Destruction Efficiency of Air-Assisted Flares

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Industrial Combustion Symposium
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Kauai, Hawaii

Greg Seefeldt, PE
Sr. Flare Applications Engineer, Zeeco Inc.
Outline

- Typical Air Flare Designs and Arrangements
- Destruction Efficiency General Discussion
- Zeeco Air Flare Destruction Efficiency Testing and Results
- Air Flare Operating Recommendations
- Question/Answer
Typical Air Flare Designs & Arrangements
Typical Air Flare Installations

- Gas Processing / Compression Plants
Typical Air Flare Installations

- LNG Facilities
Typical Air Flare Installations

- Gas Gathering
Typical Air Flare Installations

- Cold Climates and Remote Locations without Steam
Typical Air Flare Installations

- Cold Climates and Remote Locations without Steam
Typical Air Flare Installations

- Pipelines

Note: Some pipeline facilities only use flares for planned maintenance and shut them down after use, so there are no continuous flowrates and no continuous purge.
Tip Designs

Triangular Arm

Drilled Spider
Tip Designs

Tube Style

Air Ring

HPAAS
Typical Air Flare Installations

- How are flares operated on a normal, day-to-day basis…
Typical Air Flare Installations

-How are flares operated on a normal, day-to-day basis…purge only
Typical Air Flare Installations

-Are there potential issues with over-aeration…
Typical Air Flare Installations

- Are there potential issues with over-aeration... ABSOLUTELY
Typical Air Flare Installations
Options for Blower Turndown

- One Single Speed Blower
  - No air turndown capability
Options for Blower Turndown

- One Two-Speed Blower
  - Turndown to 50% air flowrate
Options for Blower Turndown

- One Two-Speed Blower + One Single Speed Blower
  - Turndown to 25% air flowrate
Options for Blower Turndown

- One Blower with VIV Damper
  - Turndown ability is situational
Options for Blower Turndown

- One Blower with VFD Control
  - Turndown to 4-8% air flowrate
Options for Blower Turndown

- One VFD Controlled Blower + One Single Speed Blower
  - Turndown to 2-4% air flowrate
Destruction Efficiency
General Discussion
Flare Destruction Efficiency – HOT TOPIC
Flare Destruction Efficiency – HOT TOPIC

- Testing
  - EPA/EER/CMA
  - TCEQ
  - Zeeco

- Regulations/Permitting

- Consent Decrees/Fines

- Product Development
  - Flares
  - PFTIR / AFTIR
  - FLIR
Flare Destruction Efficiency – Background

- 1983 – CMA Testing - McDaniel – Steam-Assisted Flare with propylene/N2
- 1983 – CMA Testing - McDaniel – Air-Assisted Flare with propylene/N2
- 1984 – Pohl – Pipe flare with propylene/N2
- 1985 – EPA/EER - Pohl and Soelberg – Steam Assist, Air Assist, High Pressure, Non-Assisted Flares with propane/N2
- 2010 – TCEQ – University of Texas – Steam-Assist and Air-Assisted Flares – Mix of Propylene, Natural Gas, and Nitrogen
- 2011 – Zeeeco – Steam Assisted Flare with Natural Gas and Natural Gas / N2 Mix
Flare Destruction Efficiency – Background

- 1983 – CMA Testing - McDaniel – Steam-Assisted Flare with propylene/N2
- 1983 – CMA Testing - McDaniel – Air-Assisted Flare with propylene/N2
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- 1985 – EPA/EER - Pohl and Soelberg – Steam Assist, Air Assist, High Pressure, Non-Assisted Flares with propane/N2
- 2010 – TCEQ – University of Texas – Steam-Assist and Air-Assisted Flares – Mix of Propylene, Natural Gas, and Nitrogen
- 2011 – ZeeCo – Steam Assisted Flare with Natural Gas and Natural Gas / N2 Mix
**Flare Destruction Efficiency – Background**

- **1983 – CMA Testing - McDaniel – Air Flare Testing**
  - 4” drilled spider tip
  - 7.5HP Blower
  - Propylene or Propylene diluted with Nitrogen
  - Main Focus was on gas flowrates above purge
  - Large heat release pilots (2 pilots at 226,300 Btu/hr each) may have masked results at low flare gas flowrates.

*Typical Drilled Spider Tip*
Flare Destruction Efficiency – Background

- 2010 – TCEQ – University of Texas – Air-Assisted Flare
  - 24” triangular arm style tip
  - Mix of Propylene and Natural Gas diluted with Nitrogen
  - Primarily focused on higher flowrates ~10-30 times normal purge rate

Photo and Data from TCEQ Report

Typical Triangular Arm Tip
Previous Testing – What is Missing?

What about air flares operating at purge rate burning natural gas…
Previous Testing – What is Missing?

What about air flares operating at purge rate burning natural gas…where has this been tested?
Previous Testing – What is Missing?

What about air flares operating at purge rate burning natural gas... where has this been tested? Nowhere!!!!
Zeeco Air Flare Destruction Efficiency Testing and Results
Zeeco Testing - Goals

- Fill in the gaps from previous tests.
- Better understand impact of blower turndown options.
- Operating guidelines for high DRE
Zeeco Testing - Setup

Air Velocity Plot
Zeeco Testing - Setup
Zeeco Testing – Completed in June 2013
Zeeco Testing – Completed in June 2013
**Zeeco Testing – Results**

**Destruction Efficiency for Natural Gas**

<table>
<thead>
<tr>
<th>Destruction Efficiency</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>No Air Blowers</td>
<td>100</td>
<td>90</td>
<td>80</td>
<td>70</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>2 Blowers - 1 Off / 1 at Min Turndown with VFD</td>
<td>90</td>
<td>80</td>
<td>70</td>
<td>60</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>1 Blower - Min Turndown with VFD</td>
<td>80</td>
<td>70</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>2 Blowers - 1 Off / 1 at Half Speed</td>
<td>70</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>1 Blower at Half Speed</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>1 Blower Full-Speed</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>10</td>
<td>0</td>
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**Purge Rate Destruction Efficiency - Example**
Zeeco Testing – Results

Destruction Efficiency for Propane

Purge Rate Destruction Efficiency - Example
Zeeco Testing – Results

Can we reliably use % Stoichiometric Air?
Zeeco Testing – Results

- Can we reliably use % Stoichiometric Air?
Zeeco Testing – Results

- Where do you draw the line? 600%....

![Graph showing Destruction Efficiency vs % Stoichiometric Air with different markers for Natural Gas, Propane, CMA, and TCEQ](image-url)
Zeeco Testing – Results

- Where do you draw the line? 600%.....950%....
Zeeco Testing – Results

- Where do you draw the line?  600%.....950%....1500% ???
Zeeco Testing – Results

- What about Combustion Zone Net Heating Value (CZNHV)?
Zeeco Testing – Results

What about Combustion Zone Net Heating Value (CZNHV)?

\[
CZNHV = \frac{\text{Flare Gas LHV} \times \text{Flare Gas Flow} + \text{Pilot Gas LHV} \times \text{Pilot Gas Flow}}{\text{Flare Gas Flow} + \text{Pilot Gas Flow} + \text{Air Assist Flow}}
\]
Zeeco Testing – Results

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Zeeco Testing – CZNHV Results

- Destruction Efficiency vs. Combustion Zone Net Heating Value
  - Natural Gas (Diamonds)
  - Propane (Red Squares)
  - TCEQ (Circles)

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Zeeco Testing – CZNHV Results

Graph showing the relationship between Destruction Efficiency and Combustion Zone Net Heating Value for different fuels:
- Natural Gas
- Propane
- CMA
- TCEQ

The graph indicates a trend where higher Destruction Efficiency correlates with higher Combustion Zone Net Heating Value.
Zeeco Testing – CZNHV Results

- Natural Gas
- Propane
- CMA
- TCEQ

Destruction Efficiency

Combustion Zone Net Heating Value

98% Destruction Efficiency
Zeeco Testing – CZNHV Results

Graph showing the relationship between destruction efficiency and combustion zone net heating value.

- Natural Gas
- Propane
- CMA
- TCEQ

99% Destruction Efficiency
Why CZNHV Instead of %SA??????

- Gas Stability
- Pilot Impact

Natural Gas

Propane
Air Flare Operating Recommendations
Recommendations

- **Design Recommendations:**
  - Design Blower Arrangement to Allow Adequate Turndown
  - Check to ensure that the combination of the purge rate, pilot quantity / heat release, and blower turndown flowrate will stay above the minimum recommended CZNHV
Recommendations

- Operating Recommendations:
  - Try to maintain visible flame

Too Much Air  Questionable  Ideal
Recommendations

Operating Recommendations:

- Try to stay just beyond incipient smoking point
- Avoid unsteady rumbling.
Recommendations

- Modifications for Existing Flares Operating Below Recommended CZNHV:
  - Increase purge gas rate, or use purge gas with a higher heating value
  - Use a VFD
  - Add a variable inlet damper
  - Systems with very large air blowers → add a small dedicated blower for purge rates
Conclusion

- Properly designed/operated air-assisted flares can achieve hydrocarbon destruction efficiencies exceeding 99%.

- Combustion Zone Net Heating Value (CZNHV) is likely the most accurate parameter for ensuring high flare destruction efficiency of air-assisted flares.

- Zeeco testing affirms that properly designed air-assisted flares can be used to reduce hydrocarbon and VOC emissions at facilities by achieving high destruction efficiency.

- Smoking flares can have equal or higher destruction efficiency than non-smoking flares, achieving destruction efficiencies of 99% or higher.
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<tbody>
<tr>
<td><strong>Scot Smith, PE – Zeeco Flares</strong></td>
<td></td>
</tr>
<tr>
<td>Director</td>
<td></td>
</tr>
<tr>
<td>Email: <a href="mailto:scot_smith@zeeco.com">scot_smith@zeeco.com</a></td>
<td></td>
</tr>
<tr>
<td>Phone: 918-893-8160</td>
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<tr>
<td><strong>Greg Seefeldt, PE – Zeeco Sr. Flare Applications Engineer</strong></td>
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</tr>
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Thank You!!!