2011 AFRC Industrial Flares Colloquium
Houston, TX
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Tom Farmer
Zeeco Flare Applications Engineer
Company Profile

- Incorporated in 1979
- 250-acre facility located in Broken Arrow, OK
- Specialists in the design and manufacturing of combustion equipment
Zeeco Product Lines

- Industrial Burners
- Flare Systems
- Incineration Systems
Background

- Flare testing conducted by TCEQ and The University of Texas
  - Determined how air assisted and steam assisted flares perform at turndown rates
  - Suggested that incorrectly designed or operated flares may reduce the Destruction and Removal Efficiency (DRE) of flares

- Zeeco testing
  - Performed testing of steam assisted flares to compliment TCEQ tests
  - Zeeco focused on API recommended purge rates
Testing Instrumentation & Setup

- Performed at Zeeco Combustion Research & Test Facility in Broken Arrow, OK

- Equipment
  - 36" Steam Assisted Flare Tip
    - QFSC Steam Assisted Tip
    - UFSC Steam Assisted Flare Tip
  - Temperature elements positioned on flare tip
Testing Instrumentation & Setup

- Sample induction probe
  - Inductor
  - Flow conditioner
  - Thermocouples at probe inlet
Testing Instrumentation & Setup

- LSI FLIR GasFindIR camera
- *Air Hygiene* emissions testing service
- Miscellaneous equipment
  - Video camera
  - Still camera
Testing

- Phase 1- Test API recommended purge rates with steam operating at cooling rates
  - Three purge rates tested
    - Velocity Seal purge rates
    - Gas Seal purge rates
    - No Seal purge rates

<table>
<thead>
<tr>
<th></th>
<th>Velocity Seal</th>
<th>Gas Seal</th>
<th>No Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purge Gas</td>
<td>NG</td>
<td>NG</td>
<td>NG</td>
</tr>
<tr>
<td>Purge Rate (SCFH)</td>
<td>990</td>
<td>250</td>
<td>1992</td>
</tr>
</tbody>
</table>
Testing

- Three steam assist methods were tested for each purge rate
  - Center steam only
  - Upper steam only
  - Combined upper and center steam
Testing

- Phase 2 - Building a Hypothesis
  - Set steam rates and adjusted gas flow to achieve a high destruction efficiency
  - Set purge rates and adjusted center, upper, and combined steam flow rates to achieve a high destruction efficiency
    - The steam flow was turned down as low as reasonably possible without condensing

- A trend developed between the DRE and the LHV of the combined steam and gas stream
Testing

- Phase 3- Verify Hypothesis
  - Test points selected to produce a combined stream LHV, which achieved a 98% destruction efficiency
Results

- Destruction Removal Efficiency (DRE) evaluation
  - CO, CO₂, NOₓ, and total hydrocarbons were measured
  - The DRE calculations are based on the measured values and carbon balance accounts for the percentage of plume captured

\[
DRE = 1 - \frac{\text{total mol THC}_{\text{out}}}{\text{mol THC}_{\text{in}}} \\
= 1 - \frac{\text{mol THC}_{\text{out measured}}}{(\% \text{ of } C \text{ in plume}) \text{mol THC}_{\text{in}}}
\]

\(DRE = \text{destruction and removal efficiency}\)

\(\text{mol THC}_{\text{out measured}} = \text{total mol hydrocarbons measured in the plume sample}\)

\(\text{mol THC}_{\text{in measured}} = \text{total mol hydrocarbons measured entering the flare}\)
Results

- Summary
  - Testing indicated that the DRE is impaired by cooling steam while operating at API recommended purge rates
  - Strong correlation between the DRE and the LHV of the combined gas and steam rates
  - The addition of center steam resulted in the largest reduction of DRE
Results

Combined LHV vs. DRE with Center Steam Only

![LHV vs. DRE with Center Steam Only graph](image)
Results

- Combined LHV vs. DRE with Upper Steam Only

![Graph showing LHV vs. DRE with Upper Steam Only]
Results

- Combined LHV vs. DRE with Upper & Center Steam

![Graph showing LHV vs. DRE Combination Only](image-url)
Results

Steam to Gas Ratio vs. DRE with Upper & Center Steam

[Graph showing the relationship between Steam to Flare Gas Ratio (lb/lb) and Destruction Efficiency % for Upper & Center Steam.]
Results

- Steam to Gas Ratio vs. DRE with Center Steam
Results

Steam to Gas Ratio vs. DRE with Upper Steam

Zeeco Testing with Natural Gas (914 TU/SCF)

CMA Testing with Propylene (2183 BTU/SCF)
Results

- Thermocouple evaluation
  - Center Steam is used as an effective means for cooling the flare tip

Flare Tip Temperature 7/18/11 Afternoon

- Center Steam Only
- Upper & Center Steam
- Upper Steam Only

Temperature vs. Time:
- Level 1
- Level 2
- Level 3
Results

Thermocouple evaluation continued

- At low center steam rates, burning was found within the flare tip

Flare Tip Temperature 7/19/11 Afternoon

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Results

- Thermocouple evaluation continued
  - When the flame was stable and located at the exit of the flare tip, a higher DRE was observed
Conclusion

- Constant cooling steam is necessary for thermal protection of the flare tips and equipment
- Strong indication that cooling steam, while operating at API Purge Rates, does reduce destruction efficiency
- LHV for combined steam and gas is necessary for predicting the destruction efficiency of flares
Recommendations

Is this a real problem?
- Many plants operate with sweep gases that are higher than API recommended rates
- API rates are listed as the minimum recommended purge rate

Increase LHV combustion zone
- A minimum of 225 Btu/SCF is recommended

Use nitrogen purge where available

Use other means of flashback protection
- Flame arrestor
- Liquid seal base of flare stack and designed for flashback