EPA Ports Call
Harbor Craft Marine Repowers

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Marine Technology
Diesel Engine Technology (current)

Unregulated (High NO\textsubscript{x} and High PM)
- Mechanical Injection, Normally aspirated (including Roots blown)

Tier 1 (Lower NO\textsubscript{x} and High PM)
- Mechanical injection, After cooled, Turbocharged

Tier 2 (Lower NO\textsubscript{x} and Lower PM)
- Electronic Fuel Injection (EFI), Separate Circuit After Cooled (SCAC), Turbocharged, Low Oil Consumption Power Assemblies

25% PM reduction options (1042 compliance)
- Low Oil Consumption Power Assemblies, Roots to turbocharger conversion, Low PM/NO\textsubscript{x} injectors, EFI conversion, Diesel Oxidation Catalyst
## EPA’s Clean **New** Marine Engine Strategy

### EPA New Engine standards – (this is only a small part of a much larger table)

**Category 2 Marine Engines**

*<3700 kw & 7-15 liters/cylinder>*

<table>
<thead>
<tr>
<th>New Engine Standard</th>
<th>First Applied (Model Year)</th>
<th>Emissions Limits (g/kwh)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NOx+HC</td>
<td>PM</td>
</tr>
<tr>
<td>Unregulated</td>
<td>Prior to 2004</td>
<td>~20.0</td>
<td>~0.70</td>
</tr>
<tr>
<td>EPA Tier 1 (IMO) NOx regulated only</td>
<td>2004</td>
<td>11.5</td>
<td>~0.50</td>
</tr>
<tr>
<td><strong>EPA Tier 2</strong></td>
<td>2007</td>
<td>7.8</td>
<td>0.27</td>
</tr>
<tr>
<td>EPA Tier 3</td>
<td>2013</td>
<td>6.2</td>
<td>0.14</td>
</tr>
<tr>
<td>EPA Tier 4</td>
<td>2016</td>
<td>1.8</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Where to Find the Rule: [www.epa.gov/otag/marine.htm](http://www.epa.gov/otag/marine.htm)
Emission Reduction Opportunities

Coastal Marine Vessel Guidelines

1. Target vessels with older, unregulated engines but significant remaining useful life
   • Older 2-stroke engines have the highest baselines
2. Target vessels that are significant contributors to diesel emissions inventories (note that they may not be fully accounted for in “Port” inventories)
   • Individual vessels are significant sources (High HP, high load factor, high annual usage)
3. Target vessels “captive” to a specific region
   • Large historically consistently operated ferry systems
4. Evaluate options to achieve least cost maximum reductions
   • Repower, Rebuild Kits, Retrofit and Hybrid (this is new)
Marine Repower Summaries
## Port Authority of NY & NJ Tier 2 Repower Programs

<table>
<thead>
<tr>
<th>Program</th>
<th>Number of Vessels</th>
<th>Annual NOx Reduction (tons)</th>
<th>Average Cost ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KVK (2003)</td>
<td>2</td>
<td>51</td>
<td>$1,620</td>
</tr>
<tr>
<td>TERP (2004)</td>
<td>3</td>
<td>171</td>
<td>$1,170</td>
</tr>
<tr>
<td>MVERP (2005)</td>
<td>8</td>
<td>177</td>
<td>$1,550</td>
</tr>
<tr>
<td>MVERP 2 (2007)</td>
<td>10</td>
<td>240</td>
<td>$1,400</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23</strong></td>
<td><strong>643</strong></td>
<td><strong>$1,400</strong></td>
</tr>
</tbody>
</table>
SIF Vessel Emission Rates: Present and Future

Staten Island Ferry Vessel Emission Upgrades - Compared to EPA Emission Standards

- **EPA EMISSION LIMITS**
  - Red: IMO/Tier 1
  - Blue: EPA Tier 2
  - Orange: EPA Tier 3
  - Green: EPA Tier 4

- **Vessel Upgrades**
  - Initial retrofit/engine upgrade
  - Future DOC retrofit

- **PM (g/kW-hr)**
  - Tier 2 (2007): 0.30
  - Tier 3 (2013)
  - Tier 4 (2016): 0.10

- **NOx+HC (g/kW-hr)**
  - 22.0 to 0.0

- **Vessels**
  - Barberi Class
  - John F. Kennedy
  - Alice Austen
  - Molinari Class

- **Tier Levels**
  - Tier 2 (2007)
  - Tier 3 (2013)
  - Tier 4 (2016)
Staten Island Ferry – Molinari Class (On-going)

PANYNJ funded Tier 2 Engine Upgrade “Kits”

Vessels originally delivered with Tier 1 Mechanical EMD 710 engines

Effort includes conversion to electronic fuel injection, low oil consumption power assemblies and separate circuit after cooling

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Technology</th>
<th>NOx Reduction (tpy)</th>
<th>NOx Reduction (%)</th>
<th>PM Reduction (tpy)</th>
<th>PM Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guy V. Molinari</td>
<td>Tier 2 upgrade w/ UL</td>
<td>70</td>
<td>32%</td>
<td>4.0</td>
<td>44%</td>
</tr>
<tr>
<td>John J. Marchi</td>
<td>Tier 2 upgrade w/ UL</td>
<td>70</td>
<td>32%</td>
<td>4.0</td>
<td>44%</td>
</tr>
<tr>
<td>Spirit of America</td>
<td>Tier 2 upgrade w/ UL</td>
<td>70</td>
<td>32%</td>
<td>4.0</td>
<td>44%</td>
</tr>
</tbody>
</table>
**PROJECT OBJECTIVE**

- This project replaced the main propulsion engines of the vessel *Park City*. The existing engines replaced were two EMD 567 main propulsion engines, each producing 1,500 HP. They were replaced with two Tier 2 CAT 3516C engines.

**Emissions Reductions**
- 61.06 tpy of NOx
- 1.38 tpy of PM

**PARTICIPANTS AND LESSONS LEARNED**

- The *Park City* is currently in service as a ferry between Connecticut and Long Island, and operated by Bridgeport Port Jefferson Steamboat Company.

**Lessons Learned**
- New EMD engines would have required a larger diameter exhaust pipe to minimize pressure drop at higher flow.
- New EMD engines would have been more expensive than comparable CAT engines.

**SCHEDULE & BUDGET**

- This project began in September of 2008 and was completed in January of 2010.
- Reductions achieved at $1,131/ton of NOx and $33,652/ton of PM based on total project costs.
Marine Repower Projects – EPA Regions 1 & 2
PROJECT OBJECTIVE

- This project replaced the main propulsion and auxiliary generator sets of the vessel *Spirit of New York*. The engines to be replaced are two Detroit Diesel 12v71 main propulsion engines, each producing 539 HP, and two Detroit Diesel 8v71 auxiliary genset engines, each producing 273 HP.

Emissions Reductions

- 8.3 tpy of NOx
- 0.69 tpy of PM

PARTICIPANTS AND LESSONS LEARNED

- The *Spirit of New York* operates out of the Chelsea Piers on the west side of Manhattan and Lincoln Harbor Marina in Weehawken, New Jersey. It is used for sight-seeing and dinner cruises along the Hudson River, and operated by Spirit Cruises.

Lessons Learned

- Limited window for installation because of nature of service (1/1-2/10).
- Procurement to satisfy competitive process is more detailed than typically followed in the marine industry—took longer than expected.

SCHEDULE & BUDGET

- This project began in June of 2009 and was completed in February of 2011.
- NOx and PM reductions achieved at $4,964/ton and $59,710/ton, respectively, based on total project costs.
PROJECT OBJECTIVE

- This project replaced the main propulsion and auxiliary engines on the vessel American Princess II. The existing engines replaced were three Detroit Diesel 12v92 engines, each producing 1100 HP, and two Isuzu 4BDI auxiliary engines, each producing 40 HP.

Emissions Reductions
- 21 tpy of NOx
- 2 tpy of PM
- 38,000 gallons of fuel per year

PARTICIPANTS AND LESSONS LEARNED

- Before and after repower the American Princess II was operated by TWM Ferry, Inc. and was in service as a commuter ferry between Rockaway, Queens and Wall Street in Manhattan.
- In early 2011 the vessel owners were forced by economic conditions to sell the vessel to the Dolphin Fleet which operates daily whale watch cruises out of Provincetown, MA.

Lessons Learned
- The repower process for a vessel of this size (100 ‘) is generally straight-forward and can be accomplished at a local marina.
- Accessing the engine compartment to remove/install the engines required removal and replacement of the ship’s galley, removal of exterior railings, and removal of part of the hull deck over the engine compartment.
- Much of the exhaust piping within the engine compartment also needed to be replaced, which required fabrication and on-site welding.

SCHEDULE & BUDGET

- This project began in July of 2009 and was completed in September of 2010.
- Reductions achieved at $4,095/ton of NOx and $43,000/ton of PM based on total project costs.
PROJECT OBJECTIVE

• This project replaced the main propulsion and auxiliary generator sets of the vessel McAllister Sisters. The existing engines replaced were two 16-645-E6 EMD main propulsion engines, each producing 1,950 HP, and two GM 6-71 auxiliary genset engines, each producing 200 HP.

Emissions Reductions

• 39.7 tpy of NOx
• 2.9 tpy of PM
• 2,967 gallons of fuel per year

PARTICIPANTS AND LESSONS LEARNED

• The McAllister Sisters is in service as a tug based in the New York City metro area, and operated by McAllister Towing.

Lessons Learned

• High fuel use, two-stroke, unregulated baseline.
• Multiple operational systems are compacted into a tight space (redundant piloting controls, propulsion, fire fighting, cable towing, electrical, hydraulics, fluid storage tanks, etc).
• Detailed photo documentation and copies of vessel general plans are critical to writing repower specifications for shipyard.

SCHEDULE & BUDGET

• This project began in October of 2009 and was completed in January of 2011.
• Reductions achieved at $2,204/ton of NOx and $38,546/ton of PM based on total project costs.
PROJECT OBJECTIVE

• This project will replace the main propulsion engines on the vessels M/V Champlain and Governor Aiken. The existing engines to be replaced are two Detroit Diesel 12v71 engines, each producing 360 HP, and a Fairbanks Morse 37D14 engine, producing 550 HP.

Emissions Reductions

• 8.93 tpy of NOx
• 0.70 tpy of PM

PARTICIPANTS AND LESSONS LEARNED

• The Governor Aiken and M/V Champlain are both in service as ferries on Lake Champlain, and operated by Lake Champlain Transportation.

Lessons Learned

• Repower timing must be scheduled against ferry service season.
• Project required funds beyond the grant for vessel upgrades such as keel cooler modifications.

SCHEDULE & BUDGET

• This project began in October of 2009 and is scheduled to be completed in May of 2011. The Governor Aiken was completed in April 2010, The Champlain in May 2011.
• Reductions achieved at $8,949/ton of NOx and $114,159/ton of PM based on total project costs.
### PROJECT OBJECTIVE

- This project replaced the main propulsion engines on the vessel *Mount Washington*. The existing engines replaced were two 1940’s vintage Enterprise DMG18 engines each producing 615 HP.

**Emissions Reductions**
- 7.36 tpy of NOx
- 0.30 tpy of PM

### PARTICIPANTS AND LESSONS LEARNED

- The *Mt. Washington* is in service as an excursion vessel used for tours on Lake Winnipesaukee, and is operated by the Winnipesaukee Flagship Corporation

**Lessons Learned**
- Old engines were 18,000 lbs, new engines only 6,000 lbs. Produced weight and balance issues.
- New engines significantly quieter.
- New engines resonated at a different frequency that required dampening.
- Wet repower due to lake berth

### SCHEDULE & BUDGET

- This project began in October of 2009 and was completed in May of 2010.
- Reductions achieved at $9,063/ton of NOx and $222,333/ton of PM based on total project costs.
PROJECT OBJECTIVE

- This project replaced the main propulsion engines on the vessels *Ft. Gaines* and *Margaret Chase Smith*. The existing engines to be replaced are three Detroit Diesel engines, each producing 250 HP, two CAT 3508B engines, each producing 600 HP, and two additional Detroit Diesel auxiliary engines, each producing 45 HP.

  **Emissions Reductions**
  - 15.94 tpy of NOx
  - 1.28 tpy of PM

PARTICIPANTS AND LESSONS LEARNED

- The *Ft. Gaines* provides transportation services to the islands off the Portland, ME coast, and is operated by Lionel Plante Associates.
- The *Margaret Chase Smith* is in service as a ferry between Islesboro and Lincolnville, ME, and is operated by the Maine State Ferry Service.

  **Lessons Learned**
  - Engine supplier communication is critical.
  - Marine architect services on marine engine repower projects should be contracted if simply for quality assurance as this will likely save time and money.

SCHEDULE & BUDGET

- This project began in November of 2009 and is scheduled to be completed in September of 2010.
- Reductions will be achieved at $3,393/ton of NOx and $42,257/ton of PM based on total project costs.
### PROJECT OBJECTIVE

- This project will replace the auxiliary generator engines on the vessels *Cameron’s Point* and *Eddie R.* The existing engines to be replaced are three Detroit Diesel engines, two 2-71 engines producing 68 HP, and one 3-71 engine producing 113 HP.

**Emissions Reductions**
- 0.29 tpy of NOx
- 0.01 tpy of PM

### PARTICIPANTS AND LESSONS LEARNED

- The *Cameron’s Point* and *Eddie R.* are in service as tugs based off the coast of Maine, and are operated by Interport Towing.

**Lessons Learned**
- Auxiliary genset repowers are relatively simple.
- Motivating ship owners to move quickly may be challenging for auxiliary repowers.

### SCHEDULE & BUDGET

- This project began in November of 2009 and was completed in March 2011.
- Reductions will be achieved at $20,690/ton of NOx and $600,000/ton of PM based on total project costs.
PROJECT OBJECTIVE

- This project replaced the main propulsion engines of the vessel *Mary Ellen*. The existing engines replaced were two CAT 3516B main propulsion engines, each producing 1,600 HP. New engines were CAT 3516C, along with RWS gearboxes.

Emissions Reductions
- 31.9 tpy of NOx
- 2.7 tpy of PM

PARTICIPANTS AND LESSONS LEARNED

- The *Mary Ellen* is currently in service as a ferry between New London, CT and Orient Point, NY, and operated by Cross Sound Ferry, which has been operating for 35 years.

Lessons Learned
- Straightforward swap from a 3516B to a 3516C.
- New gearboxes required hull modifications to fit.
- Electronic engines necessitated conversion to electronic engine controls.

SCHEDULE & BUDGET

- This project began in April of 2009 and was completed in April of 2010.
- Reductions achieved at $5,016/ton of NOx and $59,259/ton of PM based on total project costs.
PROJECT OBJECTIVE

- This project will upgrade the two EMD 645E7 main propulsion engines, each producing 2,300 HP, on the vessel M/V Susan Anne with EPA Tier-2 certified electronic engine conversion kits.

Emissions Reductions
- 25.6 tpy of NOx
- 2.6 tpy of PM

PARTICIPANTS AND LESSONS LEARNED

- The Susan Anne is currently in service as a ferry between New London, CT and Orient Point, NY, and operated by Cross Sound Ferry, which has been operating for 35 years.

Lessons Learned
- United States Coast Guard and American Bureau of Shipping involvement and review were necessary.
- The upgrade kits required a separate loop after cooling including new external coolers. This avoided a fuel penalty, but added significant cost.

SCHEDULE & BUDGET

- This project began in November of 2010 and is scheduled to be completed in December of 2011.
- Funding provided by the Connecticut Department of Environmental Protection
- Reductions will be achieved at $4,883/ton of NOx and $48,077/ton of PM based on total project costs.
SeaStreak M/V Highlands

PROJECT OBJECTIVE

- This project will replace the main propulsion and auxiliary generator sets of the vessel M/V Highlands. The existing engines to be replaced are four Cummins KTA50-M2 main propulsion engines, each producing 1,875 HP, and two Cummins 6BT auxiliary genset engines, each producing 134 HP.

Emissions Reductions
- 57.7 tpy of NOx
- 1.13 tpy of PM
- 4.275 tpy of CO$_2$

PARTICIPANTS AND LESSONS LEARNED

- The M/V Highlands is in service as a fast ferry between Manhattan and the towns of Highlands and Atlantic Highlands, NJ. The M/V Highlands is operated by SeaStreak.

Lessons Learned
- Significant schedule delays due to contracting with New York City Department of Transportation.
- Changes in currency exchange since first proposed resulting in significant additional cost, but met with increased cost share.

SCHEDULE & BUDGET

- This project began in October of 2010 and expected to be completed in December of 2012
- Reductions will be achieved at $4,698/ton of NOx and $239,867/ton of PM based on total project costs.
Beyond Repowers
Diesel Emission Technology (future)

Tier 3 (2013)

- SCAC, Common Rail Direct Injection (CRD), Variable Geometry Turbochargers (VGT), UL packs

Tier 4 (2016)

- CRD, SCAC, VGT, Exhaust Gas Recirculation (EGR), Partial/Flow Through Filter (FTF) or Diesel Particulate Filter (DPF)

- Or,

- CRD, SCAC, VGT, Selective Catalytic Reduction (SCR), DOC or DPF

- All of these technologies have been proven in on-road and off-road diesel engines

There are no proposed Marine standards beyond Tier 4, however, many of the technologies above have the capability to go well beyond Tier 4
Future Prospects

Repower Opportunities Continue

- A Tier 2 electronic engine facilitates the possibility of a future transition to Tier 3 and/or Tier 4

- Tier 2 “Kits” (EMD engines) represent an opportunity to achieve Tier 2 emission levels at about 50% the cost of a complete new engine repower

Beyond Vessel Repowers

- “Hybrid” electric marine drive system approaches may further facilitate Tier 4 while substantially improving fuel economy and cost impacts
  - Lowering idle fuel consumption from 6 gallons per hour to less than 1 gallon per hour per engine
  - Smaller primary Tier 4 engine with associated higher load factors and engine exhaust temperatures
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