Exhaust Emissions from a CNG Ferry

Sponsored By:

MARAD

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Navsea Philadelphia

Hampton Roads Transit Authority

Comparison of exhaust emissions from two ferries

- Owner: Hampton Roads Transit Authority
- Location: Elizabeth River, Norfolk/Portsmouth, VA
- Ferries have similar sizes and hull shapes
- One ferry converted from diesel to CNG in 1995

Ferry Details

- MV James C Echols (JCE)
  - Twin Cat 3406-G, natural gas fueled engines
  - Certified for 138 passengers
- MV Elizabeth River II
  - Twin Detroit Diesel 671, diesel fueled engines
  - certified for 151 passengers
- Both engines have similar fuel consumption and brake horsepower

Study Objectives

- Conduct in-use emissions testing to determine environmental benefits of ferry conversion to CNG
- Compare West Virginia University's portable laboratory grade testing equipment to new EPA portable instrumentation
- Follow ISO and CFR standards/specifications for measurement & precision
- Comparison of operating economics

Measured Parameters

- Particulate mass
- Gaseous emission analysis
  - NOx, CO, CO_2, HC
- Fuel mass flow rate
- Intake Air & exhaust flow rates
- Shaft speed/torque
- Additional signals
  - air temperature, pressure, humidity
- EPA Method

Fuel & Oil Analyses

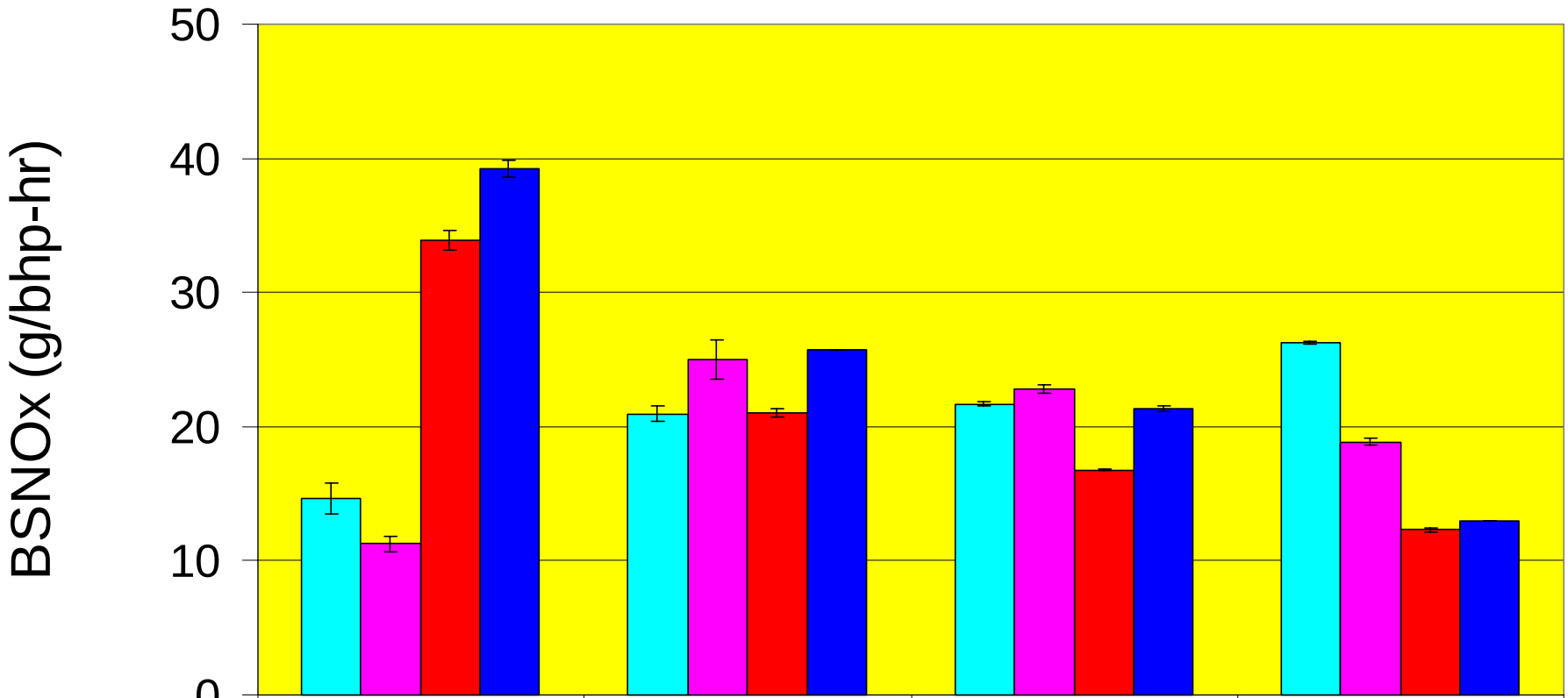
- Diesel and gas analyses typical
- JCE Oil Analysis
  - Starboard - High Tin - Wear Indicator
  - Port - High Tin - Wear Indicator
- ERII Oil Analysis
  - Starboard - High Tin - Wear Indicator
  - Port - High Water - Coolant Leak Indicator

SIERRA

Test Scheme

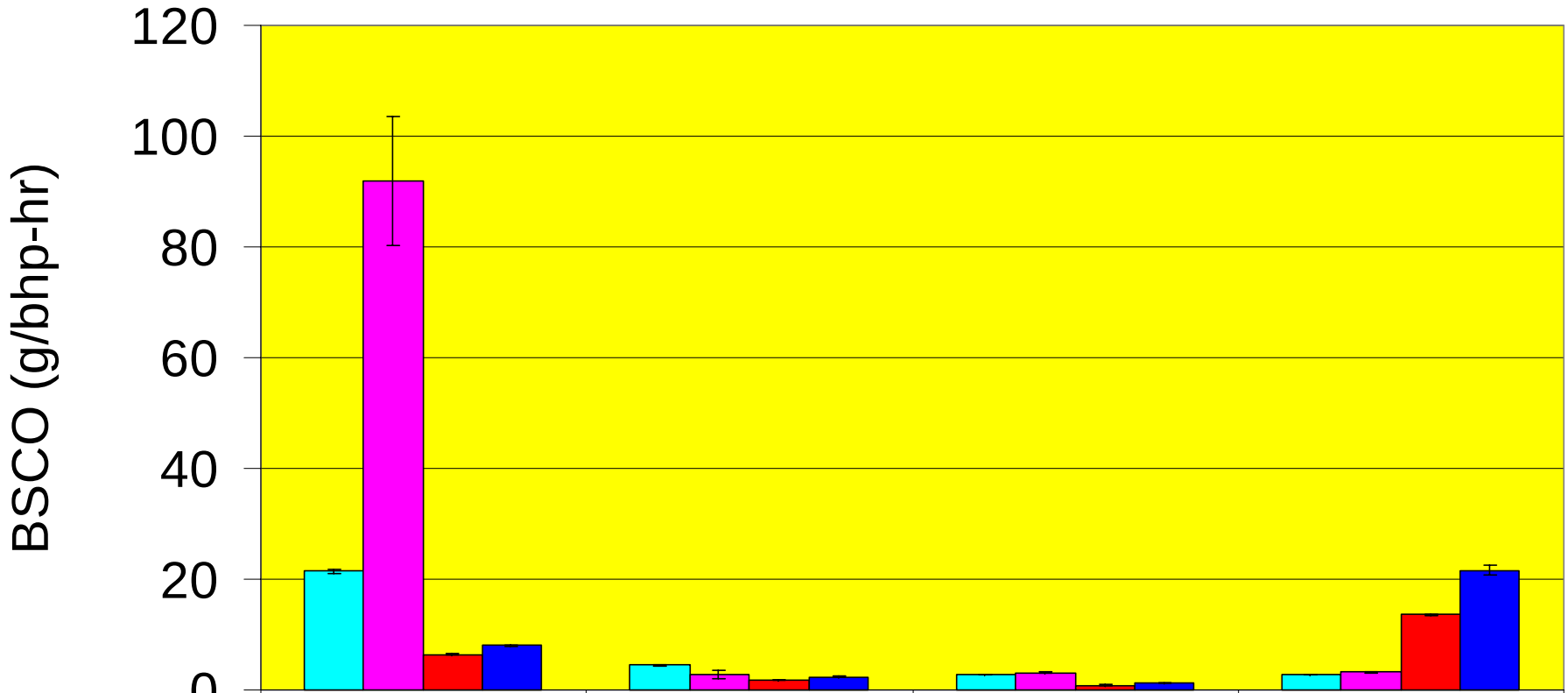
- Constant Speed Measurements
  - Idle, 40%, 60%, 80%, 100%
- Transient Measurement
  - Average emissions over one circuit of the ferry route 1.37miles
- Lean Burn Setback Experiment

NOx



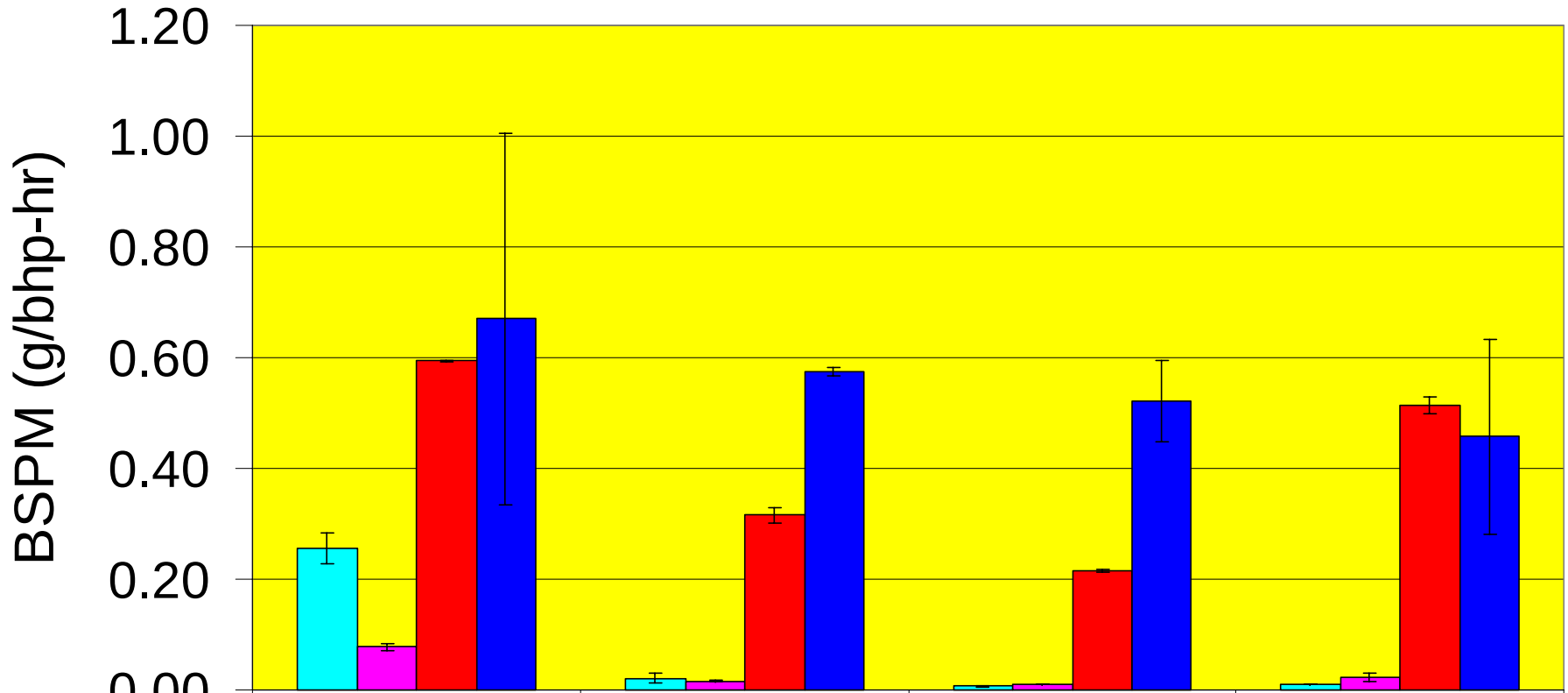
	40% Spd	60% Spd	80% Spd	100% Spd
JCE-S	14.66	20.96	21.70	26.25
JCE-P	11.25	25.02	22.79	18.83
ERFII-S	33.86	21.04	16.77	12.31
ERFII-P	39.24	25.76	21.37	12.98

CO



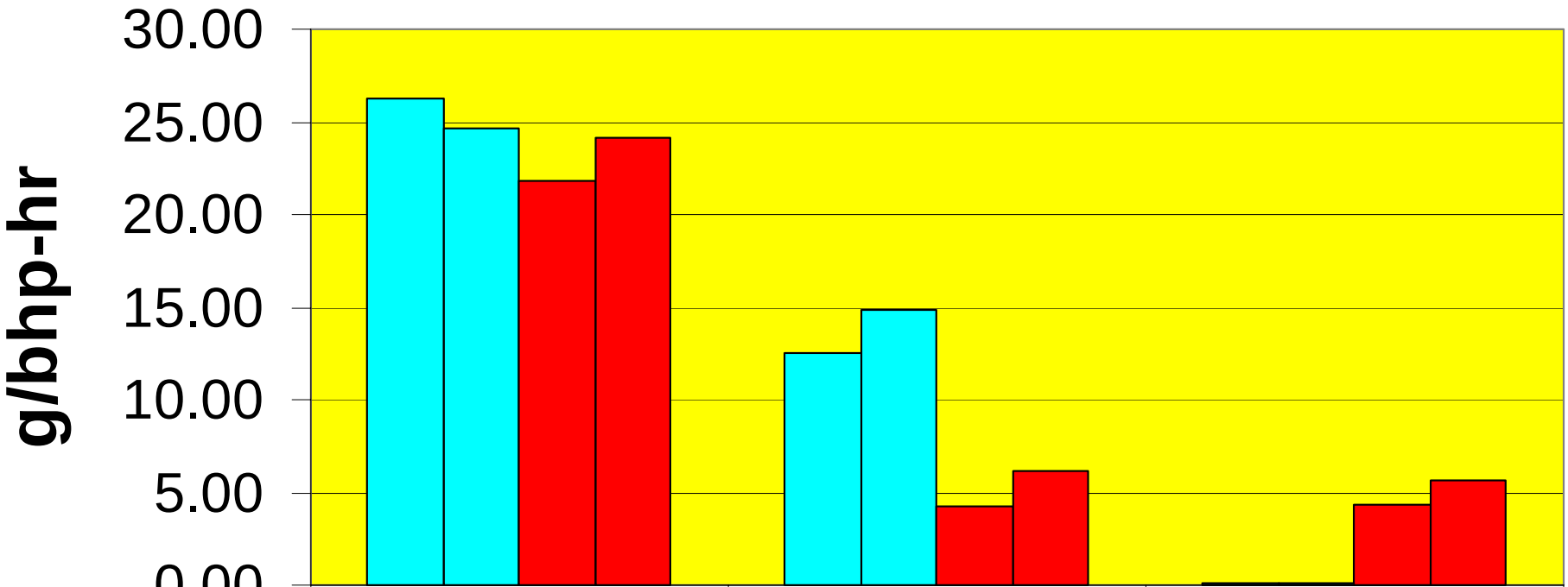
	40% Spd	60% Spd	80% Spd	100% Spd
JCE-S	21.40	4.46	2.77	2.85
JCE-P	91.92	2.86	3.12	3.19
ERFII-S	6.43	1.68	0.86	13.64
ERFII-P	7.98	2.40	1.32	21.64

Particulates



	40% Spd	60% Spd	80% Spd	100% Spd
JCE-S	0.2554	0.0214	0.0066	0.0094
JCE-P	0.0774	0.0160	0.0112	0.0226
ERFII-S	0.594	0.315	0.216	0.514
ERFII-P	0.671	0.574	0.521	0.457

Transient Emissions



	NOx_1	CO	PM x 10
JCE-P1	26.24	12.507	0.118359947
JCE-P2	24.68	14.829	0.080707588
ERFII-P1	21.82	4.283	4.333926121
ERFII-P2	24.10	6.181	5.647470569

Lean Set Back Operation

	Normal Operating	Lean Burn Setback
Air Fuel Ratio	19.9	31.6
Engine RPM	1841	1463
Engine Power (bhp)	163	76.5
CO (g/bhp-hr)	3.15	5.31
NOx (g/bhp-hr)	18.8	0
PM (g/bhp-hr)	0.022	0

Summary of Data

- Compared to diesel, gas engine emissions have:
  - 10-100x lower particulates
  - 2-3x higher CO
  - Approximately the same NOx

Other Observations

- Cannot just retrofit a vessel with a gas engine and automatically improve over diesel
- Vessels need to be designed as whole system to get optimum RPM/Power and match engine power to transmission and propeller
- Gas fueled engine needs to be properly tuned.Local Cat dealer is not an expert with gas engines

Recommended Action

- Replace air/gas mixer and install oxygen sensor in the exhaust stream
- Add closed loop control to allow precise control of air/fuel mixture
- Install
- Adjust engine for optimum power and minimum emissions
- Add permanent instrumentation to measure engine condition