TURBOSCRUBBER® - BLEACH PLANT SCRUBBER APPLICATION
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ABSTRACT
New scrubbing and stripping applications in pulp and paper mills have been made possible by the introduction of fluidized-bed mass-transfer towers employing asymmetrical fluidization elements. Element shapes have been developed and deployed in multiple industries which create tumbling motion generating improved pressure gradients and enhanced surface renewal rates resulting in improved mass transfer rates over both fixed-contact and symmetrical-element fluidized-bed contacting equipment. There is considerable scope for reducing tower diameters for new installations or for retrofitting existing units where improvements in absorption or stripping efficiency are required. Removal of small particulate matter is improved by the motion. A particular advantage of the tumbling fluidized motion is its strong resistance to plugging by particulates. Asymmetric-element fluidized bed scrubbing technology provides absorption, particulate removal and heat transfer in one unit. These characteristics are being introduced in several applications in the pulp and paper industry.

Pulp and paper plants around the world are facing increased pressure from environmental agencies and stakeholders to reduce emissions in the form of ClO2 and sometimes Cl2. It is standard to measure and report these emissions during continuous operation, but many producers are also experiencing increasingly stringent emission targets for the duration of plant start-up. During plant start-up many plants experience spikes in ClO2 concentrations, and the “green plume” or stack opacity from ClO2 slippage can be a concern. Currently the pulp and paper industry uses mostly two kinds of scrubbers for bleach plant vent gases, packed bed scrubbers or horizontal-duct mist scrubbers. Packed bed scrubbers plug often and require a shutdown for high pressure cleaning whereas horizontal-duct mist scrubber nozzles are prone to nozzle plugging. The use of E-stage filtrate as a scrubbing medium is extensively pursued by the industry as it is freely available but is not widely practiced due to fibers creating problems for both types of scrubbers. Asymmetric-element fluidized bed scrubbing technology allows use of E-stage filtrate while circumventing plugging issues.

Asymmetric-element fluidized bed scrubbing technology has higher mass and heat transfer rates for a given gas-side pressure drop, compared to other gas-liquid contacting technologies. Hence it offers the possibilities of ClO2 emission reduction, continuous and start-up emission reductions, and the use of scrubbing slurries. The asymmetric-element fluidized bed scrubbing fluidized bed technology, licensed by NORAM, has been successfully applied to a wide range of Cl2 and ClO2 scrubbing applications, and can potentially be used in the pulp and paper industry. This paper provides an overview of the asymmetric-element fluidized bed scrubbing technology, discusses kinetics of ClO2 and Cl2 absorption in water and NaOH solution, and discusses some of the technical features of asymmetric-element fluidized bed scrubbing technology and equipment.

KEYWORDS
Bleach Plant Scrubbing, Extraction Stage Filtrate, Fluidized Bed, Particulate, ClO2

INTRODUCTION AND THEORY
Mass/energy transfer processes wherein a gas phase and a liquid phase are introduced in countercurrent fashion in a tower with packing elements are common. The elements become suspended or fluidized if the operating conditions of the system are adjusted. These kinds of systems are used in scrubbing towers for removing undesired substances from gases. Fluidized bed system is generally more efficient than a conventional fixed packing system.

Fluidized beds for gas scrubbing made from spherical polypropylene elements have long been used for gas scrubbing but a disadvantage is that they cannot sustain large pressure gradients. The elements in the fluidized bed are pushed against each other and wedged to one side in a single static mass of packing by the gas instead of remaining fluidized. Impurities and debris are deposited on these de-fluidized elements. The efficiency of the process is lowered considerably by gas and/or liquid channelling. The remaining elements which do fluidize are subjected to more extreme motion and therefore breakage. However the use of ellipsoid elements over spherical elements has led to improved uniformity of fluidization.
The superior mass transfer achieved in fluidized bed equipment depends on generating turbulence by controlling the pressure gradient \( \frac{dP}{dh} \) across the bed and the role of the element shape defined by the factor \( y \). The control mechanism was shown as an equation:

\[
\frac{dP}{dh} = U_g(a + b \cdot \frac{L}{G})
\]  \( (1) \)

where, 
\( U_g = \) Superficial gas velocity \\
\( L/G = \) liquid to gas ratio \\
\( a, b = \) variable or system 'constants'

Up until that time the general equation for pressure gradient had been;

\[
\frac{dP}{dh} = C_1 \rho_p + C_2 \rho_g U_l + C_3 \rho _g U_g
\]  \( (2) \)

With \( r = \) density; subscripts: \( p = \) particle, \( g = \) gas, \( l = \) liquid \\
\( C = "\text{variable}" \) or system 'constants'

There is a mathematical concern with equation (2) since it does not reduce to zero when \( U_g = 0 \).

However it should be noted that these equations are only really considered valid from the point of full fluidization (about 10% higher in pressure gradient terms than incipient fluidization). From the designers point of view it is this operational range and its limits which are of most importance.

The expanded form of equation (1) is shown in a more recent patent [10] produced by Davis & Ruff expanding the process to take all shapes into account and is as follows;

\[
\frac{dP}{dh_0} = U_g \left( \frac{C_1 \rho_p}{\rho_s} + \frac{C_2 \rho_g \cdot g}{\rho g} + \frac{C_3 \rho_g \cdot L}{G} \right)
\]

where \( h_0 = \) static bed height (non fluidized condition) \\
\( s = \) slip velocity (between element and gas) \\
\( y = \) shape factor \\
\( f = \) accentric or offset factor (difference between center of gravity and midpoint of tumbling axis or radius for spheres) \\
\( g = \) gravitational constant

The essential difference between spherical and non-spherical shapes when used in a fluidized bed is the fact that both \( y \) and \( f \) have values of 1.0 for spheres (a special case), whereas the numbers vary (0-1) for asymmetrical 'particles' or elements. As another example Dr. Ruff's 'ellipsoids' would have a reduced value for \( y \) and with \( f = 1.0 \) since its center of gravity coincides with the center of its long axis.
Thus by varying the size and exact shape of the element it is possible to control the system pressure gradient and consequently regulate the mass, heat or particulate transfer efficiency since.

\[ K_{og} = f\left(\frac{dp}{dh}\right) \]

i.e:

where \( K_{og} \) = overall mass transfer coefficient

The key is to ensure that the elements are not merely lightly fluidized but to generate sufficient pressure gradient across the beds to violently tumble the elements around within a 'homogeneous' three phase mix. Whilst it is important to develop sufficient pressure gradient across the fluid bed the absolute value of the mass & heat transfer coefficients is in reality a function of bed turbulence and surface renewal rates which are related to the rate of pressure loss in a specific way. That is to say that simply by increasing pressure gradient will not produce optimum design conditions. Having sufficient pressure gradient combined with the fastest tumbling rate or surface renewal will produce the best designs and avoid costly loss of energy in achieving the desired efficiency. However these conditions are unlikely to be met below a minimum pressure gradient value of around 1300Pa/m due to the inexorable link between tumbling and the rate of pressure loss. In short a careful selection of element shape to achieve these optimum conditions is essential and then to ensure a good design or range of operating conditions for the gas-liquid contactor.

The work undertaken by Fluid Technologies Ltd. and Osprey Corporation Ltd, has drawn heavily on and has effectively validated the pioneering work of Danckwerts [12] who showed that:

\[ K_{og} = f\left(\sqrt{Ds}\right) \]

where \( D \) = Diffusivity & \( s \) = surface renewal rate,

and in analogous fashion

\[ h = f\left(\sqrt{\alpha s}\right) \]

where \( h \) = heat transfer coefficient & \( \alpha = \) thermal diffusivity.

Thermal Diffusivity = \( K /C_p r \)

Where \( K = \) Conductivity

\( C_p = \) Specific Heat & \( r = \) density

Since symmetrical spherical balls cannot tumble around one or more axes it is only non-symmetrical and sufficiently dense, tumbling elements that will generate the requisite pressure gradients, surface renewal rates, and mass transfer rates, that are well in excess of equivalent classical systems (i.e. fixed packing). Some recent work undertaken by Bochum University (published by Professor Billet in his book on packed towers [11]) compared light weight oblate spheroids to denser spherical balls (under controlled, non- 'gulf streaming' laboratory scale conditions) in a lightly fluidized regime (generally between 1,100 and 1,500 Pa/m) and not surprisingly, only showed more modest improvements over the spherical balls. Whilst the dense spheres generated high pressure gradients the lack of tumbling limited their efficiency and the lightly tumbled oblate spheroids suffered from operation at low pressure gradients due to their low density. This is not the industrial scale experience with well-agitated tumbling beds where efficient shapes & densities have been purposely selected and effectively used.

As a rule the onset of tumbling can be predicted using the equation
\[
\frac{dP}{dH_0} > Ax \frac{(y-r)}{y^2}
\]

where \( A = \frac{1}{\varepsilon} \) (element size & bed density)

\( y = \) longest axis

\( r = \) ‘radius’ of centre of gravity

By selecting shapes to reduce both the shape and the offset factors, bed and tower heights can be remarkably reduced over fixed beds. Since fluid bed towers can operate across a very wide range of gas and liquid velocities (turndown), there is considerable scope for reducing tower diameters (for new installations) or for retrofitting existing fixed pack and sieve plate units where improvements in absorption efficiency are sought or particulates or bottlenecking are problems. Over 400 full scale applications are in practice to date.

**CASE STUDIES**

*Kraft Paper Mill White Water Stripping Facilitates Zero-effluent Operation*

Visy Pulp & Paper in NSW, Australia operates a zero-effluent, fully integrated, unbleached Kraft pulp and paper mill. In the zero effluent design, maximum reuse of all process filtrates is mandatory and at high levels of recycle, contaminants can build up. The objective of this project was to remove TRS and volatile organic compounds from paper mill process white water. Two asymmetric fluidized bed strippers were installed for this purpose, one of which is shown in Figure 1.

*Figure 1: Asymmetric fluidized bed stripper deployed for stripping of TRS and other volatiles from kraft paper mill white water.*

The main contaminants of interest were TRS constituents, dimethyl-sulfide, dimethyl-disulfide, and methyl mercaptan; which were present in concentrations as high as 10,000 ppb. The stripper’s non-clogging nature permitted the effective treatment of the process white water without prior clarification. The characteristics of the strippers are shown in Table 2.
Removal efficiencies of up to 99.99% were achieved. This facilitated use of the white water by the mill while maintaining low odor in the process area and in the product.

Modelling of an existing ClO₂ Scrubber in an eastern Canadian Plant

A modeling study was done at an eastern Canadian pulp mill to improve the performance of the ClO₂ scrubber. Measurements taken and dispersion calculations made respectively during the spring & summer months of 2012 showed high level maximum emissions of both ClO₂ & Cl₂ at the stack. The following emission figures are shown below in table 2 below. For the emission results flowrate is 0.37 Dsm⁻³/s, exit velocity and temperature are 11.65 m/s and 297K respectively.

The scrubber tower is a 0.6m (2ft) diameter and only one saddle packing bed of maximum height of about 1.9m (6'). The scrubber tower has a low L/G ratio of 3.25 litre s/m³, which cannot be increased without increased pressure loss and flooding risk.

Sodium hydroxide solution is used to improve ClO₂ removal.

A detailed model of the scrubber was developed incorporating both chemical and mass transfer phenomena. The model showed that the sodium hydroxide would indeed improve scrubbing efficiency, albeit marginally, through a slow hydrolysis reaction, reducing the interfacial concentration of ClO₂.
As shown in Figure 2, the model shows that the optimum concentration for sodium hydroxide is about 5%, due to competing effects of reactivity and diffusivity. The optimum corresponded with mill experience as well.

The figure 3 below shows that the scrubber tower is not pinched but is limited in its performance potential by the packings employed. Saddle A offers a ClO\textsubscript{2} scrubbing efficiency of around 33% with 4.5m\textsuperscript{3}/hr of 5% w/w NaOH solution whereas saddle B is limited to around 25% removal efficiency. It should be noted that this assumes a fairly cold liquid inlet temperature of around 7-8°C.

The stack measurements from 2012 show that up to 0.722 grams/s exited as emissions being equivalent to about 2,000mg/Nm\textsuperscript{3}. This suggests that the scrubber can only be achieving chlorine removal efficiencies of the order of 70-80% which is extremely low bearing in mind the very rapid nature of absorption into NaOH solutions where there is favourable stoichiometry as in this case. These findings show that the scrubber tower is under-designed & under-powered for current and future legislative emissions requirements.

The existing scrubber tower could be converted to asymmetric (element) fluidized bed scrubbing mode by incorporating a recirculation pump to boost the L/G ratio (a fluid bed system does not flood and can run at a very wide range of L/G ratios) and create a well fluidised bed. A single step retrofit – simply using asymmetric elements where the ceramic packings are – was modelled. Figure 4 below shows that the scrubber efficiency would reach 80% as opposed to the current 25% or 33% in figure 3.
Figure 4: Pressure Vs Bed Height after converting to asymmetric (element) fluidized bed scrubbing mode

The modelling work confirmed that the effectiveness of sodium hydroxide alone is quite limited. In the main bleach plant scrubbers, mills have long employed a reducing agent to further reduce the interfacial concentration of ClO₂.

BLEACH PLANT SCRUBBING
Chlorine dioxide has been commonly used for bleaching pulp since the late 1950s. It causes highly selective oxidation of lignin and makes it soluble without significant accompanying degradation of cellulose or hemicellulose. The strength of the pulp is preserved, while the pulp is stably brightened [17]. However, part of the chlorine dioxide that is used in the bleaching process becomes entrained in vent gas that is recovered from various locations in the bleach plant. Since chlorine dioxide is an environmental contaminant whose release is subject to regulatory limitations, it must be removed from the vent gas. This is normally accomplished using a scrubber that employs reducing agents or alkali solutions that react with the gaseous chlorine dioxide converting it to non-volatile species. Reducing agents that can be employed in this application include the sulfur compounds sulfur dioxide, sodium sulfite, sodium bisulfite, sodium sulfide and sodium thiosulfate. Hydrogen peroxide can also act as a reducing agent for this application. Alkali solutions include sodium hydroxide and white liquor.

Scrubbing Medium
Chemicals such as sodium hydroxide plus sodium bisulfite, or mill liquors such as white liquor or weak wash may be employed; either approach results in additional chemical costs for the mill. E-stage bleach filtrate contains both alkali and reducing agent (organic) and has been utilized for vent scrubbing. The distribution of scrubbing mediums used in twenty-two mills is shown in figure 5 [13]. The predominant agent used is white liquor, which results in a substantial makeup chemical cost.

Figure 5: Distribution of scrubbing medium
Chilled Water
One of the most important physical properties of ClO₂ is its high solubility in water, particularly in chilled water. In contrast to the hydrolysis of chlorine gas in water, ClO₂ in water does not hydrolyse to any appreciable extent but remains in solution as a dissolved gas [19]. It is approximately ten times more soluble than chlorine, extremely volatile and can easily be removed from dilute aqueous solutions with minimal aeration or carbonation with CO₂ [20].

So the ClO₂ gas will absorb physically into aqueous solution but does not dissociate into ionic species. However it does react with OH⁻ with the following reaction taking place:
\[ 2\text{ClO}_2 + 2\text{OH}^- \rightarrow \text{H}_2\text{O} + \text{ClO}_2^- + \text{ClO}_3^- \] ………..1

ClO₂ is more soluble than Cl₂ as shown in table 3 below. The scrubbing efficiency drops from 99% and 95% to 97% and 70% for ClO₂ and Cl₂ respectively with increase in temperature of water from 10°C to 15°C [13].

<table>
<thead>
<tr>
<th></th>
<th>mm (Hg)</th>
<th>5°C</th>
<th>10°C</th>
<th>15°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClO₂</td>
<td>5</td>
<td>1.03</td>
<td>0.86</td>
<td>0.70</td>
</tr>
<tr>
<td>Cl₂</td>
<td>5</td>
<td>0.45</td>
<td>0.44</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Sodium Hydroxide Solution
Sodium hydroxide is an effective scrubbing medium for chlorine and can act as a source of hydroxide ions to force the disproportionation of ClO₂ according to the following reactions [13]:
\[ \text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaOCl} + \text{NaCl} + \text{H}_2\text{O} \]
\[ 2\text{ClO}_2 + 2\text{NaOH} \rightarrow 2\text{NaClO}_2 + \text{NaClO}_3 + \text{H}_2\text{O} \]

Bleach Plant E-Stage Filtrate
The bleaching stage following D₀ and D₁ is usually an alkaline extraction stage. Apart from being alkaline, the filtrate also contains organic material that will reduce the ClO₂ to chloride and render it non-volatile. A secondary benefit is oxidizing and decolourizing the E-stage filtrate. These properties make it suitable for scrubbing ClO₂ and Cl₂. E-stage filtrate is a waste stream and is available for use before being sent to the effluent treatment plant. The mill can benefit both economically and environmentally as using E-stage filtrate for scrubbing provides chemical savings and also reduces the color of the filtrate. Lignin content and pH define the effectiveness of the E-stage filtrate as a scrubbing medium [13]. Since the E-stage filtrate usually contains some amount of fiber, the nozzles and packing are prone to plugging.

White Liquor and Weak Wash
Both white liquor and weak wash are made of NaOH and Na₂S at different concentrations and are alkaline in nature. The reducing agent sodium sulfide is usually around 40 gpl as NaOH in white liquor and 3 gpl in weak wash [15, 16]. The sulfide is especially effective in scrubbing ClO₂ and Cl₂. Lime mud which is present in both white liquor and weak wash has a tendency to plug packed bed packing and spray nozzles.

Type of Scrubbers
Most mills typically use packed bed scrubbers or horizontal duct mist type scrubbers. The use of E-stage filtrate, typically an alkaline pulp mill waste stream, in conventional packed bed scrubber can cause severe plugging issues due to its high fiber content. This results in a large pressure drop, and a loss of scrubber capacity. The internals must undergo high pressure cleaning due to deposit formation. Typically, due to the plugging of packing, the gas flow eventually drops to half of the original value over a period of 1 year. At this stage the packing is removed, cleaned and reinstalled. This is a crucial consequence for any pulp mill, as it must abide by the environmental permit and bear the production downtime.

Crossflow wet scrubbers are an alternative technology to conventional packed bed scrubbers that mills frequently use. The crossflow scrubbers do not contain any internal packing and rely on the use of atomizing nozzles to contact the scrubbing medium with the acid gas. It has been frequently reported by various mills that frequent nozzle plugging and issues with atomizing E-stage filtrate are contributing towards the scrubber not meeting the regulatory standards. As such, mills must revert to using expensive caustic or white liquor/weak wash to meet emissions standards. However an acid wash of spray nozzles must be done regularly if using white liquor/weak wash to get rid of CaCO₃ build-up and hence ensure a good spray pattern [13].
Figure 6 below shows the process schematic practised at Cascades Fjordcell [18]. The scrubber was a packed tower of 10 feet diameter with random packing. During the course of years between 1998 and 2003, the scrubber was operated in recirculation mode using only Eop filtrate as a make-up with the scrubber overflow being sent to the mill alkaline sewer. Over the years, the mill experienced challenges with fiber in the Eop filtrate accumulating in the packing leading to a large pressure drop and loss in capacity.

ADVANTAGES OF ASSYMETRIC-ELEMENT FLUIDIZED BASED SCRUBBING
Asymmetric (element) fluidized bed scrubbing has several benefits over traditional technology. The system has the ability to handle solids, including fibre in the scrubbing liquid without regular maintenance shutdowns. This opens up continuous use of E-stage filtrate. Typically, E-stage filtrate is disposed to sewer after it is produced. The use of asymmetric-element fluidized bed scrubbing technology would facilitate an additional use of E-stage filtrate prior to disposal.

The unique asymmetric fluidized packing, that can be made of either polypropylene or polyvinylidene fluoride ensures the bed is chaotic, allowing for high mass and heat transfer coefficients compared with an equivalent packed–bed column. The patented ellipsoid shape is more energy efficient to fluidize and overcomes issues with distribution, swirling, channeling observed with sphere shaped packing. The indent adds extra thrust to the tumbling motion.

Higher transfer coefficients lead to smaller equipment size for a given capacity. It can be retrofitted into an existing vertical packed-bed scrubber, for minimized capital investment and when footprint is a premium. Mills presently using a packed bed scrubber could convert the tower to asymmetric fluidized bed operation and find relief from frequent maintenance required for conventional systems in this service.

Applicable Bleach Plant Scenario
A western Canadian mill uses two scrubbers in the bleach plant to treat gases from various tank vents and washer hoods located in the bleach plant:

- Packed Bed Scrubber
- Horizontal Duct Mist Scrubber

The packed bed scrubber uses E-stage filtrate as scrubbing liquor. Apart from the fact that the scrubber is old and its internals require frequent maintenance, it also has to undergo high pressure cleaning due to deposit formation. Due to the plugging of packing, the gas flow eventually drops to half of the original value over a period of 1 year. At this stage the packing is removed, cleaned and reinstalled. This is a crucial consequence for the mill, as it has to abide by the environmental permit and also bear the production downtime. The second scrubber located in the bleach plant, horizontal duct mist scrubber, is more than 25 years old and uses white liquor for scrubbing, which is an expensive scrubbing chemical. Hence the mill was interested in investigating a new standalone scrubber that would replace both existing scrubbers and use the readily available bleach plant byproduct, E-stage filtrate, as scrubbing liquor instead of the expensive white liquor.

The following data was collected from the mill:
Table 4: Asymmetric fluidized scrubber design basis

<table>
<thead>
<tr>
<th>Noram Scrubber Preliminary Design Conditions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet gas Volume (m³/min)  @ 52°C &amp; -3 mm Hg</td>
<td>1.336</td>
</tr>
<tr>
<td>Inlet Gas Temperature (°C)</td>
<td>57.2</td>
</tr>
<tr>
<td>Inlet ClO₂ Concentration (ppm)</td>
<td>100-500</td>
</tr>
<tr>
<td>Scrubbing Liquor</td>
<td>E-stage filtrate</td>
</tr>
<tr>
<td>Scrubbing Liquor Flow (m³/h)</td>
<td>238</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scrubbing Liquor</th>
<th>EoA</th>
<th>EoB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scrubbing Liquor pH</td>
<td>9.9 @ 30°C</td>
<td>11.2 @ 30°C</td>
</tr>
<tr>
<td>Scrubbing Liquor Temperature (°C)</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Scrubbing Liquor Fiber content (gpl)</td>
<td>0.058</td>
<td>0.035</td>
</tr>
<tr>
<td>Scrubbing Liquor COD (ppm)</td>
<td>4095</td>
<td>3699</td>
</tr>
<tr>
<td>Scrubbing Liquor Total dissolved Solids (gpl)</td>
<td>2.5</td>
<td>2.7</td>
</tr>
</tbody>
</table>

In this scenario the asymmetric fluidized bed scrubber was designed to handle the combined duty of both the packed bed scrubber and horizontal duct mist scrubber reducing the number of emission point sources. The scrubber with a diameter of 9.5 feet and a height of 42.6 feet would fit within the same footprint as the existing packed bed scrubber, requiring minimal modifications of existing ducting and foundation. The asymmetric fluidized bed scrubber will require no upstream fiber filters and allow the mill to run on E-stage filtrate instead of white liquor, saving operational costs.

CONCLUSIONS

- E-stage filtrate is freely available and can be used to scrub Cl₂ and ClO₂ due to its alkaline nature and organic content.
- Packed bed scrubber and horizontal duct mist scrubbers are the most common type of scrubbers used in pulp mills. However both packed bed and horizontal duct mist type scrubbers experience issues with bed plugging and nozzles plugging respectively.
- Asymmetric (element) fluidized bed scrubbing has inherently high mass and heat transfer rates for a given gas-side pressure drop as compared to other gas-liquid contacting technologies such as packed towers, venturis, reverse jet resulting in a smaller equipment footprint and lower capital cost.
- Asymmetric (element) fluidized bed scrubbing can handle gas turndown rates of up to 1:12 and hence the efficiency of ClO₂ removal can variably be increased during plant turndown and start-up operations.
- Low energy costs from optimized mass transfer operation.
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Turboscrubber® Bleach Plant Scrubber

Wayne Bucher
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Noram Group

- Based in Vancouver, Canada
- Founded in 1988
- Approximately 200 employees
- Focus on Technology.
- Own BC Research Laboratories
- Own Axton and Ellett Fabrication Shops
- Own Noram International AB (Sweden)

http://www.noram-eng.com/
http://www.bcri.ca/ http://www.axton.ca/
http://www.noram-intl.com/
Industrial Segments

- Nitration
- Sulphuric Acid
- Electrochemical Technology
- Biosystems
- Pulp & Paper
- Environmental

Technology Commercialization

- Vancouver Headquarters
- Fabrication & Assembly
- Technology Incubator
- European Operations
Asymmetric-Element Fluidized Bed Scrubber

- Fluidized bed technology
  - Scrubbers, absorbers, strippers
- History
  - Developed and progressed by FTL and Osprey since 1991
  - Over 500 plants installed worldwide in many various industries
- Pulp and paper applications
  - AV Group, Atholville New Brunswick
  - Visy Pulp & Paper, Australia
  - Huhtamaki Group
Asymmetric-Element Fluidized Bed Scrubber Process

- 3-phase fluidized bed
- Dynamic packing increases Gas/Liquid contact
- Non-plugging
- Particle removal < 0.5 micron
- Gas turndown ratios up to x 12
- Won’t flood even at high L/G
Asymmetric-Element Fluidized Bed Scrubber

Advantages

- High turbulence & liquid hold up = Unsurpassed mass & heat transfer

- Equipment Size Reduction
  - Smaller diameter & height
  - Retrofit advantage of improved capacity

- Guaranteed Blockage Free Application
  - Slurries, biomass, precipitating systems

- Multi Use Friendly
  - Absorption, particulate removal, heat transfer in one single unit
  - More energy efficient than combination units
Asymmetric-Element Fluidized Bed Scrubber
Pilot Movie
Asymmetric-Element Fluidized Bed Scrubber
Dynamic Packing

- Patented ellipsoid/ovoidal shapes
- More energy efficient to fluidize
- Indent adds extra thrust to the tumbling motion
- Overcomes issues with sphere shaped packing which lead to unreliable performance
  - Swirl, sideways movement
  - Channeling
  - Distribution
Asymmetric-Element Fluidized Bed Scrubber
Slow Motion Movie
Pulp and Paper Application

Huhtamaki

- Treating vacuum forming machine offgas with machine whitewater

- Recovering carbon particles & wax with up to 99% removal

- Heat transfer coeff > 150 kW / m$^3$°K

<table>
<thead>
<tr>
<th>Energy recovery</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MM Btu / hr</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

| Column diameter (ft) | 2      | 4      |
| Column height (ft)   | 14     | 21     |
Pulp and Paper Application
AVCell – Atholville, New Brunswick

- Absorbing SO$_2$ gas in Mg(OH)$_2$ Slurry
- Retrofit of existing tower
- Improved SO$_2$ removal
- Reduced pressure drop to ~50%
- Previous shutdowns due to plugging every 2-3 months
- Increased run time to > 1 year
Bleach Plant Scrubbing

Scrubbing Media Used

- ClO₂ in the bleach plant's exhaust gases are absorbed and neutralized in a bleach plant scrubber.
- Increased pressure from environmental agencies and stakeholders to reduce emissions.
- Traditionally used scrubbing media are E-Stage filtrate, caustic, SO₂, weak wash, white liquor and water.
Bleach Plant scrubbing
Types of Scrubbers

- Packed bed
  - Typically plug every 4-6 months
  - Cleaning can take up to 48 hours
  - Washer fabric tears have immediate impact on performance
  - Require fiber filter to protect scrubbing medium
  - Efficiency depends on chosen packing

- Horizontal duct mist scrubber
  - Highly dependent on size and distribution of spray
  - Nozzles prone to plugging with fiber / CaCO₃
  - Acid wash of nozzles required
Bleach Plant Scrubbing
E-Stage Filtrate

● Excellent choice for scrubbing
  o Freely available
  o Alkaline
  o Organic material which can be oxidized
  o Scrubbing also reduces the color of the filtrate
  o Effectiveness determined by lignin content and pH

● Widely used, but fibers create problems for most scrubbers
Applicable Bleach Plant Scenario

- If a mill has two bleach plant scrubbers
  - Packed bed and/or
  - Horizontal duct mist

- Retrofit existing packed bed to asymmetric fluidized bed scrubber.
- Combine duty of both with this more efficient design
- Reduces the number of emission point sources
- Requires minimal modifications of existing ducting, fan, etc
- No need for upstream fiber filters
- Helps to reduce BOD and color of E filtrate
- If WL limited, may allow added pulp production
Asymmetric-Element Fluidized Scrubber

Summary

● Unsurpassed mass and heat transfer rates
  ○ High turbulence => high mass & heat transfer coefficients
● Lower pressure drop => energy efficient
● Equipment size reduction – footprint and height
● Guaranteed blockage free application
  ○ Slurries, biomass, precipitating systems
● Multi-use friendly
  ○ Absorption, particulate removal, heat transfer in one unit
  ○ More energy efficient than combination units
● Excellent option for bleach plant vent duty
THANK YOU