Benzene Destruction Removal Efficiency & Black Carbon Yield in a Lab-Scale Flare

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Motivation

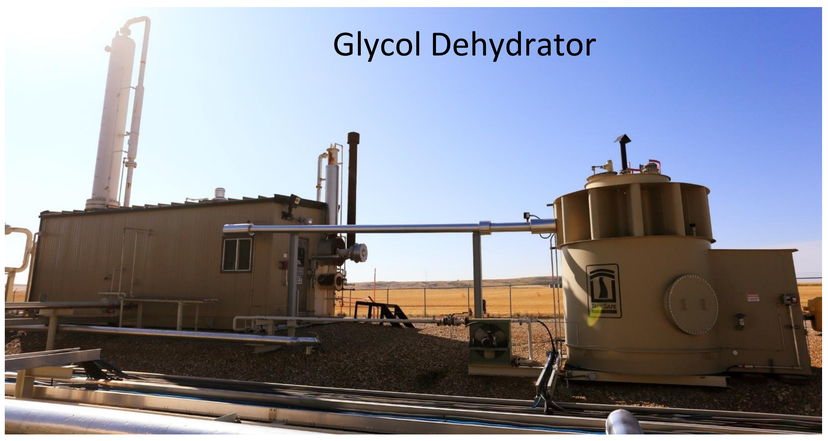
- Benzene is a serious health concern & known human carcinogen
- In 2017 Alberta had:
  - ~1500 glycol dehydrators
  - ~400 tonnes C_6H_6 emitted
- Dehydrator still gas mostly vented, but sometimes flared
  - Directive 039 sets emissions limits and distances from residences
  - AAAQO limits on ambient C_6H_6
- **Flaring is potentially a good method of emissions reduction**
- ***Large uncertainty in current factors to estimate benzene destruction removal efficiency (DRE) of flares***

Current Guidelines for Benzene Destruction in Flares

Report Title	Publisher	DRE Value (%)	Reason to Question Validity
Control of Benzene Emissions from Glycol Dehydrators[3]	CAPP	90	Source is a report that contains no mention of benzene DRE measurements
Locating and Estimating Air Emission Sources of Benzene[4]	U.S. EPA	89.5	No reference or data to validate the DRE value
Evaluation of The Efficiency of Industrial Flare Head Design and Gas Composition[5]	U.S. EPA	99.59	Flare used for experiments does not represent a typical upstream Flare

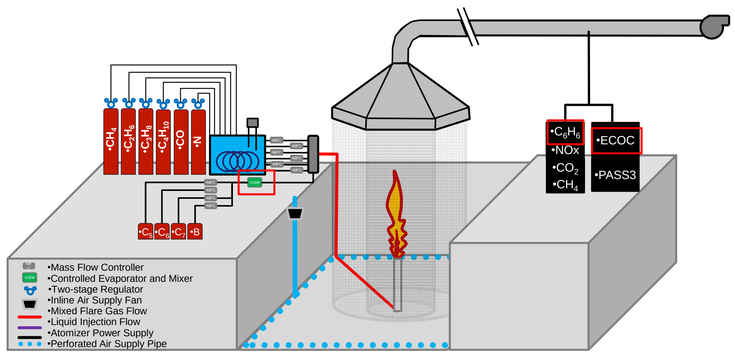
Test Selection

- Dehydrator uses liquid glycol to remove water vapour from raw natural gas
- Liquid glycol becomes saturated with water and hydrocarbons (such as benzene)
- Glycol is then heated releasing water and hydrocarbons through the still as a waste gas



- Used measured still gas compositions to develop average 11-component composition (M11) to study (includes C1-C7 alkanes, C_6H_6, CO_2, H_2O, N_2)
  - Further tests explored effects of varying C_6H_6, CH_4, CO_2, H_2O within M11

Experimental Setup

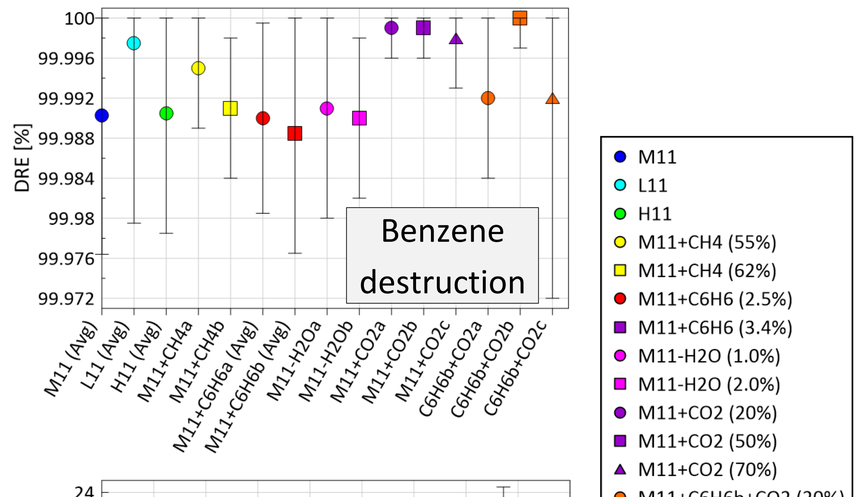


Carleton University Flare Facility (CUFF)

- Benzene
  - High precision GC
- Black Carbon:
  - Thermo-optical elemental /organic carbon analyzer
- CO_2, CO, CH_4 :
  - Cavity ringdown gas analyzers

Results: *Measured Benzene Emissions in Flares*

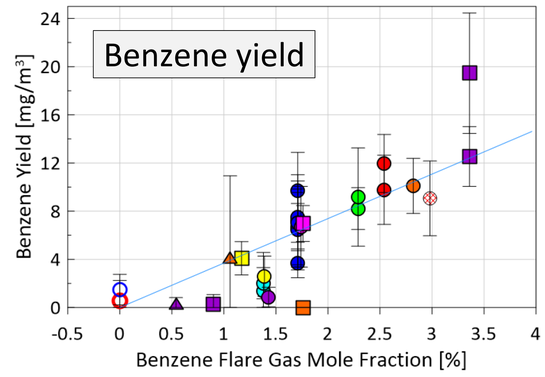
- **Lab flare has no cross-wind**
- Benzene destruction efficiency is nearly 100% for all tests
- No trends with changing flare gas composition

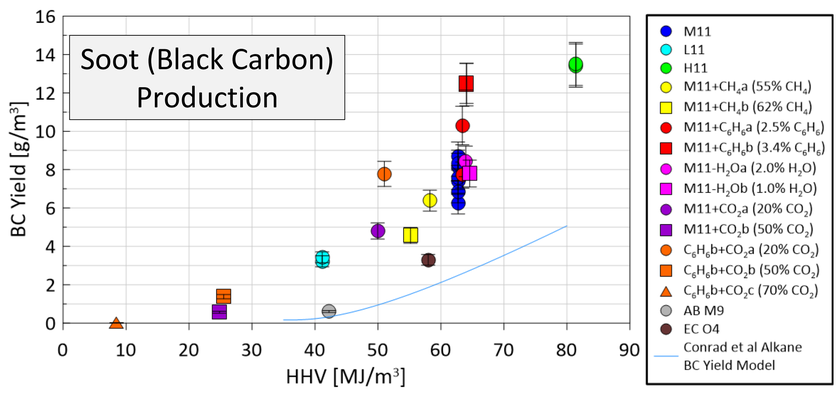


- Yield as a function of fuel-benzene:

$$Y_{C_6H_6}\left[\frac{mg}{m^3}\right] = 3.692 X_{C_6H_6,FG}$$

- Implies DRE of >99.99%





- Presence of C_6H_6 increases soot production above model predictions
- Conrad et al. model (blue curve) is based on alkane fuels
- This implies dehy still gas flares would be heavily sooting

Implications

- Flares (in negligible crosswinds) are very good at destroying benzene (>99.99%)
- If all 399 t of benzene emitted from dehydrators in Alberta were flared:
  - Benzene would be reduced to <1 t (assuming negligible crosswind effects)
  - Provincial BC emissions would increase by ~275 tonnes, or 4.4%

Future Work

- Extend results to consider turbulent crosswind conditions
  - FlareNet / NRCan objectives to measure benzene destruction from flares in the University of Western Ontario Boundary Layer Wind Tunnel
- Determine baseline (trace) benzene emissions from standard flares
  - Necessary step demonstrating uncertainties prior to submitting results for peer-review publication

References

[1] ECCC, "Guide for Reporting to the National Pollutant Release Inventory", 2017
[2] AER, "Directive 039: Revised Program to Reduce Benzene Emissions from Glycol Dehydrators", 2018
[3] CAPP, "Control of Benzene Emissions from Glycol Dehydrators", 2006
[4] U.S. EPA, "Locating and Estimating Air Emissions from Sources of Benzene", 1998
[5] J. Pohl, N. Soelberg, "Evaluating the efficiency of industrial flares: Flare head design and gas composition", 1985