# Methane Mitigator

## Development of a Scalable Vent Mitigation Strategy to Simultaneously Reduce Methane Emissions and Fuel Consumption from the Compression Industry

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U.S. Department of Energy

National Energy Technology Laboratory

Resource Sustainability Project Review Meeting

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# Project Overview

– Funding – DOE: $1,498,405, Cost Share: $433,093

– Overall Project Performance Dates

- Original: 3/20/20 to 3/19/23
- Current: 3/20/20 to 3/19/25

– Project Participants

- WVU – PI – Derek Johnson, Co-PI – Andrew Nix, ~~Nigel Clark~~ (NEW – Dr. Chris Ulishney)
- Caterpillar – Michael Bardell
- Energy Environmental Analytics (E2A)

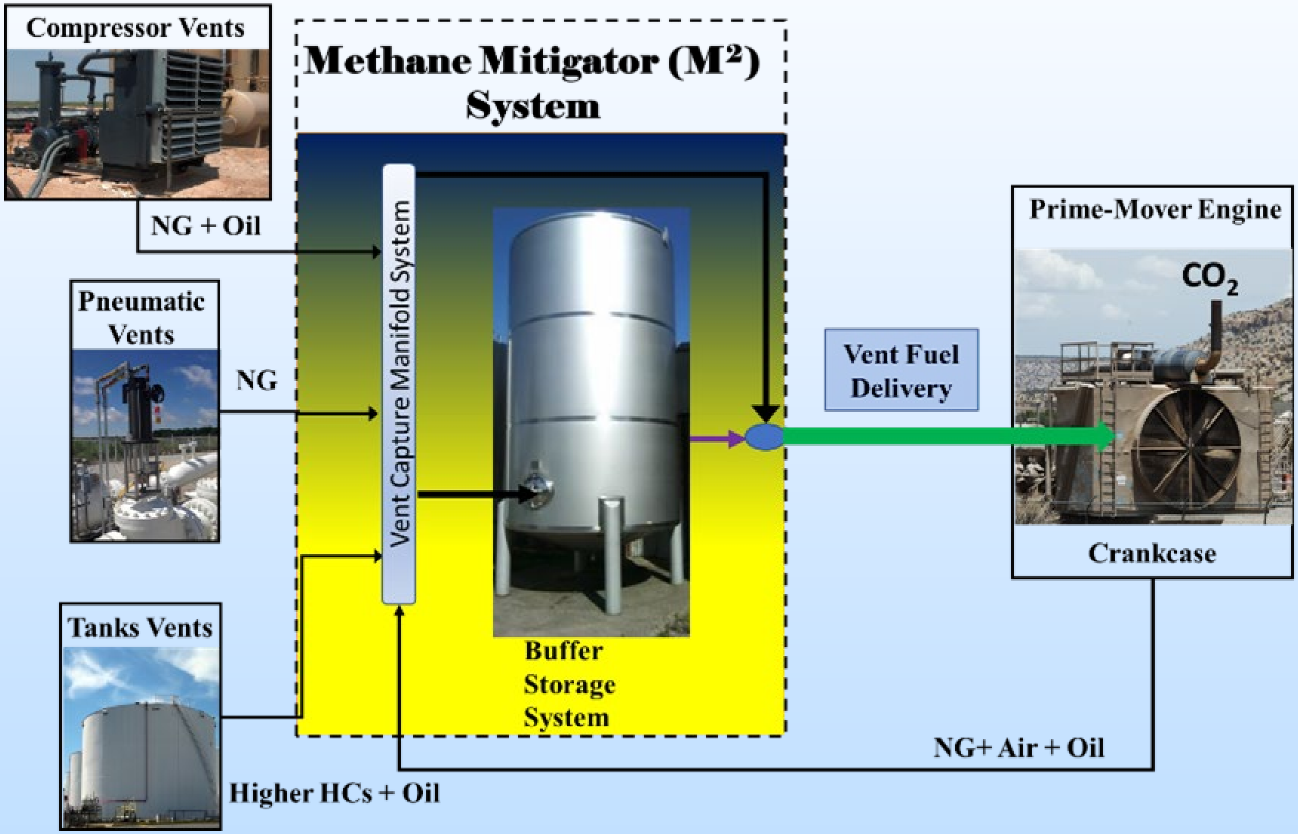
– Overall Project Objective

- Develop a stand-alone vent mitigation system and fuel delivery control system capable of consuming transient vent gas emissions in well site engines to reduce GHG and other pollutants.

# Technology Background

**Build On and Integrate Current Technologies**

- Closed Crankcase Ventilation
- Dual fuel natural gas fumigation systems



# Technical Approach/Project Scope

1) Literature review
    - Most recent data on sources

2) Filling gaps
    - New measurements
        - New activity data
        - Verification of "existing" data estimates

3) Laboratory R&D
    - Selection of representative engine technology – CAT G3508J
    - Baseline characterization
    - Evaluation of aftermarket CCV
    - Modification and redesign
        - Inclusion of other streams

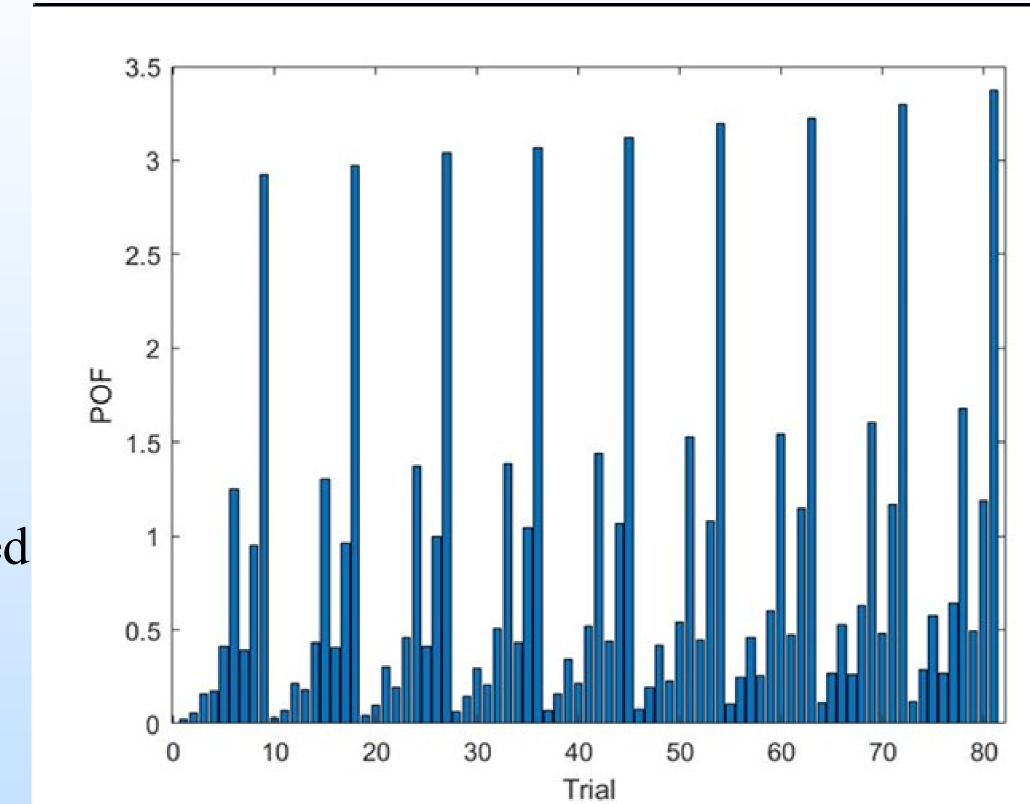
4) Modeling
    - Current and new data
    - Estimation of "methane" recovery as potential fuel offset
    - Time varying volumes, compositions, heating values, MN
    - Sizing tool – scenario capabilities

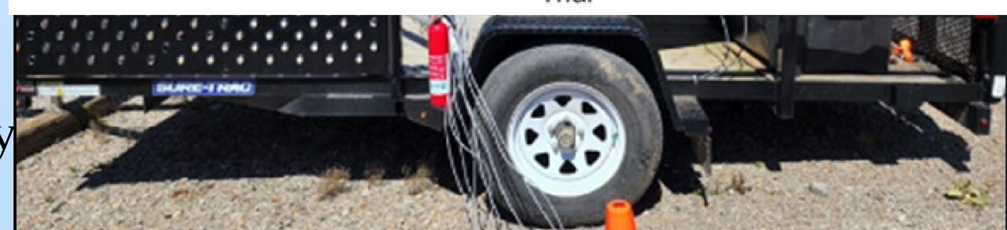
5) Technology Demonstration
    - Mimic real-world scenarios in laboratory
    - "Improved" system

# Technology Background

**Commonly Vented Sources of Methane in Compression Industry**

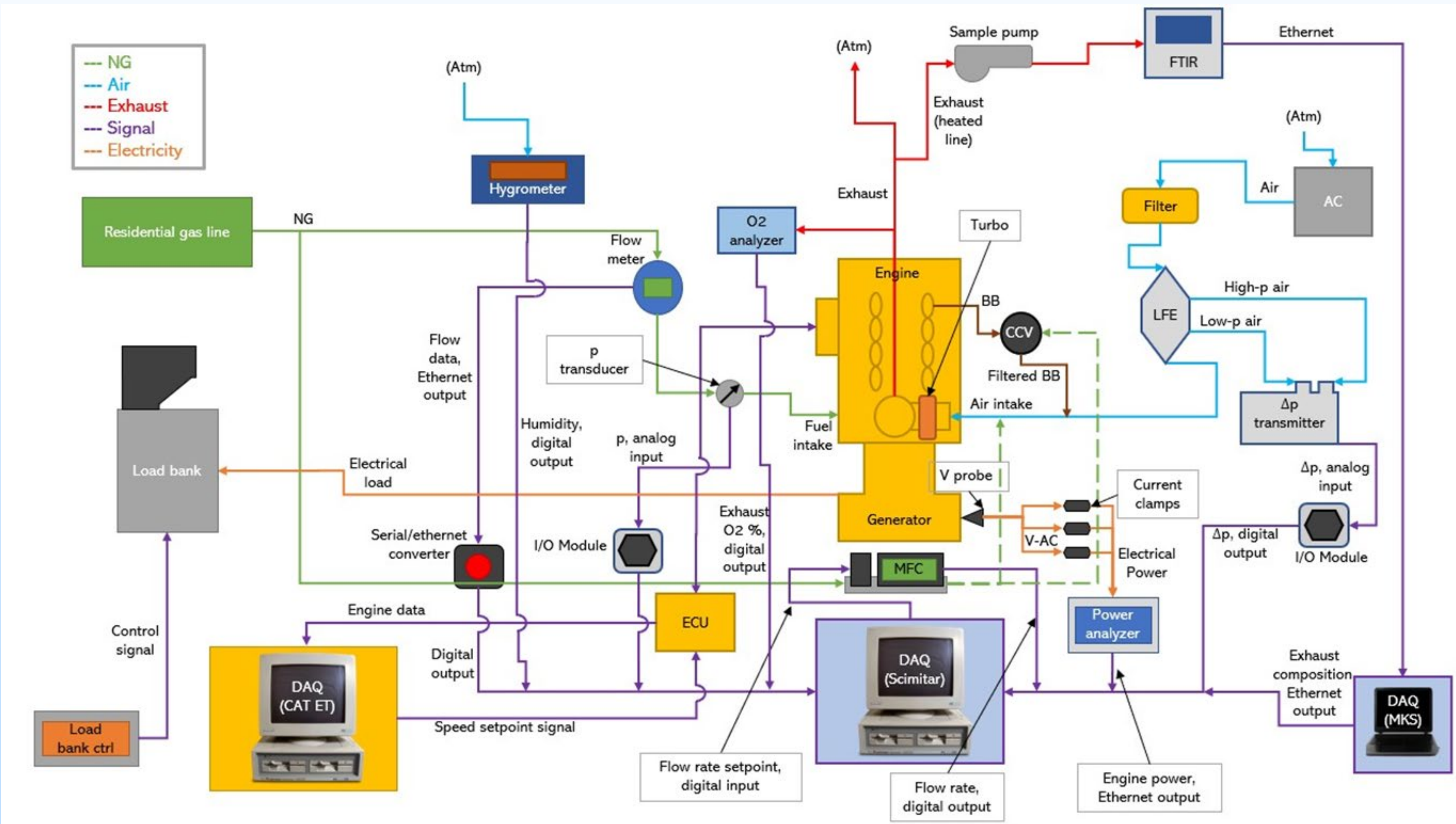
- Engine crankcases – vented to atmosphere
- Compressor vents – vented to atmosphere
- Pneumatic controllers (PCs) – vented to atmosphere
- Liquid storage tanks
  - Condensate tanks – vented to atmosphere, combustor, or VRU
  - Produced water tanks – primarily vented to atmosphere



# Progress and Current Status of Project

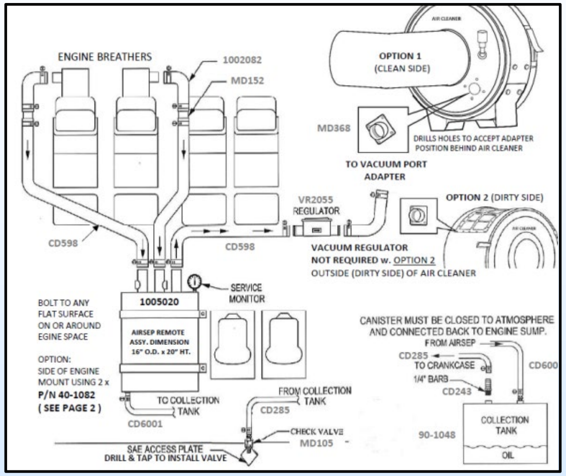
## M$^2$ R&D



# Progress and Current Status of Project

## M² R&D – Baseline and AirSep

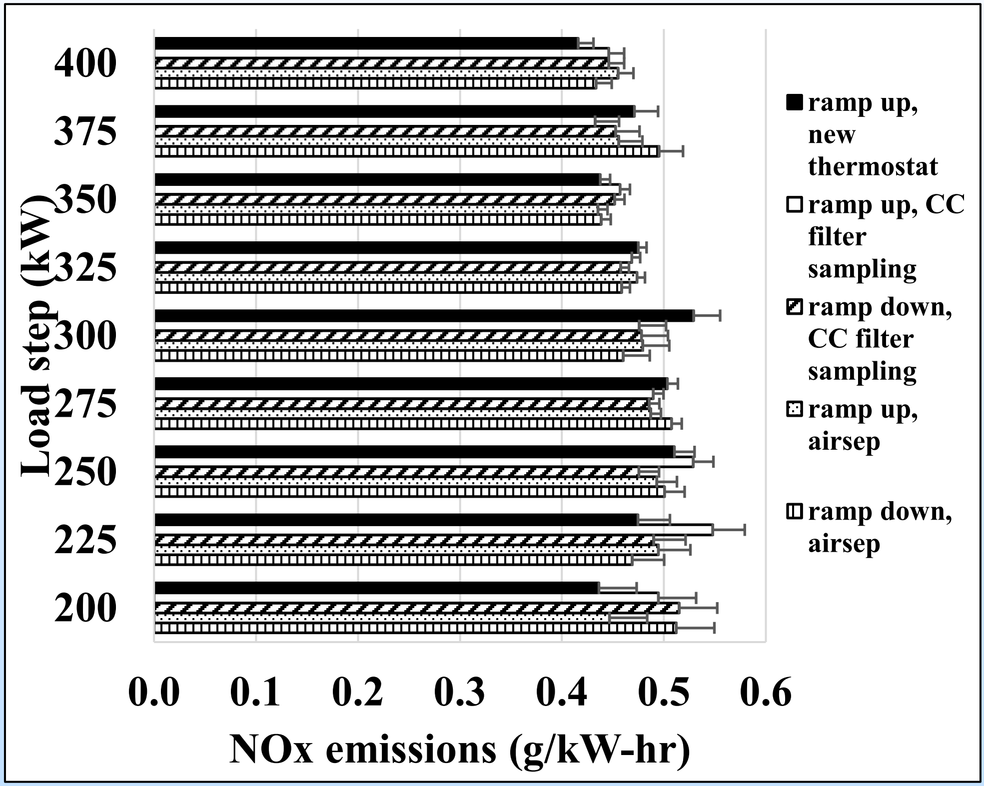
- Baseline testing completed
  - 200 to 400 kW loads
- AirSep durability testing completed (in part)
  - 60 hours running at 300 kW load
  - Collected compressor impeller images to verify oil removal efficiency
  - Pre-AirSep and Post-AirSep oil sampling
  - CCV flowrate determination using LFE




# Progress and Current Status of Project

## R&D – Baseline and AirSep

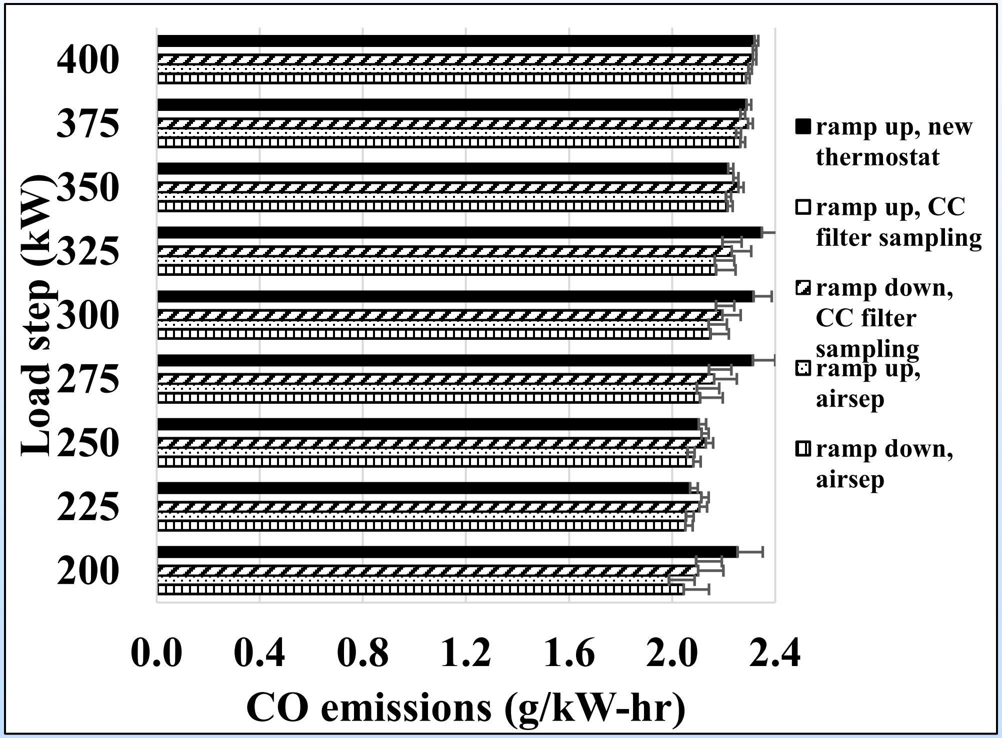
- Baseline testing vs AirSep
  - 200 to 400 kW loads
- Low $NO_x$ standard of 0.67g/kW-hr
- FTIR results show $NO_x$ at or below expected value
- AirSep system did not affect $NO_x$ emissions beyond variations



# Progress and Current Status of Project

## M² R&D – Baseline and AirSep

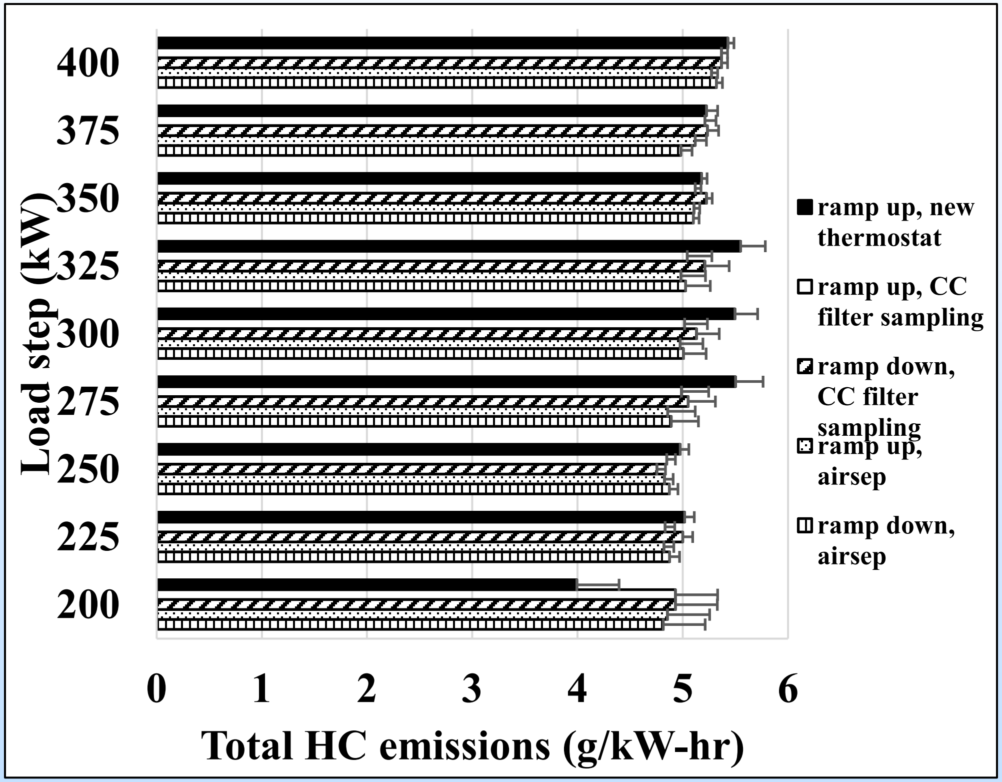
- Baseline testing vs AirSep
  - 200 to 400 kW loads
- CAT data suggests CO to be 3.2 g/kW-hr at rated power
- CO data from FTIR was below expected CO levels for all loads
- AirSep system slightly decreased CO emissions for some load steps but was within the standard deviation bands of baseline tests



# Progress and Current Status of Project

## $M^2$ R&D – Baseline and AirSep

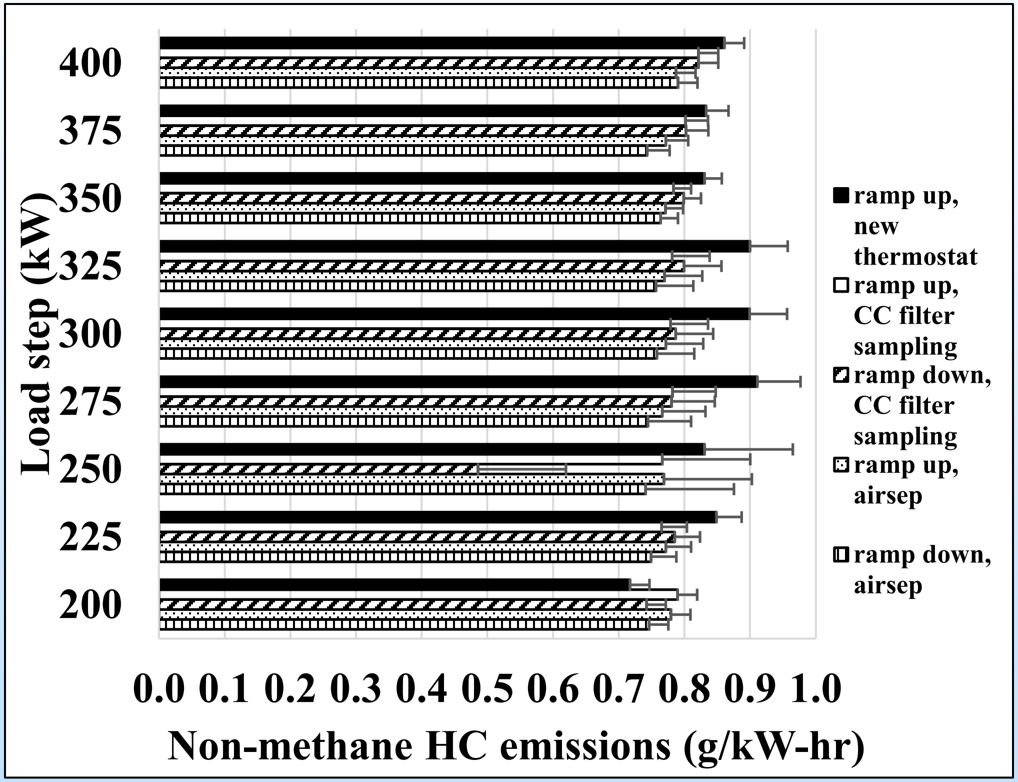
- Baseline testing vs AirSep
  - 200 to 400 kW loads
- THC at rated power expected to be 6.84 g/kW-hr
- Average THC values ~5 g/kW-hr, below expected level
- As expected, majority of HC was methane (>90%)
- AirSep system did not impact THC emissions



# Progress and Current Status of Project

## $M^2$ R&D – Baseline and AirSep

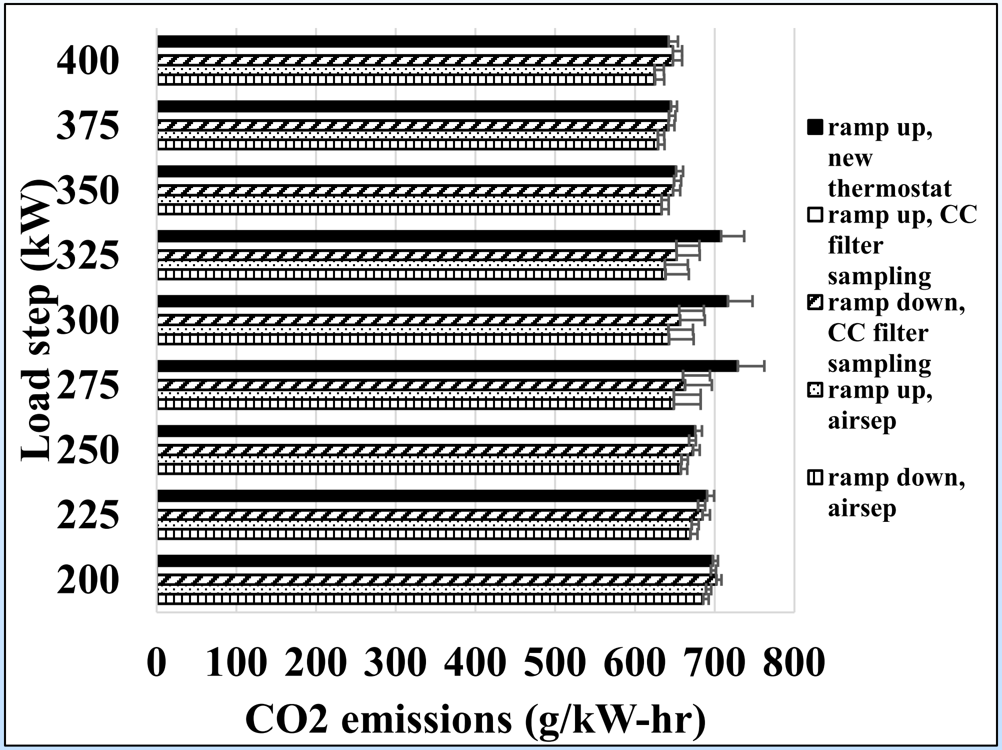
- Baseline testing vs AirSep
  - 200 to 400 kW loads
- NMHC at rated power expected to be 1.0 g/kW-hr
- NMHC data from FTIR varied between 0.7 and 0.9 g/kW-hr
- Likely fuel differences, research fuel was 96% methane with few percent ethane and little to no higher alkanes
- AirSep system slightly decreased NMHC for most load steps but was within standard deviation bands of baseline tests



# Progress and Current Status of Project

## $M^2$ R&D – Baseline and AirSep

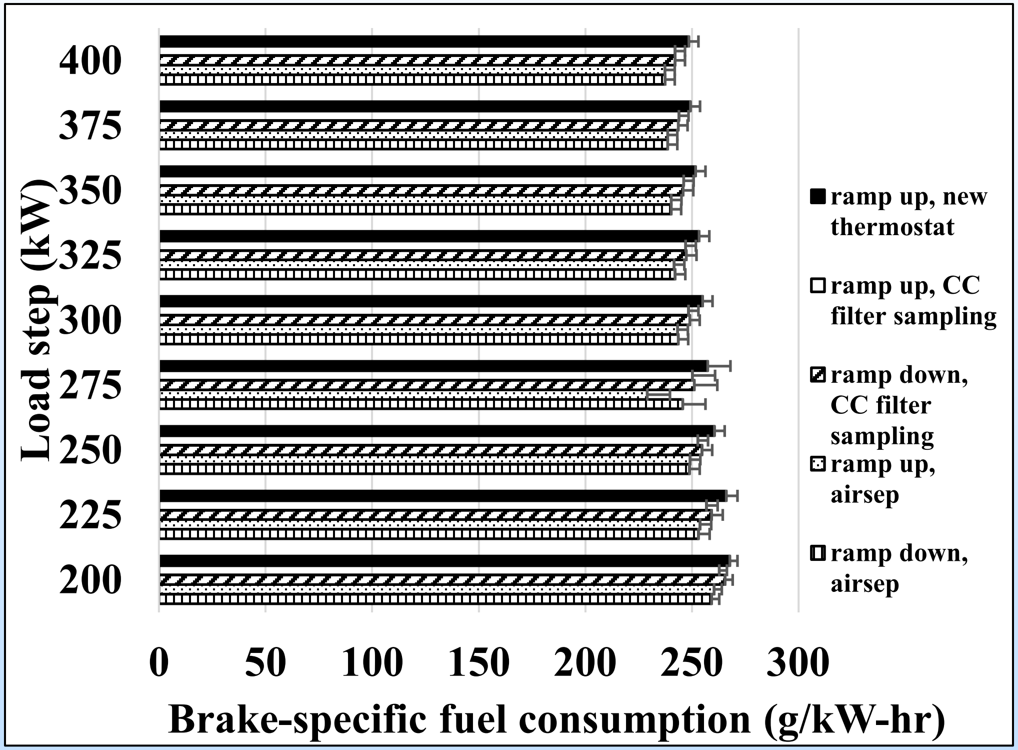
- Baseline testing vs AirSep
  - 200 to 400 kW loads
- $CO_2$ at rated power expected to be 695 g/kW-hr and at 50% load 630 g/kW-hr
- $CO_2$ data from FTIR varied between 700 and 640 g/kW-hr, respectively
- Slight $CO_2$ reductions under review during AirSep tests to determine statistical significance



# Progress and Current Status of Project

## M$^2$ R&D – Baseline and AirSep

- Baseline testing vs AirSep
  - 200 to 400 kW loads
- BSFC expected from CAT data ranges from 268 to 241 g/kW-hr from 50 to 100% load, respectively
- BSFC shows an average reduction of ~2.4% with AirSep installed over the varied load steps
- BSFC reduction attributed to combustible fuel being recirculated back to intake with AirSep installed (methane in combustion blowby)



# Progress and Current Status of Project

## $M^2$ R&D – Baseline and AirSep

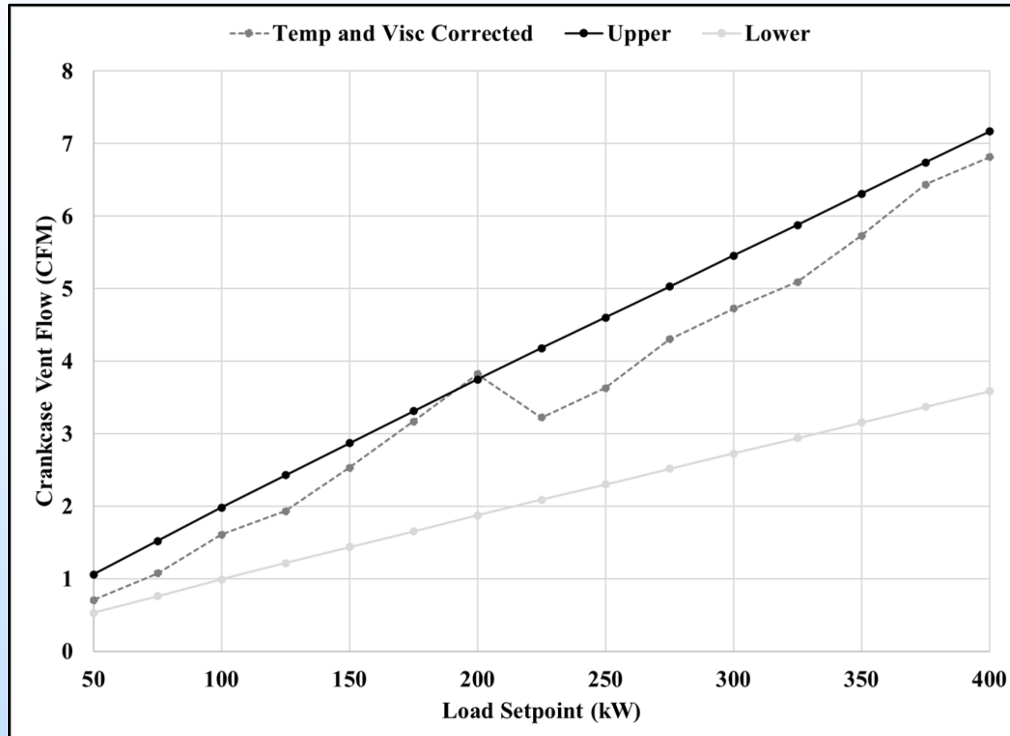
- CAT ET data comparison of baseline and AirSep data at 300 kW load
  - Baseline repeated 5 times
  - AirSep tests repeated 7 times
  - Deviation taken among repetitions
  - 0.4% reduction in fuel flow, 1% increase in intake manifold pressure, and 13.2% decrease in detonation with AirSep installed

| | | AFR act | ECT (F) | NOx (ppm) | Intake Flow (lb/hr) | Engine Load (%) | Oil P (PSI) | Oil T (F) | Speed (RPM) | Thrott Valve DP (PSI) | Fuel Temp (F) | Fuel Valve DP (PSI) | Fuel Valve Pos (%) | Fuel Flow (lb/hr) | Thrott Pos (%) | Intake Manifold P (PSIA) | Turbo Bypass Pos (%) | Turbo Out (F) | Det | Exh Port Cyl 1 (F) | Gas corr factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baseline Repeat statistics | mean | 26.73 | 184 | 74 | 4331 | 72 | 72 | 189 | 1199 | 6 | 80 | 2 | 25 | 156 | 39 | 32 | 20 | 799 | 0.0022 | 1078 | 97 |
| | max | 27.3 | 185 | 118 | 4546 | 76 | 75 | 190 | 1216 | 7 | 82 | 2 | 26 | 163 | 43 | 34 | 27 | 808 | 1 | 1083 | 99 |
| | min | 26.2 | 183 | 46 | 4112 | 67 | 70 | 183 | 1184 | 4 | 75 | 2 | 23 | 150 | 36 | 30 | 15 | 790 | 0 | 1071 | 96 |
| | std | 0.07 | 0.82 | 0.59 | 9.42 | 0.19 | 0.20 | 0.35 | 0.10 | 0.0024 | 1.98 | 0.00 | 0.34 | 0.37 | 0.19 | 0.36 | 1.88 | 3.74 | 0.0006 | 3.36 | 0.30 |
| Airsep Repeat statistics | mean | 26.87 | 184 | 74 | 4338 | 72 | 72 | 189 | 1200 | 6 | 81 | 2 | 25 | 156 | 39 | 32 | 20 | 796 | 0.0019 | 1077 | 97 |
| | max | 27.3 | 185 | 106 | 4539 | 76 | 75 | 190 | 1215 | 7 | 86 | 2 | 26 | 161 | 42 | 34 | 26 | 808 | 1 | 1092 | 98 |
| | min | 26.4 | 183 | 48 | 4154 | 68 | 69 | 181 | 1185 | 5 | 70 | 2 | 23 | 150 | 36 | 30 | 15 | 790 | 0 | 1067 | 96 |
| | std | 0.06 | 0.6 | 0.2 | 14.4 | 0.2 | 0.2 | 0.8 | 0.1 | 0.0 | 2.3 | 0.0 | 0.2 | 0.4 | 0.2 | 0.2 | 0.5 | 4.3 | 0.0009 | 4.89 | 0.34 |
| Percent Diff | | 0.54 | -0.24 | -0.37 | 0.17 | 0.37 | -0.66 | -0.11 | 0.01 | -0.11 | 0.88 | 0.00 | 0.25 | -0.35 | 0.31 | 1.05 | -0.03 | -0.36 | -13.17 | -0.06 | -0.63 |

# Progress and Current Status of Project

## $M^2$ R&D Baseline – CC Understanding

- CCV flowrates and emission analysis
  - FTIR collected emission data of CCV flow
  - Emission rates calculated in g/hr
  - Short term LFE measurements
- High variability in emissions – water concentration in CCV influenced by adsorption from oil in crankcase and did not directly increase with load
- Higher fractions of blowby gas at higher loads increase $CO_2$ and $CH_4$

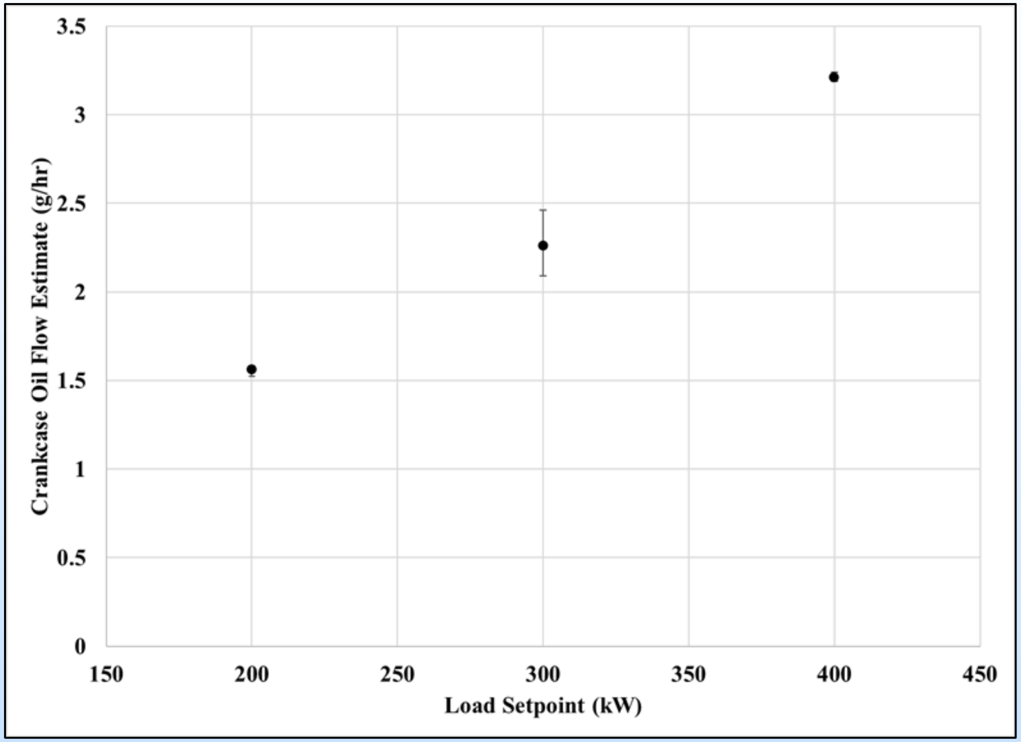



| | | | | |
|---|---|---|---|---|
| H2O | max | [illegible] | [illegible] | [illegible] |
| | mean | 339 | 279 | 302 |
| | std dev | 49 | 33 | 18 |
| | CoV | 0.14 | 0.12 | 0.06 |

# Progress and Current Status of Project

## $M^2$ R&D

- CCV out oil concentration and AirSep oil concentration reduction
  - Oil collected on weighted filters for analysis
  - Measured flow and 5-minute duration for sample mass
  - Pre-AirSep oil sample over saturated the filter
  - Repeat of Pre-AirSep sample collection with shorter duration required, will likely increase filter efficiency to above 99%

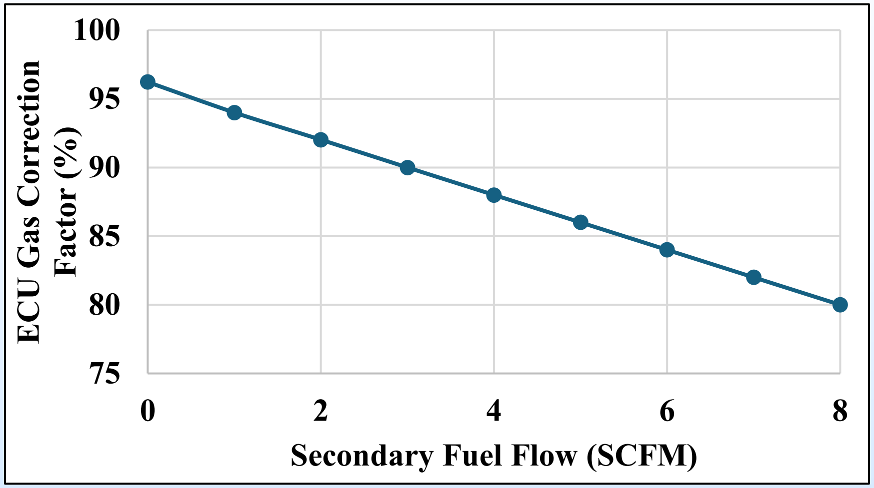


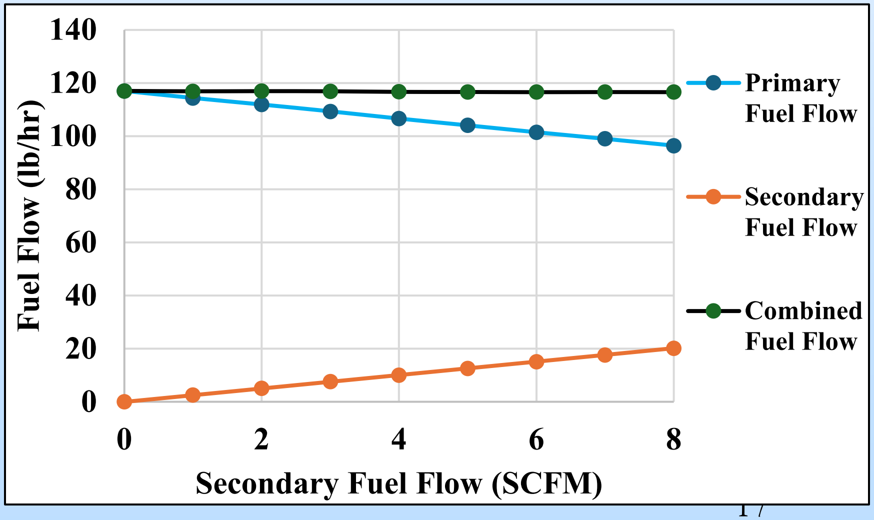

| Load step (kW) | Oil Removal Efficiency (%) |
|---|---|
| 200 | 95.8 |
| 300 | 96.6 |
| 400 | 96.9 |

# Progress and Current Status of Project

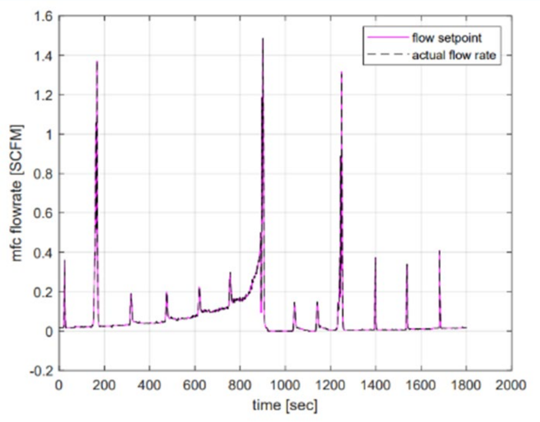
## $M^2$ R&D – Compressor Vent "Fuel Stream"

- Impact of adding secondary fuel source to engine intake
  - 1 SCFM increments (key points of 2, 4, 6, etc. to match OOOOb and California compressor limits)
  - Reduction in primary fuel flow equal to the amount added as secondary fuel, total fuel flow remains 116-117 lb/hr
  - Engine changes the gas correction factor in response, assumes fuel quality is changing rather than additional fuel delivery
  - $NO_x$ remains stable (+/- 0.3 ppm), engine load stable (+/- 0.6% engine load), slight increase in intake manifold pressure (+0.2 PSIA at 8 SCFM secondary fuel flow)



# Plans for future testing/development/ commercialization




a. In this project
   - Continued AirSep Evaluations
   - Continued Compressor Vent "Fuel" Supplementation (Direct)
   - Direct PC Admission Cycles
   - Compressor and PC Admission – to "AirSep"
   - Redesigns – oil rates, passive control (check valves and fail safes)

b. Other funding for continued R&D – refinement
   - Focus on only CCV and closed compressor vents ($CCV^2$)
   - Field deployments on multiple "engine" platforms

c. Scale-up potential, if applicable
   - Current/future modeling to highlight savings
   - https://netl.doe.gov/sites/default/files/netl-file/Brun.pdf
     - +15,000 upstream prime movers (small to large engines and compressors)
       - Most units 4SLB < 2000 hp
     - 800-900 boosting stations
     - 850 – 900 mainline compressor stations

# Summary Slide

## Methane Mitigator

- Verified industry rules of thumb
  - Engine crankcase total vent rates – including compositions
  - Total compressor vent emissions – including compositions
  - Verified and expanded on PC vent rates and behavior (6-7 continuous days)

- Tanks complex – highly transient in flows and compositions and condensate tanks may be limited due to MN/HV

- Redeveloped a large, dedicated natural gas engine research laboratory

- High potential – 95% (combustion efficiency) reduction in engine crankcase and compressor vents (steady)

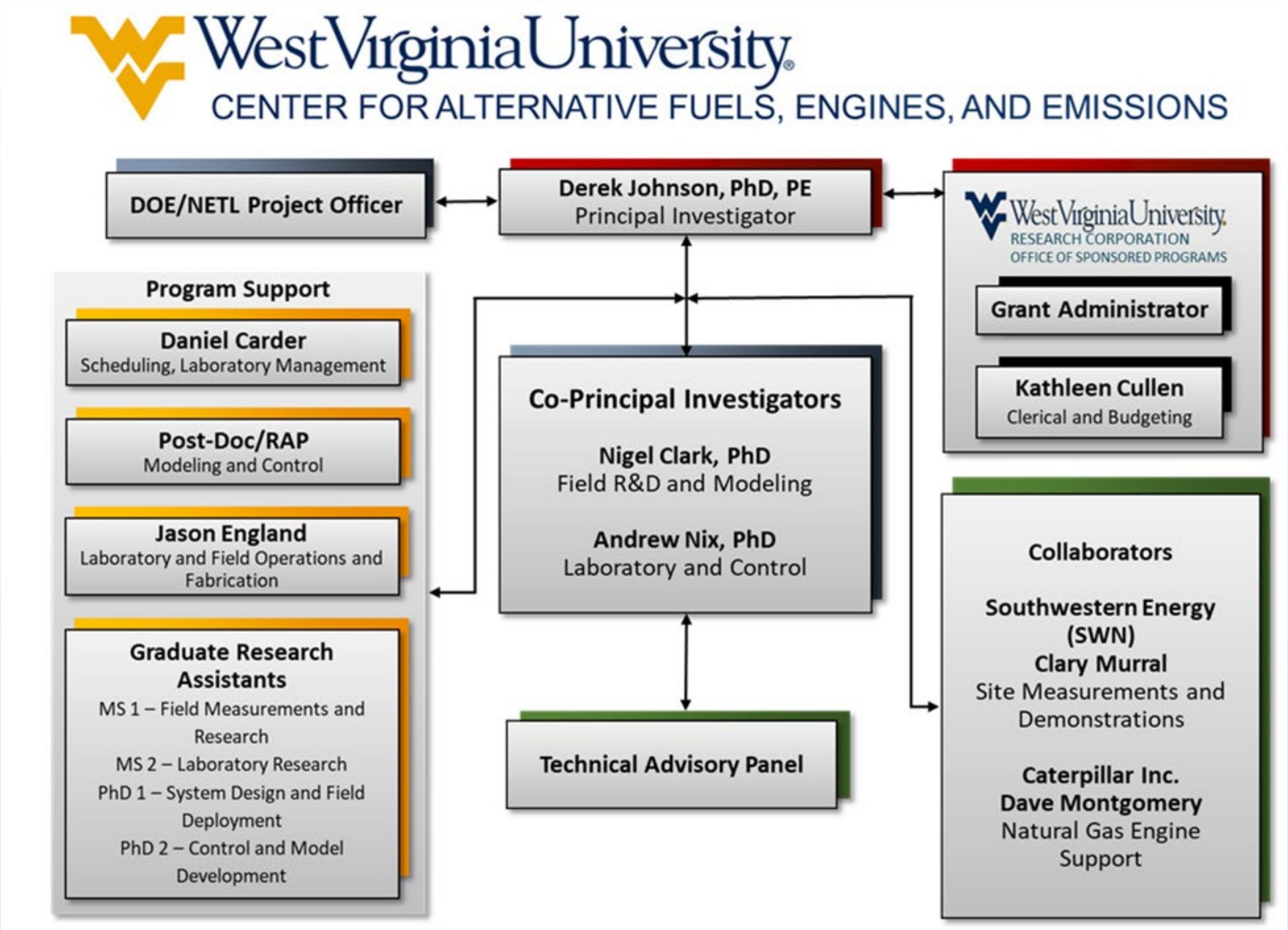
- Current commercial closed crankcase systems
  - No negative impacts on regulated emissions
  - No negative impacts on engine operation (to date)
  - Oil removal efficiency high (>90%) but may be lower than advertised (99%)

# Appendix

– These slides will not be discussed during the presentation but are mandatory.

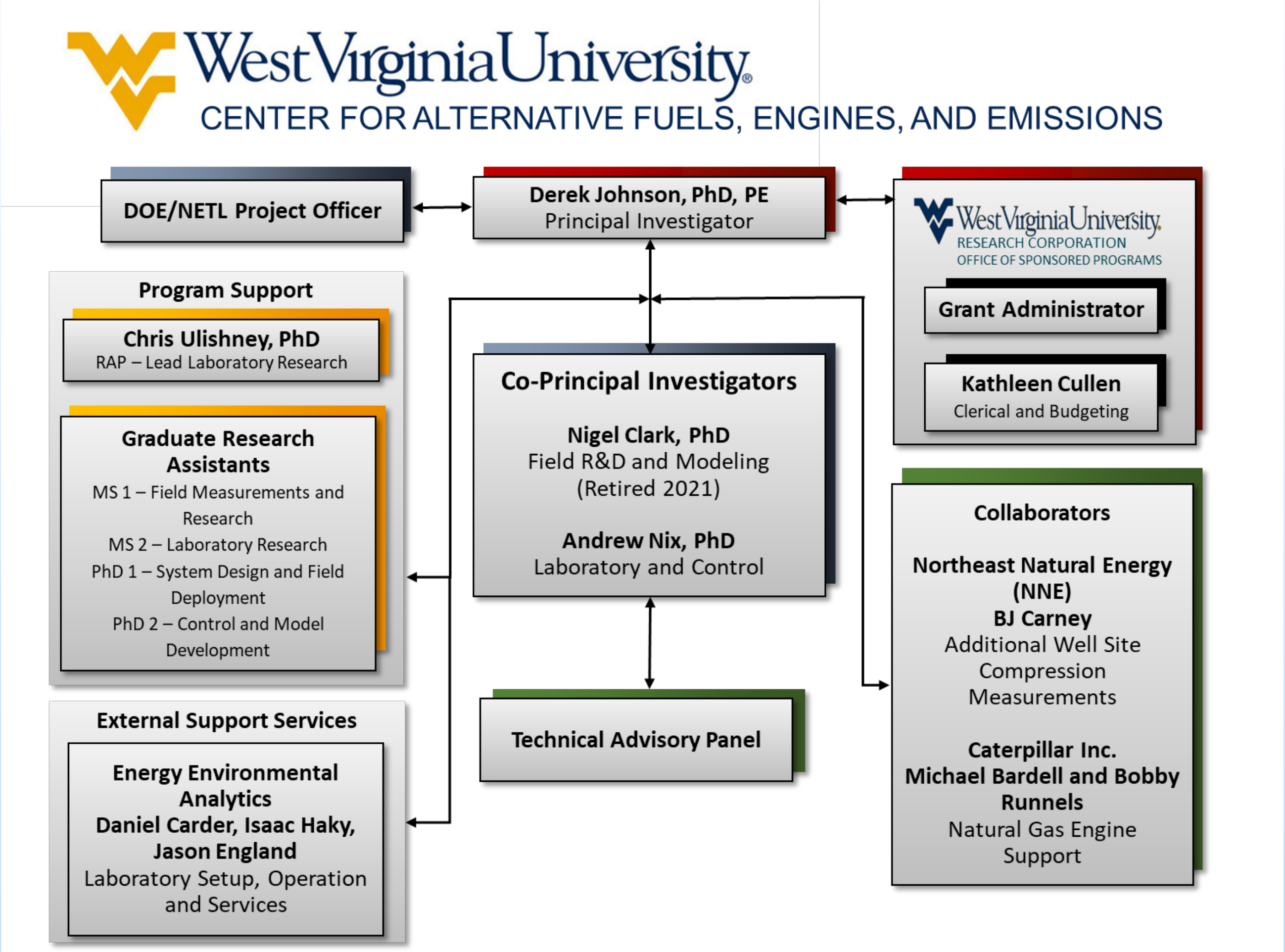
# Organization Chart

Original Organization



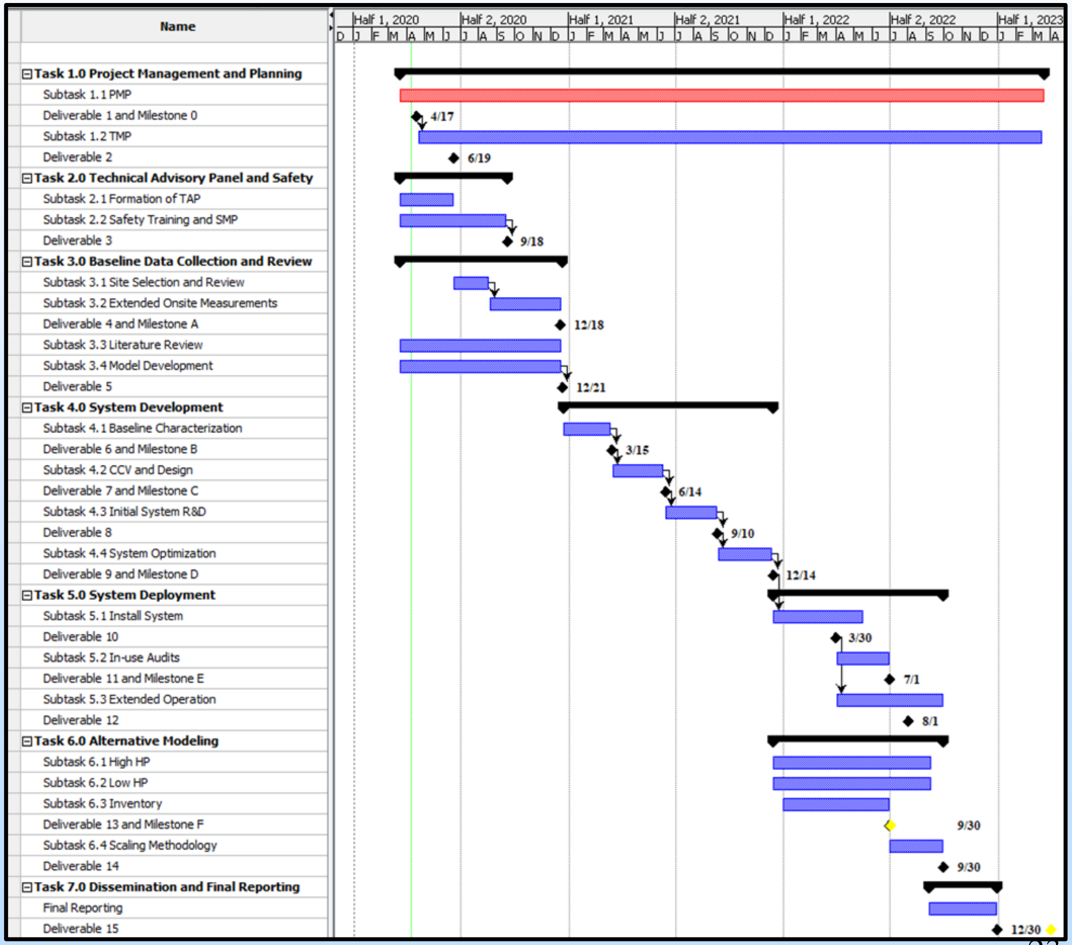
# Organization Chart

Final Organization



# Gantt Chart

- Original Gantt Chart



# Gantt Chart

- New Gantt Chart – BP 2 and 3 Focus