Membrane Scrubber Technology
SOx Removal from Engine Exhaust

Gerry Carter, Director
Edoardo Panziera, President

May 28, 2015 Seattle
Emission Control Areas (ECA)
< 0.1 % S    January 1, 2015
0.1 % Sulphur
MGO (Marine Gas Oil) $ 652

3.5 % Sulphur
IFO 380 $ 342

$ 310 / tonne
fuel price increase

Bunkerworld May 2015
http://www.bunkerworld.com/prices/
Ceramic Membrane Separation Technology

Exhaust gas containing SOx ducted to Membrane Scrubber™

Exhaust gas passes through modular unit, SOx removed

SOx captured by absorbent solution

Absorbent solution flows through porous membrane tubes

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Membrane Absorption Solution Chemistry:

\[
\text{SO}_2 + \text{NaOH} \rightarrow \text{NaHSO}_3
\]
\[
\text{NaHSO}_3 + \text{NaOH} \rightarrow \text{NaSO}_3 + \text{H}_2\text{O}
\]

\[
\text{K}_2\text{CO}_3 + \text{SO}_2 \rightarrow \text{K}_2\text{SO}_3 + \text{CO}_2
\]
\[
2\text{K}_2\text{SO}_3 + \text{O}_2 \rightarrow 2\text{K}_2\text{SO}_4
\]
$K_2CO_3$ & $2K_2SO_4$

- **Purchase Price**: $14 / tonne of fuel
- **Selling Price**: $14 / tonne of fuel

Bunkerworld May 2015 Pricing @ 1.5 % S Avg Content
Zero Wash Water Discharge

No PAH discharge  30% less power consumption
No turbidity discharge  No sludge disposal fees
No pH discharge  Scalable to match engine output

No risk of being banned from operation in any port due to discharge restrictions.

Fully VGP Compliant!

"Membrane technology keeps flue gasses separate from the absorption solution, and selectively collecting SOx makes sense to us - avoiding water contamination with hydrocarbons, complex separation processes before discharge, and significant amounts of sludge generation typical of wet scrubber technologies."

Martin LePage
Director, Concept Naval
<table>
<thead>
<tr>
<th>Owner</th>
<th>Vessel Name</th>
<th>Build Date</th>
<th>Retrofit / New Build</th>
<th>Ship Type</th>
<th>DWT</th>
<th>Drydock Location</th>
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<tbody>
<tr>
<td>CSL</td>
<td>BAIE ST. PAUL</td>
<td>CHINA 2012</td>
<td>RETROFIT 2015</td>
<td>BULK SELF UNLOADER</td>
<td>31992</td>
<td>Davies, Canada</td>
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</tbody>
</table>
Membrane Scrubber™ Efficiency

3.5 % S to 0.1 % S

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Thank You!

For additional information: Please visit Booth # 11

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