Westport™
Here and Now.

Perspectives on LNG for Rail Applications

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Vice President
Natural Gas Fuel Supply Systems

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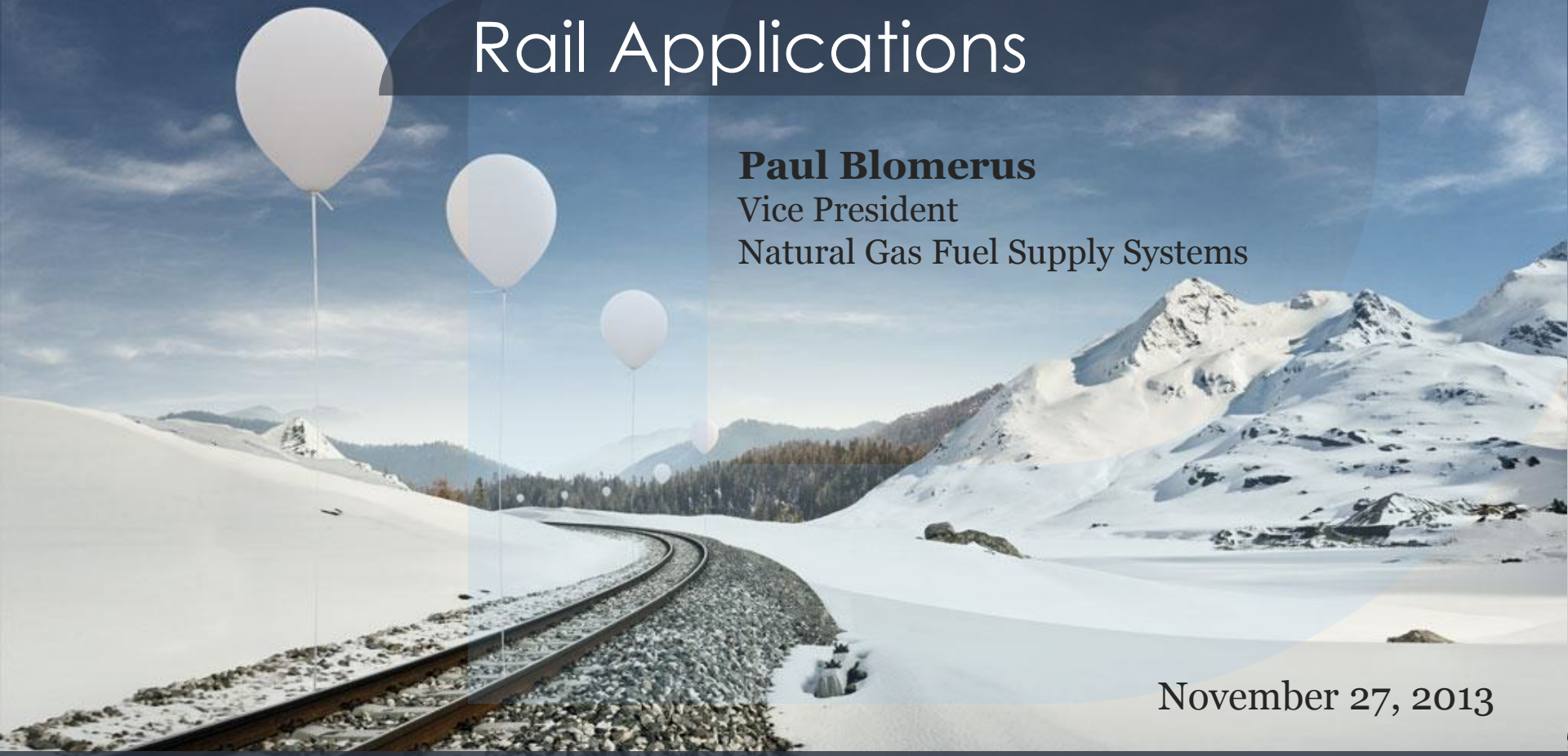


Agenda

1. Westport Background
2. Global Rail Market – Opportunity for LNG
3. Locomotive gas engine technology choices
4. Westport Demonstration Project Experience
5. Questions

Who is Westport?

We Engineer Advanced Natural Gas Solutions for Transportation

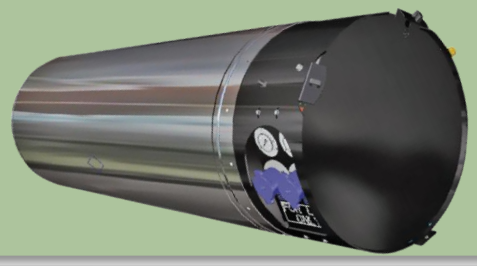
focus

Leading the shift in transportation fuels from petroleum to natural gas




position

Providing engine and fuel supply technology and component solutions

opportunity

Product leadership across key transportation sectors to enable global adoption




Experience in introducing natural gas in a broad range of applications

industrial

rail

urban

mining

automotive

trucking

Global Operations with HQ in Canada

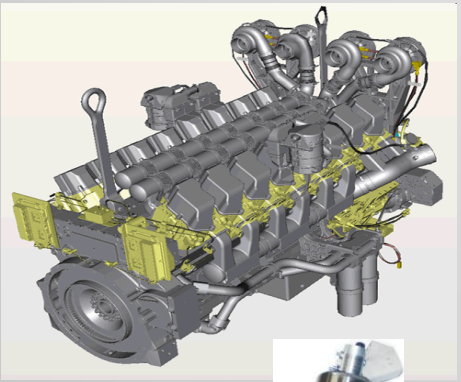
Total Global Employees: ~1000

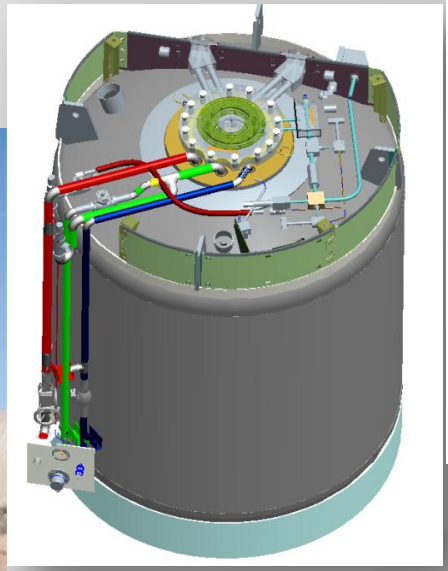
Partnerships are very important to us

We enter markets through partnerships with market-leading OEMs

Recent Westport Achievements

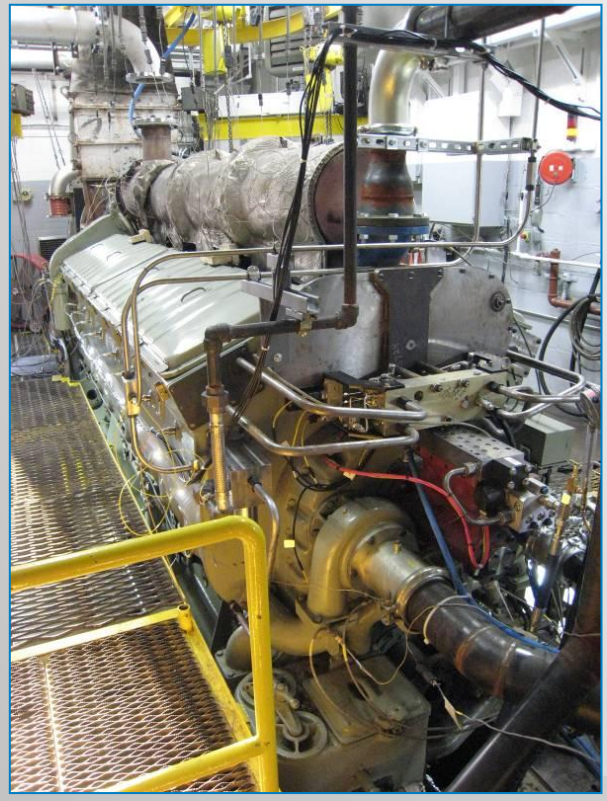
- Co-Developing a LNG-Fuelled Large Mining Truck product with Caterpillar for introduction in 2017
  - C175 engine on test at Caterpillar with HPDI fuel system
  - First tank and pump on testing at Westport

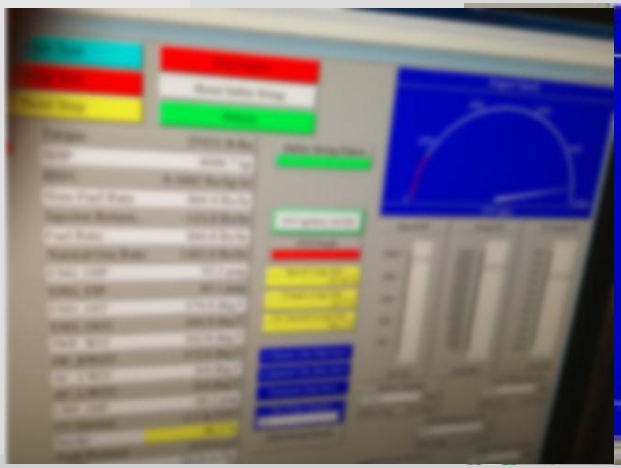


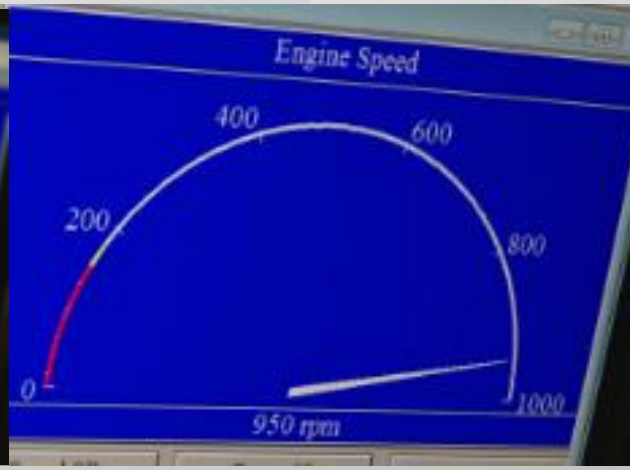


Recent Westport Achievements

- EMD 16-710 engine running at 4,600 hp on natural gas
  - US EPA Tier 3 emissions achieved easily
  - Demonstrate on locomotive with LNG fuel tender in 2014
  - Production solution available 2017

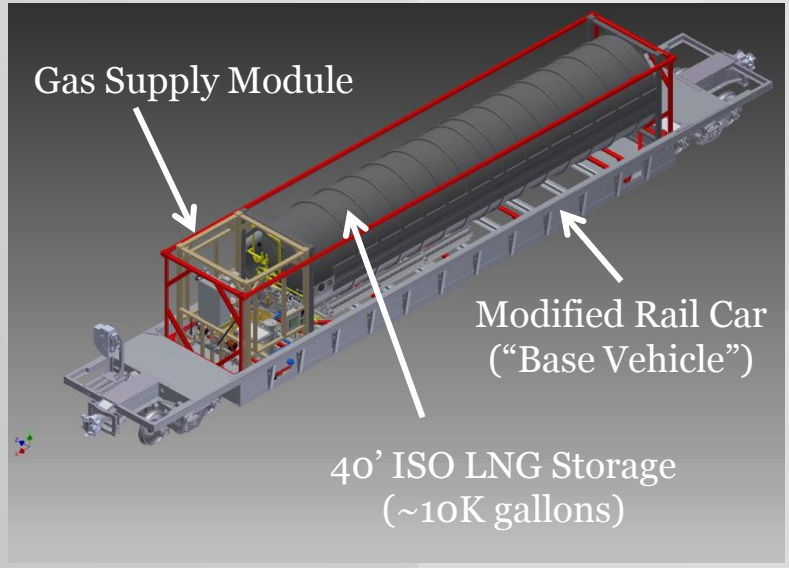






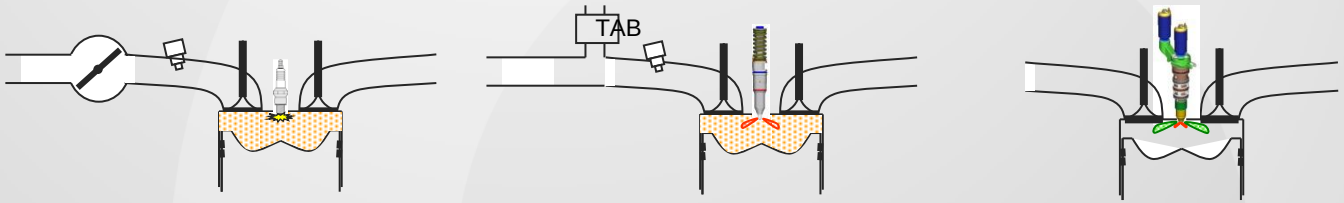
Recent Westport Achievements

- Launched a LNG fuel tender product for the North American rail market
  - First one in build for delivery to CN later this year
  - Partnering with major railcar manufacturer for tank car derived high-capacity solution to be available in 2016



LOCOMOTIVE GAS ENGINE TECHNOLOGY CHOICES

Natural Gas Locomotive Engine Technology Choices



Engine Technology Options:	Spark Ignited (SI)	Port Injected Dual Fuel* (DF)	High Pressure Direct Injection (HPDI)
horsepower	~80%	100% *(diesel or gas mix)*	100% *(gas)*
transient response	Limited	Limited *(unless revert to diesel)*	Diesel matched
diesel replacement	100%	~60%	>95%
other considerations	Efficiency, spark plugs and GHG emissions	GHG + Hydrocarbon emissions	Requires HP gas supply

Not an option

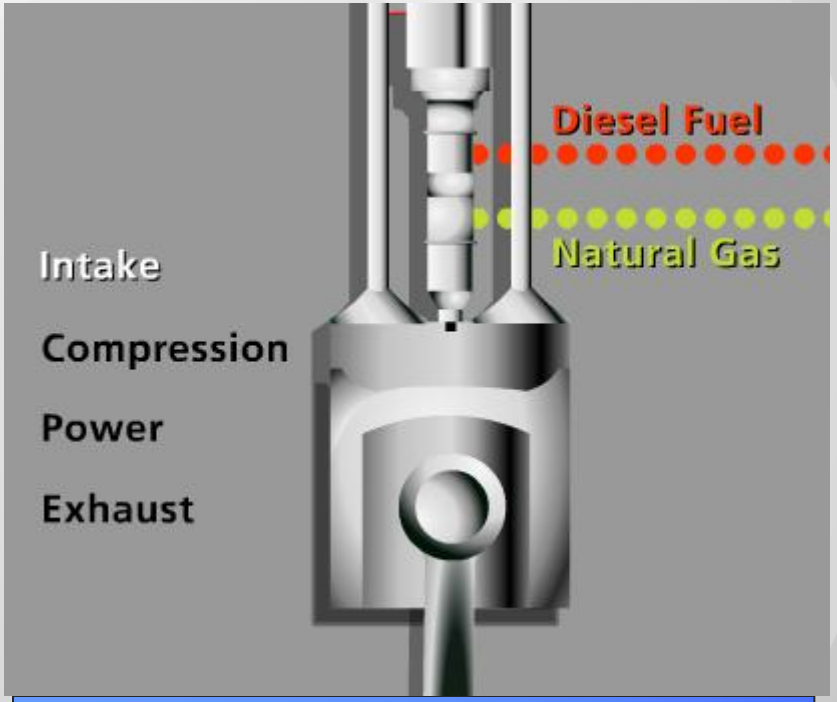
Possible interim solution

Long term emissions-compliant solution

* *Assumes unaltered compression ratio and diesel injector for base diesel engine to retain full emissions compliance in diesel-only mode*

Clean and Efficient HPDI Technology

- ~95% gas substitution (5% diesel)
- Diesel Engine Performance remains
  - Same high power and torque
  - Same efficiency
- No pre-mixing of air and fuel:
  - Not sensitive to fuel quality
  - Low methane emissions
  - Fast transient response



Typical Emission Reductions

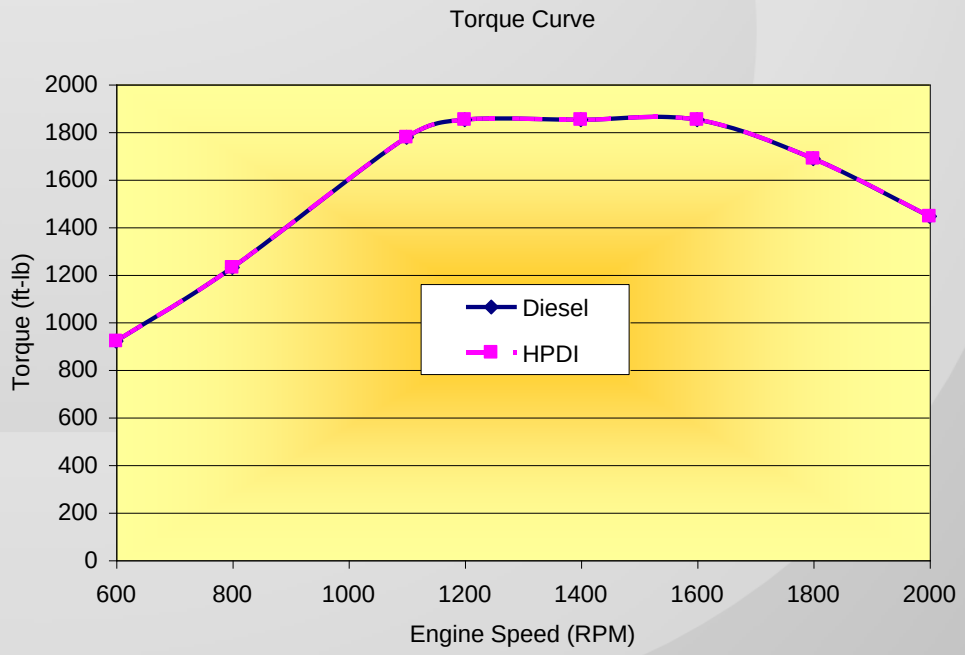
- **~ 40% lower NOx**
- **~ 70% lower PM**
- **~ 25% lower GHG**

HPDI Delivers the Required Performance

- Identical torque curve
- Same responsiveness
- Same transmission and controls
- Same cooling requirements

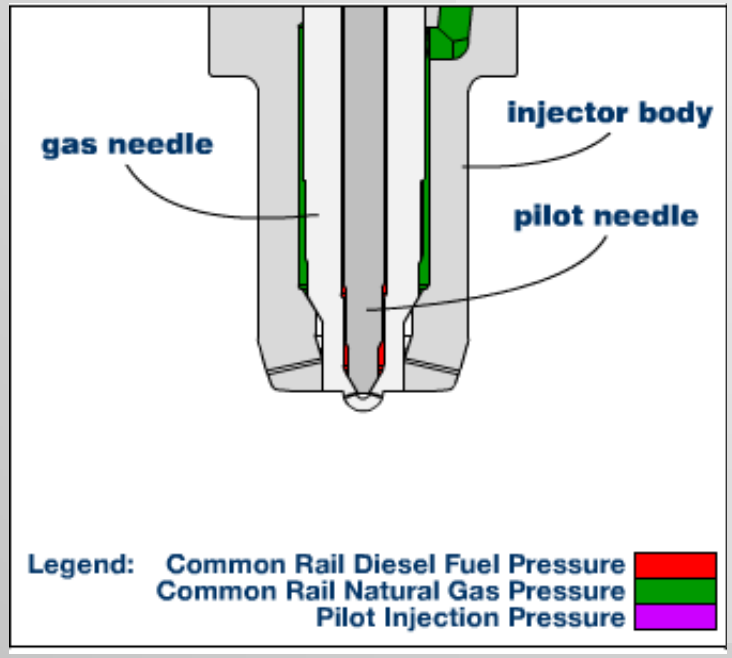
Truck engine example:

- Certified to Australian ADR 80/02
- Power: 500-580hp
- Torque: 1,650-1,850 lb-ft
- Similar BMEP as HHP engines



HPDI Injector Replaces the Diesel Injector

- Two fuels through one injector
- Directly replaces diesel injector – no engine modifications



WESTPORT DEMONSTRATION PROGRAM EXEPRIENCE

Westport's Demonstration Rail Program

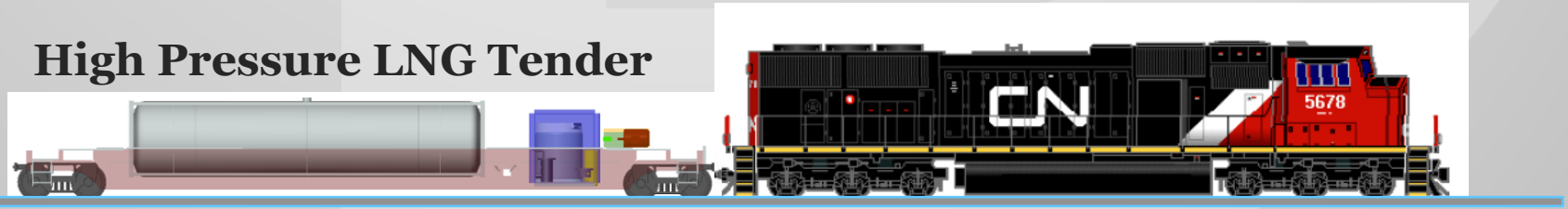
- Consortium Partners:

- Launched in 2011 with Canadian Government Funding of $2.3m
- Total budget of approximately $16m
- Deliverables:
  - Locomotive running on High Pressure Direct Injection of Natural Gas (HPDI)
  - Tier 3 emissions or better
  - Match diesel power, torque and efficiency
  - Targeting Green House Gas reductions of 26%
- Will be completed in 2014 with locomotive demonstration

Locomotive with LNG tender will run in 2014

- EMD SD70M-2 mainline locomotive
  - HPDI Fuel System Installed
  - Glycol filled secondary coolant loop to provide heat for vaporisation of LNG on Tender
- Specially constructed LNG Tender
  - 10,000 gallon LNG storage tank
  - Hydraulically-driven High Pressure LNG pump
  - Vaporiser, acumulator and controls

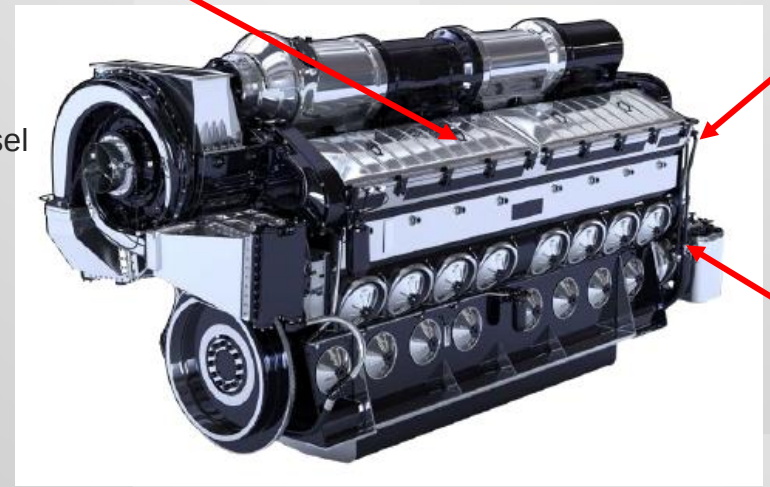
High Pressure LNG Tender

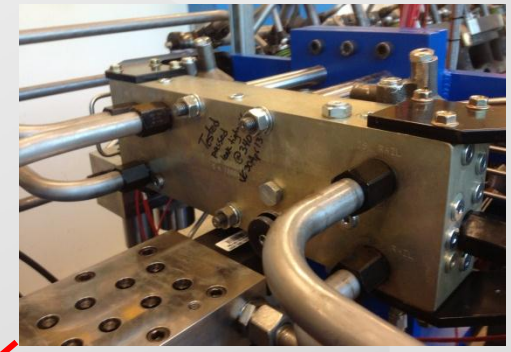


Fuel System Components

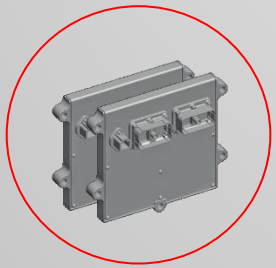
Fuel Injectors

Injects both gas and pilot diesel





Fuel Conditioning Module



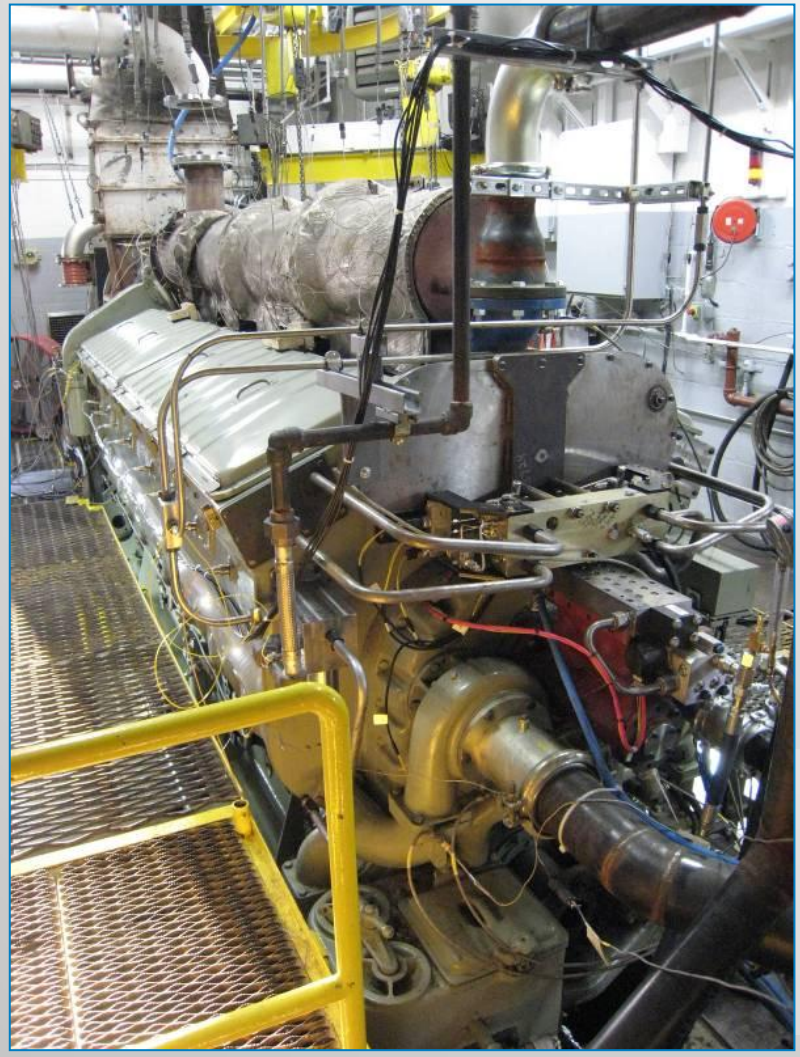
Fuel System Controllers
(on locomotive)

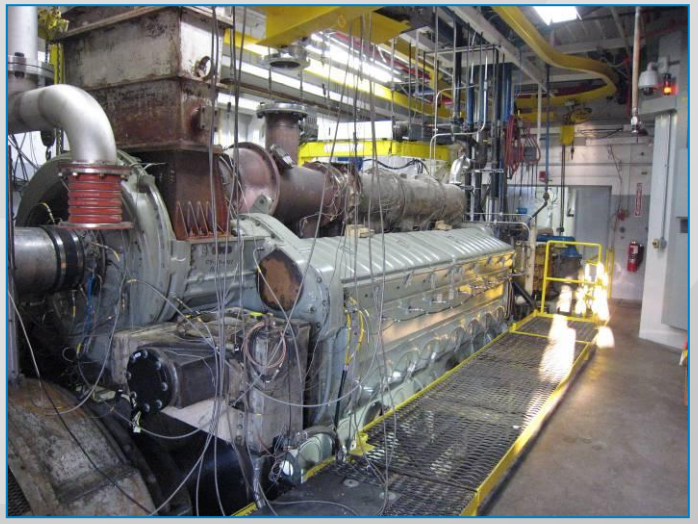
Common Rail Diesel Pump

Fuel system test bench with EMD fuel system installed

- System bench to replicate the EMD engine
  - Matched layout of full 16-cylinder engine
  - Heating/cooling capability
  - Back-pressure on injectors
  - Full controls

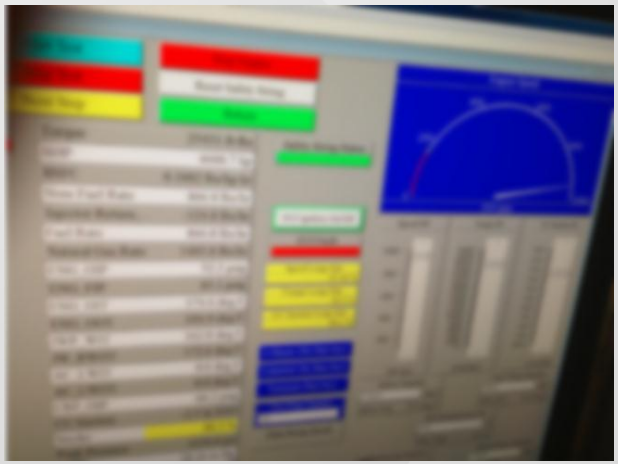
EMD 710 engine on the test bed





Demonstration System Achieves Full Power

- Westport and EMD are now running the EMD 710 engine on Natural Gas
- Full power (4600bhp) has been achieved in the test cell
- Emissions development is in progress.
- Optimization of the Fuel System is underway in parallel on test rigs at Westport



Lessons Learnt

- Large engines – the EMD710 - can make full power on natural gas using Westport's HPDI technology
- The development of large engines requires significant investment and effort
- Government funding is a welcome catalyst to kick-start programs at this level
- Strong partnerships are required to succeed