AN OVERVIEW OF LIME
SLAKING AND FACTORS THAT
AFFECT THE PROCESS

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ABSTRACT

Since lime slaking is an integral part of treatment systems in water, wastewater, air
pollution, and process industries its performance will influence the overall effectiveness
of the process as well as operating costs. This paper reviewr factors that affect efficiency
and performance of lime slaking systems.

INTRODUCTION

Research on lime slaking has been done on a limited basis in recent years. Most of this
research has been done under auspices of the National Lime Association. The
information presented in this paper builds upon the research done by others and the
author's years of hands on experience in lime slaking.

Because limestone is a naturally occurring mineral its chemical composition and physical
characteristics change not only from area to area but within veins of limestone in the
same area. This variation in raw mineral results in variation of the quality of the calcium
oxide produced from this limestone.

The use of lime in its various forms has been steadily on the rise with no end in site.
Today lime is the most important chemical used throughout the world for pollution
control. It is, therefore, imperative that handling and processing lime be well understood
by all those who use this chemical.

LIME MANUFACTURING AND LIME SLAKING PROCESS

Limestone or calcium carbonate ($CaCO_3$) exists as a natural stone throughout the world.
Limestone in its natural form is very slow reacting, therefore, it has a limited use. The
most significant use of pulverized limestone is in agriculture and finely ground in flue gas
desulphurization in slurry from. In this paper we will concentrate on calcium oxide and
calcium hydroxide.

In most pollution control applications lime is used as calcium hydroxide. To manufacture
calcium hydroxide the limestone, calcium carbonate, must be converted to calcium oxide
and the calcium oxide then converted to calcium hydroxide. The following are the
chemical formulas of this process:

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(Limestone) $CaCO_3$ + HEAT $\longrightarrow$ (Calcium Oxide) CaO + CO_2
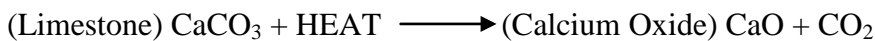
However CaO is unstable in the presence of moisture and CO_2. A more stable form of lime is calcium hydroxide $Ca(OH)_2$.

(Calcium Oxide) CaO + (Water) H_2O $\longrightarrow$ Calcium Hydroxide $Ca(OH)_2$ + HEAT

The atomic weight of the above formula is:

Ca= 40   O= 16   H= 1
(40+16) + (2+16) = 74
   56   +   18   = 74

Therefore, 56 units of CaO plus 18 units of H_2O results in 74 units of $Ca(OH)_2$. The ratio of hydroxide to CaO is 74 ÷ 56= 1.32. This means that 1 Kg of CaO and 0.32 Kg of water will produce 1.32 Kg of $Ca(OH)_2$, this is the minimum water required for chemical reaction, so calcium hydroxide contains 75.7% CaO and 24.3% H_2O. The process of adding water to calcium oxide to produce calcium hydroxide is referred to as hydration process or lime slaking. The hydration of CaO, commercially referred to as quick lime, is an exothermic process releasing a great quantity of heat.

This hydration process when done with just the right amount of water for chemical reaction is called "Dry Hydration." In this case the hydrate material is a dry powder. If excess water is used for hydration, the process is called "Slaking". In this case the resultant hydrate is in a slurry form. Lime manufacturers generally use the dry hydration process for producing powdered hydrated lime. Our discussion here is limited to the lime slaking. The slaking process is normally done with considerable excess water ranging from 2½ parts water to 1 part CaO to 6 parts water to 1 part CaO.

EQUIPMENT USED FOR THE SLAKING PROCESS

It is not the intent of this paper to evaluate the slaking equipment described below. The intent is to show the types of equipment available for slaking process. There are basically three types of lime slakers available on the market. They are:

  A. Slurry Detention Slakers
  B. Paste Slakers
  C. Ball Mill Slakers

A slaker must mix the correct amount of quick lime (CaO) and water, hydrate the quicklime, and separate the impurities and grit from resultant calcium hydroxide slurry.

A. SLURRY DETENTION SLAKERS

A slurry slaker generally uses an initial lime to water ratio of 1 to 3.3 to 1 to 5 depending on the make of equipment and quality of CaO and water. Typically a slurry slaker, sometimes called a detention type slaker, is comprised of two chambers. The first chamber is called the slaking chamber where lime and water are mixed. The second chamber is usually used as a grit removal chamber. The lime slurry flows by gravity from the first chamber to the grit chamber. The slurry viscosity is reduced in the second chamber by addition of cold water to dilute the slurry and allow the heavier grit to settle to the bottom of the second chamber, where the grit is elevated and discharged by a screw.

Figure 1 shows one such slaker. The slurry slakers are generally designed for a retention time of 10 minutes at full rated capacity. This means that a particle of CaO from the time it enters the slaker until it exits into the grit remover takes an average of 10 minutes.
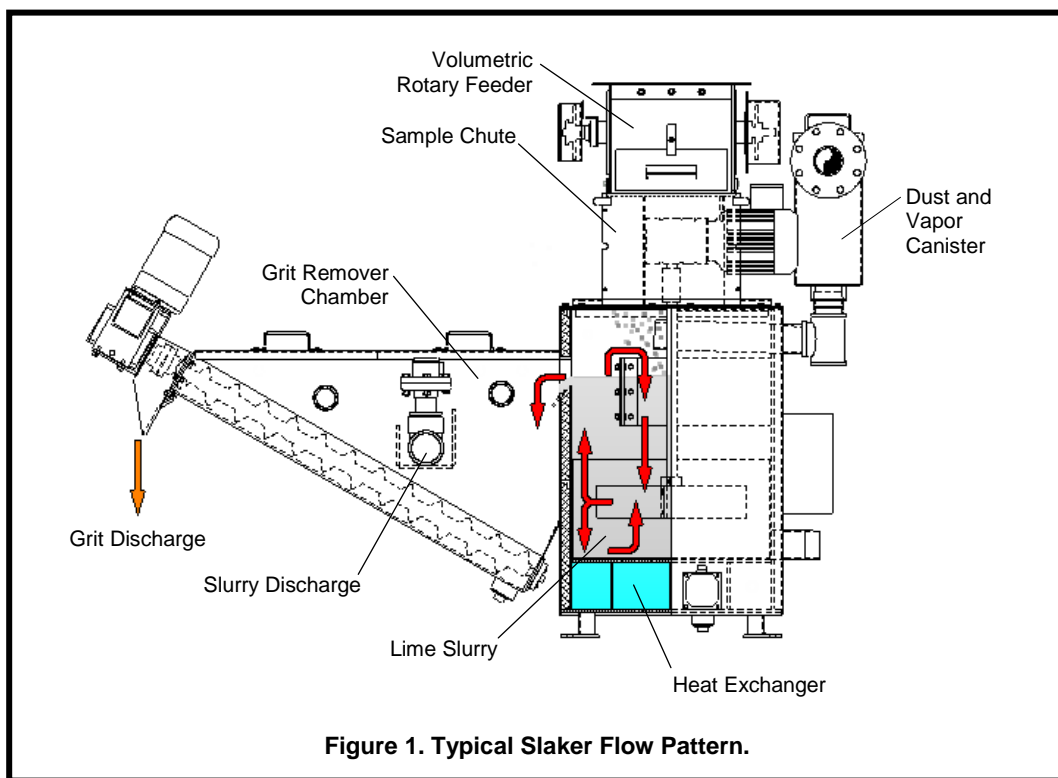
Figure 1


Figure 1. Typical Slaker Flow Pattern.

The slurry slakers are available in a variety of sizes ranging from 150lb/hr to 25 tons/hr. Slurry slakers also are available with external vibratory grit separation screens. Slurry or detention types slakers are the most common types in Europe and the USA.

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B. PASTE SLAKERS

Paste slakers, as the name implies, slake the lime in a paste form. The lime to water ratio is generally 1 to 2.5. Paste slakers are compact in size and are designed for a retention time of 5 minutes in the slaking chamber. In a paste slaker, since the hydroxide paste is too heavy to flow by gravity, a pair of horizontal rotating paddles push the paste forward toward the discharge point. Once the paste exits the slaking chamber it is diluted to approximately 1 part hydrated lime to 5 parts water. This dilution allows grit separation by gravity or by an external vibrating grit screen. The slurry consistency from a paste slaker and a slurry slaker is exactly the same after dilution for grit removal.

Paste slakers are available in sizes ranging from 1000lb/hr to 8000lb/hr. Paste slakers are mostly used in the USA. Figure 2 is a graphic depiction of a paste slaker. The grit separator is not shown in this figure.

Figure 2
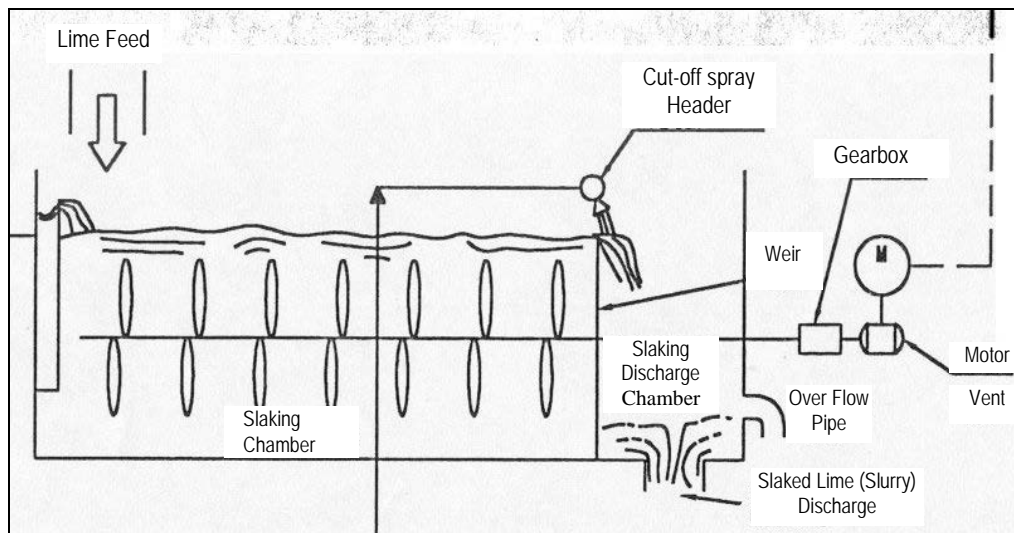
C. ATTRITOR VERTICAL BALL MILL SLAKERS

The Attritor Ball mill is an adaptation of ball mills, which originally were designed for wet and dry grinding, to the job of slaking. Ball mill slakers are generally used when due to zero discharge conditions at the site no grit discharge is allowed.

The ball mill slakers are more expensive than paste or slurry slakers. They are available in sizes ranging from 1000lb/hr to 25 tons/hr. Figure 3 shows an attritor type vertical ball mill lime slaker.

The ball mill slakers are equipped with an external classifier hydrocyclones, which separates slurry from the oversized grit and impurities. The oversize grit is recycled back into the mill for regrind.

Figure 3

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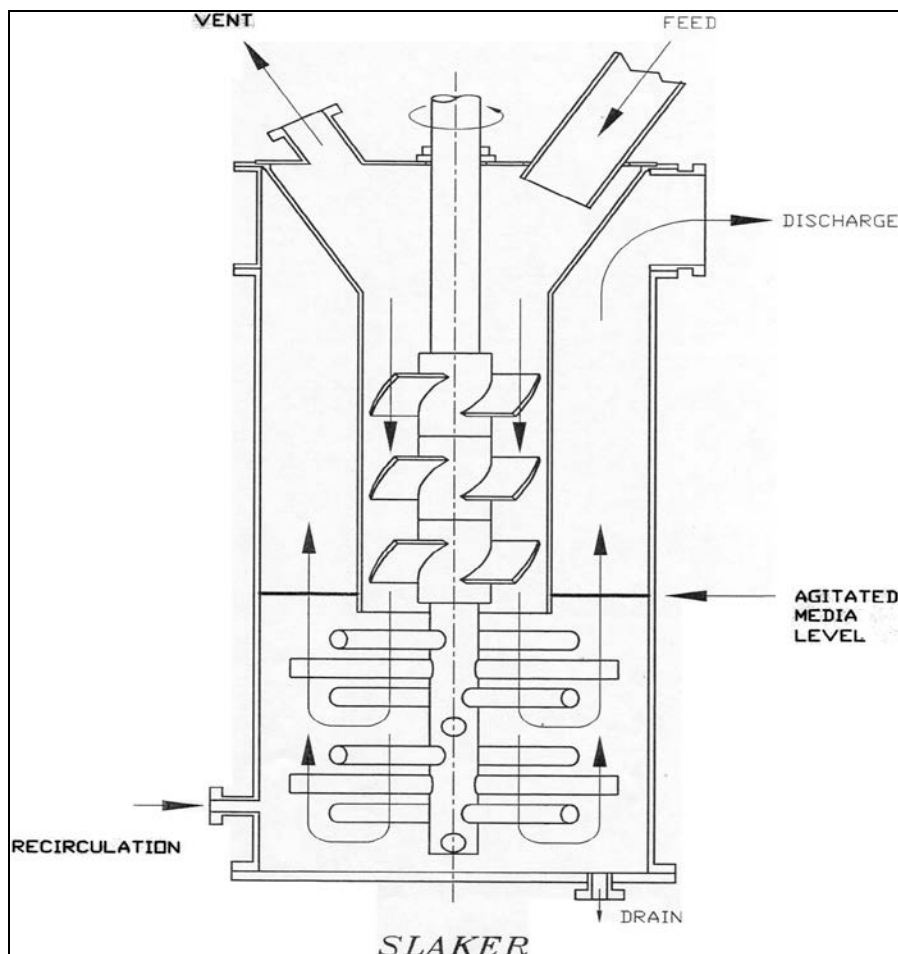
D. BATCH SLAKER

Batch slakers are a variation of the slurry slaker. They typically work as follows:

As the name implies, the operator decides the size of the batch of lime slurry to be made. The controls using the desired batch set point calculate how much water and lime is needed to make one batch. First, the cold water in a predetermined quantity (volumetrically or gravimetrically) is added to the batch tank. Then the quicklime is added in a predetermined quantity (volumetrically or gravimetrically) to the batch tank. The lime and water are mixed and agitated until the mixture's temperature reaches a preset temperature between 175⁰F to 185⁰F. Once the desired temperature is reached, the resultant slurry is dumped into a second tank for use or grit removal depending on whether a pulverized or pebble quicklime is used.

Once the slaking tank is emptied, the water for the next batch is added to the slaking tank and the system goes to a stand-by mode waiting for an operator to start the next batch cycle. Figure 4 shows a batch slaker for use with pulverized quicklime. Batch slakers are used where only a few small batches are needed periodically when a continuous slurry slaker cannot be used.

Figure 4
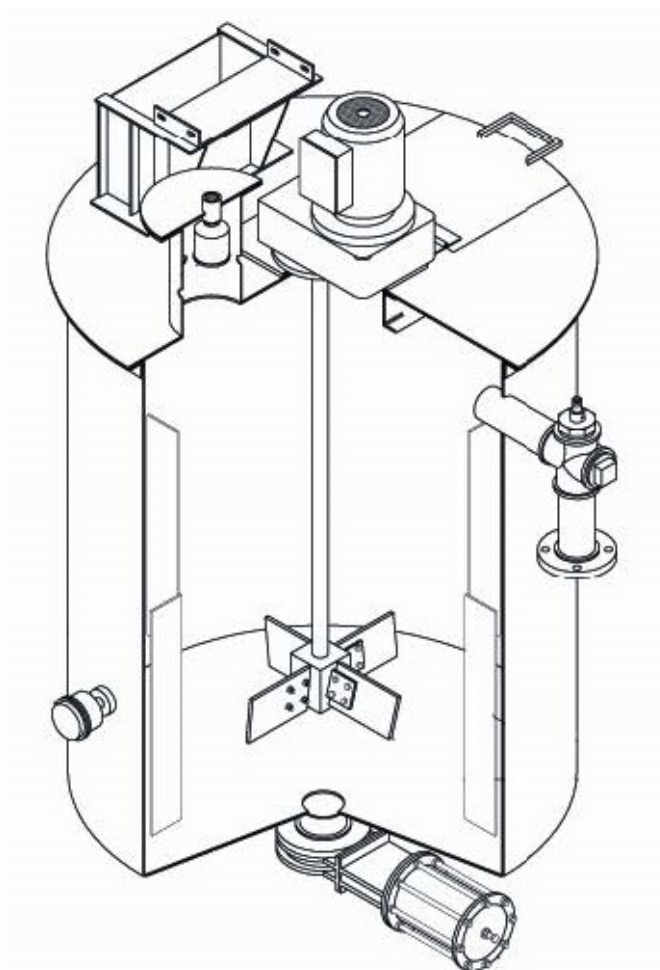
FACTORS AFFECTING QUALITY OF CaO

As stated previously the calcium carbonate is heated in the rotary or vertical kilns to drive away CO_2 from limestone, $CaCO_3$, to produce calcium oxide CaO. This process is called calcination.

Calcination conditions highly affect the quality of quicklime CaO that results from this process. The following factors are the major determinants of the quality of CaO:

A. Chemical composition of limestone.
B. Temperature of kiln during calcination
C. Residence time of lime in kiln
D. The extent of CO_2 in the kiln atmosphere.

A. CHEMCIAL COMPOSITION OF LIMESTONE

The chemical composition of the limestone cannot be controlled without a major cost impact on manufacturing, therefore, variation is generally accepted. The calcination temperature should be controlled very closely. To heat the limestone uniformly, in the kiln, the particle size of feed must be relatively uniform. In addition, to avoid long residence time in the kiln, the particle size of limestone must be small, typically about 1 ½". However, due to the nature of the crushing operation in reality there is a range in size from ½" to 2". Since the residence time and temperature in the kiln are constant the heat penetration in the particles of limestone is different due to variation of the size of the limestone. As shown in figure 5, on larger size of stones, heat does not quite penetrate to the core, therefore the center of these pieces remain as calcium carbonate, while the outside is converted to CaO. These center cores are referred to as grit. For medium size stone the heat penetration is complete and the entire stone is converted to CaO. For the smaller stones the heat reaches the core rapidly and the outside layer is overheated forming a hard outer shell where water cannot penetrate, therefore, the slaking process is greatly retarded or prevented.

Figure 5
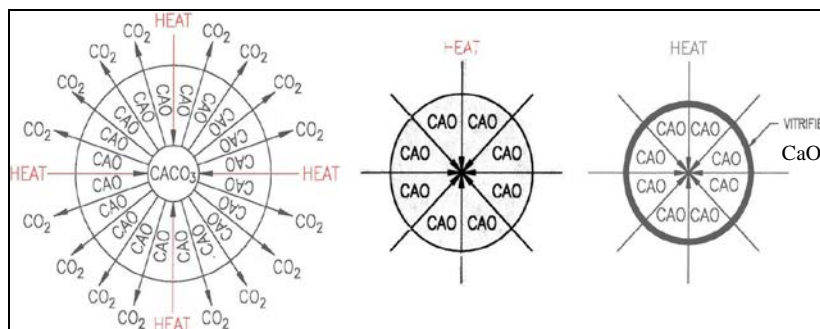
In this illustration the large and medium size particles are highly reactive and they are called soft-burned quicklime, and the smaller particles are called hard-burned quicklime.

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B. KILN TEMPERATURE

Calcination temperature in the kiln impacts the size of the hydrated lime particles slaked from this lime and thus surface area of particles of hydrated lime. The larger the surface area in particles of hydrate the more efficiency of neutralization, this hydrated lime will have. Figure 6 shows the impact of kiln temperature on particle size, thus surface area, of hydrated lime particles produce from limes calcined at different temperature.

Figure 6

Calcination Temperature °F (°C)
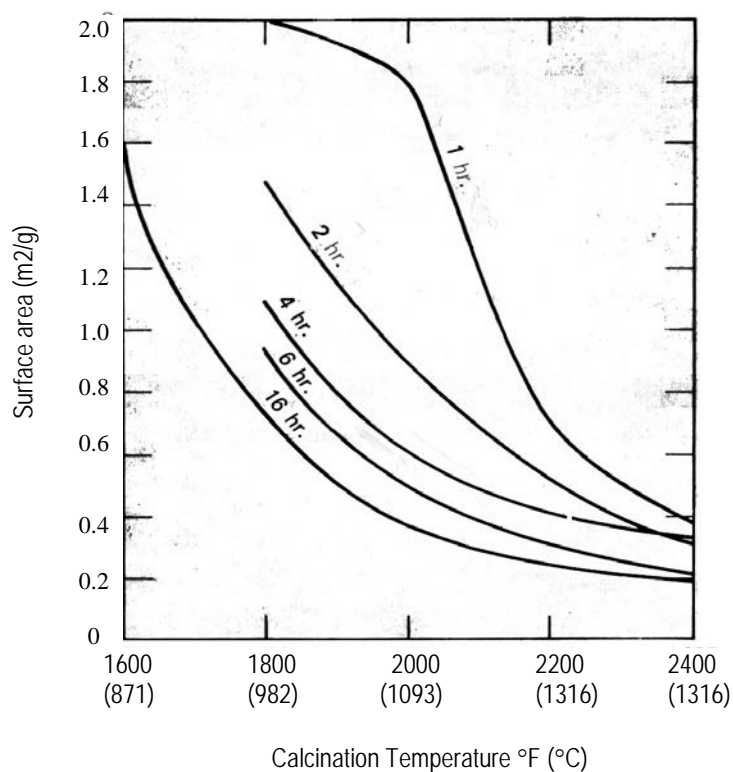
Relation of surface area to calcination temperature

A soft-burned lime pebble is full of small hair like cracks where CO_2 has escaped from the limestone during the calcination process. When this lime is exposed to water the water penetrates the cracks fishers in the quicklime pebbles and fills these cavities. The hydration takes place quickly, releasing a lot of heat energy. This heat will boil off the water and generate steam, which makes the particles burst, exposing the inner surfaces to water for further slaking. This process will continue until hydration is complete.

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C. RESIDENCE TIME

The residence time of $CaCO_3$ in the kiln is very critical during the calcination process. It is important that the resident time be as short as possible. However, enough time must be allowed for heat to penetrate the particles of $CaCO_3$ and drive the CO_2 out of these particles. Calcination is done either with low temperature high residence time, or high temperature and low residence time. Each lime manufacturer must balance the time of residence and temperature to suit their system.

Figure 7 shows a time/temperature rise graph of a soft burned high reactive lime during slaking, which is often used as a measure of reactivity. As stated before, the quality of limestone as well as the calcination process affects the final hydrate quality.

Figure 7
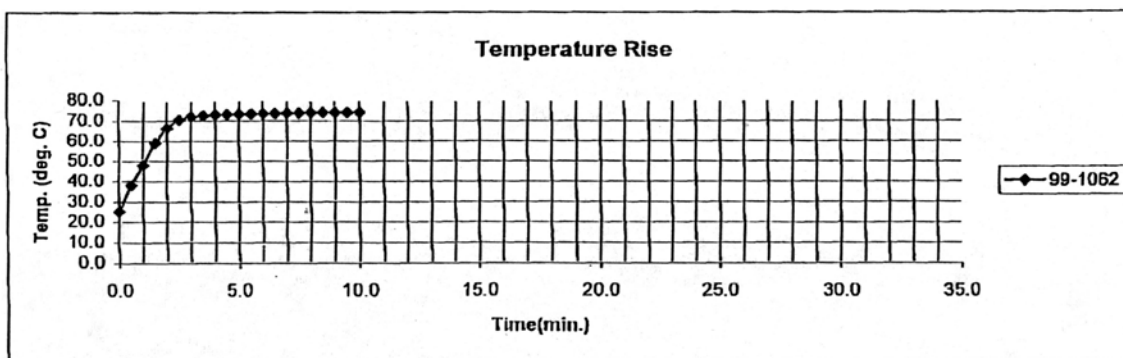
Per ASTM C-110 standard, a reactive lime is defined as a lime that during slaking it will have a temperature rise of 40°C in three minutes, and slaking completed in ten minutes.

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D. KILN ATMOSPHERE

In addition to kiln temperature and residence time, kiln atmosphere affects the quality of CaO. As the temperature of $CaCO_3$ increases the CO_2 gas is released and CaO is produced. The CO_2 must be vented out of the kiln. The CaO has an affinity to absorb moisture and CO2 and revert back to $CaCO_3$. The effect of this conversion is more pronounced with small particles of CaO versus larger pebbles due to the specific surface of the pebbles.

Figure 8 shows a slaking rate of four different limes supplied by different manufacturers. There is a great difference between the reactivity of these limes, the rate of temperature rise, and the time required to complete the slaking process. These variables are dealt with in detail later in this paper.

Figure 8

6194 — Prepared by Dravo Lime Company 3/9/98 — Page 1

Slaking Rate
100g. lime/400ml DI H2O

Sample #	98-0375	98-0261.1	98-0261.2	98-0261.3	
Start Temperature	25.0	25.0	30.0	35.0	°C
Temp. Rise @ 0.5 min.	16.1	3.5	3.0	2.6	°C
Temp. Rise @ 1.0 min.	31.2	4.6	4.5	4.6	°C
Temp. Rise @ 3.0 min.	37.9	11.1	12.1	14.9	°C
Temp. Rise @10.0 min.	41.5	43.9	45.0	45.3	°C
Total Temp. Rise	48.6	44.9	44.8	44.3	°C
Total Time (active slaking)	5.0	11.0	9.5	8.0	minutes
Net Slope (°C/min.)	9.7	4.1	4.7	5.5	°C/min.
Absolute Temp. Rise	50.0	45.3	45.8	46.0	°C
Total Time (absolute)	12.5	14.0	13.5	13.0	minutes

FACTORS AFFECTING SLAKING PROCESS

The most important single factor that affects the process efficiency of a slaking system is the specific surface area of the particles of calcium hydroxide. The larger the specific surface area of the hydrate, the more surface is available for reaction, therefore, the more efficient the reaction and less consumption of lime. The specific surface of calcium hydroxide varies a great deal based upon variable that are described below. Typical specific surface of calcium hydroxide range between 8,000 to 58,000 Cm^2/gr. Empirical data shows that the relationship between the particle size of hydrate and specific surface, even though related, is not linear. Figure 9 shows 10 different limes and their hydrates' particle size and specific surface. These figures confirm a lack of direct correlation between particle size and specific surface.

Figure 9

LIME	PARTICLE SIZE (MICRONS)	SPECIFIC SURFACE CM^2/gr
1	2.9	110000
2	3.0	110000
3	2.5	9000
4	3.4	7000
5	3.9	9000
6	2.2	7000
7	2.2	5000
8	2.4	7000
9	2.2	6000
10	3.1	12000

Specific surface of particles is different than surface area of particles. The specific surface takes into consideration the shape of particles and texture of particles.

$$\text{Specific Surface} = \frac{\text{Surface area } 14^2}{\text{Volume } 14^3}$$

The lack of direct correlation between size of particles and surface area is due to particle shape and texture surface texture.

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The following factors affect slaking efficiency by affecting specific surface of the calcium hydroxide, directly or indirectly:

A. Type of limestone used in calcination
B. Calcination process to manufacture CaO
C. Slaking temperature
D. Lime to water ratio
E. Degree of agitation during slaking
F. Viscosity of slurry
G. Slaking time
H. Water temperature
I. Air slaking

A. TYPE OF LIMESTONE

Calcium carbonate deposits are generally not pure. They contain many other elements, such as magnesium, alumina, and compounds that affect the quality of hydrate produced from these limestones. Manufacturers of lime have no control over the impurities that are interspersed in a vein of limestone.

B. CALCINATION PROCESS

Proper temperature and residence time during calcination have a great deal of influence on the quality of calcium oxide produced. The most common problem associated with the calcination process is hard-burned lime. When a lime is hard-burned, an impervious layer forms on the outside of the CaO making it difficult for water to penetrate, to start the slaking process. To slake a hard-burned lime the outer layer of the particle must wear off to open up the pores for water to penetrate. This is done by vigorous agitation that abrades the outer layer of CaO. This type of lime generally requires more retention time in the slaker. In practice using hard-burned lime the slaker capacity must be derated by 50% to minimize CaO carry over.

C. SLAKING TEMPERATURE

Slaking temperature is the most important factor that affects particle size and specific surface of hydrate particles. The closer the slaking temperature is to 210°F the finer the particle sizes and greater the surface area of particles will be. However, the relationship between temperature and particle size and specific surface is not linear due to shape and surface texture of particles.

In some instances when slaking at high temperatures around the boiling point of water, hot spots can develop within the slurry, which will cause hydrate particles to crystallize and agglomerate forming larger flat particles with reduced surface area. This problem is more likely to happen in paste slakers since they operate at higher temperatures and in the areas where mixing is not vigorous.

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Even though from a theoretical point of view temperatures around 212°F is desirable, from a practical point of view it is very difficult to slake successfully at these high temperatures without safety problems or adverse affects due to agglomeration.

In practice slaking temperatures between 175°F to 185°F are more practical for optimum operation. The heat release due to exothermic reaction is different for different quality limes. A High Reactive soft-burned lime will produce 490 BTU's of heat per pound of quicklime. A low reactive lime will produce about 380 BTU's per pound of quicklime.

These BTU's will bring the slurry temperature to a certain degree based on temperature of dry lime, temperature of incoming water, and heat losses from the slaker vessel. Figure 10 shows the relationship of incoming water temperature, incoming lime temperature, heat loss for Chemco slakers with a capacity rating of 500, 1500, 4000, 5000, and 6000 pounds per hour and desired final slaking temperature. As indicated in the chart, to achieve a certain final slaking temperature sometimes auxiliary heat is necessary to augment the heat of process.

Figure 10

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PROCESS PARAMETERS          CHEMCO LIMESLAKER DATA SHEET      17-Jul-92

LIME TEMP.           50.0 (deg. F) =   10.0 (deg. C)
INLET WATER TEMP.    38 (deg. F) =    3.3 (deg. C)

RESULTS   System Inputs       (lb of lime)      System Outputs
                                                     Q REQ'D (lb/hr)
Tank Temp|q GENERATED+ q Lime +q Water =q added | q WIER |q REQ'D |  500      1500      3000      4000      5000      6000
(deg. F) | (BTU/lb)  (BTU/lb) (BTU/lb) (BTU/lb)|(BTU/lb)|(BTU/LB)|                   (BTU/hr)/(KW)

  130.0  .  490.0 +   3.5 +  21.0 =  515.0 | 355.7 | -159.4 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  140.0     490.0 +   3.5 +  21.0 =  515.0 | 391.9 | -123.1 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  150.0     490.0 +   3.5 +  21.0 =  515.0 | 428.2 |  -86.8 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  160.0     490.0 +   3.5 +  21.0 =  515.0 | 464.5 |  -50.5 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  170.0     490.0 +   3.5 +  21.0 =  515.0 | 500.8 |  -14.2 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  180.0     490.0 +   3.5 +  21.0 =  515.0 | 537.1 |   22.1 | 11045.6  33136.7   66273.5   88364.7  110455.8  132547.0
                                                                    3.2      9.7      19.4      25.9      32.4      38.8

  130.0     435.0 +   3.5 +  21.0 =  459.5 | 355.7 | -103.9 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  140.0     435.0 +   3.5 +  21.0 =  459.5 | 391.9 |  -67.6 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  150.0     435.0 +   3.5 +  21.0 =  459.5 | 428.2 |  -31.3 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  160.0     435.0 +   3.5 +  21.0 =  459.5 | 464.5 |    5.0 |  2495.3   7485.8   14971.6   19962.1   24952.7   29943.2
                                                                    0.7      2.2       4.4       5.9       7.3       8.8
  170.0     435.0 +   3.5 +  21.0 =  459.5 | 500.8 |   41.3 | 20640.7  61922.1  123844.1  165125.5  206406.9  247688.3
                                                                    6.0     18.1      36.3      48.4      60.5      72.6
  180.0     435.0 +   3.5 +  21.0 =  459.5 | 537.1 |   77.6 | 38786.1 116358.4  232716.7  310288.9  387861.2  465433.4
                                                                   11.4     34.1      68.2      90.9     113.7     136.4

  130.0     380.0 +   3.5 +  21.0 =  404.5 | 355.7 |  -48.9 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  140.0     380.0 +   3.5 +  21.0 =  404.5 | 391.9 |  -12.6 |-------  -------   -------   -------   -------   -------
                                                                  -------  -------   -------   -------   -------   -------
  150.0     380.0 +   3.5 +  21.0 =  404.5 | 428.2 |   23.7 | 11849.8  35549.5   71099.0   94798.7  118498.4  142198.1
                                                                    3.5     10.4      20.8      27.8      34.7      41.7
  160.0     380.0 +   3.5 +  21.0 =  404.5 | 464.5 |   60.0 | 29995.3  89985.8  179971.6  239962.1  299952.7  359943.2
                                                                    8.8     26.4      52.7      70.3      87.9     105.5
  170.0     380.0 +   3.5 +  21.0 =  404.5 | 500.8 |   96.3 | 48140.7 144422.1  288844.1  385125.5  481406.9  577688.3
                                                                   14.1     42.3      84.7     112.9     141.1     169.3
  180.0     380.0 +   3.5 +  21.0 =  404.5 | 537.1 |  132.6 | 66286.1 198858.4  397716.7  530288.9  662861.2  795433.4
                                                                   19.4     58.3     116.6     155.4     194.3     233.1
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Figures 11 and 12 show the heat balance for a 6000ld/hr Chemco slaker with incoming high reactive quicklime (490BTU) at dry lime inlet temperature of 65°F and inlet water temperature of 38°F. According to this chart when this slaker is run at 350lb/hr rate and required slaking temperature is 160°F process generated heat is not enough to maintain 160°F slaking temperature, therefore auxiliary heat is necessary. This auxiliary heat must come from an external source, such as heated water or an internal source, such as increasing

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the lime feed rate to 400-500lb/hr. Since we rely on the heat of the reaction to provide us with desired slaking temperature in addition to the incoming water temperature, the lime to water ratio also affects the final slaking temperature.

Figure 11

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New Lime Slaker Calculations                    14-Jan-93      Slaker Size        6000 (lb/hr ideal)

Process Parameters:                           Dimensions:      Constants:              Dimensions:
            Temperatures
                    Lime Inlet      65 (deg F)                 Air:
                    Water Inlet     38 (deg F)                     Density        1.164 (kg/m^3)
                    Air Ambient     70 (deg F)                     Cp              1012 (J/kgK)
                    Req'd Reaction 160 (deg F)                     K             0.0251 (W/mK)
                    {Air Out}      100 (deg F)                     u           1.82E-05 (Ns/m^2)
            Dimensions                                             v           1.57E-05 (m^2/)
                    Surface Area   2916 (in^2)                     Pr             0.735
                    Volume          600 (gal)                      Re          2332.063
                    A (from dwg) 56.875 (in)                       hc             0.363 (W/m^2K)
                    Height       47.528 (in)
                    Wall thk      1.438 (in)                   K fiber            0.4 (BTUin/hrft^2F)
                    Insulation thk 0.938 (in)                 k steel             26 (BTUin/hrft^2F)
                    Steel thk     0.250 (in)                  Cp water in      1.008 (BTU/lbF)
                                                              Cp water out     1.001 (BTU/lbF)
                                       3.5                    Cp CaO           0.197 (BTU/lbF)
            Lime Inlet Rate          100 (#/hr)               Cp Ca(OH)2       0.320 (BTU/lbF)
            Volemetric Air Flow       75 (ft^3/min)
            Heat Content of Lime     490 (BTU/#)


     Q Water    Q Lime   Q Generated           Q Wier     Q Air    Q Wall       (Positive means add energy)
     (BTU/hr)  (BTU/hr)   (BTU/hr)             (BTU/hr)  (BTU/hr)  (BTU/hr)                       (BTU/hr)

     505.428     650        49000             46134.144 13300.0   2515.443                     -11794.060
                                                                                                   (kw)
   totals     50155.52                        61949.588                                          -6.211

     Case      #CaO/hr      Qin       Qout       Delta
        a        6000    1584.693  1465.963     118.730
        1        5000    1320.577  1223.024      97.553
        2        2000     528.231   494.207      34.024
        3        1000     264.115   251.267      12.848
        4         750     198.087   190.533       7.554
        5         500     132.058   129.798       2.260
        6         400     105.646   105.504       0.142
        7         350      92.440    93.357      -0.917
        8         300      79.235    81.210      -1.975
        9         200      52.823    56.916      -4.093
       10         100      26.412    32.622      -6.210

   NOTES:  Changing inlet water temperature and/or Reaction Temperature must be accompanied by the
           corresponding changes to Cp for water at these different Temperatures to maintain accuracy
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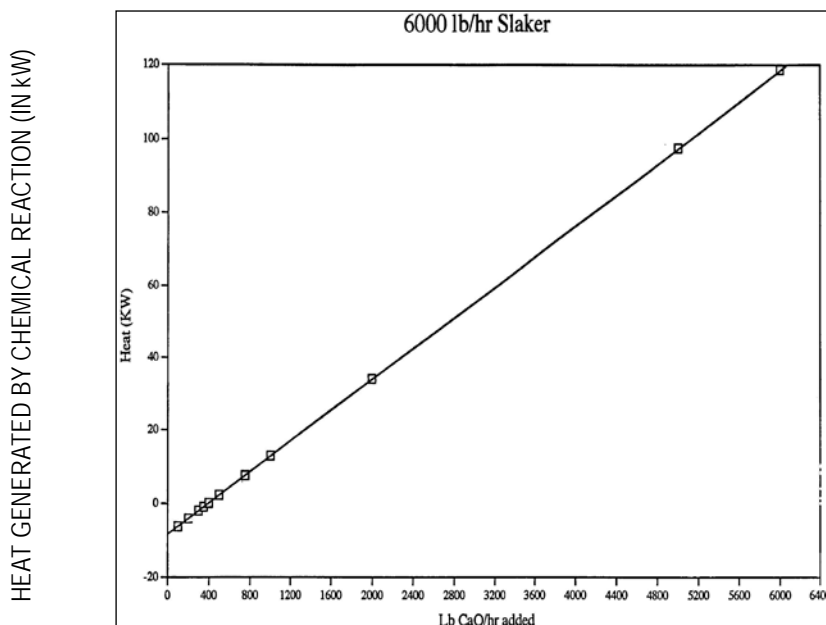
Figure 12

HEAT GENERATED BY SLAKING
LIME TEMP 65°F, WATER TEMP 38° HEAT GENERATED 490 BTU/#

As stated before optimum temperature for slaking varies from job to job depending on equipment and site conditions. Since temperature is the most important factor affecting surface area, temperature control is essential for a uniform quality product. Controlling a slaking process by lime to water ratio or slurry consistency is not the best way because of variables such as lime reactivity, incoming water and lime temperature, which results in variation in hydrate quality. The optimum way to control a slaking process is by controlling slaking temperature by varying the lime to water ratio as necessary. Figure 13 shows particle size distribution of calcium hydroxide slaked in a 8000lb/hr slaker with temperature control operating at 168°F ± 2°F. Ninety five percent of the hydroxide particles are between 3 and 11 microns.

Figure 13

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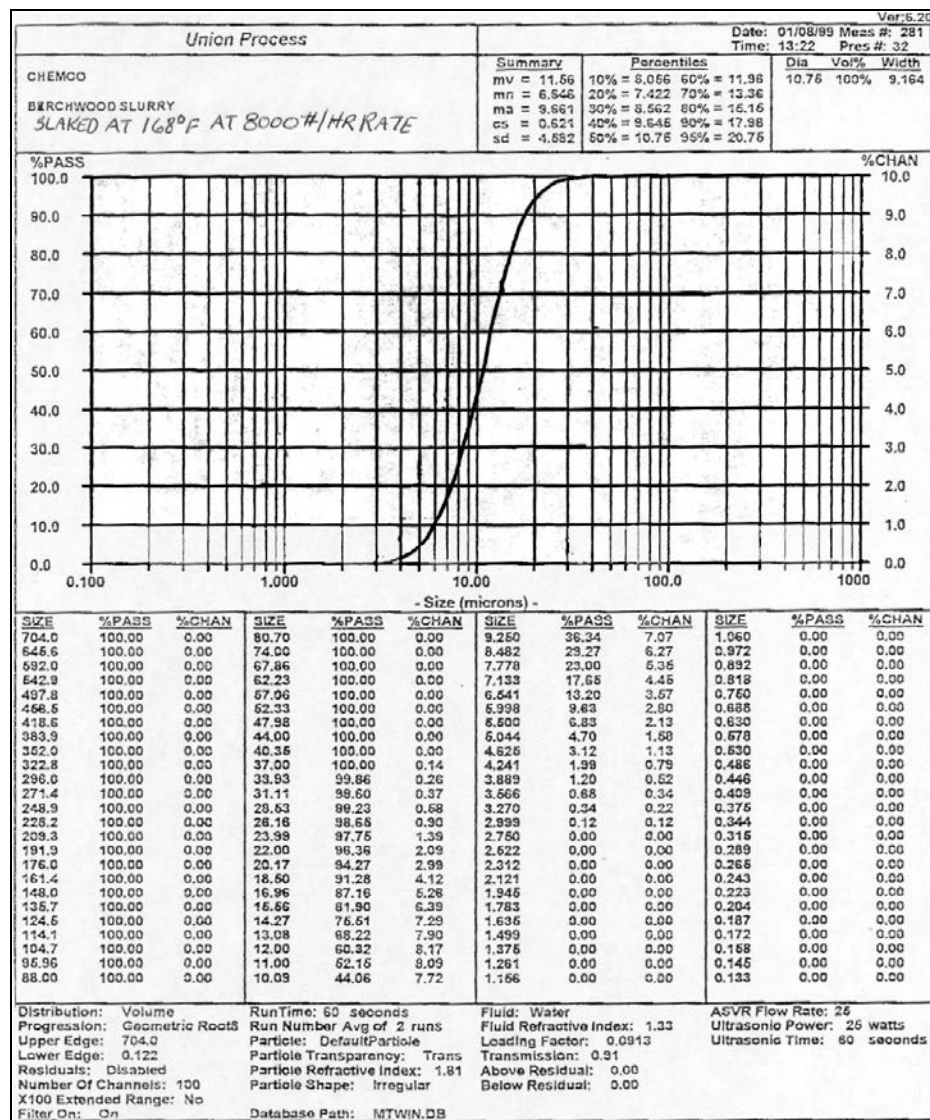
D. LIME TO WATER RATIO

Water to lime ratio also affects slaking time by affecting the slaking temperature. The higher the temperature the shorter the slaking time. Controlling a constant lime to water ratio in a slaking process does not guarantee a constant temperature. Temperature will vary due to variation in water temperature, lime reactivity, and quality of water, thus requiring operator adjustment frequently. As stated before, a better way to maintain a correct lime to water ratio is to control the slaking temperature.

E. DEGREE OF AGITATION

Degree of agitation during the slaking process has an impact on the end product. Too little agitation will result in uneven temperature within the slaking chamber resulting in hot and cold spots. The hot spots will result when slaking temperatures are over 212°F. Slaking at these temperatures will result in hexagonal crystals [2] of large size and reduced surface area and agglomeration of particles and cold spots will result in either drowning or unhydrated particles of CaO.

F. VISCOSITY OF SLURRY

Viscosity of hydroxide slurry can vary greatly from lime to lime as well as process conditions. Certain changes in the hydration conditions will increase the viscosity of the slurry, thus affecting settling time. Often times the viscosity increases at slaking temperatures of 180°F and above. The relationship of viscosity, particle size, specific surface are not completely researched. In general it is presumed that higher viscosity means smaller particle size of hydrate and greater surface area. Variations of viscosity of hydrated lime slurry have been reported between a range of 45-700 centipoises.

G. SLAKING TIME

Slaking time is the time required to complete hydration. This time varies from lime to lime. A high reactive lime will hydrate completely in 2-3 minutes. Medium reactive limes will hydrate completely in 5-10 minutes. Low reactive limes, hard-burned limes, and magnesium limes will hydrate in 15-30 minutes. The field results vary a great deal depending on field conditions. Refer to figure 7 and 8 for more detail.

H. WATER CHEMISTRY

Water chemistry is a major factor in the slaking process. Presence of certain chemicals in the slaking water will accelerate or hinder the slaking process.

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Water with high dissolved solids generally causes excessive foaming, which results in operational problems. Waters containing over 1500 PPM of sulfates or sulfites will retard slaking temperature rise slightly.

Even though the sulfates in slaking water will retard temperature rise, in applications such as acid water neutralization, there is enough contact time between the lime slurry and acid water that the hydrate fully utilized without any noticeable impact on total neutralization capacity of the slaked lime.

Figure 14 shows the effect of chlorides in the slaking water on the slaking process.

Figure 14[4]

Effect of chlorides on lime slaking.
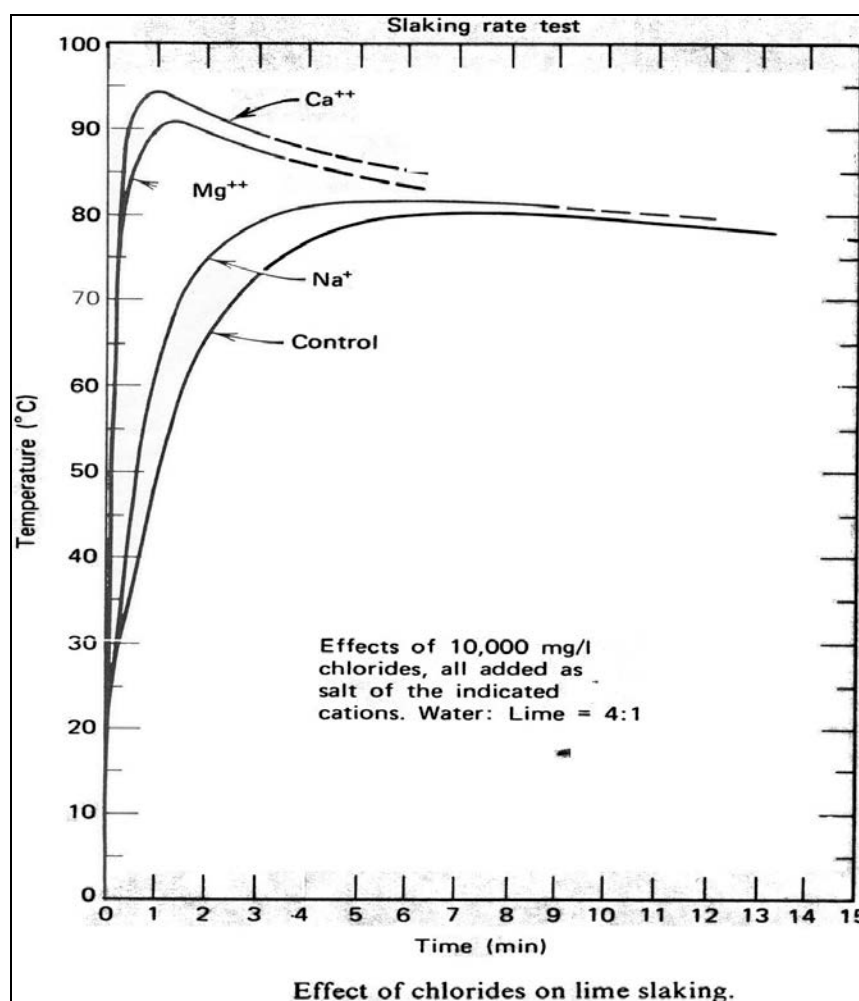
Seawater can effectively be used for slaking. However, the material of construction for the slaker must take into consideration corrosion caused by chlorides.

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I. WATER TEMPERATURE

Slaking water temperature has a great influence on the slaking process and specific area of the hydrate particles. The incoming water temperature and the water to lime ratio inversely affect the slaking time.

Cool slaking water should not contact the dry lime in the slaker. The water and lime must enter the slaker apart from each other so that by the time water comes in contact with the lime its temperature is raised to over 150°F. If a cool water and lime come in contact a condition called "drowning" takes place. Particles of hydrate formed under "drowning" conditions are very coarse and not very reactive.

J. AIR SLAKING

Air slaking is caused by hydration of CaO with moisture in the air at ambient temperatures. The finer the particles of the quicklime the more prone to air slaking they are due to greater surface area. Air slaking not only will produce extremely large particles of hydrate but also will convert calcium oxide to calcium carbonate due to absorption of CO_2 from the atmosphere. An air slaked lime will not yield much BTU's during slaking and will increase consumption due to lack of reactivity.

SUMMARY

Lime slaking is a critical process and there is not enough known about the process by people who generally operate the equipment. The method and type of control used for slaking greatly affects the efficiency of the process. In addition to the quality of quicklime, the temperature at which slaking is done affects the quality of hydrated lime produced. Proper instrumentation is essential in maintaining proper slaking temperature and water to lime ratio within a certain range.

References:

The author acknowledges the valuable information obtained from the following references:

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2. E.F. Hively, "Practical Lime Slaking," Alis Mineral System Grinding Division.
3. Wire and Wire Products, October 1995.
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