GE Simple Cycle Turbines: VOC, Filterable and Condensable PM Test Results

Great River Energy
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Agenda

• GRE Overview
• Total Hydrocarbon (THC) Tests
• Particulate Matter (PM) Tests
• Conclusion
GRE Overview

- 4th largest G&T in the nation
- 28 Member Coops w/ ~1.7MM people
  - 3.7 billion in assets
  - 921.2 million in revenue
  - 880+ employees in MN and ND
  - ~3,600MW Generation
    - 468MW Wind
  - 4,600+ miles of transmission
A diverse mix of generation

2012 capacity by fuel type

Coal 46%
Natural Gas 39%
Oil 3%
Hydro 8%
Purchases - Other Contracts 2%
Renewable 2%

2012 energy sources

Coal 70%
Natural Gas 3%
Oil 0%
Renewable 11%
Purchases - Other Contracts 4%
Hydro 12%
Generation

- **Baseload Plants**
  - Coal Creek 1,100 MW
  - Stanton 180 MW
  - Spiritwood Station 99 MW
  - Genoa #3 170 MW

- **Biomass**
  - Elk River Station 30 MW

- **Peaking Plants**
  - 110 MW Oil Only (4 plants)
  - ~1400 MW Gas-Fired (4 plants)
Lakefield Junction Station

• 6 GE 7EA Simple Cycle Combustion Turbines
  – 2001 start of commercial operation
  – Natural gas, with fuel oil as secondary
• Load range ~45-85MW
• Dry Low NOx Burners (DLN)
  – 9ppm BACT NOx limit
Emission Guarantees and Permit Limits

- Vendor emission guarantees
  - Natural gas: THC <6ppm@15%O2
  - Natural gas: PM10 <10 lb/hr
- Title V Permit incorporates emission guarantees as BACT limits
  - Periodic stack testing required to demonstrate compliance
3 Hypotheses

1. Total hydrocarbons (THC) are correlated to carbon monoxide emissions
2. Total hydrocarbons are correlated to unit load (MW)
3. PM10 = PM2.5
THC Test Overview I

- 2003 – All at 100% Load
- 2008 – Min, Mid and Max Loads
- 2013 – Min, Mid and Max Loads
THC Test Overview II

- EPA Method 25A
  - TECO Monitors – Model 51HT
  - Stack temp ~1100F
  - ~1 hour run w/ load held constant
  - Propane as cal gas

- 2013 Observations
  - Monitor switch mid run
  - ‘Background’ 2-4ppm?
Hypothesis 1 – 2013 THC v. CO
Hypothesis 1 – 2008 THC v. CO

2008 THC v CO

THC ppm @ 15% O2 vs. CO ppm @ 15% O2

- Linear (CT1)
- Linear (CT2)
- Linear (CT3)
- Linear (CT4)
- Linear (CT5)
- Linear (CT6)
Hypothesis 1 – 2003 THC v. CO

2003 THC v CO

THC ppm @ 15% O2

CO ppm @ 15% O2

CT1
CT2
CT3
CT4
CT5
CT6

Linear (CT1)
Linear (CT2)
Linear (CT3)
Linear (CT4)
Linear (CT5)
Hypothesis 2 – 2013 THC v. Load

![Graph showing THC ppm @ 15% O2 vs Load (MW) for different CTs (CT1 to CT6)]
Hypothesis 2 – 2008 THC v. Load

2008 THC v Load

- THC ppm @ 15% O2
- Load (MW)
- Linear (CT1)
- Linear (CT2)
- Linear (CT3)
- Linear (CT4)
- Linear (CT5)
- Linear (CT6)

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THC Summary Issues

• Monitor accuracy/​span?
  – 2003 – 0-11ppm
  – 2008 – 0-49ppm
  – 2013 – 0-100ppm

• Ambient or ‘background’ influences?
  – Fuel oil testing prior to THC?

• Inherent engine differences?

• Auto-tune installed 2009?

• Variable/transitional load?
PM Test Drivers

• 2009 pending permit provision for PM2.5
• No site specific test data
• Vendor assumption that PM10 = PM2.5
• Potential PSD threshold issues, if units modified
  – 15tpy v 10tpy

Particulate Matter < 2.5 micron: less than or equal to 10.0 lbs/hour using 3-hour Average while burning natural gas.
Hypothesis 3 – PM10 = PM2.5

- 3 units tested
- ~4hrs per test run needed for sufficient volume
- PM Tests during RATA
  - Multiple stable loads
- EPA Method 5: Filterable
- EPA OTM-028: Condensable
<table>
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<tr>
<th>PM Concentration (gr/dscf):</th>
<th>Filterable</th>
<th>Aqueous Condensible</th>
<th>Organic Condensible</th>
<th>Total:</th>
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<td>PM Emission Rate (lb/hr):</td>
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<td>Filterable</td>
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<td>Organic Condensible:</td>
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<td>PM Emission Rate (lb/MMBtu):</td>
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<td>Total:</td>
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<td>Isokinetic Variance</td>
<td>96.6</td>
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Filter did not contain enough mass for PSD analysis
PSD Performed on probe rinse

Particle Size Distribution (mass)

Geometric Mean Size: 15.69 μm
Geom. Std Deviation: 2.378 μm
Geom. Skewness: -0.436
Geom. Coeff Variation: 15.16
Arithmetic Mean Size: 22.35 μm
Median Size: 15.54 μm
Mode Size: 16.72 μm
Kurtosis: 3.805
Arith Std Deviation 20.87 μm

-- PERCENTILES --
0.100% Volume above 115.6 μm
1.000% Volume above 94.06 μm
6.000% Volume above 61.03 μm
22.00% Volume above 31.79 μm
50.00% Volume above 16.07 μm
78.00% Volume above 7.622 μm
94.00% Volume above 3.994 μm
99.00% Volume above 2.199 μm
99.50% Volume above 1.282 μm
PM Summary

- Filterable test results likely impacted by rust/debris in stack
  - Would results have been different if longer warm up time allowed?
  - ~1hr ‘startup’ prior to tests following an outage
- Condensable PM was less than filterable
  - Without ‘rust’ influence, would condensable emissions have been closer to filterable?
- Would more variable load have influenced results?
Hypotheses

1. Total hydrocarbons (THC) are correlated to carbon monoxide emission
2. Total hydrocarbons are correlated to unit load (MW)
3. PM10 = PM2.5?