EMD Product Overview
Agenda

• Progress Rail / EMD Overview
• EMD Two Cycle Advantage
• Transient Response
• New Products
• Dual Fuel Solutions
• Lifetime Cost Analysis
Combined Strength: Progress Rail Services and EMD

June 2006: Progress Rail Services, one of the largest providers of rail and transit products and services, acquired by Caterpillar

August 2010: Progress Rail Services acquired EMD, one of two diesel-electric locomotive OEMs in North America
Diversified Business

Rolling Stock

Locomotives
- New Locomotives
- Freight & Transit
  - Marine
  - Power Generation
  - Off Shore Oil

Engines
- Power Products

Freight Car
- Wheels, Axles, Bearings & Parts
- Freight Car Repair
- Leasing

Infrastructure

Track
- Trackwork & Fasteners
- Rail Welding
- Maintenance-of-Way Equipment

Signal
- Signal Engineering
- Signal Infrastructure

Recycling
Major Facilities and Operations

La Grange, Illinois (EMD)

- Administrative offices
- Engineering, Sales
- Manufacturing: Engine Generator, Main Electrical Cabinet
- Remanufacturing: Engine, Turbochargers, Electronics

Muncie, Indiana (PRS)

- 

Brazil (PRS)

- 

San Luis Potosi, Mexico

- Traction Motor Maintenance, Rebuild and Overhaul
EMD has over 80 years in the Marine, Offshore Drilling, and Power Generation Industry
USA Department Of Defence

USS Enterprise

T-AGS Class survey ship

USS George H W Bush

Zeus Class Pipelay and cable ship
EMD Two Cycle Advantage
Value-Adding Advantages

- High power / weight ratio
- Easy condition-based monitoring
- Lowest maintenance and life cycle cost
  - No mid-life cylinder head replacement
- Mild steel fabricated crankcase
- Low vibration
- Lightweight replacement components
- Lightweight, simple tooling
- Ease of application
- Transient response
- 200 rpm idle capability
EMD E23 Engine Basic Facts

Two Cycle  (Uniflow Scavenged)

Single Turbo

Bore: 230 mm

Stroke: 279 mm

Displacement: 11.6 L/cyl

Available variants: 8, 12, 16, and 20 cylinders

Available continuous outputs:
1250 bkW – 3729 bkW

<table>
<thead>
<tr>
<th>RPM</th>
<th>900</th>
<th>800</th>
<th>720/750</th>
</tr>
</thead>
<tbody>
<tr>
<td>bkW/cyl</td>
<td>186</td>
<td>164</td>
<td>156</td>
</tr>
</tbody>
</table>

(Higher intermittent outputs also available)
EMD E23
Internal Design

- Inboard overhead camshafts
- Partially water-cooled exhaust
- Full liner cooling
- Oil jet lubrication
- Structural oil pan
Clutched Turbocharger Design

Turbocharger Functions

- Gear-Driven Supercharger at Low Speeds & Light Loads
- Gas-Driven Turbocharger at High Speeds & High Loads

Abundant Charge Air at All Speeds & Loads

1. Turbocharger
2. Turbo compressor
3. Exhaust turbine
4. Exhaust gas from cylinders
5. Planetary speed multiplier
6. Overrunning clutch
7. Crankshaft gear
Owning & Operating Cost Advantage: Overhaul Intervals & Serviceability

- No mid-life top-end overhaul
  - Cylinder heads do not require replacement / reconditioning
- No oil change required between overhauls unless indicated by oil sample analysis
- Overhauls to minimize downtime
  - Power Assembly (head, liner, piston, rod) can be removed and replaced as one unit in under 4 hours
  - Lightweight components and simple traditional tooling (No hydraulic tensioning equipment required)
- Fully welded low carbon steel construction
  - Can be reconditioned in situ
Easy Assessment Condition-Based Monitoring

Allows full inspection of power assemblies without removal from engine

Sustainability and low OPEX

- Maximum time between overhauls
- Reduced consumption of service components
- Minimal handling and disposal of fluids
2 Cycle Advantage

[Link to video: EMD 2Cycle Advantage - HD1080p.mov]
EMD Transient Response
Performance Advantage: Transient Response
2-stroke vs 4-stroke Comparison
Performance Advantage: Transient Response
Fixed Pitch Applications

- High power margin across rpm range
- Match propeller to 100% rating
- Superior transient thrust
  - Up to 80 rpm/sec
  - Optimum vessel dynamics
Low off-idle propeller speeds allow slow propeller rotation for better control of low-thrust maneuvers.

Thrust vectoring (fuel wasted) is reduced or eliminated vs. engines with higher idle speeds.
Tug Engine Operational Profile is.... Engine-Specific!

- Operational Profile Represents Engine load to achieve vessel demand for a specific engine.
- Any operational requirement below minimum clutched in speed may require additional KW to cancel thrust for low speed operation
- Example
  - EMD Engine
    - Clutched in @ 200 RPM
    - = 1.8 Knots
  - Typical High Speed Engine
    - Clutched in @ 700 RPM
    - = 3.8 Knots
- High Torque low speed operation may shift the engine operational profile and account for unpredicted fuel economy performance
## Terminal Tug

### Customer Field Data Experience

<table>
<thead>
<tr>
<th>4000 Operating hours per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average load factor = 20%</td>
</tr>
<tr>
<td>Four 80T tugboats</td>
</tr>
<tr>
<td>Three (3) vessels powered by high speed engines 2200 bkW</td>
</tr>
<tr>
<td>One (1) vessels powered by EMD 2200 bkW</td>
</tr>
</tbody>
</table>

### Fuel consumption

- High speed engines = 110 lph
- EMD engine = 110 lph @ 350 rpm idle
  - Based on test data, 200 rpm idle → 98 lph (11% reduction)

Detailed customer mission profiles needed to fairly compare engines.

Testing done on Andrew McAlister operating in ship assist service in Port of Houston (leased to G&H Towing)
Moran Tug

Moran Towing - EMD.mp4
EMD New Products
Active Engine Development Programs

- EPA Tier 4F / IMO III Diesel
- Dynamic Gas Blending
  US Replacement Engines / IMO II
- High Pressure Direct Gas Injection
  Platform for Future T4F / IMO III Product
Example in Harbor Tug Engine Room
IMO II Engine and Accessory Rack
(For Reference)

REQUESTED BY U.S. NAVAL ARCHITECTS
AND SHipyards: CONSIDER USING AVAILABLE OVERHEAD SPACE FOR IMO III
/ EPA T4F AND MAKE SCR SERVICEABLE IN ENGINE ROOM
The Integrated SCR
Owning & Operating Cost Advantage: Application & Installation

- Multiple Exhaust Outlets (Choose One)
- SCR & mixing tube completely integrated with engine and is fully serviceable from within engine room
- More compact accessory package arranged underneath SCR
- SCR and structure stand rigidly on vessel bedframe
- Same proven EMD engine, but with optimized fuel system for reduced PM and improved air system for additional back pressure capability

Application & Installation
WSF T4F Engine
EMD Dual Fuel Solutions
EMD Gas Solutions Under Development

**Dynamic Gas Blending (DGB®)**
- Low pressure gas 10 Bar
- Up to 80% gas substitution
- 14:1 power assembly
- Runs diesel cycle with no power loss
- 100% power on diesel only
- EPA T3/IMO II

**Direct Injected Gas (DIG)**
- High pressure gas system 340 Bar
- 95% Gas substitution
- Up to 10% fuel (BTU) improvement
- Runs diesel cycle with no power loss
- 30% power on diesel only
- EPA T4 Requires SCR
- IMO III Requires mild EGR
Natural Gas

E 23 GB
Dynamic Gas Blending (DGB)

E 23 GD
High Pressure Direct Injected Gas (DIG)
# Natural Gas – New Engines

<table>
<thead>
<tr>
<th>Gas Solution</th>
<th>Max Diesel Power</th>
<th>Max Gas Substitution</th>
<th>Methane Slip?</th>
<th>Efficiency Impact</th>
<th>IMO Emission Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DGB</strong>&lt;br&gt;Dynamic Gas Blending</td>
<td>100%</td>
<td>Up to 70%</td>
<td>Yes</td>
<td>Reduced due to knock sensitivity</td>
<td>Retrofit + New Engines</td>
</tr>
<tr>
<td><strong>DIG</strong>&lt;br&gt;High Pressure Direct Injection</td>
<td>≤ 30%</td>
<td>Up to 98%</td>
<td>No</td>
<td>Significant efficiency improvement; superior knock tolerance</td>
<td>Retrofit + New Engines (SCR or EGR)</td>
</tr>
</tbody>
</table>

**IMO Emission Certification**
- Up to IMO II
- IMO III

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<tr>
<th></th>
<th>Up to IMO II</th>
<th>IMO III</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DGB</strong> Dynamic Gas Blending</td>
<td>Retrofit + New Engines</td>
<td>Not Currently Offered</td>
</tr>
<tr>
<td><strong>DIG</strong> High Pressure Direct Injection</td>
<td>Retrofit + New Engines</td>
<td>Retrofit + New Engines (SCR or EGR)</td>
</tr>
</tbody>
</table>
EMD Lifetime Cost Analysis Tool
Life Cycle Analysis Tool

Introduction
EMD is pleased to furnish the following life cycle cost estimates for the 16-710 engine. The distinct heritage of the Series 710 two-cycle engine is rich in leadership in efficiency, performance, and serviceability—a hallmark the company is proud to maintain. These fuel-saving features are summarized below for consideration along with costs estimated herein.

Emissions Leadership
Enabled by refinement and optimization of the proven Series 710-72 engine family, the Series 710-73 model line meets the stringent US EPA Marine Tier 3 exhaust emission standards for Category 2 engines without need for aftertreatment or expensive high pressure fuel injection systems.

Performance Leadership
Long renowned for its world class power margin per ton, the EMD Series 710 meets US EPA Marine Tier 3 emissions without compromise of the benchmark reliable power. Therefore, customers and operators can feel safe knowing that response is available immediately when needed, when seconds count.

Serviceability and Maintainability Leadership
The Series 710 engines receive key features unique to its Series 567 and Series 645 predecessors which make them legendary for unmatched serviceability and maintainability, including:

Power Assembly/Engine Block
Designed by the infinitely-remarkable two-stroke design, the Series 710 diesel in Traction relies on the proven design in the engine block, piston, skirt, piston rings, and cylinder head design. This provides the owner/operator with an exclusive means of condition-based health monitoring to ensure maximum life from cylinder power assembly and associated components.

Simple Design and Simple Tooling
The long journey to the two-stroke Series 710 produces fewer internal stresses than comparable four-stroke engines of the same size and speed. This simplifies cylinder power assembly components, tooling, and tooling, resulting in the lowest replacement costs in the industry with traditional tooling. No special hydraulic boring equipment is needed to accomplish critical internal bores such as main bearing cap, connecting rod cap or cylinder power assembly reduction block.

Fabricated Mild Steel Connecting Rod and Oil Pan
Fabricated with steel connecting rods and oil pan components (built as a package) these major assemblies will not exceed prices of $2200 to be delivered from their parent vessels, operation of service hall. Distinct the most critical structural components can be quickly assembled and commissioned by skilled personnel, allowing for vessels to return to service in minimum time.
Lifetime Cost Analysis

TCO Report - Example.pdf
Product Support Advantage: Global Dealer Network
Thank You