Factors Affecting Quick Lime Consumption In Dry FGD

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It has been an ongoing discussion as to what affects lime consumption in dry flue gas desulphurization. The purpose of this paper is to differentiate between fact and fiction as related to this subject. At this time, there is no specific comprehensive study on what affects lime consumption in dry FGD. I will try to shed some light on the subject.

There are many factors that influence lime consumption, such as:

A. Quality of slaking water used
B. Temperature of slaking water used
C. Quality of quick lime used
D. Type of equipment used for slaking
E. Degree of agitation in the slaking process
F. Temperature at which the slaking process takes place

We will discuss each factor and explain what impact each factor has on the slaking process; thus on lime consumption.

A. QUALITY OF SLAKING WATER

The slaking water purity and chemical composition has a pronounced effect on the final quality of the slaked lime; thus, SO_2 removal efficiency of the semi-dry FGD. The chemicals in the water that affect the slaking process are as follows:

Chlorides

Chloride content in slaking water has a positive effect on the slaking process. Chloride acts as an accelerant for slaking. Water with chloride content up to 10,000 PPM can be used in the slaker. With the slurry PH of 12 to 13, this water would cause no corrosion within the slaker or slurry lines. However, it would cause corrosion in the slaking water feed lines. In this case, it is advisable to use plastic lines. If the chloride content is above 10,000 PPM, such as brackish water or sea water (25,000 to 30,000 PPM), the slaker body may have to be rubber-lined to prevent corrosion. Any rubber lining used inside the slaker must be good up to 212°F. The slurry lines must also be FRP or other plastics or exotic metals.

Sulphites and Sulphates

These salts have substantial impact on the slaking process. The chemicals form a coating on the particles of lime (CaO), which prevents water from penetrating the pores of the lime; thus retarding the slaking process. The sulphite and sulphate content of the slaking water should not exceed 500 PPM (mg/l). If the sulphite or sulphate content of the slaking water exceeds 1,000 PPM, a ball mill slaker should be used.

The following chart compares the effect of water chemistry on the slaking time/temperature for deionized water, tap water and industrial water.

Slaking Time (min.)	Deionized Water	Tap Water	Industrial Water with 5,000 PPM SO_3, SO_4
1 Min	68.5° C	64.9° C	56.4° C
2 Min	70.1 ° C	68.3° C	61.1° C
3 Min	70.0° C	70.1° C	63.6° C
5 Min	70.1° C	70.1° C	65.1° C
6 Min	70.1° C	70.1° C	66.4° C

Note: The starting slaking water temperature for these tests was 25° prior.

Dissolved and Suspended Solids

High dissolved solids in the slaking water could cause foaming, which would cause operational problems for the slaking process. In addition, some dissolved solids react with lime and cause deposits in the slaker and slurry-handling equipment, such as pumps and piping.

B. TEMPERATURE OF SLAKING WATER

The temperature of the slaking water has a definite effect on the final slaking temperature.

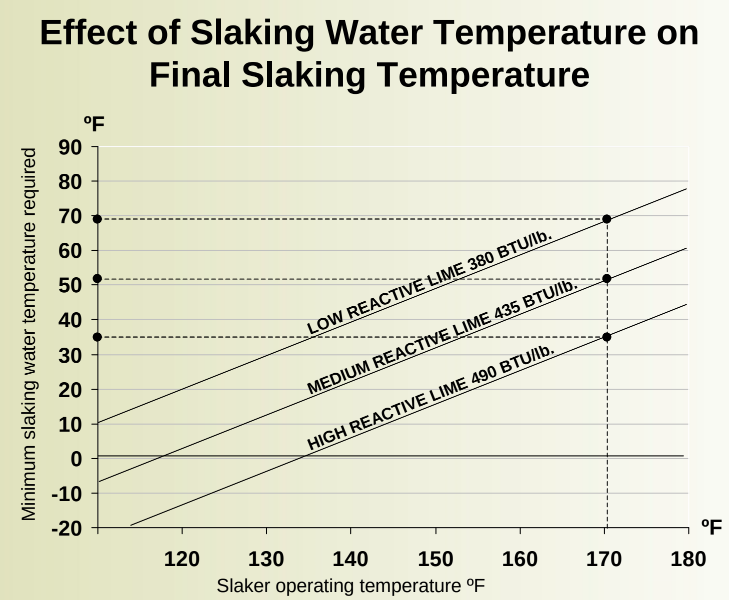
Final slaking temp = Initial temperature of water + heat of exothermic reaction – heat losses

If we assume a lime-to-water ratio of 1 to 4, that the slaker heat loss is constant, and also that the quality of lime does not change, then any increase or decrease of the incoming water temperature will result in an increase or decrease of the final slaking temperature.

Furthermore, if we keep the quality and quantity of the lime constant, to increase or decrease the final slaking temperature, we must increase or decrease the quantity of water fed to the process.

The following chart shows the effect of the slaking water temperature on the final slaking temperature for high, medium and low reactive limes. One pound of dry lime will release the following BTU's during the hydration:

High reactive lime	490 BTU's
Medium reactive lime	435 BTU's
Low reactive lime	380 BTU's



Above presumes minimum slaker throughput to be at least 50% of the slaker's maximum rated throughput.

C. QUALITY OF LIME

There are several factors affecting the quality of lime. They are:

- Soft or hard burned
- CaO content and CaO available
- Size distribution
- Air slaking
- BTU produced during exothermic reaction
- Magnesium content

Soft or Hard burned lime:

To convert calcium carbonate ($CaCO_3$) to calcium oxide (CaO), the limestone is calcined in a kiln at a temperature of about 1,000°C. This drives the carbon dioxide from the limestone and converts it to calcium oxide or lime. Due to the variations in the size of the limestone that is fed to the kiln, some particles of lime are overheated and form a solid hard surface (vitrified). This hard surface prevents water from penetrating the lime particles; thus retarding or preventing the conversion of lime to hydroxide. This type of lime is not very reactive and is called “hard burned lime”. Hard burned lime has a slow temperature rise and is classified as a low reactive lime.

According to the ASTM Standards, a high reactive lime is a lime that when tested in accordance with ASTM-C112, has a temperature rise of 40°C in three minutes. For example, if the initial water temperature is 20°C, the final slaking temperature after three minutes should be 60°C.

Calcium Oxide Content:

Since calcium oxide is the only chemical useful in lime, it is used as a yardstick to evaluate the quality of lime. However, not all of the CaO content of lime is usable or chemically reactive. A better factor for measuring lime quality is “calcium oxide available” for reaction.

The following chart is a typical chemical composition of lime:

CHEMICAL ANALYSIS	¾” X ¼” PEBBLE QUICKLIME
Total CaO	93.00
Available CaO	88.50
MgO	2.65
Total Oxides	95.65
SiO_2	1.95
R_2O_3	0.86
Fe_2O_3	0.16
Al_2O_3	0.70
Sulfur	0.045
P	0.004
Loss on Ignition Total	1.50
CO_2	1.10
H_2O	0.40

The magnesium oxide content of calcium lime should not exceed 2% to 3%. Since MgO will not hydrate readily at temperatures of 160°F to 180°F, it will end up as grit in the grit bin. SiO_2 and AL_2O_3 content of lime should be under

2%. Higher percentages would cause excessive wear on the slaker mixer paddles.

Size Distribution of Lime

The smaller particles of CaO would react with water quicker than the larger pieces. However, small particles have other disadvantages. Powdery lime is more susceptible to air slaking than pebble lime. A good pebble lime will slake quickly and slaking is complete in three to four minutes versus a good powder lime that slakes almost instantly. Most slakers have a retention time of five to ten minutes; therefore, will be able to slake pebble lime completely.

When pebble lime is used for slaking, typically grit and impurities are larger than particles of $Ca(OH)_2$; therefore, separated from the lime slurry by the grit removal systems. In powdery lime, the grit and impurities are ground; therefore, they end up in the process, causing wear and tear in the sprayers and atomizers.

The following chart is a typical size distribution of a ¾" x ¼" pebble lime.

PHYSICAL ANALYSIS SCREEN SIZE	% PASSING
3/4"	100.0
1/2"	95.0
1/4"	70.0
1/2"	48.0
3/8"	18.0
1/4"	10.0
1/8"	8.0
#50	7.0

Air Slaking

Quicklime or lime have an affinity for water and absorb water in liquid form or vapor. A powdery lime has a lot of fine particles; therefore, a large surface area exposed to the atmosphere either at storage, transportation or pneumatic loading in the silo. These particles absorb moisture from the air and slake slowly without temperature rise. When lime is slaked slowly with little water, the particles of hydrate formed are very large and low reactive. This results in a substantial increase in lime consumption. It is best to avoid pulverized or crushed lime due to the danger of air slaking as well as difficulties in handling powder lime versus pebble lime.

Heat Content of Lime

The reaction of lime and water is exothermic and releases a large quantity of heat. To understand the extent of heat produced by lime slaking, a pound of reactive lime, when slaked, produces enough heat to bring 2.3 pounds of water from 0°C to 100°C or can heat 3.4 pounds of water from a room temperature of 70°F to 212°F.

D. TYPE OF EQUIPMENT USED FOR SLAKING

Research shows that slaking with an excess amount of water[(1)] will result in a finer particle size of hydrate. The slurry slaker uses 4 - 1 to 5 - 1 water-to-lime ratio versus paste slakers that use a 2 - 2 ½ -1 water-to-lime ratio. In addition, a thinner slurry (25% to 30% solid) is less prone to develop localized hot spots (over 212° F), which cause agglomeration of fine hydrate particles.

E. DEGREE OF AGITATION IN THE SLAKER

A vigorous agitation in the slaker is essential for the slaking process because agitation will:

- Thoroughly wet the lime pebbles quickly
- Even out the temperature within the slaking chamber
- Prevent hot and cold spots in the slaker, which will result in agglomeration
- On partially hard-burned lime, cause abrasion of lime particles to speed the slaking process

F. TEMPERATURES AT WHICH THE SLAKING PROCESS TAKES PLACE

The slaking temperature is one of the most important factors that determine the final quality of the slurry. Theoretically, the higher the slaking temperature, the finer the particle size of hydrate; the smaller hydrate particle size, the larger surface area, and finally, the larger the surfaces are the less lime consumption. However, in practice, the gain of the surface area beyond a certain temperature (180°F to 185°F) is offset by additional maintenance and safety hazards due to operating temperatures above 185°.

It should also be pointed out that the surface area is not the sole determinant of process efficiency. The porosity of the particles, as well as the shape of the particles has an effect in reaction efficiency. The porosity and particle shape are a function of the chemical composition of the lime. This is the area that is the least studied in the lime slaking process. The fine particles of hydrate have a tendency to agglomerate and form a larger, flat-sided particle if they are kept at a high temperature after the slaking process is complete. It is important to cool the slurry to below 140°F to prevent agglomeration.

SUMMARY

To reduce lime consumption, you must have hydrated lime with the smallest possible particle size and the largest possible surface area. These particles also have to have good porosity. To achieve such a highly efficient reaction in FGD:

1. You must have good quality water
2. You must have good quality lime
3. You must slake at a high temperature
4. You must avoid air slaking.

(1) Chemistry and Technology of Lime and Limestone, by Boynton J. Will & Sons, 2nd Ed.