE - Validated thru comprehensive blind tests organized by industry consortium
- Has been deployed to hundreds of flares (mostly in oil and gas fields) to quantify methane emissions by measuring flare CE and DE
- Highly sophisticated sensor; high cost
- Suitable for closed loop control
- Well-established method
- High accuracy and high precision



Mantis Lite

- Measures NHVcz, a surrogate used by EPA for flare CE
- Validated through EPA sponsored testing
- Provides bracketed DE measurement
 - < 90%, 90-98%, 98-99%, 99-99.5%, > 99.5%
- Lower-cost solution
- Suitable for closed loop control
- New method
- Lower accuracy and precision in CE measurement compared to Mantis

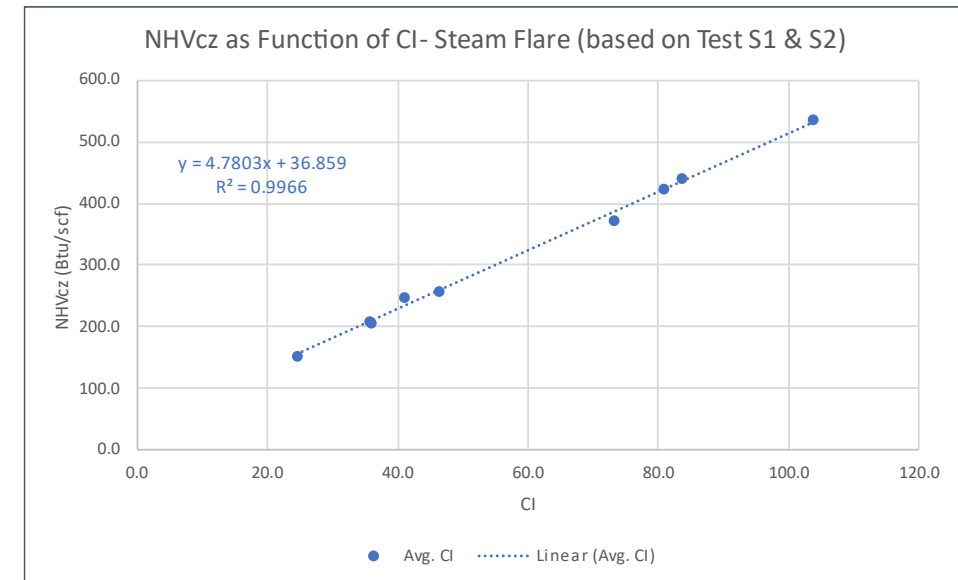
Validation of NHVcz Measurement by Mantis Lite

- Validation test funded by EPA, conducted at the John Zink R&D test facility in Tulsa, OK. Four Mantis Lite units were tested.
- Reference Method used for validation: the method as specified in the Refinery MACT and EMACT rule (i.e., 40 CFR 63.670 & 671)
- Calibration – see calibration curve on the right
- Precision: well below the 20% RSD threshold

	ML06	ML07	ML08	ML09
Avg RSD	5.7%	6.1%	7.3%	6.4%

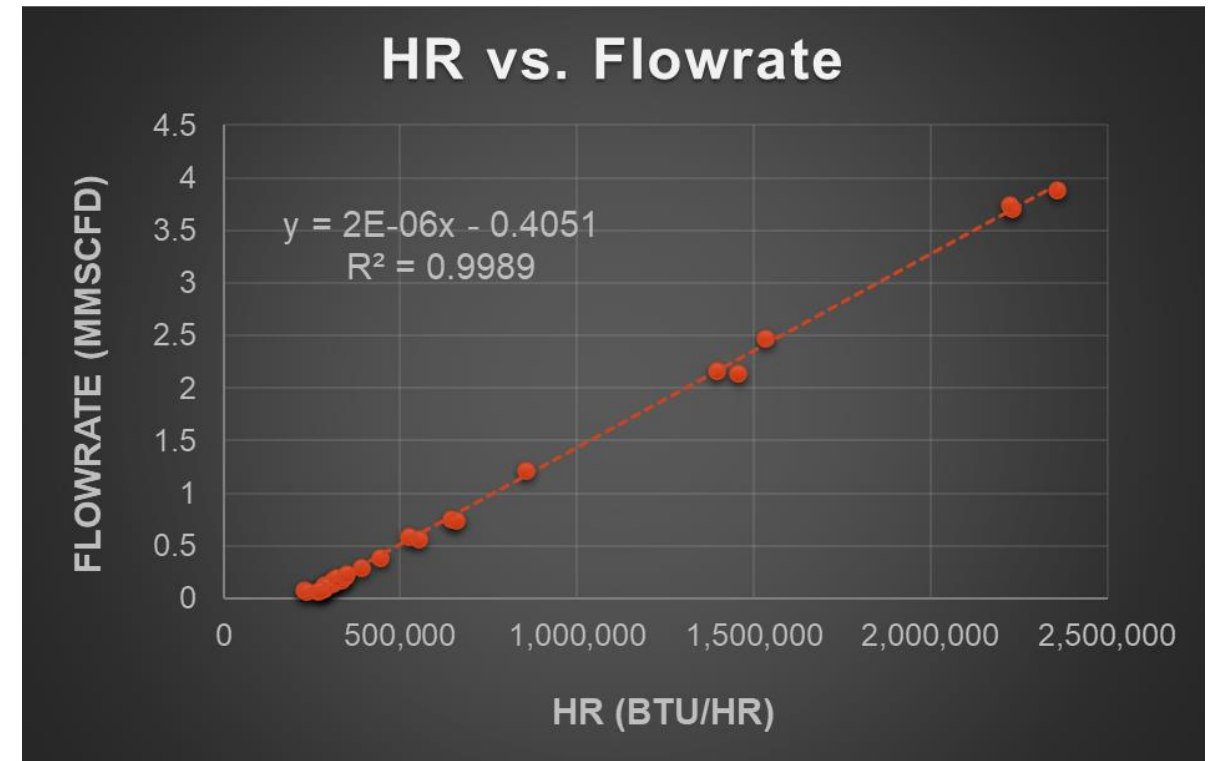
- Accuracy:

	ML06	ML07	ML08	ML09
Avg Diff. from Ref. Method	1.5%	-0.7%	-4.4%	-0.3%



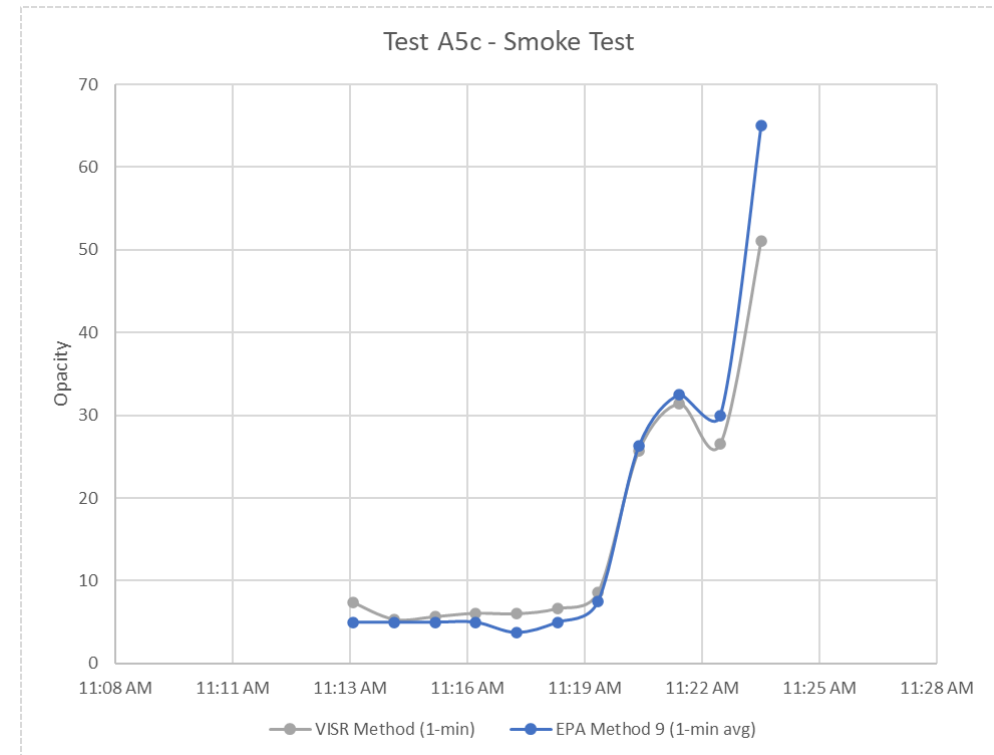
Measuring Flowrate with VISR

- Fractional Heat Release (HR) measured by Mantis can be calibrated for remote flowrate measurement.
- Mantis Lite is designed to directly measure flare gas flowrate.
- Flowrate measured by the VISR method excludes non-hydrocarbon components in the gas stream (e.g., nitrogen, water vapor, etc.), i.e., it is equivalent to (FR x C).
- VISR can be used for regulatory demarcation of “flaring events”.



Monitoring Smoke/Visible Emissions

- VISR can distinguish aerosol/soot from combustion gases and derive Smoke Index (SI).
- SI can be used as an alternative to EPA Method 22 or Method 9.
- Flare VE regulation: <5 min VE during any 2 consecutive hours.
 - VISR monitors VE continuously by numeric values (not images as a visible camera does)
 - No image recordkeeping and retrieving issues
 - Easy trending
 - Compliance with the “< 5 min VE in 2 hours” regulation can be automated
 - If VISR is used in a closed-loop control, non-compliance could be avoided.



All-in-One Flare Monitoring Devices

- Mantis and Mantis Lite are All-in-One flare monitoring devices
 - Flare efficiency
 - Flaring rate
 - Smoke Index/visible emissions
 - Flare footprint
 - Flame stability
 - Presence of pilot flame
- Remote sensing devices (distance ~100 to 1500 ft)
 - No process shutdown needed for installation
 - Extremely low maintenance
- Real-time monitoring (1-sec data cycle), and no latency
- Ready for integration with PLC, DCS, and other common industrial data systems; ready for closed loop control for optimum flare operations
- Both provide scientifically sound and defensible data





Thank You!

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