Measurement of the Energy Use and Emissions of Passenger Rail Locomotives

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NCDOT Passenger Rail Service

The *Piedmont* provides service between Raleigh and Charlotte, NC

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Policy Issues for Passenger Rail Service

- What are the baseline emissions from the locomotives?
- What is the effectiveness of engine rebuilds in reducing emissions?
- What is the effect of switching to soy-based B20 biodiesel?
- How do emissions compare to avoided highway vehicle usage?

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NCDOT Motive Power: 1968 GP40

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NCDOT Motive Power: 1997 and 1998 F59s

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Passenger Locomotives

- **Prime Mover** Engine-Generator
  - Generates direct current for traction motors
  - 3,000 hp 2-stroke diesel engines for all 3 locomotives
  - "Dynamic braking" electrical resistance grid: can reject some electrical power as heat
- **Head-End Power (HEP)** Engine-Generator
  - Generates alternating current for "hotel services" in the passenger cars (lighting, air conditioning, heating)
  - 600 to 625 hp 4-stroke diesel engines

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Locomotive Operation

- **Prime Mover**
  - RPM and load depends on throttle notch. position, including idle and 8 increments up to full load.
  - Engine operates between approximately 100 and 900 RPM.
- **Head-End Power**
  - Synchronized with A/C generator.
  - Operates at constant 1,800 RPM.
  - Load depends on demand for hotel services.

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Engine Characteristics

Item	NC 1755 and NC 1797 (F59)		NC 1792 (GP40)	
	Prime Mover	HEP	Prime Mover	HEP
Engine Model	EMD 12-710G3	CAT 3412	EMD 16-645E3	Cummins KTA19
Strokes	2	4	2	4
Cylinders	12	12	16	6
Displacement (L)	140	27	169	19
Horsepower (hp)	3,000	625	3,000	600

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Railyard "Idle" Tests

- All measurements reported here were conducted at NCDOT's rail yard in Raleigh, NC
- The locomotives were stationary
- Prime Mover load was rejected to the dynamic braking grid
- Grid gets very hot at Notch Settings 6, 7, and 8: limits the duration of operation at these settings
- Head-End Power load was simulated by connecting passenger cars, turning on lights and space conditioning, and measuring electrical current (at 480 volts).

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Instrumentation

Portable Emission Measurement System

- Montana system
- Clean Air Technologies International, Inc.
- Two 5-gas analyzers in parallel
- One laser-light scattering photometer for relative PM levels
- Engine sensor array for engine RPM, Manifold Absolute Pressure, and Intake Air Temperature

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Logistics of Instrumenting the Locomotives

- HEP engines have a tailpipe with which existing sample probes can be used.
- Prime Mover engines have a duct. Mechanic developed a fitting from which to sample exhaust gases.
- Mechanic created ports from which Manifold Absolute Pressure could be measured.
- Temperatures in the engine compartment get too high for the main unit of the PEMS. Positioned the PEMS on a forklift next to the locomotives.
- Used shorepower for the PEMS.
- Mechanic arranged coupling of passenger cars to simulate “hotel service” loads.
- Engines were operated by mechanic according to standard railyard idle test procedures.

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Positioning of PEMS Main Unit

F59

GP40

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Examples of Sampling Location for Exhaust: Prime Mover and HEP Engines

GP40

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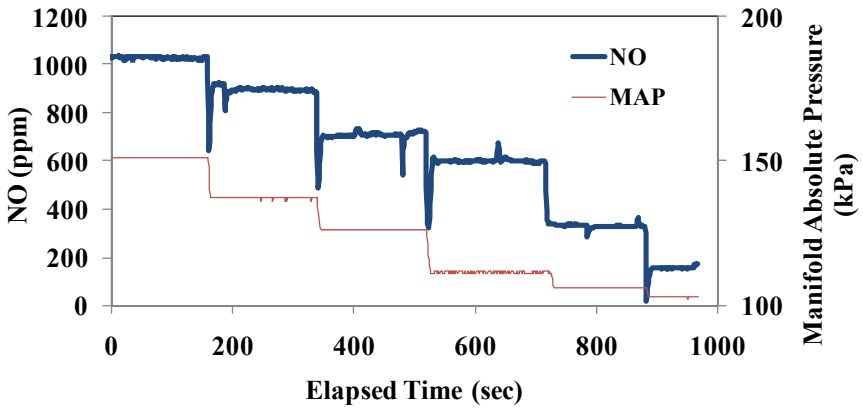
Example of Measured Data: NC 1755 (F59) Prime Mover, Notches 5 to idle



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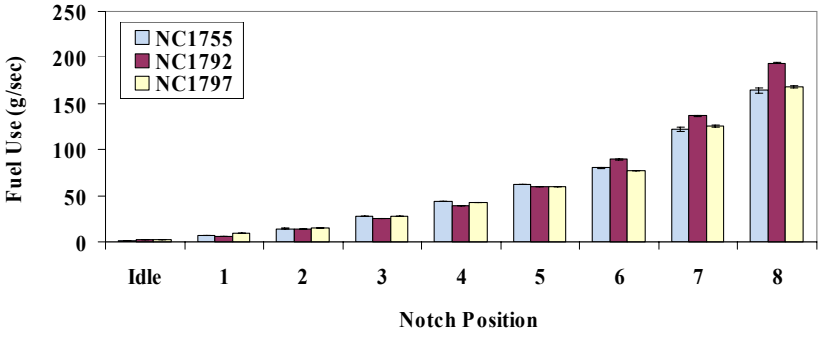
Example Results: Prime Mover Engine Estimated Fuel Use



NC 1755: F59

NC 1792: GP40

NC 1797: F59

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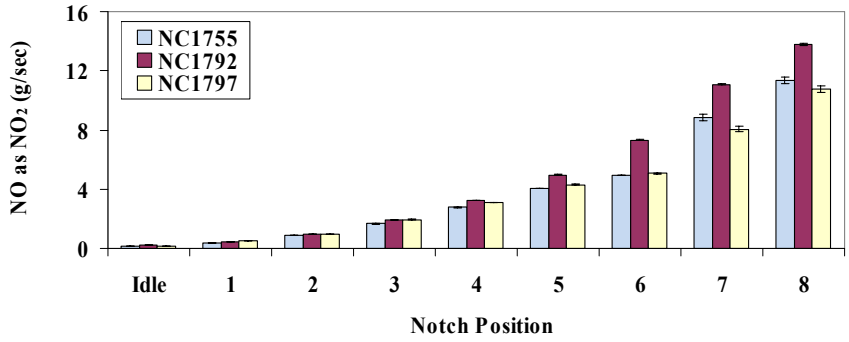
Example Results: Prime Mover Engine NO Emission Rate



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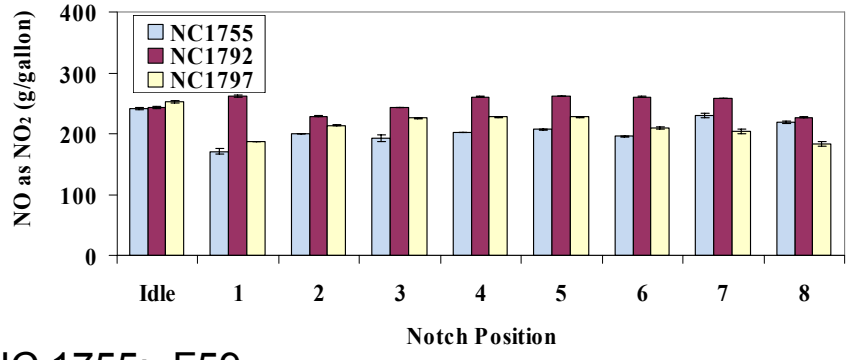
Example Results: Prime Mover Engine Fuel-Based NO Emission Rate



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Comparison of Line-Haul Cycle Average Fuel-Based Emission Factors to Benchmark Data

		NO_x[a] (g/gal)	HC (g/gal)	CO (g/gal)	PM[b] (g/gal)
NCSU	NC 1755	215	1.9	11.0	0.5
	NC 1792	236	3.5	12.6	0.5
	NC 1797	207	4.7	45.0	0.5
EPA	Minimum	215	3.1	10.8	5.0
	Maximum	323	15	50.8	8.5
	Weighted Average	261	10	31.8	6.3

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Findings

- The use of PEMS to assess ***relative*** variations in fuel use and emissions is appropriate.
- PEMS reports reasonable **absolute magnitudes** of emission rates for NO and CO.
- The reported HC emission rates are consistent with other data, taking into account that NDIR responds partially depending on the mix of HC species.
- The PM detector is assumed to be a qualitative indicator of relative PM levels and not capable of reporting accurate magnitudes

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Conclusions

- Baseline modal fuel use and emissions have been measured for 3 passenger rail locomotives, including 3 prime mover and 3 head-end power engines.
- The results are consistent with reported emission factors from other studies, when compared on a fuel-basis
- Regulatory emission factors are in g/bhp-hr, which are not directly measured here but can be estimated from typical or engine-specific brake-specific fuel consumption data.
- The method demonstrated here is relatively inexpensive and enables a small railroad to assess trends and evaluate effectiveness of emissions reduction strategies.
- Lessons learned from the initial measurement campaign will inform data collection procedures for over-the-rail tests

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Future Plans

- All three locomotives are currently having prime mover engine rebuilds. Two are currently having HEP engine rebuilds.
- Establish new baseline after rebuilds.
- Compare B20 versus petroleum diesel.
- Over-the-rail testing of actual duty cycles.
- Comparison of over-the-rail fuel use and emissions on a per passenger basis to avoided highway vehicle fuel use and emissions.

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Acknowledgments

DISCLAIMER

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Questions?

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