Tri-Mer Corporation

UltraTemp High Temp Filter
for PM, PM+SO2/HCl

&

UltraCat Catalyst Filter
for NOx removal, PM+SO2/HCl

Rod Gravley
Technology Director

Kevin Moss
Business Development Director
Tri-Mer Corporation – Company Profile

- Technology leaders in pollution control
- In-house manufacturing facility and fabrication line in central Michigan
- 15 lines of equipment to fit applications
- Turn-key project services
- Over 6,000 installed scrubber systems
- Projects from 10 cfm to 300,000 cfm
- Worldwide installations, many industries
Tri-Mer Product Line, Wet Scrubbing, Dry Filtration, SCR
Filter reference list

Over 400 installations primarily in Europe and Japan across many industries.

U.S. military applications plus a rapidly growing number of U.S. industrial installations since introduction to the industrial sector. Market driven by strict new regulatory laws.
Micrograph of low-density ceramic fiber

Available and utilized in Europe since 1989.
Types of ceramic filter technology

The new generation of ceramic filter is not the old style “candle” filter

<table>
<thead>
<tr>
<th>CHARACTERISTICS OF HIGH- AND LOW-DENSITY CERAMIC-FILTER ELEMENTS</th>
<th>High Density</th>
<th>Low Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Granular</td>
<td>Fibrous</td>
</tr>
<tr>
<td>Density</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Filter Drag</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Porosity, % (Inverse of resistance to flow)</td>
<td>0.3 - 0.4</td>
<td>0.8 - 0.9</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Fracture mechanism</td>
<td>Brittle</td>
<td>Ductile</td>
</tr>
<tr>
<td>Thermal shock resistance</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Cost</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Source: Reported in Chemical Engineering magazine Jan 2009
UltraTemp filter for particulate control

- Operating temperature to 1650 F (900 C)
- Typical removal to below 2 mg/Nm³ (0.001 grains/dscf)
- State-of-the-art for fine particulate control in industry
- High inlet loading capacity up to 10,000+ mg/Nm³ (5 grains/dscf)
UltraTemp Filter system module, ceramic tube filters

Tubes are 3 meters (10 ft) long, 150 mm (6 in) in diameter. This length utilized since 1997.
Operation of filters in housing

Jet pipe

Manifold

Filter tubes

Particles captured on outside of tubes

Dirty air enters

Clean air exits

Pressure drop: 6-10 inches w.g.

Valve

Filter

PLenum
Examples of ceramic filter tube longevity

- Aluminium powder: 5 years
- Waste pyrolysis: 5 years
- Wood waste incineration: 6 years+
- Meat waste incineration: 4 years+
- Lab waste incineration: 15 years
- Asphalt reclamation: 4 years+
- Fluid bed metal cleaning: 5 years+
- Catalyst elements on waste application: 5 years+
- Zirconia production: 6 years+
- Munitions incineration by U.S. Army: 10 years
- Bauxite liquor burner: 10 years
Typical filter results for particulate

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>PARTICLE SIZE</th>
<th>INLET PM LOADING</th>
<th>OUTLET PM LOADING</th>
<th>INFERRED EFFICIENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum powder production</td>
<td>&lt;50 d₅₀, μm</td>
<td>550 mg/Nm³</td>
<td>0.24 gr/dscf</td>
<td>&lt;1 mg/Nm³</td>
</tr>
<tr>
<td>Nickel refining</td>
<td>&lt;10</td>
<td>11,800 gr/dscf</td>
<td>5.16</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Smokeless fuel production</td>
<td>4.8</td>
<td>1000 mg/Nm³</td>
<td>0.44</td>
<td>1.5</td>
</tr>
<tr>
<td>Zirconia production</td>
<td>1.2</td>
<td>8000 mg/Nm³</td>
<td>3.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Secondary aluminum</td>
<td>&lt;1.0</td>
<td>870 mg/Nm³</td>
<td>0.38</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Source: Reported in Chemical Engineering magazine Jan 2009
SO$_2$, HCl, acid gases – dry powdered sorbent injection

- Operating temperatures 350 F – 1200 F
- Typically 90% or better. Some applications reach 97%
- Both calcium (lime) and sodium-based sorbents used
- Sodium based is preferred due to advantageous chemistry
  - Sodium bicarbonate (baking soda powder) to 800F
  - Trona (a naturally occurring soda compound) to 1200F
What about NOx removal?

Wouldn’t it be great to be able to control NOx in the same system?

First, a quick review of Selective Catalytic Reduction (SCR)

\[2\text{NO}_x \text{ (nitrogen oxides gas)} + 2\text{NH}_3 \text{ (ammonia liquid)} + \frac{1}{2}\text{O}_2 \text{ (oxygen gas)} \rightarrow 2\text{N}_2 \text{ (nitrogen gas)} + 3\text{H}_2\text{O} \text{ (water vapor gas)}\]

REACTING on the surface of the proper CATALYST

Harmless basic constituents of our atmosphere
Catalytic filter technology for NO$_x$

The combination of two well established and effective technologies

Standard filter tube + SCR catalyst
Award for Innovation

The catalyst-embedded filter received the prestigious ABB Environmental Award 2005 at the annual award ceremony of the Institute of Chemical Engineers in London.
Micrograph of Embedded SCR Nano-catalysts
Nano-catalysts embedded in UltraCat filter walls for NOx control

- Particulate captured on filter surface
- Nano-catalysts embedded in the walls of the filter
- PM does not penetrate walls of the filter
- Clean air
- Dirty air
- NOx + process PM + sorbent PM

NOx and ammonia react with catalyst to destroy NOx

Tri-Mer Corporation

50th Anniversary
NO$_x$ removal – low temp nanocatalyst & ammonia injection

- UltraCat Catalyst Filters preceded by upstream ammonia injection
  - Selective Catalytic Reduction (SCR) with proprietary catalyst
  - Catalyst formulation much less sensitive to SO$_2$ → SO$_3$, HCl

- UltraCat Catalyst Filter performance: up to 95% removal of NO$_x$
  - Lower operating temperature limit of 350 F
  - Upper operating temperature limit of 700 F
Additional Key Points for UltraCat Catalyst Filters

- Surface filtration of ceramic filter prevents poisoning of catalyst by PM. Sorbent injection lowers SO2 load.
- Catalyst does not affect filtration performance.
- Increase in pressure drop by catalyst is negligible.
- No reaction between ceramic and catalyst.
- Catalyst does not require regeneration and lifetime is expected to be 5+ years.
- Catalyst-embedded filters available since 2005.
- Recent scientific evaluation by European catalyst manufacturer on glass applications (PM+SO2+NOx removal) concluded there was no sign of catalyst deterioration after five years of service.
Two large glass plants operating for approx. 3 years, both companies have ordered another system, two additional systems being installed, many under review.

### TYPICAL GLASS FURNACE RESULTS FOR PM, SO$_2$, NO$_x$ CONTROL

<table>
<thead>
<tr>
<th>POLLUTANTS</th>
<th>UNITS</th>
<th>FILTER INLET</th>
<th>FILTER OUTLET</th>
<th>EFFICIENCY %</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM</td>
<td>mg/Nm$^3$</td>
<td>1500</td>
<td>0.5</td>
<td>99.97</td>
</tr>
<tr>
<td>NOx</td>
<td>mg/Nm$^3$</td>
<td>1000</td>
<td>150</td>
<td>85.00</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>mg/Nm$^3$</td>
<td>850</td>
<td>25</td>
<td>97.10</td>
</tr>
<tr>
<td>HCl</td>
<td>mg/Nm$^3$</td>
<td>600</td>
<td>5</td>
<td>99.20</td>
</tr>
</tbody>
</table>

Source: Glass Problems Conference, Columbus OH, October 2009

Pilot test results on flat glass that incorporates SO$_2$ and NO$_x$ control. NOx removal could have been increased with more ammonia injection. Note that particulate loading includes the dry sorbent to control SO$_2$. Commercial systems initially based on these results.
Pilot test results in various industries

<table>
<thead>
<tr>
<th>POLLUTANT</th>
<th>TEMP</th>
<th>INLET mg/Nm³</th>
<th>OUTLET 11%O₂ Dry</th>
<th>REAGENT</th>
<th>PERFORMANCE</th>
<th>APPLICATION</th>
</tr>
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<tbody>
<tr>
<td>Particulate Matter</td>
<td>290°C</td>
<td>130</td>
<td>&lt;1</td>
<td>–</td>
<td>&gt;99%</td>
<td>Glass Industry</td>
</tr>
<tr>
<td></td>
<td>325°C</td>
<td>330</td>
<td>&lt;1</td>
<td>–</td>
<td>&gt;99%</td>
<td>Glass Industry</td>
</tr>
<tr>
<td></td>
<td>185°C</td>
<td>725</td>
<td>&lt;1.5</td>
<td>–</td>
<td>&gt;99%</td>
<td>Waste from Slaughterhouse</td>
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<tr>
<td>SO₂</td>
<td>290°C</td>
<td>630</td>
<td>30</td>
<td>Sodium Bicarbonate</td>
<td>95%</td>
<td>Glass Industry</td>
</tr>
<tr>
<td></td>
<td>300°C</td>
<td>590</td>
<td>18</td>
<td>Lime with Large Specific Area</td>
<td>97%</td>
<td>Glass Industry</td>
</tr>
<tr>
<td></td>
<td>330°C</td>
<td>1165</td>
<td>480</td>
<td>Standard Lime</td>
<td>59%</td>
<td>Glass Industry</td>
</tr>
<tr>
<td></td>
<td>320°C</td>
<td>1070</td>
<td>250</td>
<td>Sodium Carbonate</td>
<td>77%</td>
<td>Glass Industry</td>
</tr>
<tr>
<td></td>
<td>330°C</td>
<td>355</td>
<td>8</td>
<td>Sodium Bicarbonate</td>
<td>98%</td>
<td>Chemical Industry</td>
</tr>
<tr>
<td></td>
<td>180°C</td>
<td>870</td>
<td>&lt;5</td>
<td>Sodium Bicarbonate</td>
<td>&gt;99%</td>
<td>Waste from Slaughterhouse</td>
</tr>
<tr>
<td>HCl</td>
<td>330°C</td>
<td>650</td>
<td>40</td>
<td>Sodium Carbonate</td>
<td>94%</td>
<td>Chemical Industry</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>30</td>
<td>&lt;1</td>
<td>Sodium Bicarbonate</td>
<td>96%</td>
<td>Waste from Slaughterhouse</td>
</tr>
<tr>
<td>NOₓ</td>
<td>280°C</td>
<td>1200</td>
<td>250</td>
<td>Ammonia</td>
<td>79%</td>
<td>Glass Industry</td>
</tr>
<tr>
<td></td>
<td>290°C</td>
<td>2570</td>
<td>113</td>
<td>Ammonia</td>
<td>96%</td>
<td>Engine Fumes</td>
</tr>
<tr>
<td></td>
<td>320°C</td>
<td>350</td>
<td>50</td>
<td>Ammonia</td>
<td>86%</td>
<td>Glass Industry</td>
</tr>
<tr>
<td></td>
<td>280°C</td>
<td>800</td>
<td>&lt;9</td>
<td>Ammonia</td>
<td>97%</td>
<td>Engine Fumes</td>
</tr>
<tr>
<td></td>
<td>180°C</td>
<td>450</td>
<td>48</td>
<td>Ammonia</td>
<td>89%</td>
<td>Waste from Slaughterhouse</td>
</tr>
</tbody>
</table>

Source: Reported in Glass International Feb 2008
Control of PM, SO$_2$, NO$_x$ in One System

Sorbent Injection for SO$_2$ / HCl Control

Urea/Ammonia Injection for NO$_x$ Control

Ceramic Filters with Embedded Catalyst for NO$_x$ and Dioxin Control, PM Capture

Pollutant gas → Cleaned gas

Tri-Mer offers complete equipment set, engineering, and installation.
Technology transfer of module designs from European collaborator with dozens of installed filter systems over the last decade.

Tri-Mer is expert in steel fabrication, with steel APC equipment in place for over 40 years.
Module, shipping & install

a. Walk-in plenum module shipped in three pieces.

b. Simple installation with a crane.

c. Filter tubes installed in the field by Tri-Mer personnel.
UltraTemp or UltraCat module with walk-in plenum

a) 30 ft. Walk-in Plenum provides easy filter placement, more weather-friendly enclosure.

b) All plenums insulated.

c) Outdoor/indoor placement.
Multiple modules in parallel to match the project flow volume
With 3 or more modules, if a module needs to be serviced, the other modules are designed to temporarily operate at higher pressure with minimal change in performance.
Typical arrangement for large flow volumes

“Super sack” for bicarb and “totes” for ammonia also typical

With 3 or more modules, if a module needs to be serviced, the other modules are designed to temporarily operate at higher pressure with minimal change in performance.
Filter tube sealing mechanism, standard pulse-jet cleaning

Jet pipe

PLENUM

Manifold

Filter tubes

Compression plate

Filter lip

Spongy gasket

Valve

Pressure drop: 6-10 inches w.g.
Filters cleaned either on a timer or when dP is 1.0 in w.g.
Module, internal detail. Standard pulse-jet baghouse cleaning

Venturi elements generate short air pulse down each filter tube: online reverse flow pulse jet cleaning
Module, internal

Air Jet pipes for online filter cleaning
Module, underside

Supports set on cement piers. No slab needed.
Auger conveys captured particulate to a rotary valve or slide gate valve.
Filter housing fabrication in Tri-Mer factory, Michigan
Module sizes vary according to flow volume required. The width stays the same but length changes.

Number of modules also varies according to application size.
Summary: UTF, UCF advantages

- Lower initial cost because of all-in-one capability
- Lower total operating cost than a train of equipment
- Lower cost of long-term ownership
- Flexibility, simplicity of design, operation, maintenance
- Unsurpassed PM removal
- Low temp NOx removal, dioxin destruction
- SO2 & HCl removal, mercury options
- Performance guarantees
- Backed by Tri-Mer’s 50 years of service and reliability