A New Approach
for Particle Size Reduction
in Lime Slaking and Wet Limestone Grinding

By: Mohamad Hassibi
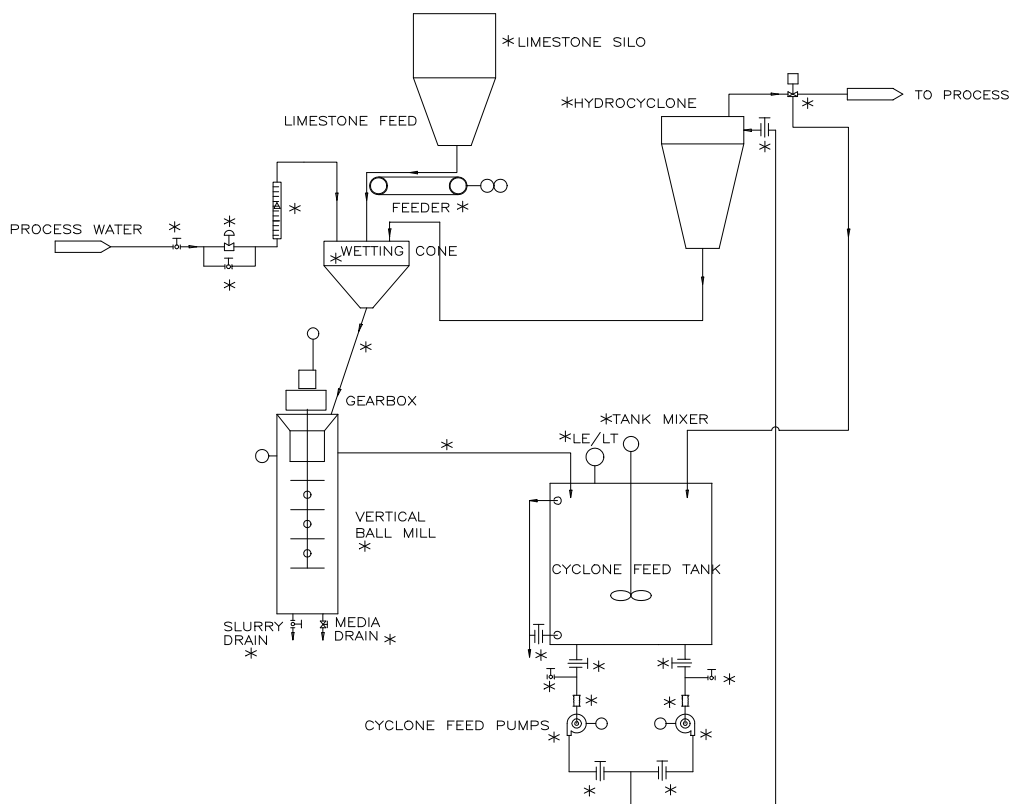*Chemco Systems, L.P.*
2005
Revision 1 – Feburary 2009

Lime and ground limestone slurry are used extensively in the air pollution control industry for SO_2 capture. Lime is used for lowering the "PH" of wastewater in industrial or municipal wastewater treatment systems.

One of the most important factors in either process is the surface area of the hydrated lime particles exposed to the wastewater to adjust PH, or SO_2 capture in flue gas. The larger the surface area available in one gram of particles, the more efficient the reaction. The present state of the art generally accepts a particle size range for lime or limestone of 95% less than 44 microns or 325 mesh.

For example, for SO_2 capture with ground limestone in wet FGD, much of the coarser particles never react with gasses because of a short contact period and these particles are basically wasted. For limestone to react with SO_2 gas, there should be some dissolution of limestone so that it can ionize[1]. Fine pulverization generally improves the rate of dissolution, thus increasing SO_2 capture efficiency.
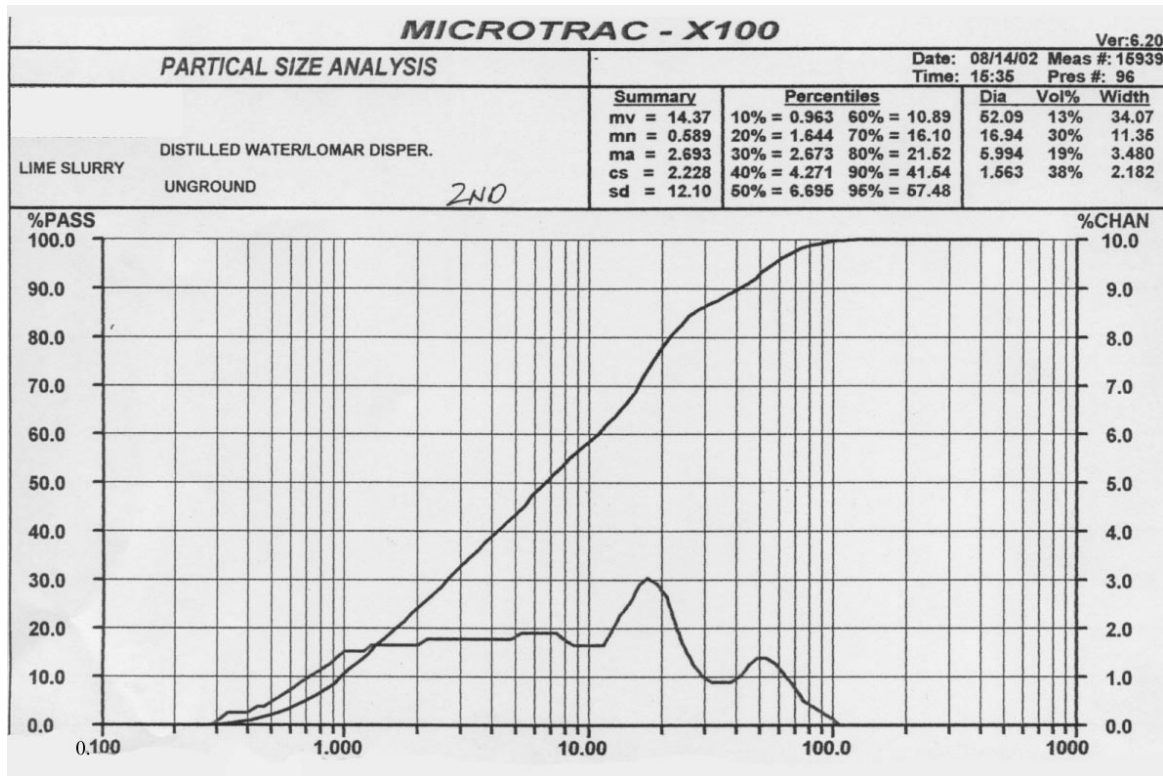
In the case of lime, the finer particle sizes will react quicker with gasses, and they are much easier to disburse evenly across the gas flow. Furthermore, due to an increased surface area, less lime is required to capture a certain volume of gas vs. lime hydrate with a larger particle size.

For limestone, the particle size reduction is typically done by a grinding system, which includes a feeder, a ball mill and a hydrocyclone. Sketch 1 shows a process flow diagram of a typical limestone grinding system.

Sketch 1

Air and Water Pollution Control Solutions

For lime, the particles of CaO are combined with water, which results in a chemical reaction called "hydration process" or "lime slaking". Graph 1 shows a typical particle size distribution achieved by the lime slaking process.

MICROTRAC - X100

Ver:6.20

PARTICAL SIZE ANALYSIS

Date: 08/14/02   Meas #: 15939
Time: 15:35   Pres #: 96

LIME SLURRY

DISTILLED WATER/LOMAR DISPER.

UNGROUND   2ND

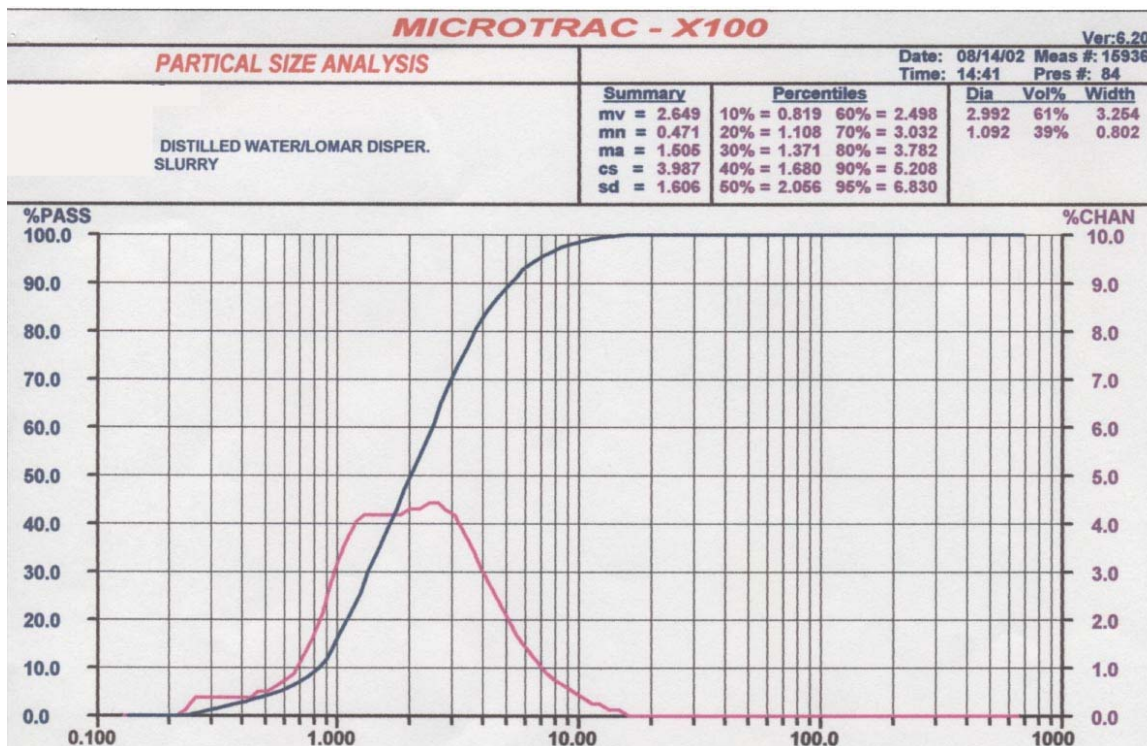| Summary	Percentiles		Dia	Vol%	Width
mv = 14.37	10% = 0.963	60% = 10.89	52.09	13%	34.07
mn = 0.589	20% = 1.644	70% = 16.10	16.94	30%	11.35
ma = 2.693	30% = 2.673	80% = 21.52	5.994	19%	3.480
cs = 2.228	40% = 4.271	90% = 41.54	1.563	38%	2.182
sd = 12.10	50% = 6.695	95% = 57.48			

Graph 1

This graph shows a wide range of particle sizes ranging from .5 micron to 57.48 microns. The median particles are 14.37 microns. If we narrow the particle size distribution band and reduce the median particle size, we would improve the quality of reactant substantially and reduce the consumption of lime.

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The Objective of New Technology

The objective is to produce:

Finer particles of hydrate than existing technology can produce;

Tighter particle range than existing technology can achieve

Both objectives are achieved by the new technology. Graph 2 shows particle size distribution achieved by the new method.

MICROTRAC - X100

PARTICAL SIZE ANALYSIS   Ver:6.20
Date: 08/14/02 Meas #: 15936
Time: 14:41 Pres #: 84

DISTILLED WATER/LOMAR DISPER.
SLURRY

Summary	Percentiles		Dia	Vol%	Width
mv = 2.649	10% = 0.819	60% = 2.498	2.992	61%	3.254
mn = 0.471	20% = 1.108	70% = 3.032	1.092	39%	0.802
ma = 1.505	30% = 1.371	80% = 3.782			
cs = 3.987	40% = 1.680	90% = 5.208			
sd = 1.606	50% = 2.056	95% = 6.830			

Graph 2

As stated above, the reduction of the particle size will result in the increased surface area of particles, thus improving the reaction for SO_2 capture. The following pages will clearly show how the new process can increase the surface area of the particles in a gram of Calcium Hydroxide, or Calcium Carbonate.

Surface Area Calculations

See Graphs 1 and 2.

In the slaked hydrated lime slurry as shown in Graph 1, one-half of the particles are smaller than 6.695 microns and one-half larger;

In the ground hydrated lime slurry Graph 2 proposed system, one-half of the particles are smaller than 2.055 microns and one-half larger.

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Assuming spherical particles:

$$\text{Volume of each particle is } V = \frac{D^3}{6}$$
$$\text{Surface of each particle is } S = D^2$$

Calculating above values for particles for Graph 1 for D50

$$V = \frac{3.14\,(6.695/1000)^3}{6} = 0.000{,}000{,}157 \text{ cubic millimeter - volume}$$

$$S = 3.14 \times \left(\frac{6.695}{1{,}000}\right)^2 = 0.000{,}140{,}744 \text{ square millimeter - surface}$$

Calculating above values for particles for Graph 2 for D50

$$V = \frac{3.14\,(2.055/1000)^3}{6} = 0.000{,}000{,}005 \text{ cubic millimeter - volume}$$

$$S = 3.14 \left(\frac{2.055}{1{,}000}\right)^2 = 0.000{,}001{,}326 \text{ square millimeter - surface}$$

To determine D50 size relationship between Graph 1 and Graph 2:

$$\text{Volume Ratio} = \frac{V}{V} = \frac{0.000{,}000{,}157}{0.000{,}000{,}005} = 31.4$$

That is the D50 volume of particles in Graph 1 are 31.4 times larger than D50 particles of Graph 2.

Specific Surface Area for the D50 particles of Graph 1:

$$\text{S.S.} = \frac{\text{Surface Area}}{\text{Volume}} = \frac{D^2}{D^3/6} = \frac{6}{D}$$

Where D is particle diameter at D50 point.

For Graph 1, D50 = 6.995 microns or 0.006,995 mm
For Graph 2, D50 = 2.055 microns or 0.002,055 mm

$$\text{S.S.}_1 = \frac{6}{0.006{,}995} = 857.7 = \text{Specific surface of D50 particles of Graph 1.}$$

$$\text{S.S.}_2 = \frac{6}{0.002{,}055} = 2919.7 = \text{Specific surface of D50 particles of Graph 2.}$$
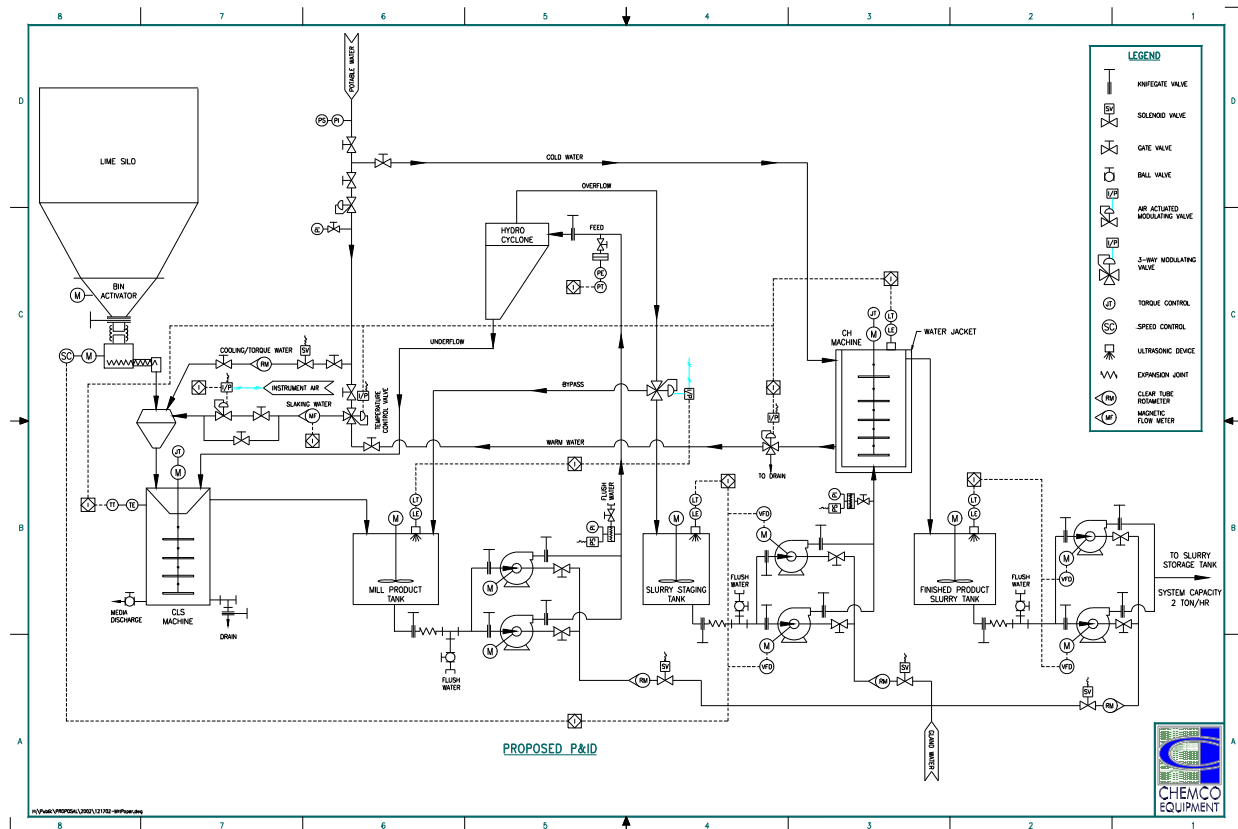
Specific Surface Ratio

$$\frac{SS_2}{SS_1} = \frac{2{,}919.7}{857.7} = 3.40$$

The specific surface of D50 particles of Graph 2 is 3.40 times the D50 specific surface of Graph 1.

The above calculations are conservative since we used D50 (midrange) particle sizes. In fact, there will be a much greater surface area than shown above for Graph 2 since there are a lot more particles below the mid range than above the mid range.

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Process Flow

Sketch 2

The above sketch shows the P & ID for the proposed system.

Process Description

Pebble Quicklime with the size range of ¼" x 0" is stored in the storage silo. The quicklime is withdrawn from the lime silo via the screw feeder at a predetermined rate. The lime and the water are fed simultaneously to the wetting cone where the lime and water are mixed thoroughly and flow down into the Slaking Mill. The mixture is agitated in the mill and the grit is ground. Due to the exothermic reaction of the lime and water, the temperature of the slurry rises. The RTD temperature element senses the slurry temperature and adjusts the water feed for the slaking to the wetting cone to maintain the preset value for the slaking temperature. In the winter time, when the water temperature is low, if the BTU input from the chemical reaction is not sufficient to attain the proper temperature, an auxiliary external water heater may be necessary to achieve the proper slaking temperature particularly at feed rates of less than 50% of the systems maximum capacity.

The slaked lime slurry will flow out of the Attritor Ball Mill Slaker into the Mill Product Tank. A high-energy mixer will keep the lager particles of grit in suspension in this tank.
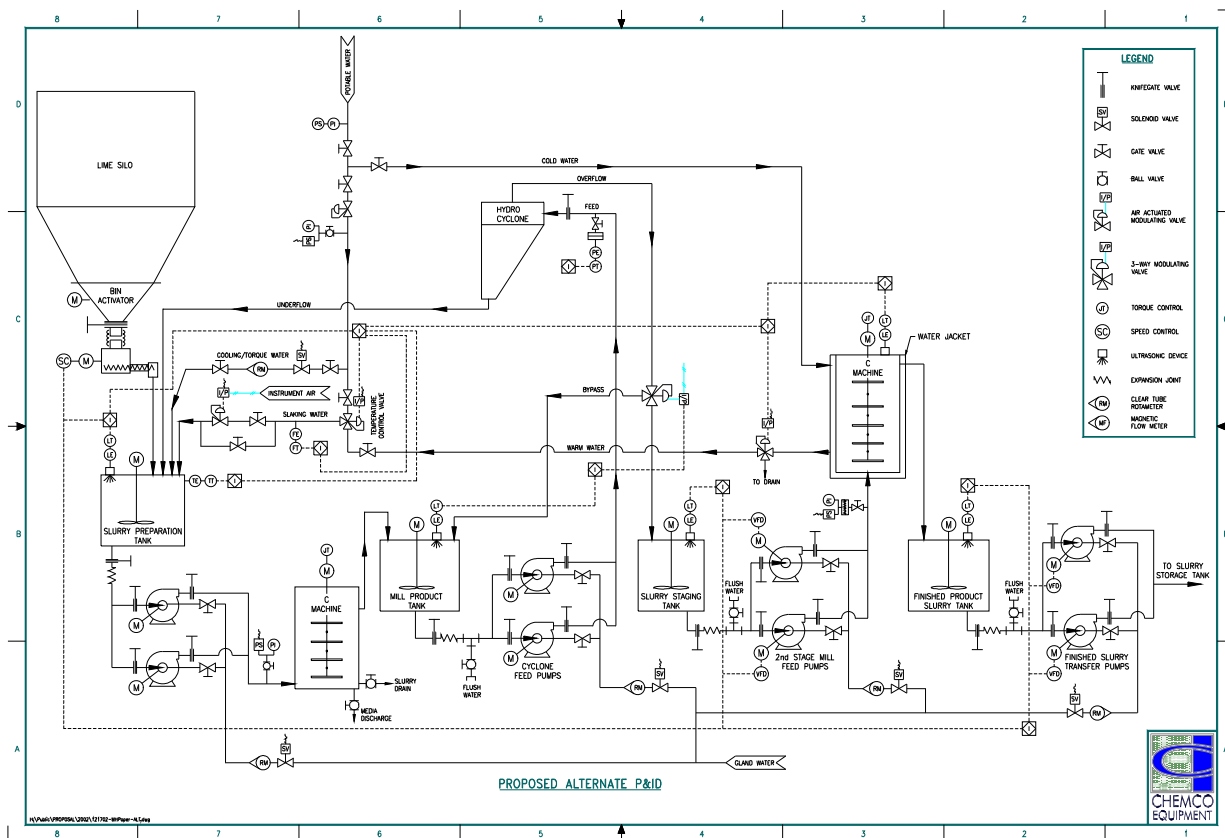The lime slurry is pumped from the Mill Product Tank to the Hydrocyclones for coarse separation. The Hydrocyclone underflow is returned to the Ball Mill Slaker for regrind; the overflow is discharged to the interim Slurry Staging Tank. A portion of the overflow from the Hydrocyclone is returned to the Mill Product Tank to maintain a constant level in this tank. The overflow from the Hydrocyclone is 100% smaller than 60 microns. The slurry from the Slurry Staging Tank is pumped from this tank to the bottom of an Attritor Model "C" Grinding Machine with a water-cooled jacket. When grinding the slaked lime

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slurry, it is important to keep the temperature of the lime slurry below 140°F to prevent agglomeration of the smaller particles. In the Attritor model "C" Grinding Machine, a portion of consumed power turns into heat due to the friction of media against media. This heat rise must be controlled so that the slurry temperature remains below 140°F. This is achieved by circulating cold water in the jacket of the mill. The pumps that feed the slurry to the Attritor model "C" Grinding Machines are equipped with a variable frequency drive. The feed rate of these pumps is controlled by the level element in the Slurry Staging Tank. The finished lime slurry exits the second mill into the Finished Product Slurry Tank. Finally, the lime slurry is transferred from this tank via transfer pumps to the Lime Slurry Storage Tank for use.

The media size in the slaking mill is 5/16" and the media size for the grinding mill is 1/8" or 3/16", depending on the final grind required. Graph 2 shows the particle size distribution achieved by the new process.

In addition to SO_2 capture in air pollution, the new process will be of great value in other industries, such as in Paper Coating for manufacturing of Precipitated Calcium Carbonate of superior quality. In this process, limestone is converted to Calcium Oxide, (CaO), by calcination. Then the Calcium Oxide (CaO) is slaked (mixed with water) to produce a slurry of Calcium Hydroxide. This slurry is converted back to Calcium Carbonate by reacting Calcium Hydroxide with CO2. In this process, Calcium Hydroxide particle size and distribution range determine the quality of the final product, Precipitated Calcium Carbonate.

An alternate to the above process is to provide a tank with temperature control as shown in Sketch 3 ahead of the slaking mill and pump the mixture of lime and water to the bottom of the slaking mill for a one pass-through. This alternate will produce even finer particles since 100% of the mixed slurry goes through the entire bed of media in the first pass through.

Sketch 3

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Conclusions

The new process can reduce the particle size of lime slurry, and increase the particle surface area. In addition, particle size range will be reduced to a much narrower band.

The systems shown in Sketch 2 and 3 can also be used for grinding limestone, with some modifications. For the limestone, the Lime Slaking Mill is replaced with a special Grinding Machine. The rest of the system remains the same.

Benefits

The new process has major benefits for the dry and wet FGD (Flue Gas Desulphurization) systems, resulting in substantial economic benefits, such as:

> Less consumption of lime;
>
> Due to the higher efficiency of SO_2 capture, new systems require smaller storage tanks, smaller pumps and smaller reactors;
>
> Reduction of wear and maintenance of pumps, valves, atomizer nozzles or spray nozzles, due to the finer particle size and less abrasion;
>
> In existing FGD's, where improved scrubbing or additional capacity is required, the existing system can be retrofitted to achieve the required results without having to install a completely new system.

The above comments apply to dry as well as wet FGD.

[1] *Chemistry and Technology of Lime and Limestone*, by Robert S. Boyton, John Worley and Sons, 1980

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