TCEQ

# Texas Commission on Environmental Quality 2010 Flare Study Draft Report

Flare Task Force
Presented by Air Quality Division (AQD)

May 18-19, 2011

# Overview

- Objectives and Limitations
- Study Design
- Preliminary Results
- Next Steps
- Additional Flare Research
- Preliminary Results Summary

# Objectives

Assess the impact of high turndown (low flow) rate of vent gas on flare destruction and removal efficiency (DRE) and combustion efficiency (CE)

- DRE is the percent removal of hydrocarbon from flare vent gas.
- CE is the percent of hydrocarbon in vent gas converted to carbon dioxide.

# Objectives

- Assess if flares operating within 40 Code of Federal Regulations (CFR) §60.18 achieve the assumed hydrocarbon DRE of at least 98% at high turndown, varying assist ratios, and vent gas heat content
- Identify and quantify the hydrocarbon species in flare plumes

# Limitations

- Limited vent gas composition: Tulsa natural gas, propylene, and nitrogen
  - Propane was used for limited test runs.
  - Hydrogen was not included in any test run.
- Two flare tip sizes and assist configurations were tested.
- High turndown (low flow) operating conditions were focus of study.
- Study was not designed to evaluate:
  - Flare operations under upset or emergency conditions
  - Hydrogen flares
  - Flares specifically designed for routine, low flow applications

# Study Design: Flare Tips

- 36-inch steam-assisted flare with upper and center steam assist
  - Upper steam carries ambient oxygen into the combustion zone to prevent smoke.
  - Center steam helps push the combustion outside of the tip.
- 24-inch air-assisted flare

  The fan motor had a variable frequency drive capable of small air flow adjustments by the control room.
- Both flare tip designs are commonly used for routine low-flow vent gas streams

# Representativeness

- Flare configurations tested represent flares commonly used in both routine process and emergency service (dual service).
- For these dual-service flares, 2009 TCEQ emissions inventory data indicates:
  - 21% of dual-service flares are air-assisted. Of these air-assisted, dual-service flares:

    77% are 12 to 36 inches in diameter and represent 95% of total 2009 emissions for dual-service, air-assisted flares.
  - 45% of dual-service flares are steam-assisted. Of these steam-assisted, dual-service flares:

    41% are 24 to 48 inches in diameter and represent 57% of total 2009 emissions for dual-service, steam-assisted flares.

# Representativeness

- All test points are within 40 CFR §60.18 criteria.
- Tip velocities are similar to those observed during field testing at Marathon facilities.
- Steam-assist rates are representative of manufacturer recommendations for this size flare tip configuration.
- Testing performed on stable flames, per John Zink staff.

# Operating Conditions

- Vent gas streams with heat content of 350, 600, and 2,149 British thermal units per standard cubic foot (Btu/scf)

  40 CFR §60.18 minimum heating value for an assisted flare is 300 Btu/scf.

- Vent gas streams with low flow rate
  - 0.1% and 0.25% of rated design capacity
  - Steam-assisted flare = 937 lb/hr and 2,342 lb/hr
  - Air-assisted flare = 359 lb/hr and 937 lb/hr

# Operating Conditions

- Assist rates varied between zero assist to over assist near flameout (snuff point).
- Measurements were taken at points between the incipient smoke point and near snuff point.
  - Four to six points per test series with up to three repetitions per point
- Tip velocity of vent gas, including center steam, was between 0.6 and 2.0 feet per second (fps).

# Data Collection

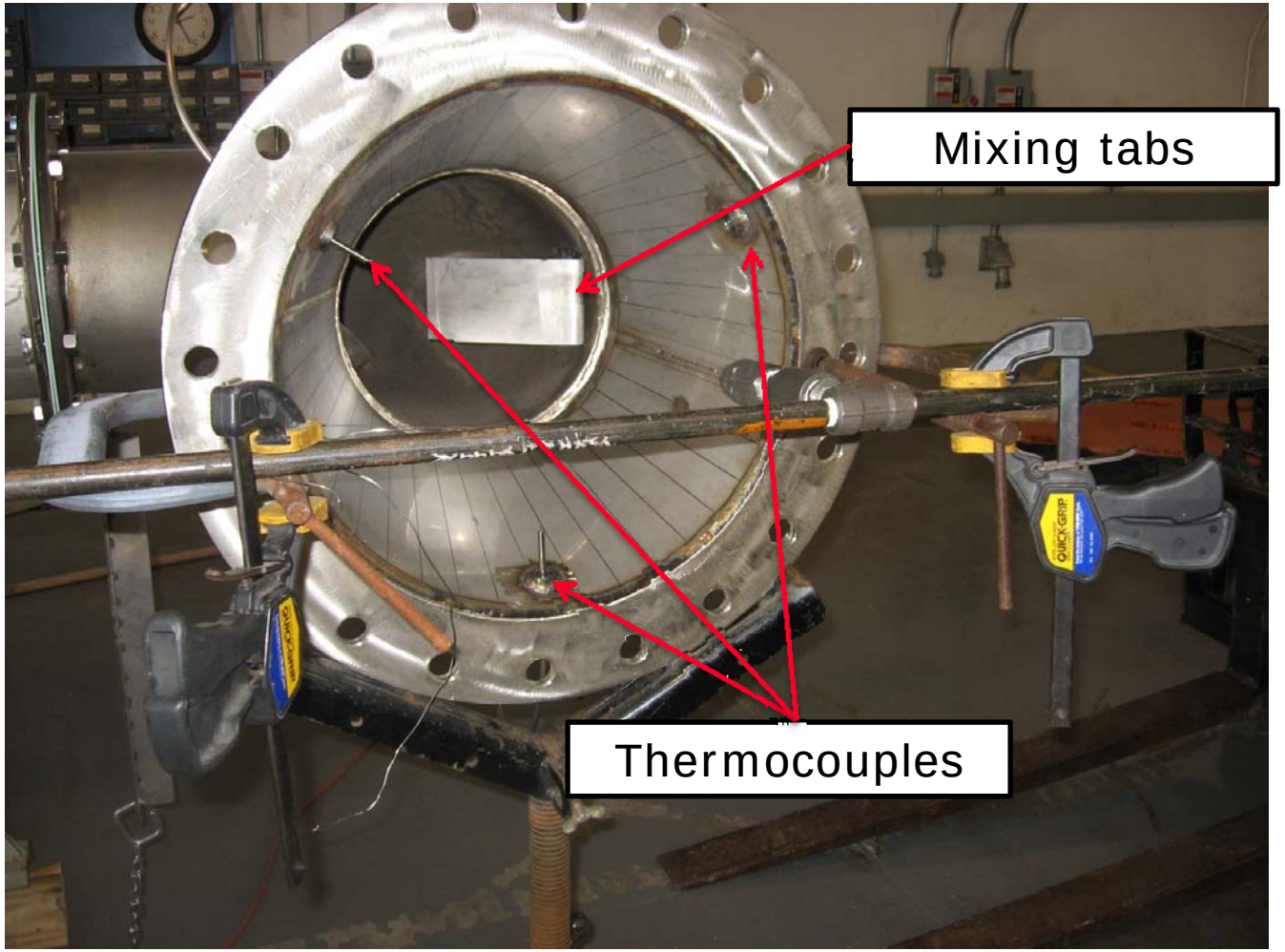
- Extractive measurements
  - Aerodyne Research: quantum cascade laser, proton transfer reaction mass spectrometer, gas chromatograph (GC), aerosol mass spectrometer, particle analyzers
  - TRC: GC
- Remote sensing measurements
  - Telops: Field portable radiometric spectrometer
  - Industrial Monitor and Control Corporation: passive and active Fourier transform infrared (PFTIR and AFTIR) detectors
  - **All remote sensing companies performed single-blind measurements**.
- Leak Surveys, Inc: FLIR GasFindIR infrared cameras

# Extractive Sampler

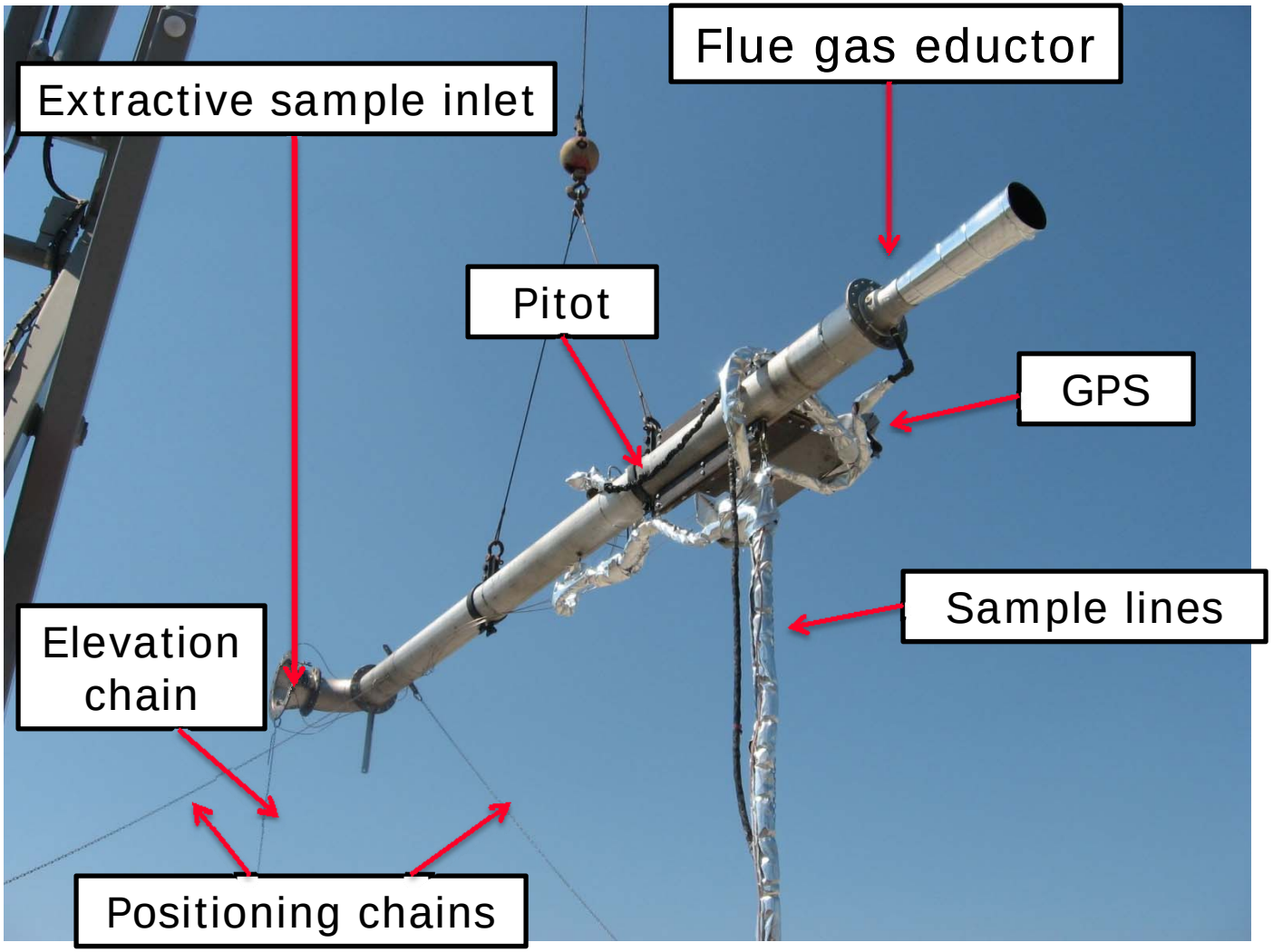
- Forced air device designed by Aerodyne, the University of Texas at Austin Center for Environmental and Energy Resources (UTCEER), and John Zink
- Extensive calibration procedures
- Positioning of the sampler during measurements
  - Two FLIR GasFindIR infrared cameras
  - Temperature of three thermocouples
  - Visual line of sight by crew holding the position chains and project personnel in the control room
  - Oxygen and carbon dioxide measurements
  - Global positioning system coordinates

# Extractive Sampler

# Extractive Sampler Inlet



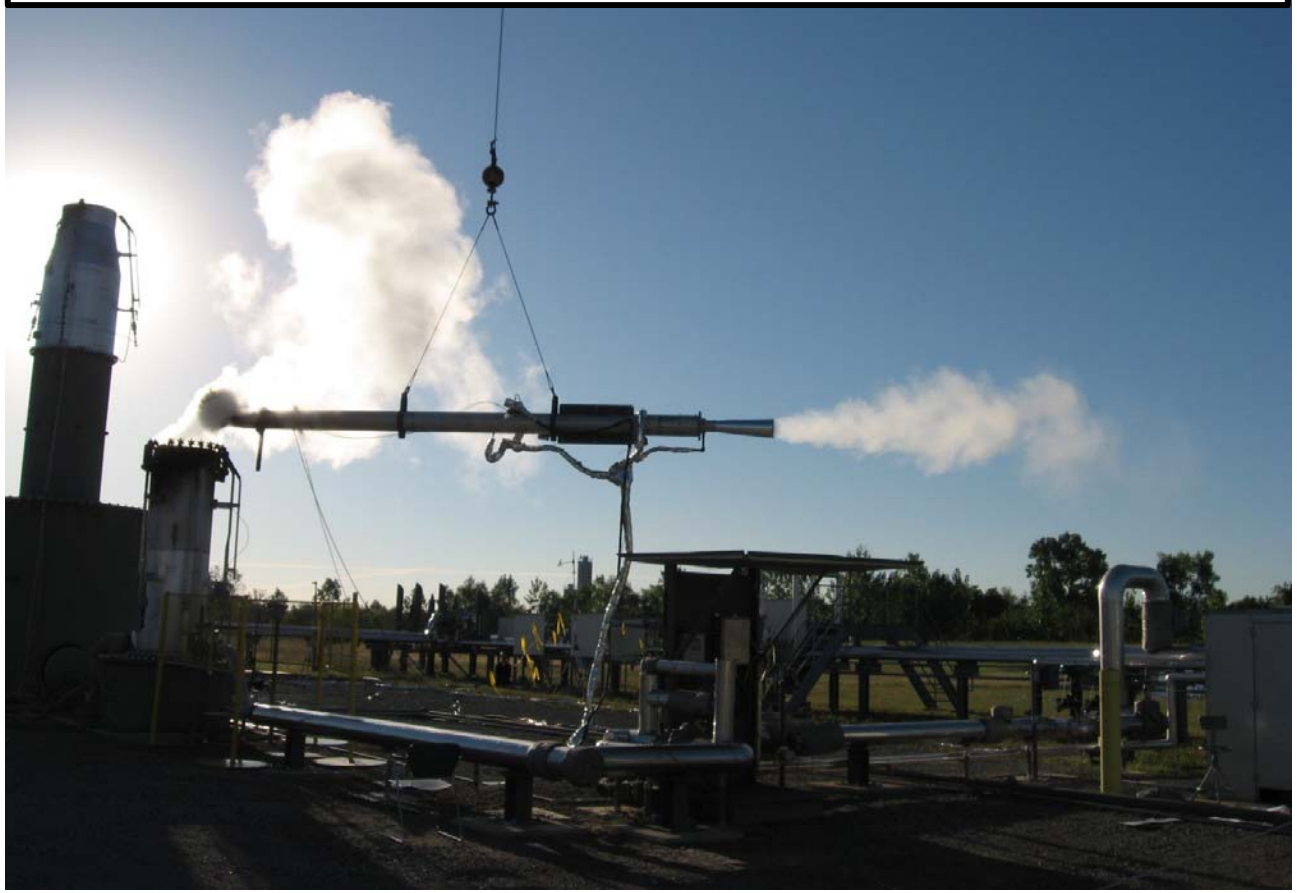
# Extractive Sampler



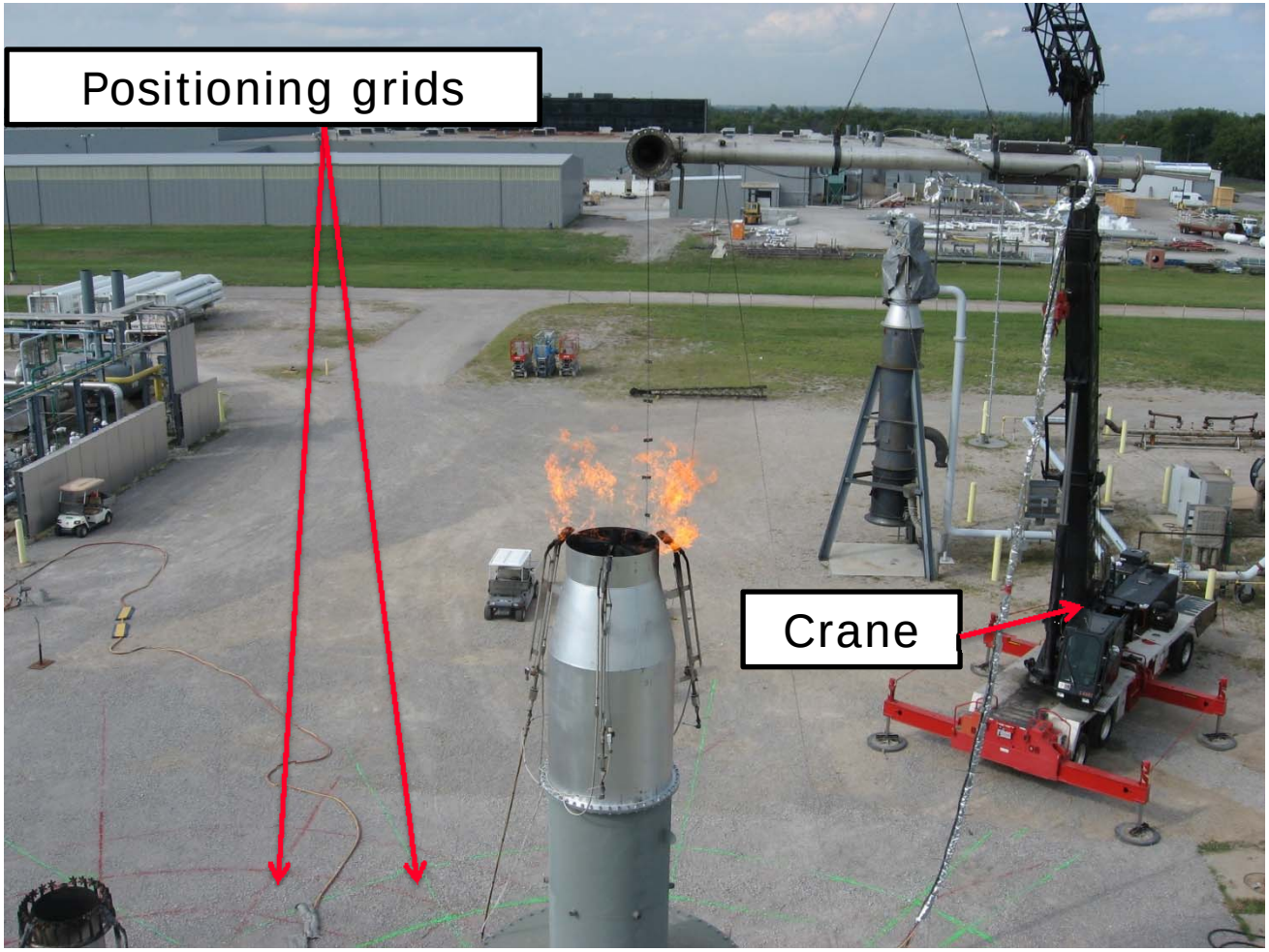
# Extractive Sampler Positioning

# Extractive Sampler

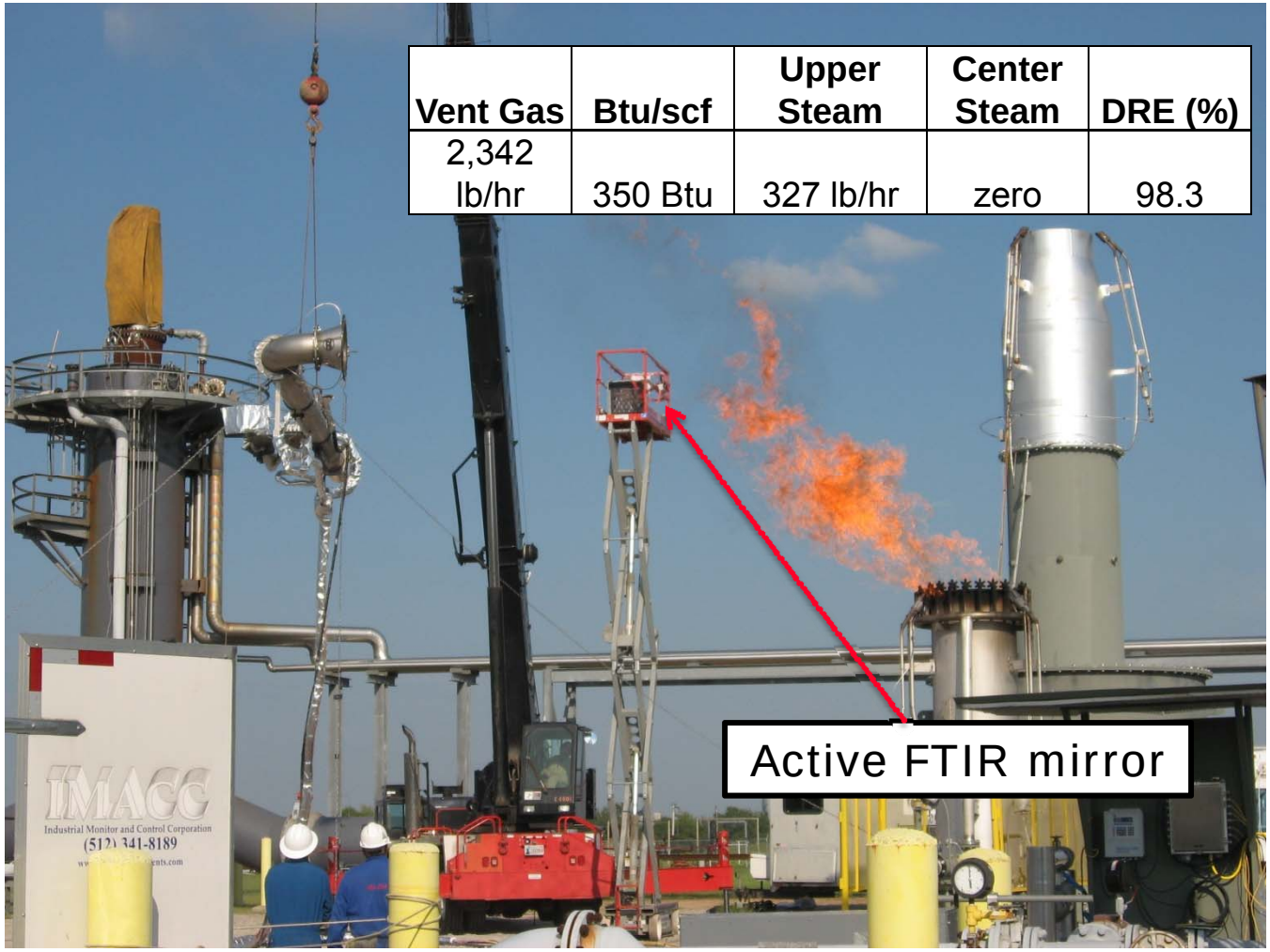
During morning start-up procedures



# Elevated Position

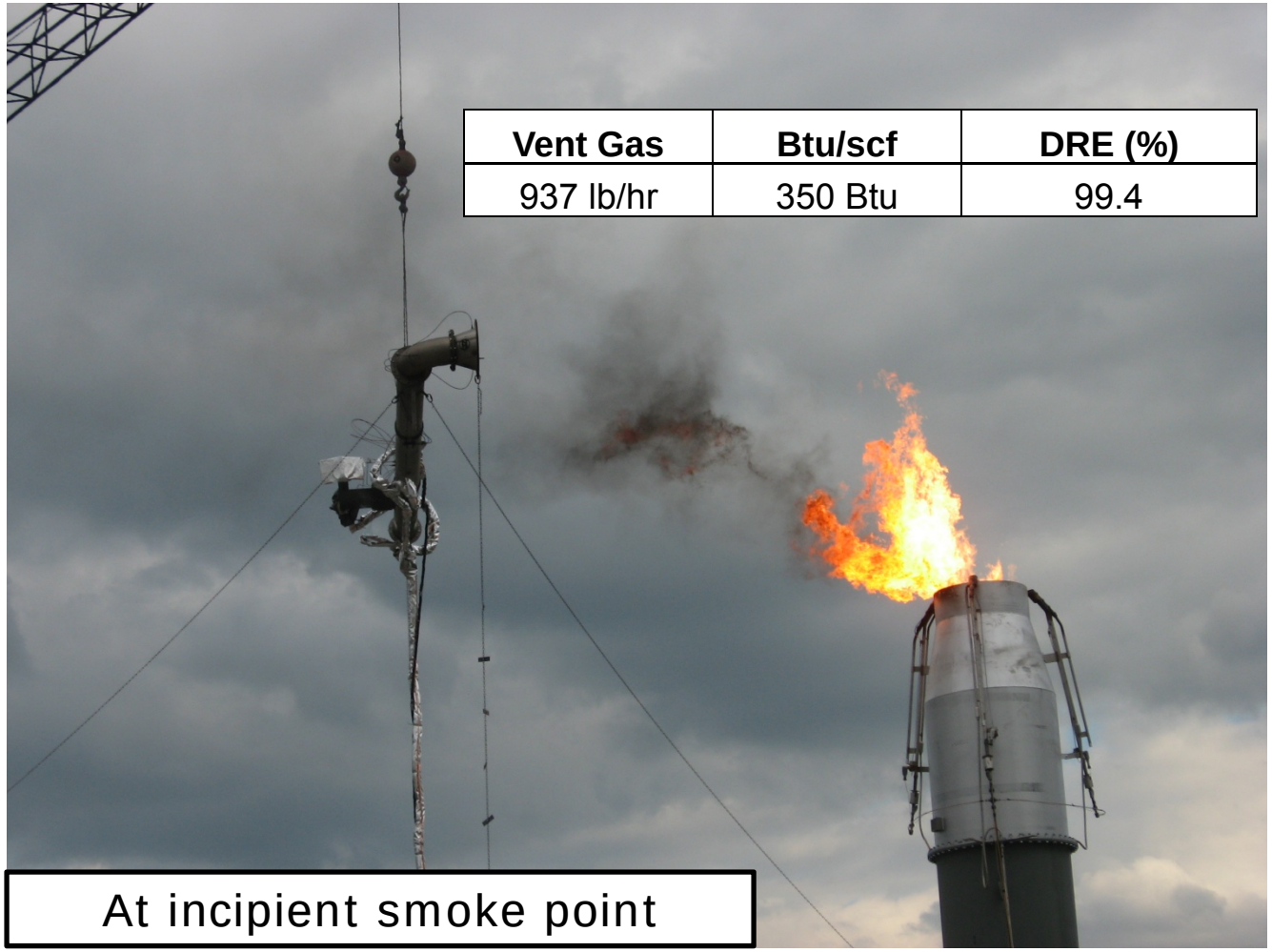


# Test Point S4.4




| Vent Gas | Btu/scf | Upper Steam | Center Steam | DRE (%) |
|---|---|---|---|---|
| 2,342 lb/hr | 350 Btu | 327 lb/hr | zero | 98.3 |

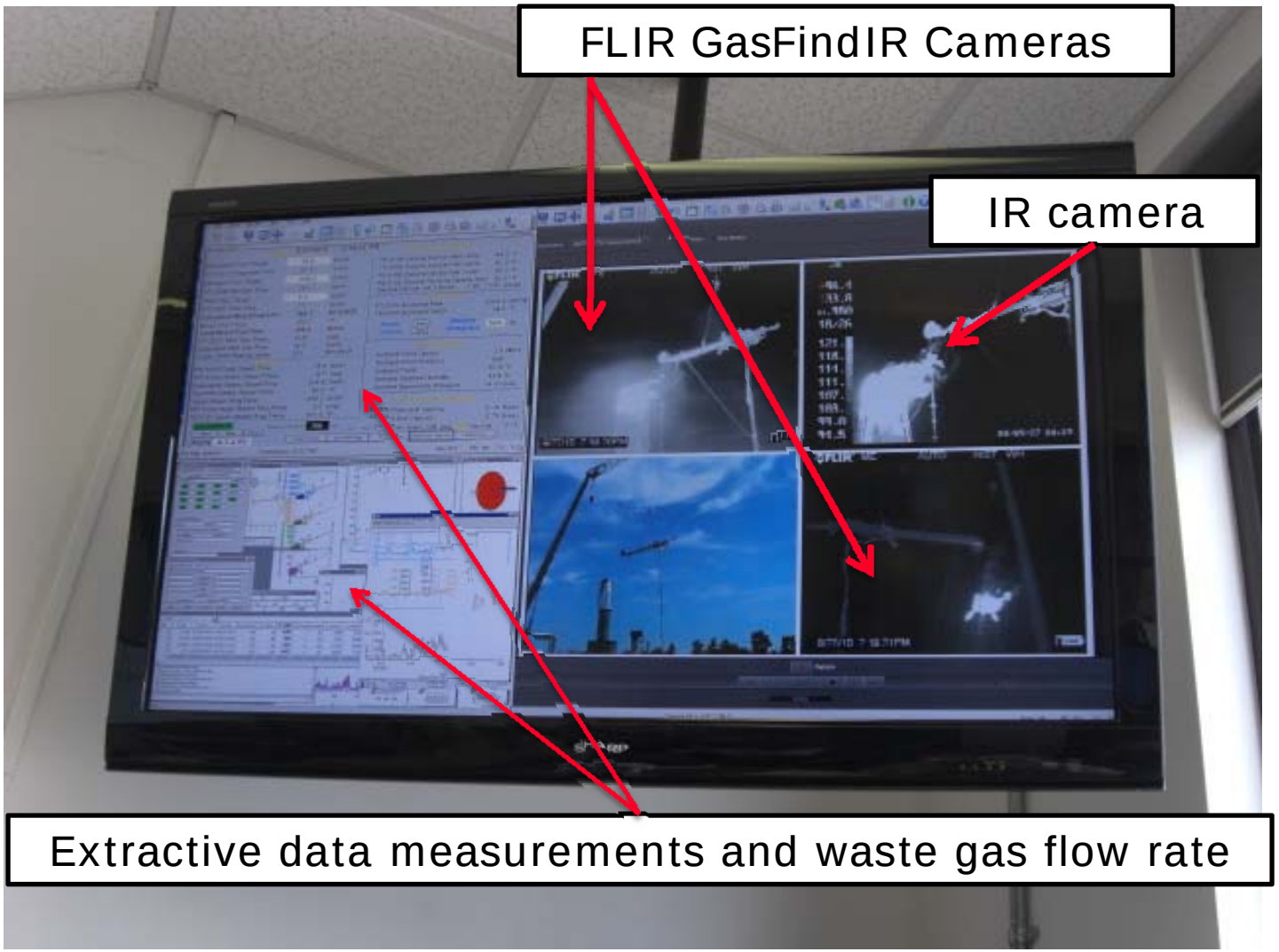
# Test Point A4.6



| Vent Gas | Btu/scf | DRE (%) |
|---|---|---|
| 937 lb/hr | 350 Btu | 99.4 |

At incipient smoke point

# Control Room Real-Time Observations and Measurements

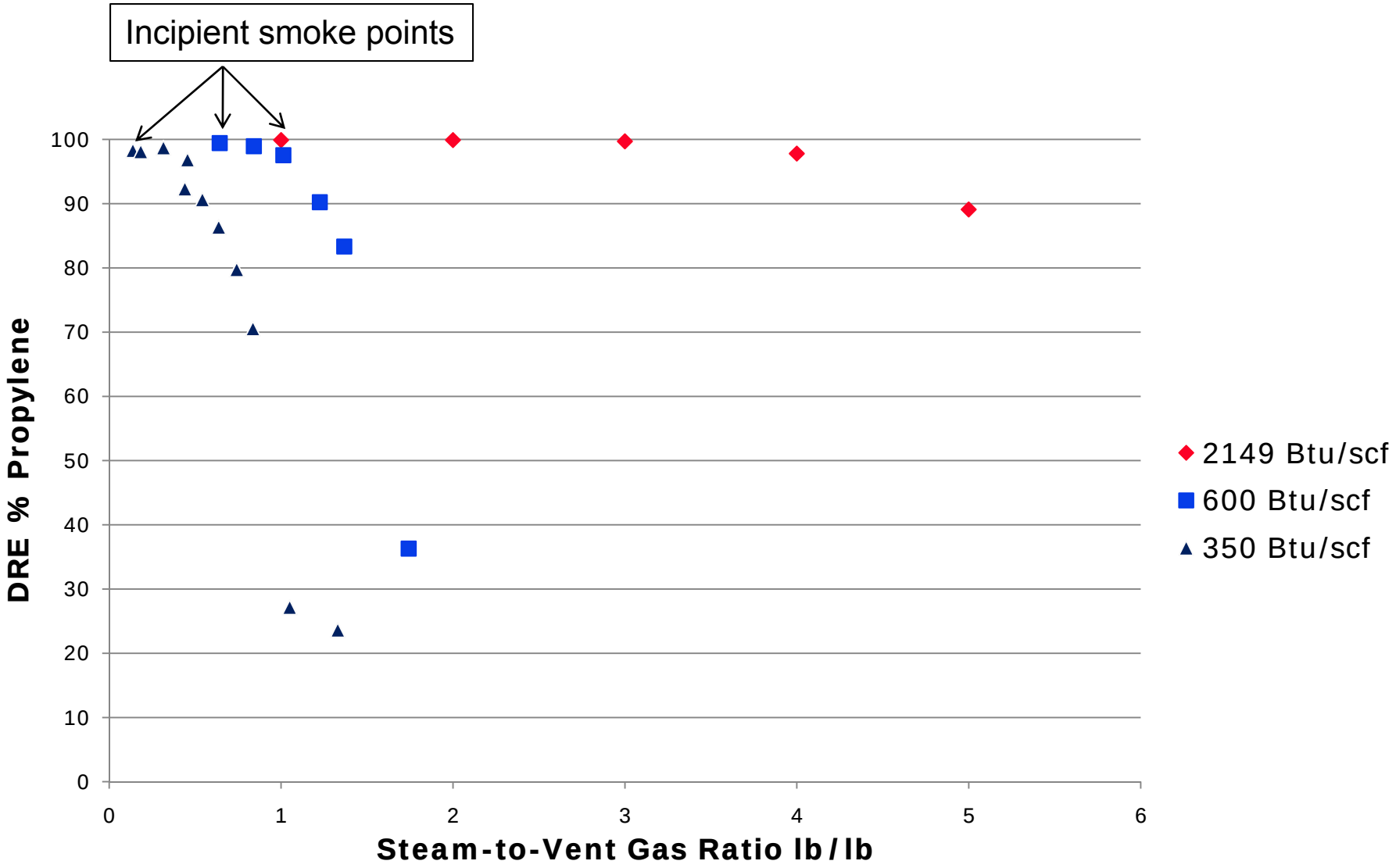


# Results: High DRE Measured

- The flares tested were able to achieve greater than 99% DRE and CE for vent gas streams with low heating value at low flow rate conditions.
- For the conditions tested, the highest DRE and CE was achieved at or near the incipient smoke point.

# Steam-Assisted Flare DRE

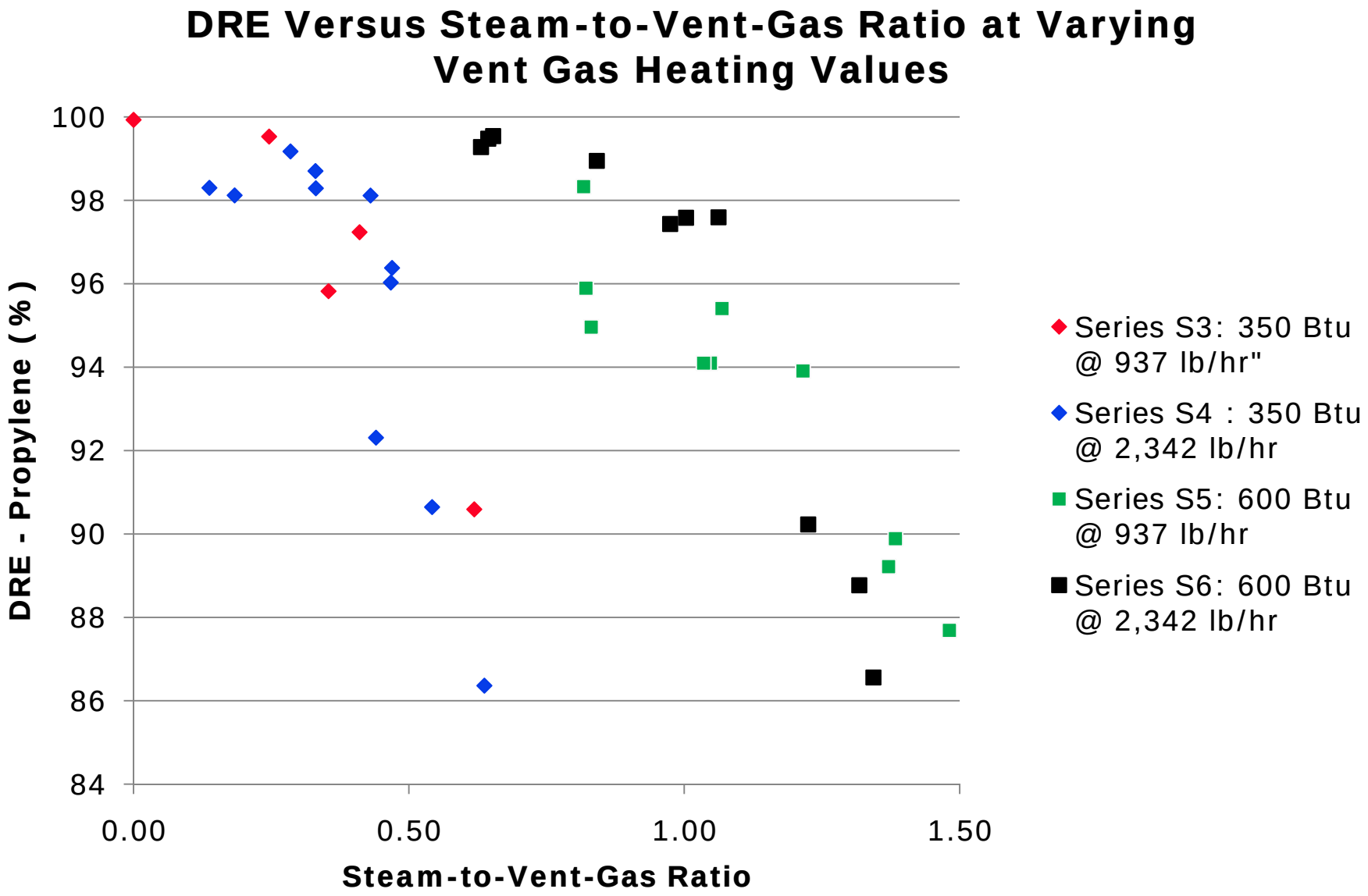
## Constant Vent Gas Flow Rate of 2,342 lb/hr



# Results: Heating Value Critical

- Vent gas with high heating value (2,149 Btu/scf) has a wider operating range for steam to vent gas ratios, regardless of tested flow rate.
- Vent gas with lower heating values (350 and 600 Btu/scf) has a narrower operating range for steam to vent gas ratios, regardless of tested flow rate.

# Results: Heating Value Critical

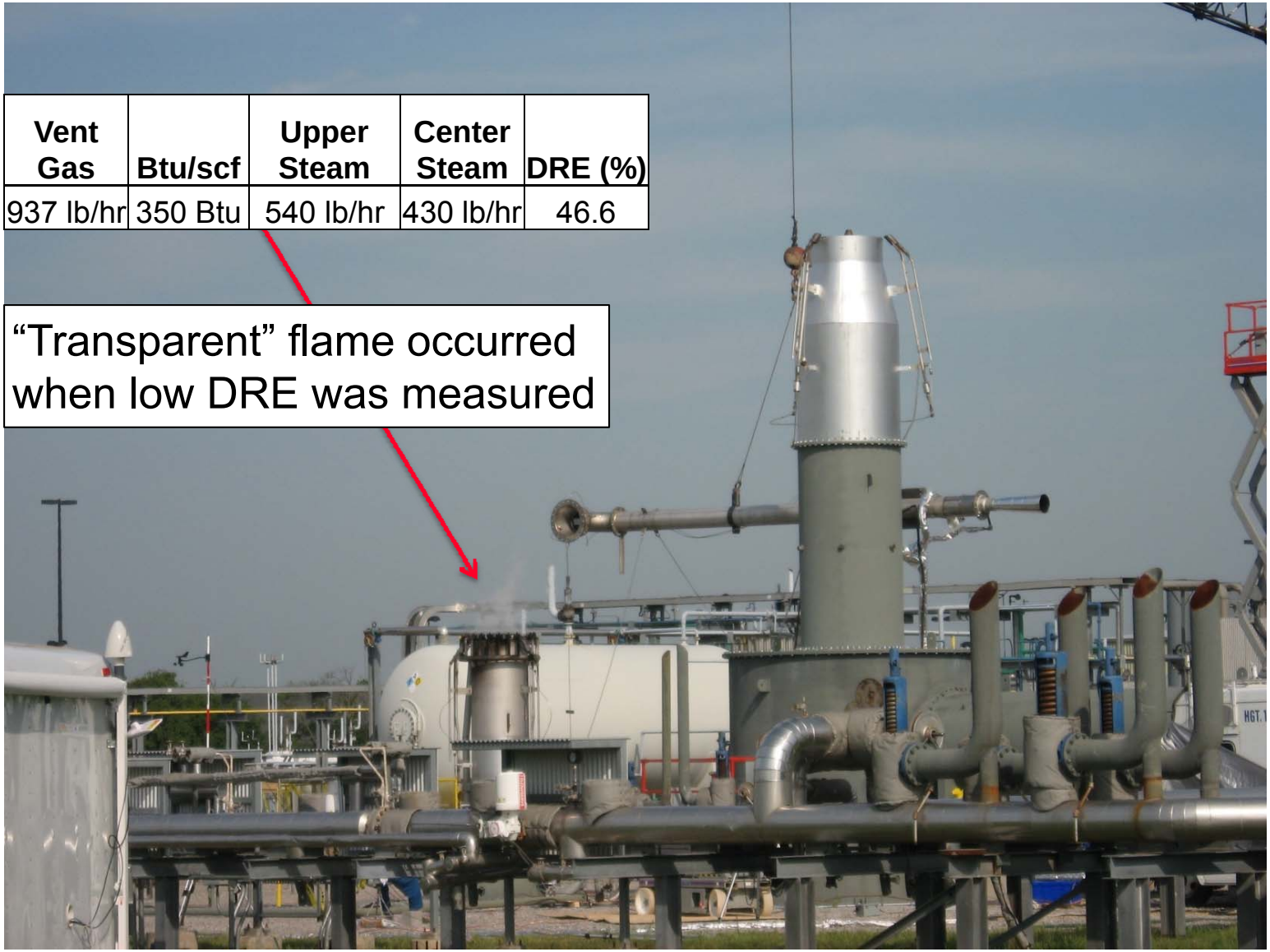


# Results: Center Steam Impacts DRE

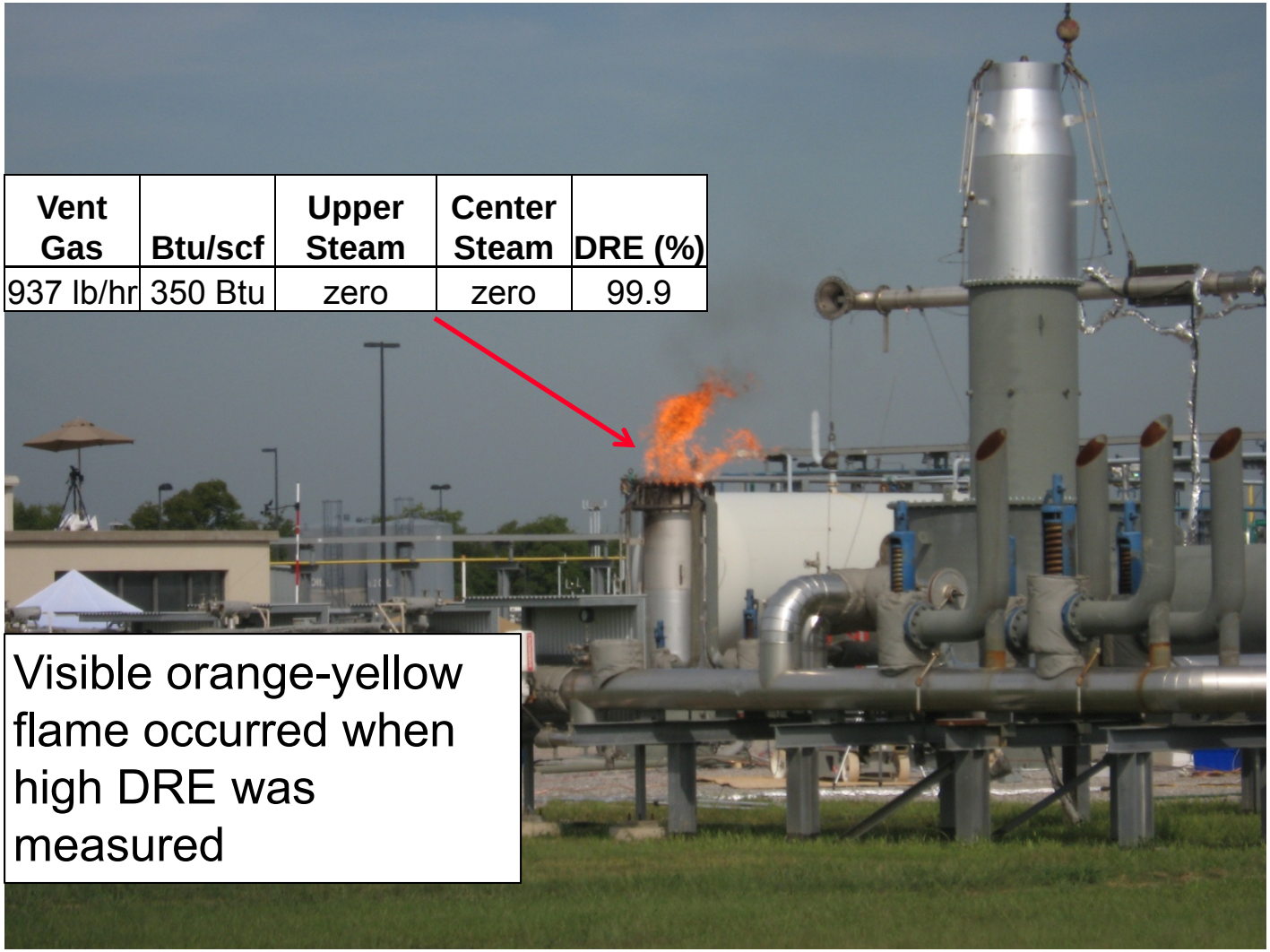
- At minimum recommended center-steam assist rates, the steam-assisted flare was not able to achieve 99% DRE for the vent gas stream of 350 Btu/scf at 937 lb/hr flow rate.
  - Manufacturer recommended a minimum center steam operating range of 300-500 lb/hr.
- At 937 lb/hr flow rate, a steam-to-vent-gas ratio of less than 0.25 (with zero center steam) was required to achieve 99% DRE.

# Test Point S3.1

| Vent Gas | Btu/scf | Upper Steam | Center Steam | DRE (%) |
|---|---|---|---|---|
| 937 lb/hr | 350 Btu | 540 lb/hr | 430 lb/hr | 46.6 |



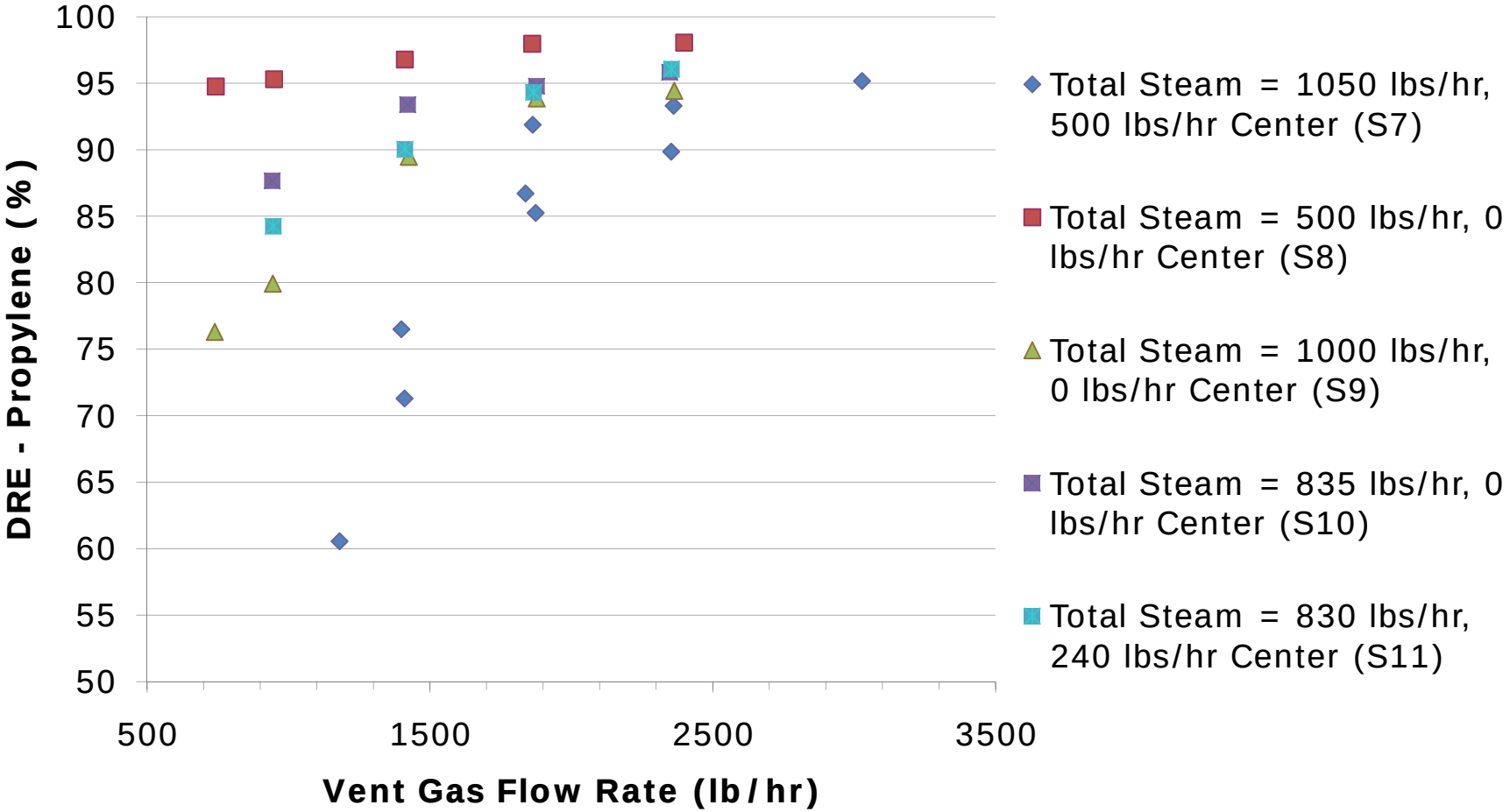
# Test Point S3.6



| Vent Gas | Btu/scf | Upper Steam | Center Steam | DRE (%) |
|---|---|---|---|---|
| 937 lb/hr | 350 Btu | zero | zero | 99.9 |

Visible orange-yellow flame occurred when high DRE was measured

# Impact of Center Steam

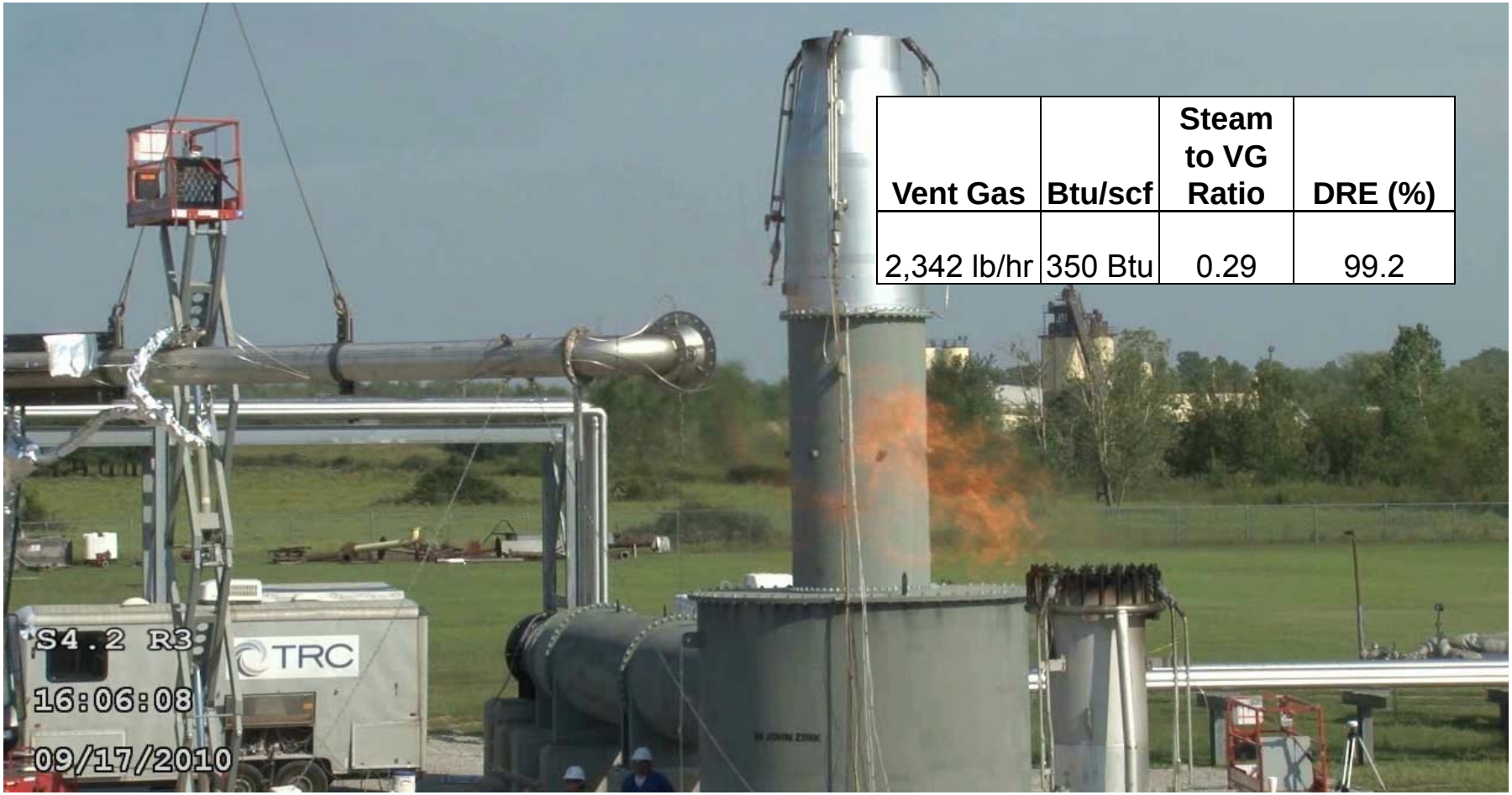


# Results: Operating Conditions Critical

Steam-assisted flare DRE measured at 98% under limited operating conditions when vent gas stream had low heating value and low flow rates.

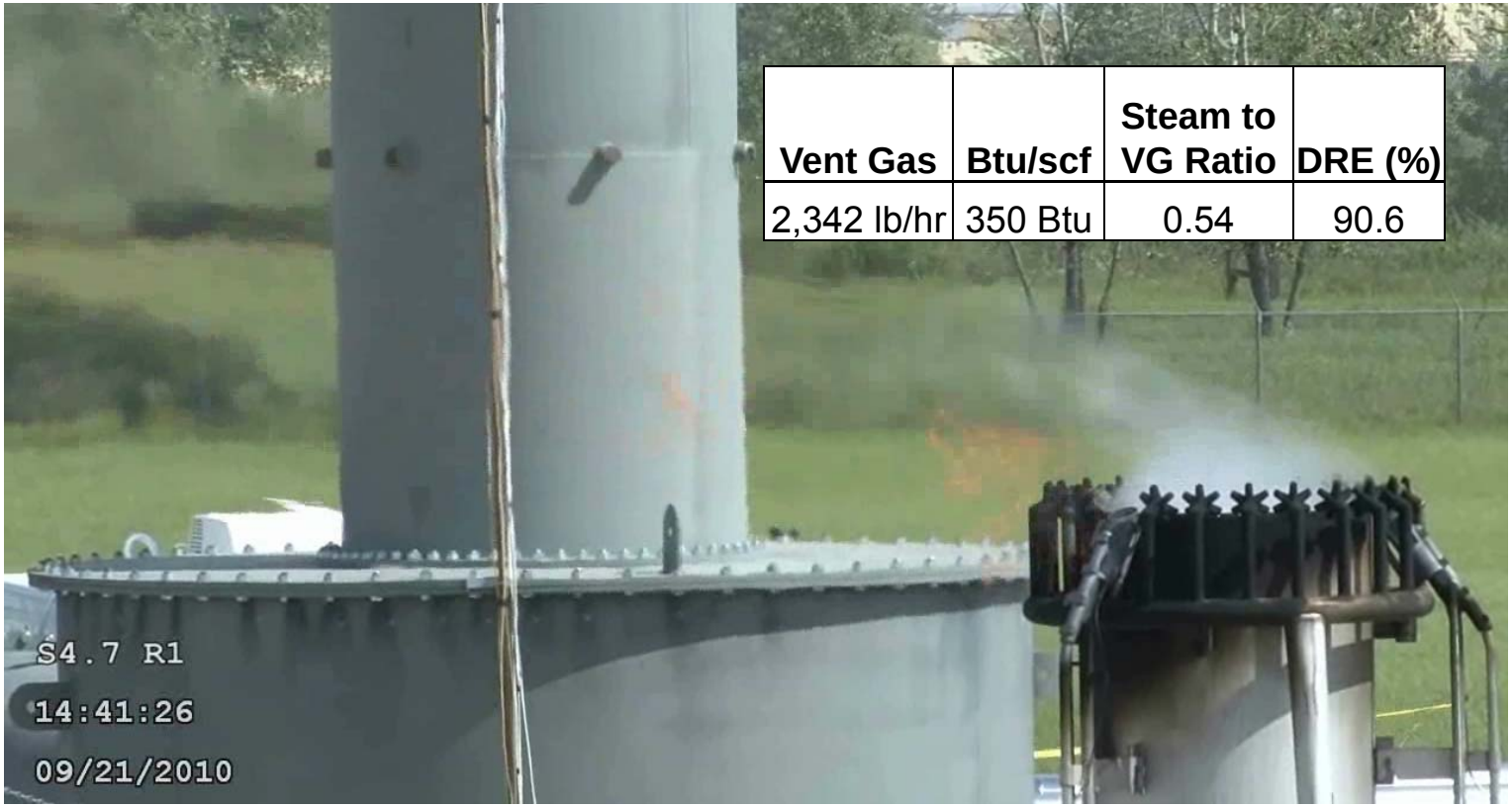
- The DRE and CE decrease almost linearly as steam assist rate increases.
- As DRE decreases, flame becomes more "transparent."

# Test Point S4.2



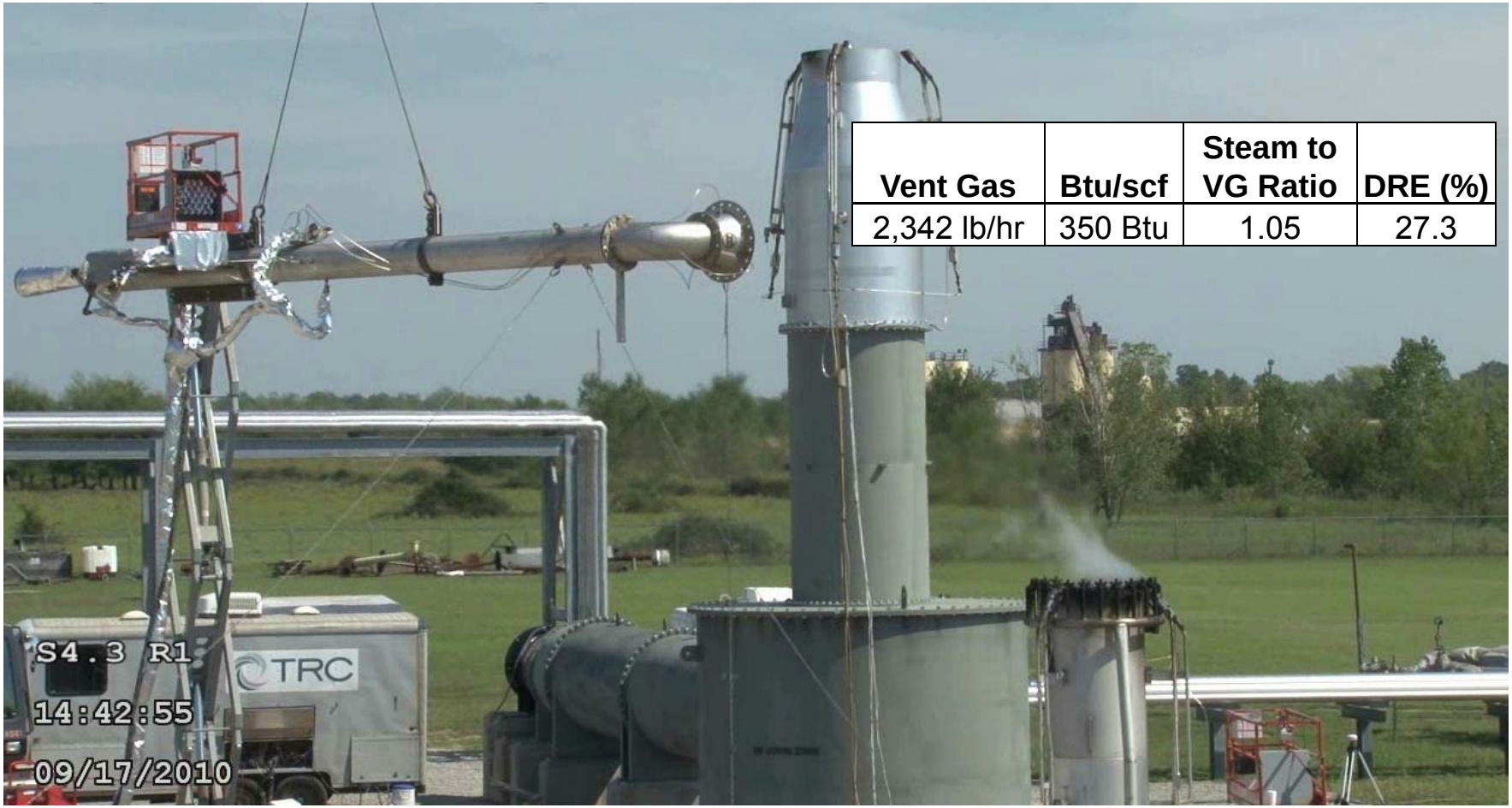

| Vent Gas | Btu/scf | Steam to VG Ratio | DRE (%) |
|---|---|---|---|
| 2,342 lb/hr | 350 Btu | 0.29 | 99.2 |

# Test Point S4.7



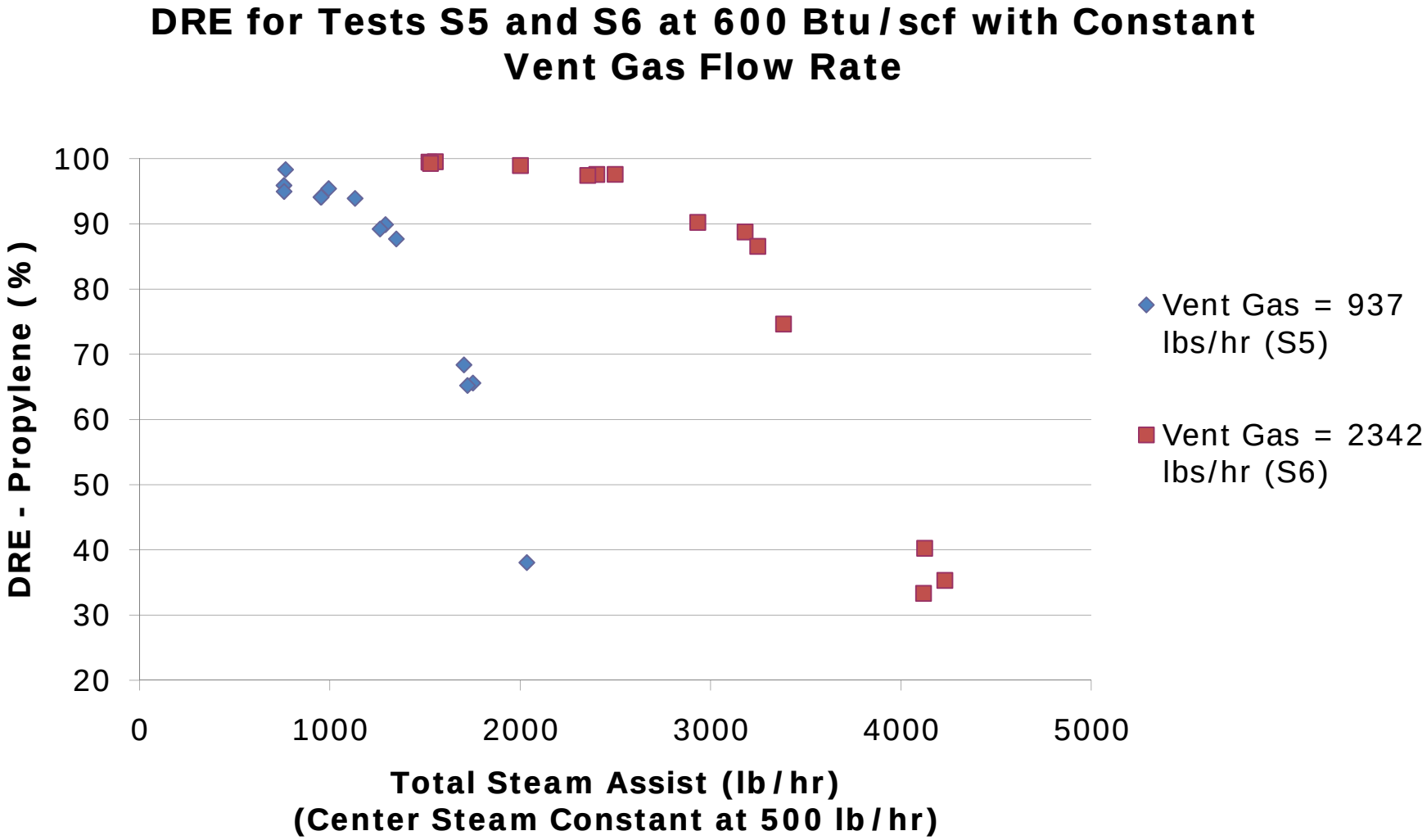

| Vent Gas | Btu/scf | Steam to VG Ratio | DRE (%) |
|---|---|---|---|
| 2,342 lb/hr | 350 Btu | 0.54 | 90.6 |

# Test Point S4.3




| Vent Gas | Btu/scf | Steam to VG Ratio | DRE (%) |
|---|---|---|---|
| 2,342 lb/hr | 350 Btu | 1.05 | 27.3 |

# DRE Versus Steam Assist Rate

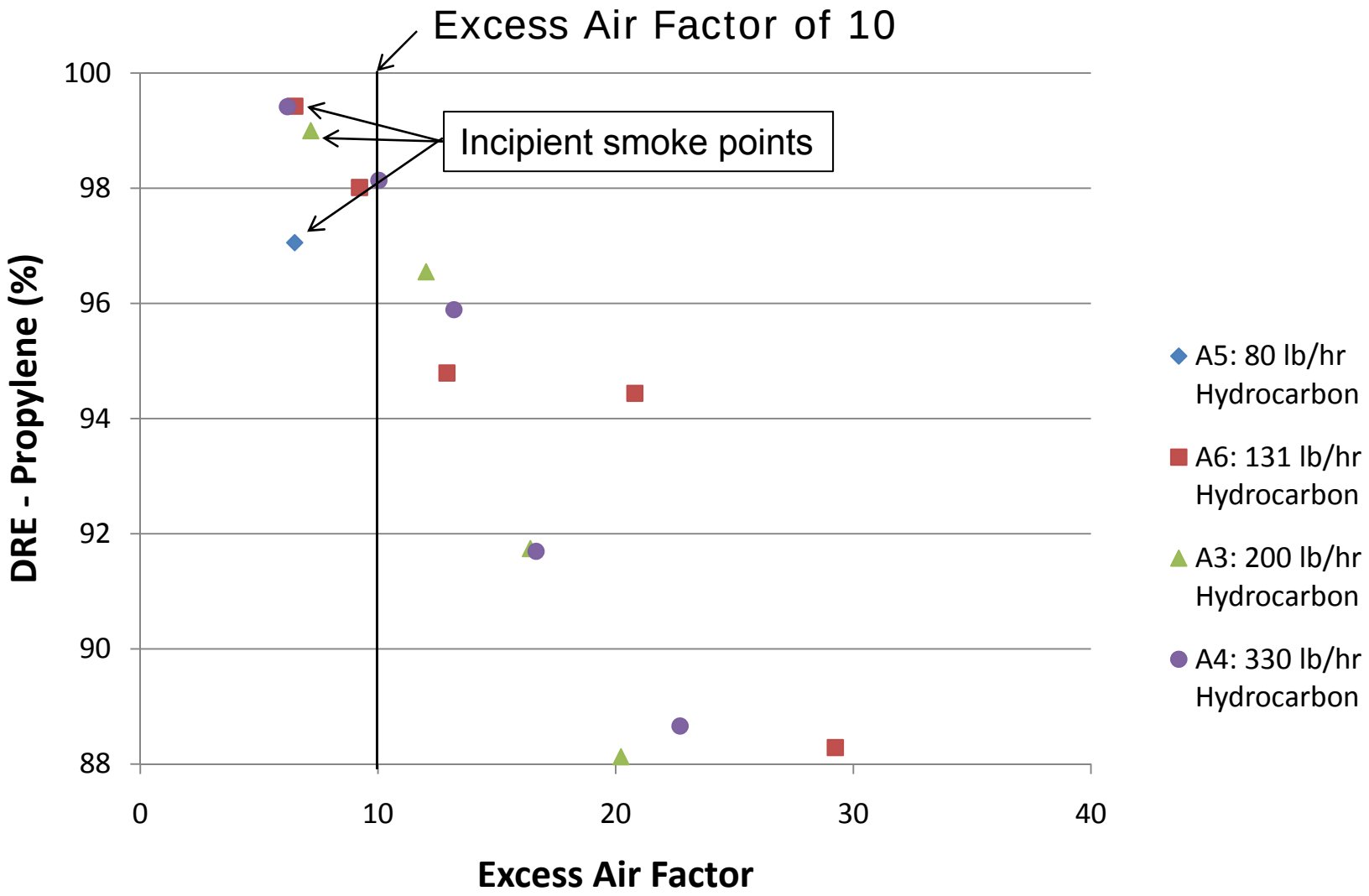


# Results: Air Assist Rates Critical

The air-assisted flare DRE measured greater than 97% when the excess air factor was less than 10.

- Excess air factor: The amount of air in excess of what is required to achieve theoretical stoichiometric combustion represented as a factor.
- Example: 15 pounds of air is required to burn 1 pound of propylene. If the air assist rate is 150 pounds of air per pound of propylene, the excess air factor would be 10.

# DRE Versus Excess Air

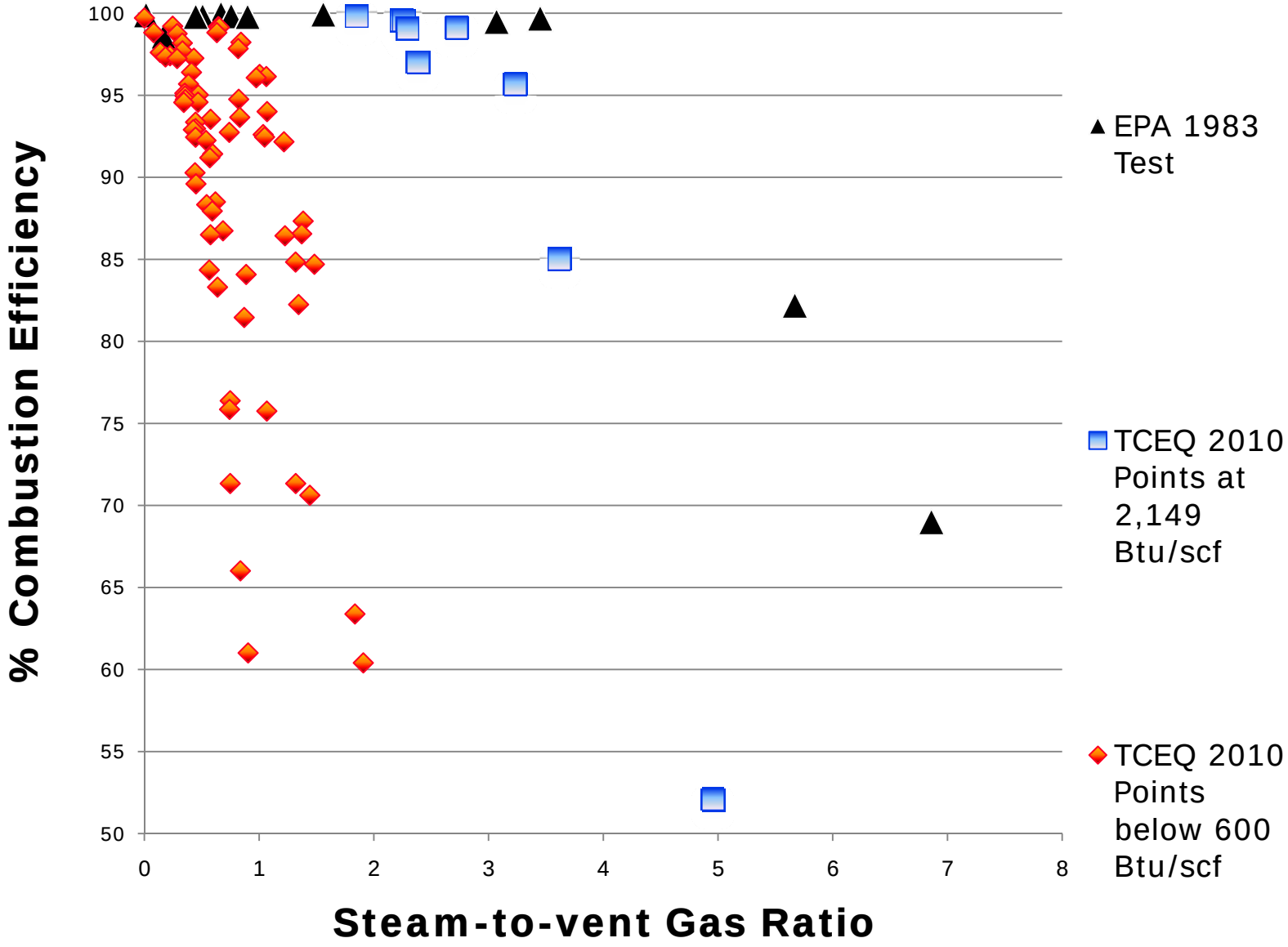


# Results: Comparison to 1983 Steam-Assisted Tests

- TCEQ 2010 test points at 2,149 Btu/scf are similar to EPA 1983 test points at 2,183 Btu/scf.
- TCEQ 2010 test points at 350 and 600 Btu/scf are significantly different than EPA 1983 test points.

  During the EPA 1983 test at vent gas heating values below 600 Btu/scf, the steam assist was not used and the tip was unassisted. High CE would be expected in this configuration.
- An 8-inch upper steam-assisted tip was used in EPA 1983 tests.
- EPA 1983 testing occurred during calm wind conditions.

# TCEQ 2010 and EPA 1983 Steam-Assisted Flare Test Data

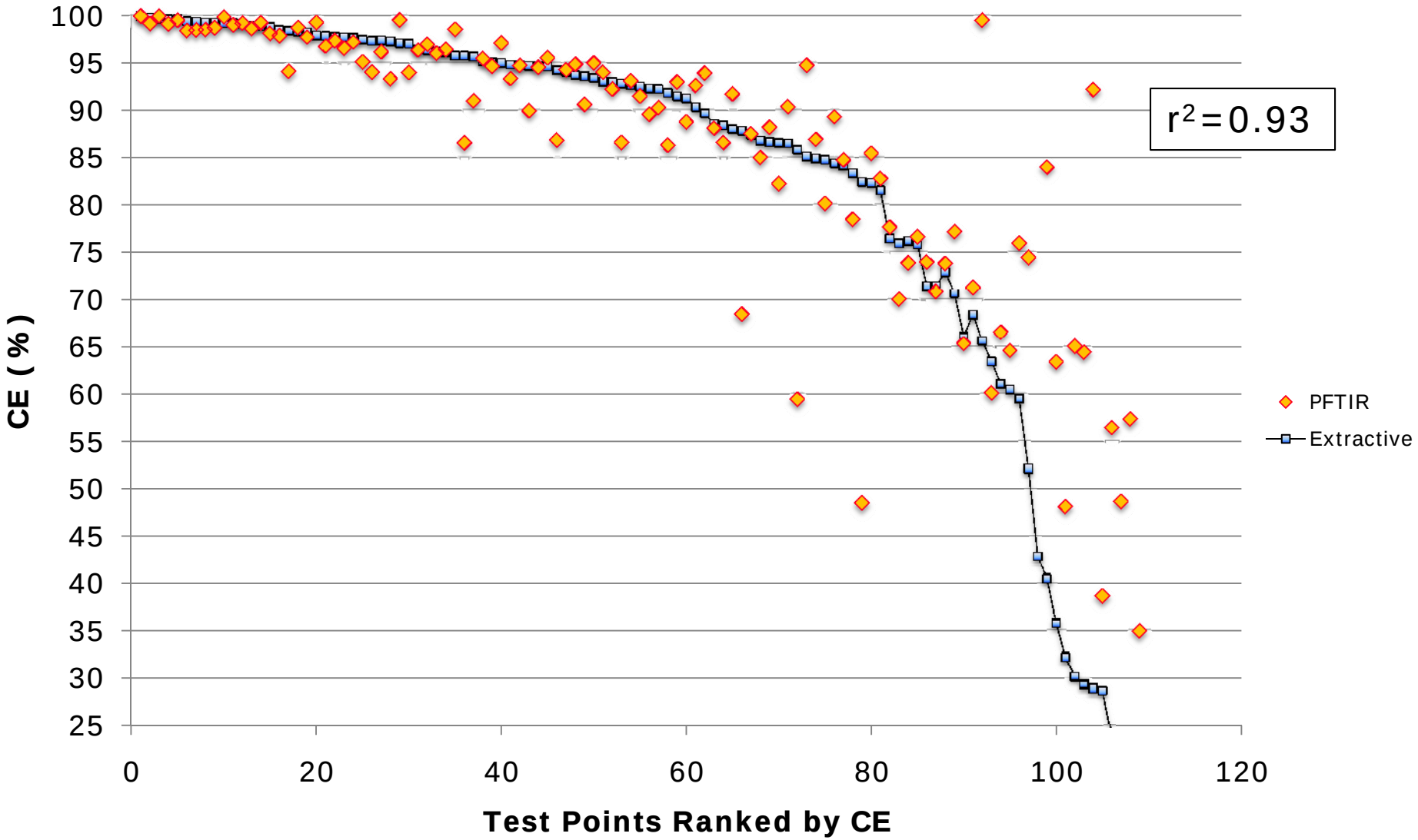


# Results: How Well Do Passive Techniques Agree with Direct Measurement?

Single-blind CE measurements from the PFTIR were comparable to the Aerodyne extractive CE measurements at higher CE conditions.

- Below 87% CE, some instances of poor correlation were observed.

# PFTIR Versus Extractive Measurements



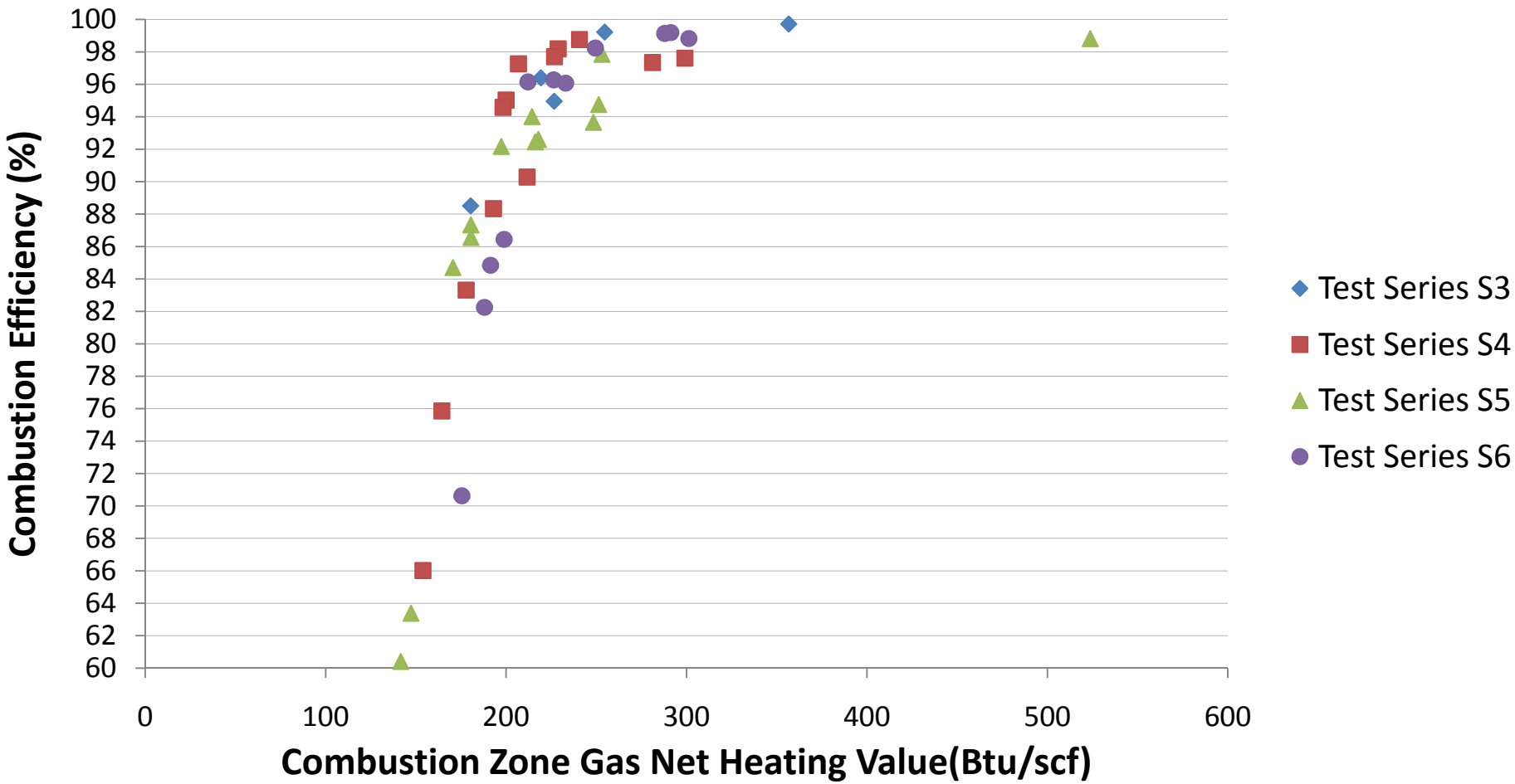
# Results: Combustion Zone Gas Net Heating Value

The TCEQ 2010 combustion zone gas net heating value data curve above 200 Btu/scf is very similar to recent Marathon passive FTIR measurements.

- Marathon measurement performed on different flare tip configurations and different vent gas flow conditions.
- Marathon, Texas City, test on 24-inch diameter flare with center, upper, and lower steam and tested under refinery base load conditions at a tip velocity 1 to 3 fps.
- Marathon, Detroit, test on 16-inch diameter flare with center and upper steam and tested under refinery base load conditions at a velocity of 2 fps.

# Combustion Zone Gas Net Heating Value

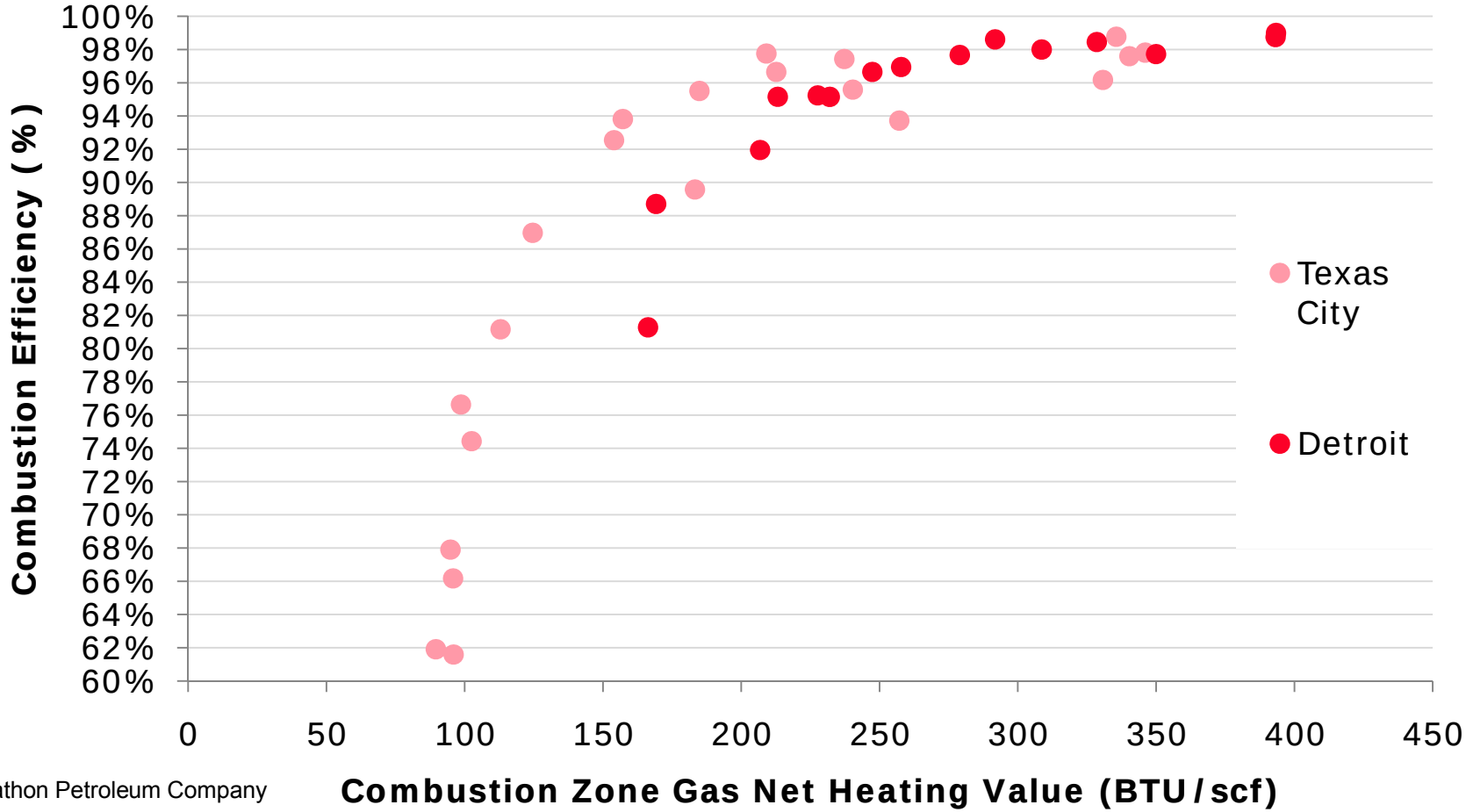
## CE Versus Combustion Zone Gas Net Heating Value



# Marathon Petroleum Company
# Passive FTIR Test Results

Marathon Petroleum Company
Detroit Refinery - CP Flare (2010)
Texas City Refinery - Main Flare (2009)

## Detroit and Texas City Comparison
## A Series Runs (Base Load)
## CE Versus Combustion Zone Gas Net Heating Value




Source: Marathon Petroleum Company

# Next Steps

- May 23, 2011:
  - The UTCEER will deliver the revised draft final report to the TCEQ.
  - The TCEQ posts the revised draft final report on the Web for public comment.
- June 1, 2011:

  The TCEQ holds a stakeholder meeting to discuss the draft final report.
- June 6, 2011:

  The TCEQ provides comments from staff and the public to the UTCEER.

# Next Steps

- June 8, 2011:

  The UTCEER presents study results at the Texas Chemical Council's and the Association of Chemical Industry of Texas' Environmental Health and Safety Seminar in Galveston.

- June 14, 2011:

  The UTCEER submits the final report to the TCEQ.

- June 14-15, 2011:

  The TCEQ presents the study results at the joint TCEQ-EPA flare and leak detection and repair workshop.

# TCEQ-Funded Ongoing Flare Research

- UTCEER Air Quality Research Program Projects
  - University of Texas at Austin project to use multivariate image analysis and Fluent computational fluid dynamic (CFD) modeling software
  - Lamar University project to replicate TCEQ 2010 Flare Study Project results using CFD modeling software
- Lamar Supplemental Environmental Program Project

  Use CFD modeling software to identify speciated VOC emissions from flaring operations of various chemical processes

# Other Ongoing Flare Research

- EPA PFTIR Projects

  EPA consent decree requirement to use PFTIR testing on flares at refineries and chemical plants

- John Zink Pressure Assist Flare Testing
  - High CE at all vent gas flows (98-100%)
  - Potential alternative to an air assist flare under specific vent gas flow conditions.

- International Flaring Consortium Test

  Test results have not been released.

# Preliminary Results Summary

- Air- and steam-assisted flares can efficiently control low Btu vent gas at low flow rates under limited operating conditions.
  - The assist-to-vent gas flow operating range to achieve greater than 98% DRE was limited.
  - A slow rolling, bright orange flame near the incipient smoke point was observed when DRE was measured to be greater than 98%.
- Controlling flare assist rates is critical to achieving high DRE.
  - The assist-to-vent gas ratio operating range increased with increased heating value of vent gas.
  - Increasing vent gas flow rate had a marginal effect on the assist-to-vent gas ratio operating range.

# Preliminary Results Summary

- A flare can be operated under 40 CFR §60.18 criteria and not achieve 98% DRE.
- Flares were easily over-assisted.
  - Air-assisted flare with an excess air factor greater than 10 measured less than assumed 98% DRE.
  - Steam-assisted flare combusting 350 and 600 Btu/scf waste gas required a steam-to-vent gas ratio of less than 1.1:1 to achieve 98% DRE.
  - Steam-assisted flare combusting 2,149 Btu/scf waste gas required a steam-to-vent gas ratio of less than 3.3:1 to achieve 98% DRE.
  - Type of steam assist (center versus upper) impacts flare DRE.

# Contact Information

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- Draft study results will be posted at:
  - Flare Task Force Stakeholder Group Web site
  - Sign up for e-mail updates through TCEQ's GovDelivery listserver. Select "*SIP Hot Topics*" under the "*Air Quality*" heading to receive Flare Task Force updates.