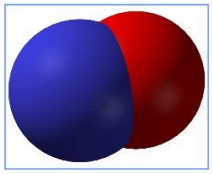
NEW, PATENTED

NOx BREAKTHROUGH

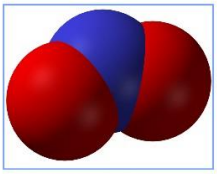
NOx Scrubbing Technology Process Overview:

Pacific Rim Design and Development (PRDD) is proud to highlight its very effective NOx abatement technology. Nitrogen Oxides are a family of poisonous, highly reactive gases. These gases form when fuel is burned at high temperatures. The PRDD NOx process turns the NOx into mineral acids with commercial value.

The PRDD NOx process is fully commercialized, cost-effective, and a very effective breakthrough in the treatment of problematic NOx, both nitric oxide (NO) and nitrogen dioxide (NO_2), two compounds identified as atmospheric pollutants (indirect greenhouse gases) and subject to regulatory control by the Environmental Protection Agency (EPA), and many other organizations.



Nitric Oxide,NO



Nitrogen Dioxide, NO_2

PRDD's patented NOx scrubbing process is likely the ***best available control technology*** for scrubbing NOx gas.

- It has been independently verified to have a 99.4% removal efficiency.
- The reaction vessels are less expensive and smaller than those required by wet scrubbing technology and selective catalytic reduction because the PRDD NOx process uses simple ducting for its reaction vessels.
- The ducting used as a reaction vessel can be oriented in any direction.
- The process can selectively remove all of the NOx or convert NO into NO_2 when it is required for a commercial process.
- The byproducts of NOx scrubbing are mineral acids with commercial value.
- The process simultaneously treats NOx, SO_2 and some VOCs with no change in the equipment.
- It can adapt in real time to variations in NOx, SO_2 and VOC concentrations in exhaust gas.

The PRDD NOx process utilizes chlorine dioxide (ClO_2) in a proprietary way. It transforms the NOx into mineral acids in a two-step process that can be described in equations 1 and 2 below:

- $5NO + 2ClO_2 + H_2O \rightarrow 5NO_2 + 2HCl$ (1)
- $5NO_2 + ClO_2 + 3H_2O \rightarrow 5HNO_3 + HCl$ (2)

Both of these processes proceed rapidly to completion with minimal excess ClO_2 present in the reaction environment, making for the safe and efficient elimination of NOx. The acid byproducts are used for commercial applications or neutralized in a second alkaline mist scrubbing stage.

PRDD NOx technology is simple, just a reaction in the exhaust gas between chlorine dioxide (ClO_2) and NOx. The reaction produces mineral acids that have commercial value. (See Equations 1 & 2). If the acids are not used commercially, they can be neutralized into salts that have commercial value if separated.

The PRDD NOx process is cost effective:

- It is done at ambient temperatures in simple ducting that can be oriented in any direction. There is no need for large reaction vessels or catalysts required by conventional NOx abatement processes.
- It does not generate waste product when the electrochemical process is used for chlorine dioxide generation,
- The process also treats SO_2, and some VOCs with no additional equipment or chemicals.

How can this process be more effective and less expensive?

This PRDD NOx process is more efficient and physically smaller than a wet scrubbing NOx process and selective catalytic reduction (SCR) NOx processes.

The PRDD NOx equipment is smaller for two reasons:

- NOx treatment with wet scrubbing involves the solubilization of NOx into process liquor. This requires large reaction vessels. The PRDD NOx process has no need for solubilization.
- SCR scrubbing requires a large and expensive catalyst bed. The PRDD NOx process has no need for catalyst.

The PRDD NOx process simply requires mixing ClO_2 into the exhaust gas with NOx. This is done in exhaust gas ducting; there is no need for a large reaction vessel.

The PRDD NOx process has a higher NOx removal efficient than wet scrubbing or SCR scrubbing for many reasons:

The PRDD NOx chemical processes are simpler and more efficient than those used in wet scrubbing or SCR technology.

- Wet scrubbing requires dissolving the NOx into the liquid used in the process. This is difficult because the NO gas is essentially insoluble in water ($1.94 \pm \times 10^{-6}$ mol/cm^3 at 1 atmosphere and 25^{o}C). This problem requires the wet scrubber vessels to be very large and use large amounts of process chemicals that ultimately need to be processed before disposal. The wet scrubber's NOx removal efficiency is between 50 and 95% because the solubilization process steps are less efficient than the PRDD NOx gas phase reactions.
- NOx scrubbing by wet scrubbing is typically done in a three stage process, each requiring a large reaction vessel.
    - First stage: Converts the NO into NO_2
    - Second stage: Treats the NO_2
    - Third stage: Treats the odors created in the second stage.

  Each of the three stages has a level of inefficiency. When combined, the inefficiency is dramatically larger than the PRDD NOx process.

- SCR scrubbing requires a simultaneous interaction between three compounds (atoms); NOx, Urea or ammonia, and a catalyst. The PRDD NOx process only requires the NOx to simultaneously interact with ClO_2. Statistically, an interaction between two items is higher than an interaction between three items. For this and other reasons, the SCR removal efficiency is between 70-95%.

The PRDD NOx process occurs in the gas phase. It is a direct interaction between chlorine dioxide and NOx in the exhaust gas. There is no need to dissolve the NOx into water in large vessels, and there is no need for a catalyst. For these and other reasons the PRDD NOx process is faster, has a smaller equipment footprint, and dramatically removes more NOx than the wet scrubbing and SCR NOx processes.

For all of these reasons, the PRDD NOx process is less expensive to purchase and operate than the wet scrubbing process or SCR process.

The mineral acid byproducts of the PRDD NOx process (**see equations 1 and 2 above**) are typically clean enough to have commercial value. At the very least these products pose less challenge as hazardous materials and neutralization than the complicated chemistry typically produced in countercurrent packed bed scrubbing systems. Details of various multi-stage NOx treatment processes, and their waste products are available upon request.

All of the above contribute to the PRDD NOx technology being recognized at the Best Available Control Technology.

Generating Chlorine Dioxide (ClO_2)

The ClO_2 used in the PRDD NOx process can be generated in a number of ways, including electrochemical and chemical processes. All of the processes can use either sodium chlorite ($NaClO_2$ or sodium chlorate ($NaClO_3$). Either of these is the only chemical required for the electrochemical generation process. The electrochemical processes also create commercially viable sodium hydroxide (NaOH) a byproduct that is typically used in the NOx abatement process.

PRDD will review the advantages and disadvantages of each ClO_2 generation option.

For additional information:

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