Norfolk Southern – Locomotive Hydrogen Fuel Perspective

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Norfolk Southern - Fast Facts

- 19,500 route miles in 22 states and District of Columbia
- 26,000 employees
- 7.9 Million cars and intermodal Units (2018)
- 61,000 Freight Cars
- 3,400 Locomotives
Locomotives

- Two Major Locomotives Types
  - Road – 2241 units
  - Yard and Local – 1171 units
Road Locomotives

- Used on intermodal trains, unit trains and major freight trains between terminals
- High Horsepower
  - 4000 to 4400
- Weigh 415,000 to 432,000 pounds
- Majority of fleet built since the year 2000
- Life expectancy 20 to 30 years
Yard and Local Locomotives

- Used in rail yards and on local trains to spot cars at industries
- Lower horsepower (2000-3000 hp)
- Lighter weight 250,000 – 390,000 lbs.
- Grouped into 4 and 6 axles
- Average age 29 years
- Low cost Maintenance
- Very Reliable

EMD SD40-2
A Typical 6 Axle Yard and Local Locomotive
Norfolk Southern Repower Successes

- **Georgia (GA EPD/GDOT –Grant)**
  - **Atlanta**
    - 10 GP33ECO Mother/Slug sets
    - 8 SD33ECO Mothers & 2 slugs
  - **Rome**
    - 1 GP33ECO Mother & Slug
  - **Macon**
    - 6 SD33ECO Mothers & 2 slugs

- **Illinois (CMAP Grant)**
  - **Chicago**
    - 15 GP33ECO Mothers & 3 Slugs

- **Pennsylvania (SW PA Commission Grant)**
  - **Pittsburgh**
    - 2 GP33ECO Mothers & Slug sets
Locomotive Slug

- Slug - Engineless locomotive that gets power from a mother locomotive
- Provides extra tractive effort at low speeds
- Very suitable for switching service
- Reduces the need of powered locomotive where 2 locos are needed for switching

Slug under construction at NS Juniata Shops
ECO Locomotive Repower – Norfolk Southern – Juniata Shops
• Fuel Savings do NOT justify repowering – 75+ year payback
• Funding through Public/Private partnerships (70/30 split)
• Funding determined by $/Ton of emissions savings
NS 999 Electric Switcher

- Battery Management System (TMV Gen 2)
- Individual Battery String Control (IGBTs)
- Advanced Lead Carbon Batteries (Axion PbC®)
- 144 Removable IntraPack Battery Trays
- OBN / DAQ / Dashboard (Remote Monitoring)
- 480VAC Wayside Charging Stations
- Cattron Remote Control Locomotive Kit
Natural Gas Mother/Slug

Reduced Particulate and NOx Emissions
CNG Fueled Locomotive

- Converted Rail Engine
- Spark ignited with Pre-Ignition Chamber

- CNG Storage in Slug
- Gas Compression is an Issue
  - Expensive Infrastructure
  - Fill Time can be lengthy
New Technology – Lessons Learned from Gensets

• Made from proven industrial products – engines, alternators, electrical choppers etc.

• Lessons Learned
  • Parts availability issues
  • Training Issues
  • Dealer vs. Railroad Maintenance
  • Not Railroad Rugged
Locomotive Equipment must be Designed for Coupler Slack & Hard Couplings

- Coupler movement 1” between pairs
- Slack can run in at any time
  - Abrupt force on locomotive(s)
- Potential to cause damage to the propulsion system
- Radio Controlled Switchers see hard couplings at 5 mph

Entire train couple slack reacts against the locomotives
Advantages

- Zero Point Emissions
- Better emissions savings than Auto Engine Start/Stop
- Better Energy Savings – Up to 400 kW on a winter day
- Reduces Starting Battery issues

Disadvantages

- 3 Phase 480 Volt Electrical Connection
Locomotive Idle Reduction – Shore Power Wayside Station

Safety
- Ground Fault Detection
- Loop Complete Detection
- Phase Imbalance Detection

Ergonomic
- Less than 18 pound force to manipulate

Disadvantage
- 9 Feet Rail Clearance
NS – Hydrogen Perspective - Safety

• Fuel Handling
  – Flammability

• Maintenance Shops
  Sources of Ignition
  • Open Flame heaters
  • Welders
Hydrogen Performance Issues

• Economics
  – Benchmark against diesel fuel cost
  – Trucking Competition

• Power and Tractive Effort
  – 4300 Traction HP per loco (3168 kW to traction motors)
  – 200,000 pound starting tractive effort

• Fuel Range
  – At least 1000 miles between fuel fills Newark, NJ to Chicago for NS
  – Tenders increase cost

• Proven Reliability – Extremely important!
Maintenance Considerations for Hydrogen

- 184 Day Maintenance Intervals
- Long Term equipment overhauls
  - 34,000 MW hours between overhauls
- Parts Availability
- Training of Shop crews
Infrastructure

- **Shops**
  - Gas detection
  - Heating Systems
  - Ventilation

- **Tooling**
  - Lifting fixtures etc

- **Servicing Facilities**
Summary

- Meet or Exceed Safety of current locomotives
- Meet Economic expectations
  - Cost of fuel, infrastructure and maintenance
- Performance equivalent to today’s locomotives
  - 4300 Traction/ 200,000 lb starting TE
  - Equivalent Fuel Range
- Durable, Reliable and Rugged for Railroad Use
- Maintenance
  - By railroad employees
  - Time intervals equivalent or better than existing locos