Technical Bulletin No. 2

Modern Gas Cleaning Techniques For TRS and SO_2 Control in the Pulp and Paper Industry

The control of SO_2 and total reduced sulfur (TRS) emissions in the pulp and paper industry can be effectively achieved using the RotaBed™ Fluidized Bed Scrubber*. As the US pulp and paper industry develops and implements strategies to meet the Cluster Rule requirements, particular attention will be paid to the control of both sulfur dioxide (SO_2) and total reduced sulfur compounds (TRS).

Sources of SO_2 emissions may be:

- Power Boilers
- Waste Sludge Boilers (Incinerators)
- Noncondensible Gas (NCG) Thermal Oxidizers
- Lime Sludge Kilns burning NCGs
- Recovery Boilers

Sources requiring TRS control may include:

- Low Concentration High Volume NCG Sources
- High Concentration Low Volume NCG Sources
- Dissolving Tank Vents
- Miscellaneous Mill Odorous Sources

To meet the Cluster Rules' MACT I and MACT II guidelines, odorous mercaptan and hydrogen sulfide sources are collected and scrubbed or are thermally oxidized either in stand-alone oxidizers or are injected into the combustion zone of a lime-kiln or boiler. In some cases, a wet scrubber using a chemical oxidant (such as sodium hypochlorite or chlorine dioxide) is used to oxidize water-soluble TRS compounds. Emissions from thermal oxidation type devices are typically controlled using a wet scrubber with traditional alkaline chemistry to scrub out the SO_2. Many paper mills are already treating their odorous emissions sources using these techniques.

Until recently, packed towers, tray towers, and spray towers were commonly used to control SO_2 and TRS emissions. These designs operate by increasing the absorption of contaminant gases by extending the scrubbing liquid surface.

Comparison Scrubber Types for Absorption

Common absorbers are usually one of the following type:

1. Spray Tower
2. Tray Tower
3. Packed Tower
4. Venturi Scrubber
5. Fluidized Bed Scrubber (Swirling or Ebullient)

Table 1 provides a comparison of these various scrubber types.

The common purpose of all of these absorbers is to place a large surface area of scrubbing liquid into direct contact with the flue gas. The gas diffuses to the liquid surface, penetrates into and through the liquid film, and is absorbed. Once the gas is absorbed into the liquid, the chemicals in the liquid react with the absorbed gas usually forming a low vapor pressure salt. These devices all accomplish the same desired result using vastly different techniques.

Traditional Scrubber Technology

Spray Tower

The spray tower may be a hydraulically atomized unit or may use steam or air atomized spray. The atomized droplets create the liquid surface area. This technology requires that the scrubbing liquid be elevated in pressure, passed through a small orifice spray nozzle, and then flashed back down to atmospheric pressure in the scrubber vessel. The energy imparted into the liquid is primarily used to create the liquid droplets. The gas pressure drop, in contrast, is low. Spray towers have been used for decades on utility power boiler flue gas desulfurization (FGD) systems usually by administering a spray of lime or limestone.

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To generate smaller droplets of greater surface area per unit volume to enhance the mass transfer, more energy input is needed.Some designs introduce this extra energy in the form of compressed air or steam.The fan, liquid pump, and air compressor or steam source contribute the total energy input. Each increase in energy input increases the power consumption of the device and increases the system's complexity and maintenance challenge. In addition to high-energy consumption (usually in the form of pump energy), these designs are also limited by scaling and plugging problems in the nozzles.

At any given instant, there must be enough scrubbing liquid in contact with the gas in the spray tower to allow that gas to be absorbed.This is particularly important under the Cluster Rule where consistently low outlet loadings are required even though the inlet loading may vary. Therefore, spray towers typically allow for retention of the spray in the vessel or for the use of excess spray in multiple spray zones. Vertical counterflow spray towers operate typically at 6-8 feet/second vertical velocity and may have two or more spray zones. Air atomized or "fog" type scrubbers may use even more spray zones in either a counterflow or concurrent gas/liquid path.The fog, once created, must be removed prior to the gases leaving the tower.This requires high efficiency droplet control since the drops created are quite small (typically below 50 microns diameter).

Tray Tower

The tray tower creates the liquid surface area by bubbling the flue gas through small orifices in a horizontal tray.These holes are typically less than 3/16" diameter and can be a source of plugging. A froth of liquid and gas is created above the tray as the gas passes through the orifice.To create more liquid to gas surface area, additional trays are generally used in stages. The energy input is mostly derived from the fan (i.e. fan pressure). These towers typically operate at 8-12 feet/second through the tray but the tray occupies only about 50-70% of the available area of the vessel.The rest is consumed by tray supports, liquid distribution weirs and other internal devices.

Packed Tower

In a packed tower, the surface area is created by extending the area of the liquid making the liquid pass over some media inside the tower. This media, or packing, may be in the form of hundreds of individual pieces that are dumped into the tower ("dumped type" packing) or may be in the form of corrugated, formed sheets ("structural type" packing).The latter is similar to cooling tower fill.Only the liquid surface away from the packing is available for mass transfer, therefore, packing designers try to maximize the wetted packing surface in their designs. Packed towers can unfortunately act as liquid filters and can plug with solids. They are used primarily where the gas and liquid are free of solids.

The energy input to a packed tower is part fan energy (pressure drop) and part pump energy. Since the packing occupies space in the tower, the resulting packing depth can be a significant contributor to the pressure drop.The higher the packing height, the greater the pumping power required to deliver the liquid to that elevation.

Packed towers typically operate at gas velocities of 6-9 feet/second vertical. As gas speed and/or liquid rates increase, the packed section can flood and become turbulent with a resulting loss of efficiency and tower damage.Therefore, packed towers are typically designed to operate well below the flooding point.

Venturi Scrubbers

The venturi scrubber is primarily used for particulate removal but can also absorb gases.It works by atomizing droplets through the use of the difference in speed (shearing action) of the gases and the injected liquid.The minimum pressure drop for suitable absorption is typically 8-12" w.c. The liquid breaks up into tiny droplets.The size of these droplets are related to the total energy input of the device and the smaller the droplet the greater the surface area per unit volume.As codes have tightened, venturi scrubbers alone are only infrequently used for gas absorption since their efficiency is limited given the very low contact time (milliseconds) in the device. The fan energy required in a venturi when used as an absorber may be

Table 1

Scrubber Type	Pressure Drop (" w.c.)	Gas Velocity (feet/sec.)	Liquid Pressure (psig)	Footprint Dia. for 60,000 acfm, (feet-inches)
RotaBed™ Scrubber (Fluidized Bed)	3 to 5	16 to 30	3 to 5	8-6
Spray Tower	2 to 4	6 to 8	20 to 60	12-6 to 14-6
Tray Tower	4 to 6	6 to 8	5 to 10	12-6 to 14-6
Packed Tower	3 to 4	6 to 8	10 to 20	12-6 to 14-6
Venturi with Separator	8 to 12	~200 at throat	5 to 10	11-6

3-5 times higher than that of other devices. Its use is typically avoided on anything but low volume sources (under 50,000 acfm).

Drawbacks of Traditional Control Devices

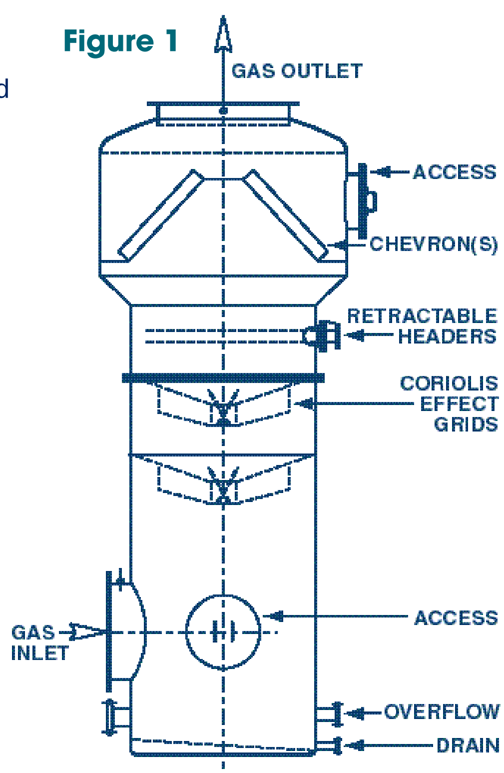
All of these devices operate at relatively low gas velocity, typically in the order of 6-8 feet per second. The result is a tower that can be of considerable size that is both costly to build and can consume valuable real estate (pad or roof space). In many cases in older mills where the scrubber must be retrofitted to an existing source, there is insufficient room for such a large tower.

Also, scrubber operating history to date proves that the scrubbing liquid can often plug the packed, tray, and spray towers.Packed towers use media that is in direct contact with adjacent pieces. Openings of less than 1/8” can result. Solids in the liquid or gas stream can become lodged in these small spaces and plug the packing. The media also presents a large surface area upon which scale (usually calcium carbonate) can build. Since the tower “trickles down” it is very hard to acid wash such designs. Unfortunately, the packing must be removed, cleaned, and be replaced or discarded. Spray towers can have spray nozzle orifices of less than 1/8” which can also plug.The spray scrubber performance is directly related to the integrity of the spray pattern and if the latter fails, the efficiency fails. The high liquid velocity through the spray nozzles is typically erosive and spray pattern performance can decrease over time.Tray scrubbers also have perforations of typically less than 3/16” and can similarly plug.The latter uses internal weirs and downcomers which are all out of sight and require shutdown for maintenance.

The RotaBed™ Fluidized Bed Scrubber

A reliable, plugging resistant, yet efficient gas/liquid contact device is a real need that has not been truly satisfied until the invention of the deep fluidized bed wet scrubber. This design produces a random “bubbling” or ebullient fluidized bed through which the contaminant gas is forced to pass. A major break-through in these designs is the patent pending RotaBed scrubber which uses a stabilized, swirling, fluidized bed. **Figure 1** below shows a typical RotaBed.Operating at up to five (5) times the velocity of a packed tower, the RotaBed scrubber conserves space and reduces the capital cost of installing and operating the emissions control system.The RotaBed scrubber balances the fan and liquid energy by passing the flue gas through a highly open grid and uses the Coriolis effect to impart a stabilizing “swirl”to the bed.The grid is typically 60-90+% open.Gas velocities are 16-30 feet/second. The liquid is usually injected free flow (below about 3 psig) using open horizontal headers.The grid pressure drop is typically 2” per grid with multiple grids used to create additional gas/liquid mass transfer surface as required for the application.This design can use Eo filtrate, white liquor, weak wash, and certain alkaline “waste” chemical streams that would plug traditional scrubbers.The net result is a lower chemical and operating cost.

Figure 1



Range of Scrubber Chemistries

A variety of scrubbing chemistries can be used in the RotaBed scrubber given its large liquid recycle path and resistance to plugging.

The most common scrubber chemistry is the use of an alkaline scrubbing solution.These units typically scrub the contaminants from the flue gases using a solution such as:

- Caustic
- Eo Filtrate/Caustic Extract
- Soda Ash
- White Liquor (Kraft mill)
- Weak wash
- Lime Slurry
- Alkaline Supplements

The reaction products are typically sulfurous compounds as a sulfide, sulfite, bisulfite, and sulfate at a basic pH (usually above pH 8) and are returned to the process or are treated in the water treatment plant.

The RotaBed scrubber can operate at various liquid to gas ratios (L/G) so that even a waste liquor stream that may be low in alkalinity can still be used by increasing its volume that is retained in the scrubber. A case in point is the use of Eo filtrate to remove SO_2. A high volumetric rate of Eo can be passed through the scrubber converting a waste stream into a supplemental process stream. This conserves valuable alkali.

For high sulfidity mills that do not want to return the sulfur salts to the process, the RotaBed scrubber can be integrated with a wastewater treatment system to convert the sulfurous waste to a solid, crystal-lized salt. Specialized chemistries and processes are also available to convert the liquor to elemental sulfur, or even produce sulfuric acid that can be removed from the process loop. In this case, the reaction byproducts are separated from the system.

No matter what chemical system is selected, the uniqueness of the RotaBed scrubber lends itself to handling a greater variety of chemistries than any other control device.

Direct TRS Gas Control

The RotaBed™ scrubber design can be used as either an SO_2 control device to scrub thermal oxidizer exhaust gas, or when employing a chemical oxidant, a stand-alone TRS scrubber as a backup to the oxidizer.

The low solubility of dimethyl disulfide makes it difficult to control with a wet scrubber unless the high liquid to gas ratio of the RotaBed scrubber is used.Though the scrubber will have a lower NCG destruction efficiency than the oxidizer, it can serve as a valuable temporary backup.The scrubber can be designed to use caustic for normal SO_2 scrubbing and an oxidant, such as sodium hypochlorite or hydrogen peroxide, as an emergency mercaptan/sulfide control scrubber.The liquid circuits are arranged so that the scrubber chemistry may be switched on the run.This requires primary pH control in either mode and ORP control in backup (oxidant) mode. This flexibility and the elimination of a backup thermal oxidizer can make this arrangement very attractive.

Since fluidized bed type scrubbers require the gas motion to create the extended liquid surface, the design must provide for a minimum gas movement through the scrubber at all times.This is often accomplished using a simple gas reflux system as shown in **Figure 2**. Using the NCG system draft as the control point, for example, a modulating damper can regulate the return flow of scrubbed gases back to the scrubber inlet. This also serves to keep the NCG system draft constant if the thermal oxidizer goes off line.The NCG draft becomes a mill set point for control rather than a variable.This helps maintain a constant draft on the NCG ventilation system, a plus for worker safety.

Extensive testing shows conclusively that an SO_2 removal efficiency of over 99% is obtainable using the RotaBed scrubber as the gas absorber when scrubbing with Eo filtrate. As a backup scrubber, it has proven its efficiency on soluble organic odors using oxidants such as sodium hypochlorite and chlorine dioxide.

On dissolving tank vent applications, the gas contains both TRS particulate and gaseous compounds.

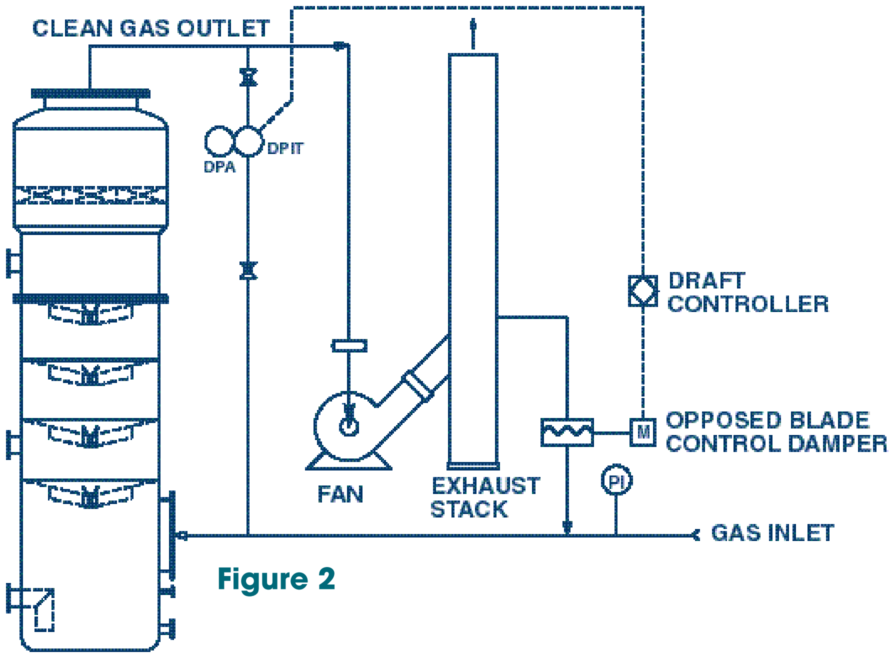


Figure 2

The RotaBed Plus™ using a special precleaning section is able to remove TRS compounds with greater removal efficiency than wet dynamic and venturi scrubbers.

TRS Removal by Conversion to SO_2 in a Kiln or Boiler

Some Kraft pulp mills control total reduced sulfur compounds (TRS) by accumulating and burning these gases in the lime-kiln, or black liquor recovery boiler.The combustion process converts the TRS to SO_2, some of which is collected in the kiln's gas cleaning system.Many mills use electrostatic precipitators for particulate control. Though excellent particulate control devices, they are poor gas absorbers.

The RotaBed scrubber can be applied for use after a precipitator for SO_2 control.A fluidized lime slurry up to 25% wt. can be used in the RotaBed scrubber, often eliminating the dewatering step that would be required for scrubbers limited to operating at low suspended solids such as spray, tray, or packed towers.The fluidized slurry can be recycled and a portion be bled back to the process.

Using lime, removal efficiencies in excess of 98% are attained on SO_2.

Conclusion

New regulations such as the paper industry Cluster Rule are causing plant process and environmental personnel to recognize more than ever that their plant's production and environmental processes are integrated.This is not necessarily bad news.The portion of the new rules concerning the control of TRS and SO_2 can be most economically accomplished using modern gas cleaning techniques like the RotaBed scrubber such that the resulting system provides high removal efficiencies along with the operating flexibility and process compatibility that mill engineers demand.

The RotaBed scrubber has the following advantages over other traditional technologies:

- High gas and liquid throughput
- Exceptional plugging resistance
- Stabilized Coriolis induced fluidized bed
- Lower installed cost
- Flexibility in operation
- Compatible with proven scrubbing chemistry
- Simplicity of operation
- Lower chemical/operating costs

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Engineered Air Pollution Control Systems with Unequaled Performance

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