NCDOT Locomotive Emissions Improvement Via Selective Catalytic Reduction

Mr. Lynn Harris
BS Nuclear Engineering, NCSU

Sr. Project Engineer
McDowell Engineers & Assoc. / NCDOT Rail Div.

Topics of Discussion

- Piedmont Service Overview
- Current Scope of Operations
- Alternate Fuels Research
- Emissions Treatment System
- Future Projects

Piedmont Program Overview

- NCDOT Rail Division is equipment owner/maintainer for Piedmont passenger rail service
  - Operated by Amtrak
  - Dispatched by Norfolk Southern

- Two daily round-trip trains between Raleigh and Charlotte, NC
  - 173 miles (278 km) each way
  - Nine total stops
  - 3 hrs 15 minutes travel time each way

Piedmont Corridor

Piedmont Fleet Size

- Six (6) locomotives in fleet, eight by end of 2016
  - F59PH and PHI units
  - Originally EMD-built GO Transit units
- 19 passenger cars, 22 by end of 2017
  - 6 lounge cars, 16 coach cars
  - Originally built 1950's / 60's by Pullman & St. Louis Car Co.
- All rebuilt/refurbished to like-new condition

Current NCDOT Rail Operation

- Four F59PH and two F59PHI diesel/electric locomotives
  - ~3000Hp EMD 710 in^3 diesel-electric prime mover
  - ~600Hp Caterpillar C18 Head End Power engine

Coach Car Exterior

Coach Car Interior

Before

After

Naming Conventions

- Locomotive and car names are tribute to NC
  - Locomotives: Cities, number is year founded
  - Coach Cars: State Symbols
  - Lounge Cars: State Bodies of Water

- Each car has a information plaque associated with its name

Fleet Expansion

- NCDOT acquires used locomotives and railcars, and rebuilds to like-new condition
  - Max. 1/3 cost of purchasing new equipment

- New Equipment/Operations
  - Two F59PH locomotives, four cab control units (CCUs) currently being rebuilt in Altoona, PA
  - Will support planned third round trip in 2017
    - ARRA mandated project

Current EPA Ratings

- Current Fleet:
  - F59PHI Prime Movers: EPA Tier 2
  - F59PH Prime Movers: EPA Tier 0+
  - CAT C18 HEPs: EPA Tier 2

- New F59PH locomotives (Q4 2016):
  - same Prime Movers: EPA Tier 0+
  - new CAT C15 HEPs: EPA Tier 3

GOING GREEN!

- NCDOT recognizes the need to reduce air pollution caused by locomotives
  - >50% population of NC's population lives within one hour of Piedmont corridor

- How to best reduce emissions?
  - Alternative fuels
  - Emissions reduction systems
  - New locomotives (expensive!)
  - Advanced propulsion system options

Emissions Reduction Systems

- Locomotives built to EPA standards for year of original construction
  - 40 CFR 1033 Identified pollutants: NOx, HC, CO, PM
  - New locomotives must be Tier 4 compliant

- New locomotives are cost prohibitive for NCDOT
  - $6-10 million per locomotive, taxpayer money
  - NCDOT's locomotives are early in life cycle

- Are retrofits / alternative fuels viable options?

Biodiesel Fuel

- Biodiesel is an alternative to standard fuel
  - Normally run on Ultra-Low Sulfur Diesel (ULSD)
  - Must maintain performance and fuel economy

- NC State EE Dept. performed testing using biodiesel blends, 2011-2016
  - Soybean based blend
  - Comparison testing performed using Portable Emissions Measurement System (PEMS)

Biodiesel Testing

- All locomotives tested on B10/B20/B40
- One locomotive additional testing B60/B80/B100
  - No engine degradation or loss of fuel economy
- Testing – static and during normal operations (over-the-rail)
- Demonstrated lower emissions vs. ULSD
  - Reduced HC, CO, PM by up to 60%
  - NCDOT planning to permanently implement

Biodiesel Testing

- Piedmont service is uniquely well equipped for biodiesel use
  - Not too hot/cold, no fuel degradation
  - Captive fleet (returns to Raleigh every night)
  - Corridor is long enough to provide assessment, short enough for easy logistics
- Opportunities for research
  - Colder climates, long hauls, extended OOS

Biodiesel Testing

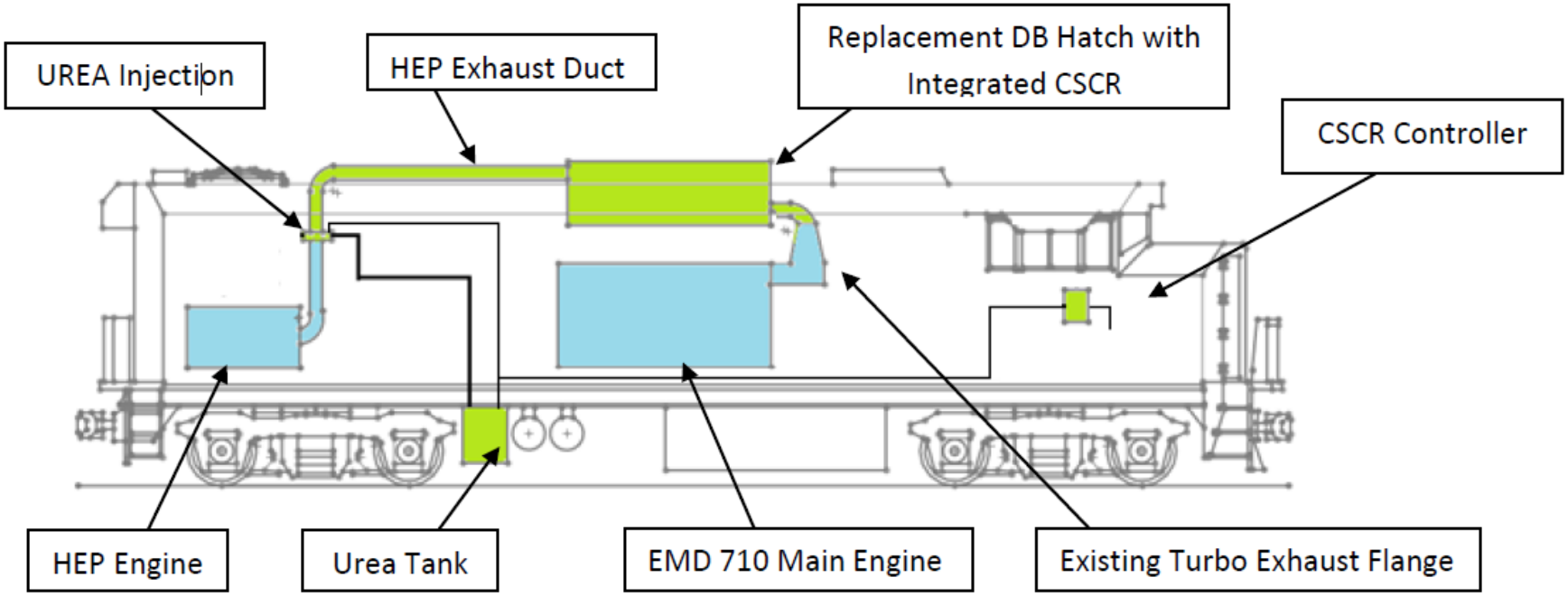
Emissions Reduction Systems

- Concept: Retrofit Existing Locomotives
  - Install new hardware to mitigate emissions

- Selective Catalytic Reduction systems are an emerging technology
  - Exhaust combined with Diesel Exhaust Fluid (DEF)
    - 67.5% DI water / 32.5% urea – $CO(NH_2)_2$
  - No commercially available retrofit system for F59PH/PHI locomotives

Blended Aftertreatment System (BATS)

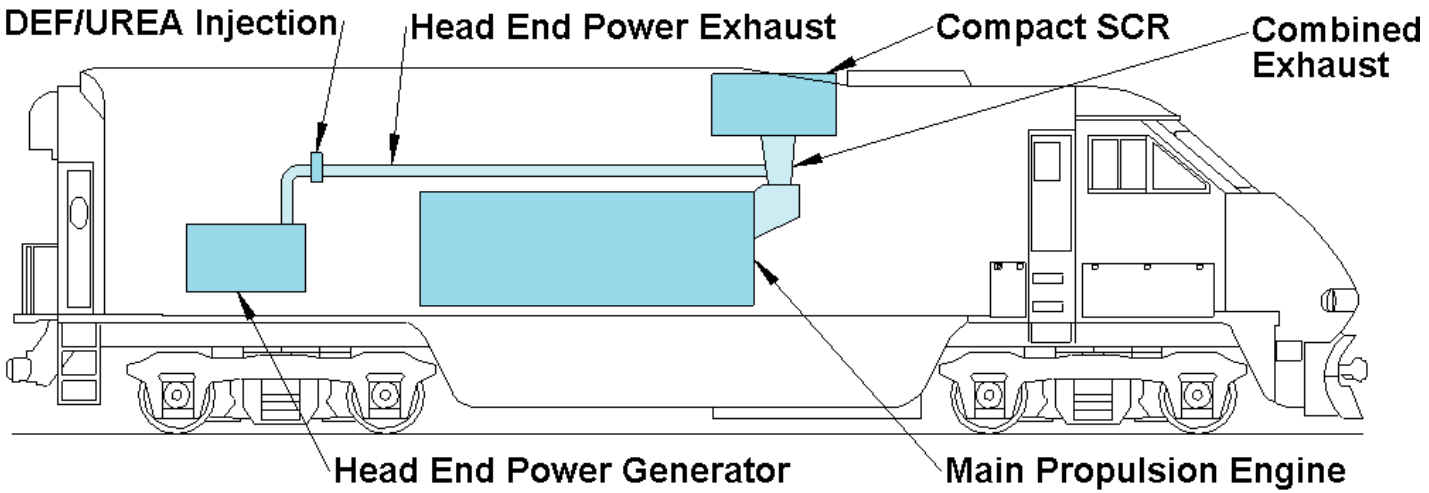
- NCDOT has partnered with Rail Propulsion Systems (RPS) to build a customized SCR
- Reduces exhaust from **both** the PM and HEP



Demo SCR Prototype

- Compact SCR demonstrated on Metrolink 865
  - Installed for over one year of commuter service
  - Reduced NOx 71% and PM 61%
  - Suffered from low temperatures and poor mixing

- Blended HEP and Prime engine exhaust solve both issues
  - Hot HEP exhaust achieves proper mixing temperatures
  - Reduces emissions from both engines



BATS Implementation

- Pilot system design & testing completed March 2016
- Implementation on NCDOT locomotive by June 2016
- Achieves Tier 4 NOx, min. Tier 3+ HC/CO/PM
  - Verification testing completed before end of 2017
  - Plan to seek EPA verification/approval

BATS Implementation

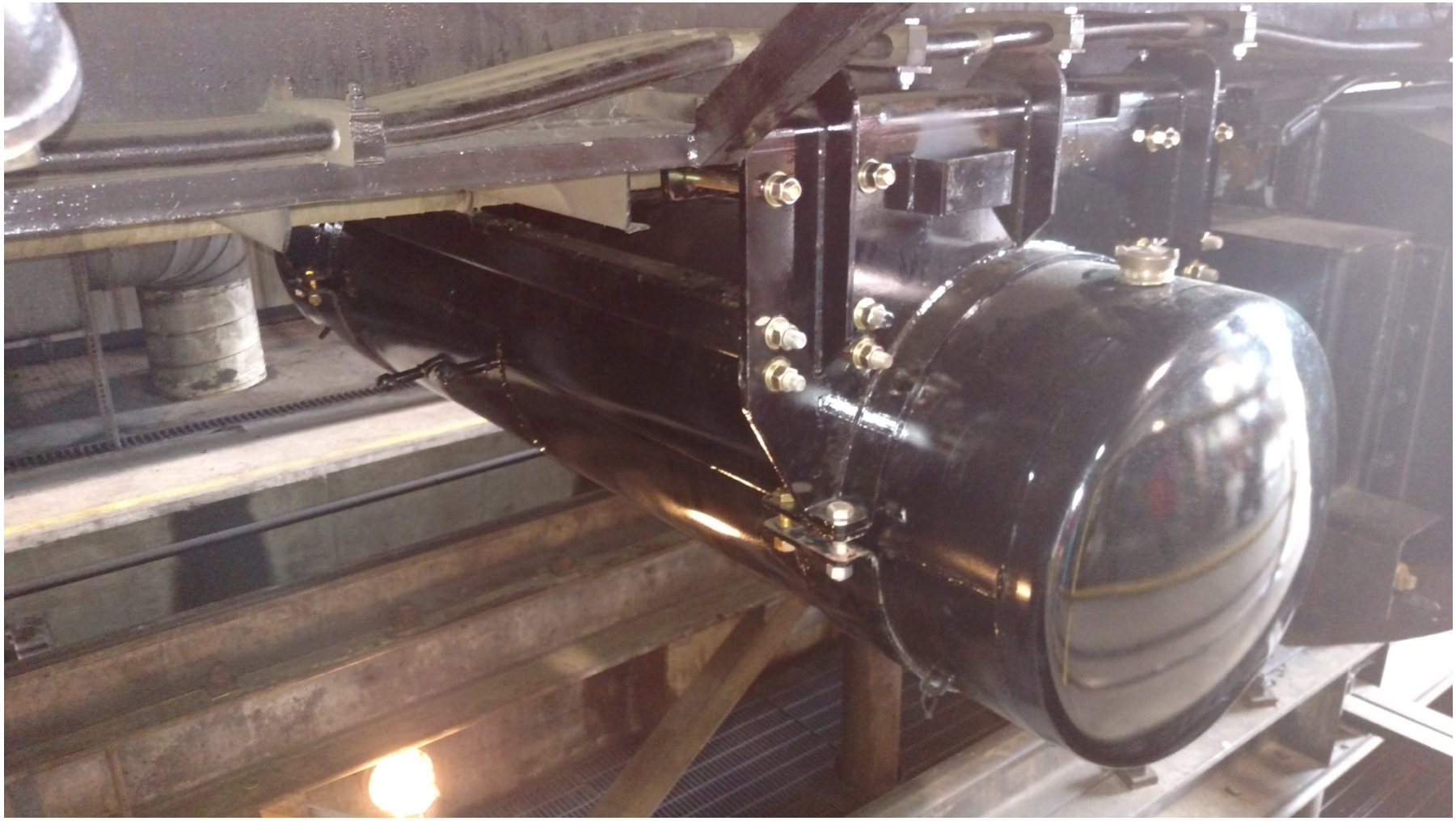
- NCDOT will have first retrofitted emissions improvement system near/at Tier 4
  - First inter-city passenger rail service to achieve this
  - Substantially less expensive than new locomotives
  - Preserves the life of in-service equipment
  - Drop-in retrofit / locomotive profile unchanged

- Nearly 90% of cost covered by federal grants
  - Minimal cost to NC taxpayers

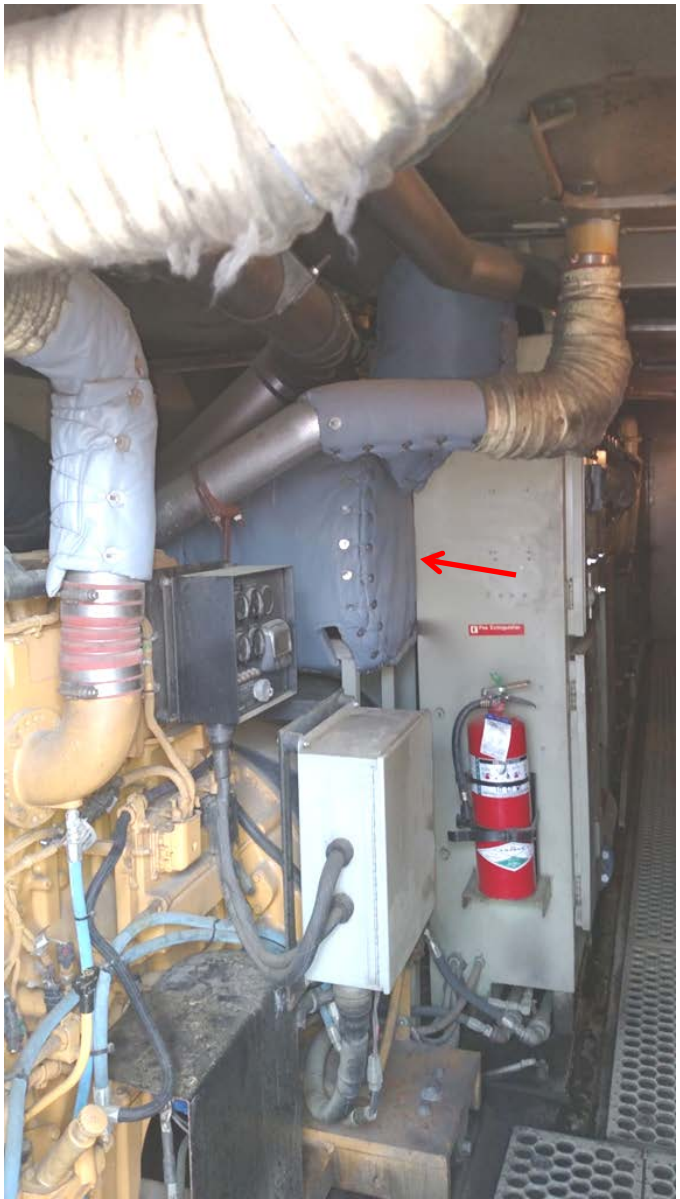
BATS Prototype

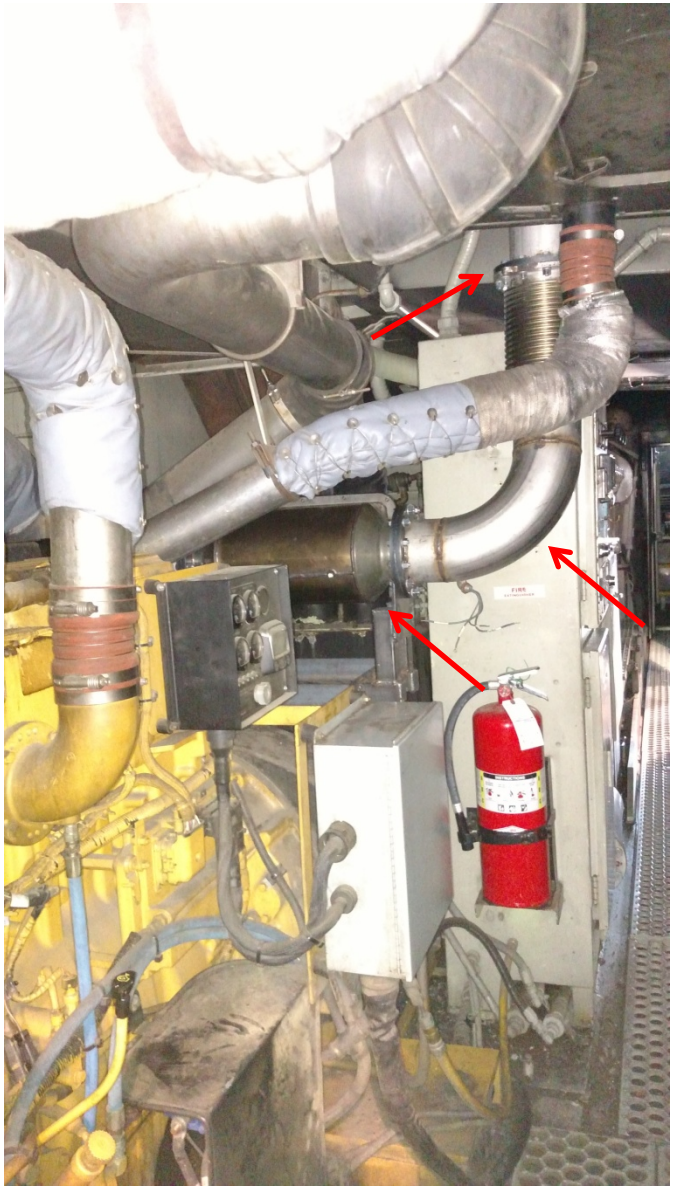
BATS Installation

BATS Installation



BATS Installation





Path to Tier 4 Emissions

- BATS – Tier 4 NOx, min. Tier 3+ HC/CO/PM
- Biodiesel fuel (B20/B40) – 30-60% reduction of HC/CO/PM
- COMBINED → **EXPECTED TIER 4 EMISSIONS**
  - Opens a new path to Tier 4 compliance
  - In service by Q4 2016
  - Less than 30% of cost of a new Tier 4 locomotive

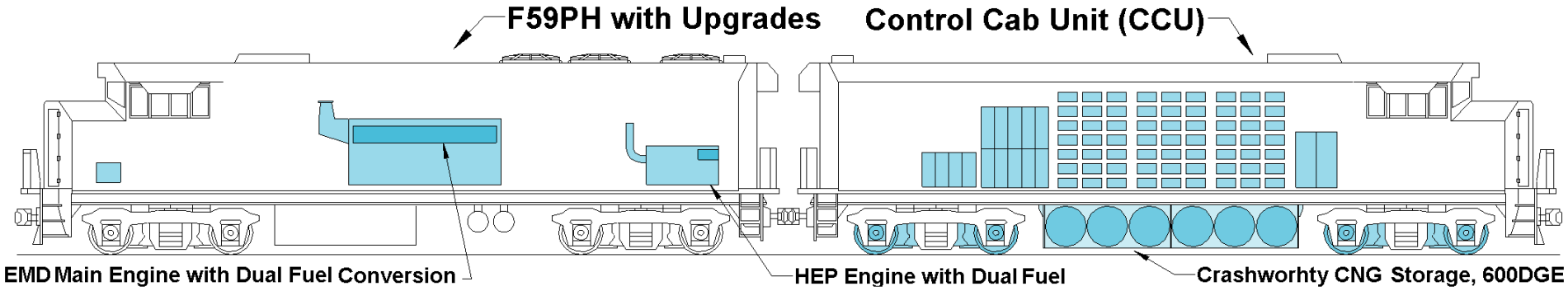
Advanced BATS (ABATS)

- Continued work with RPS to improve BATS
  - From prototype to production system
  - Plan to retrofit NCDOT fleet (8 locomotives) within two years

- ABATS features
  - Particulate filter in HEP exhaust (Tier 4 PM)
  - Internal exhaust duct routing
  - Improved mixing chamber flow configuration

Future Plans

- In 2017, NCDOT will begin running locomotive and CCU back to back in pull-pull mode
  - operational configuration provides an ideal platform for introduction of emissions reduction technology: compressed natural gas, batteries, etc.



Future Plans

- Plan to eventually implement dual fuel diesel / natural gas (CNG) hybrid locomotives
  - Hope to have new locomotives delivered “dual fuel ready”: injectors and fuel rails in place
- Also investigating battery technology and hydrogen propulsion
  - Configuration for CNG / dual fuel and hydrogen propulsion are very similar

Conclusions

- Biodiesel Testing:
  - No engine degradation or loss of fuel economy
  - Significant emissions improvements – up to 60%
  - Viable fuel alternative for small, captive fleets

- Blended Aftertreatment System (BATS):
  - Working prototype in place by June 2016
  - First in service Tier 4/3+ retrofit

Conclusions

- Path to Tier 4 emissions:
  - BATS + biodiesel → at or above Tier 4
  - First ever working inter-city retrofit
  - Tremendous cost savings to NC taxpayers
  - Easily ported to other locomotives (w/ HEP)
  - Plan to retrofit fleet

Energy Conversions Inc
dave@energyconversions.com

Conclusions

- Future projects include dual fuel hybrid diesel/CNG locomotives and battery systems
  - NCDOT's planned operational configuration provides ideal platform
- NCDOT Rail Division wants to be a technological leader in the rail industry
  - Large focus on emissions improvement

Future Philosophy

- Many industry-wide opportunities for implementation of new technology
  - Hope others follow NCDOT lead
- Small rail agencies can and should serve as the R&D / new technology proving grounds
- NCDOT willing to be “first to be first”

THANK YOU!!!

Questions?