White Paper

LIME SLAKING 101

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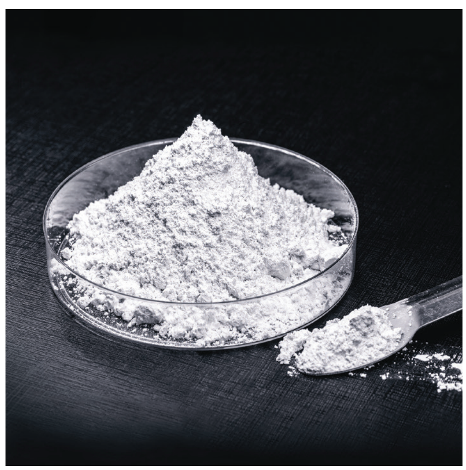
The slaking of quicklime to produce a hydrated lime slurry occurs in a broad range of industries. In this article, we explain the six fundamental factors that impact the slaking process and discuss the various types of slakers available on the market today.

WHAT IS LIME SLAKING?

Lime is used in a wide variety of industrial processes: from pH control to water and flue gas treatment, pulp and paper manufacturing to the production of some metals (to name just a few).

In many of these applications, hydrated lime, or calcium hydroxide ($Ca(OH)_2$), is used. This is produced by adding water to quicklime (calcium oxide, CaO). Initially forming a dry hydrated lime product, the further addition of water creates a hydrated lime slurry in a process known as slaking—the focus of this white paper.



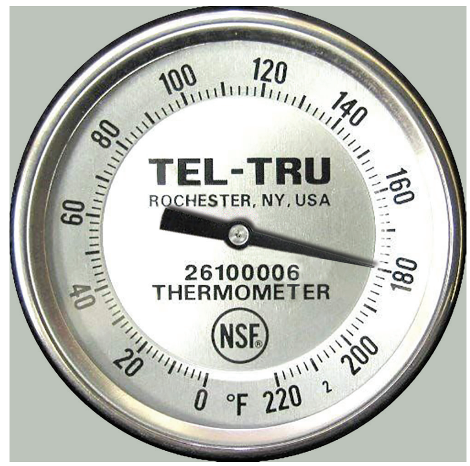
This white paper will begin by detailing the six main factors that influence the slaking reaction, before describing the four different types of slaker (detention, ball mill, paste and batch). It will conclude with brief discussions on the importance of grit removal and the use of a day tank.

THE SIX FUNDAMENTAL FACTORS OF LIME SLAKING

The aim of the slaking reaction is to produce a slurry containing calcium hydroxide particles with high surface areas. Because particles with higher surface areas are more highly reactive, such slurries are more efficient in the end-use process, creating the required result from the minimum input of lime.

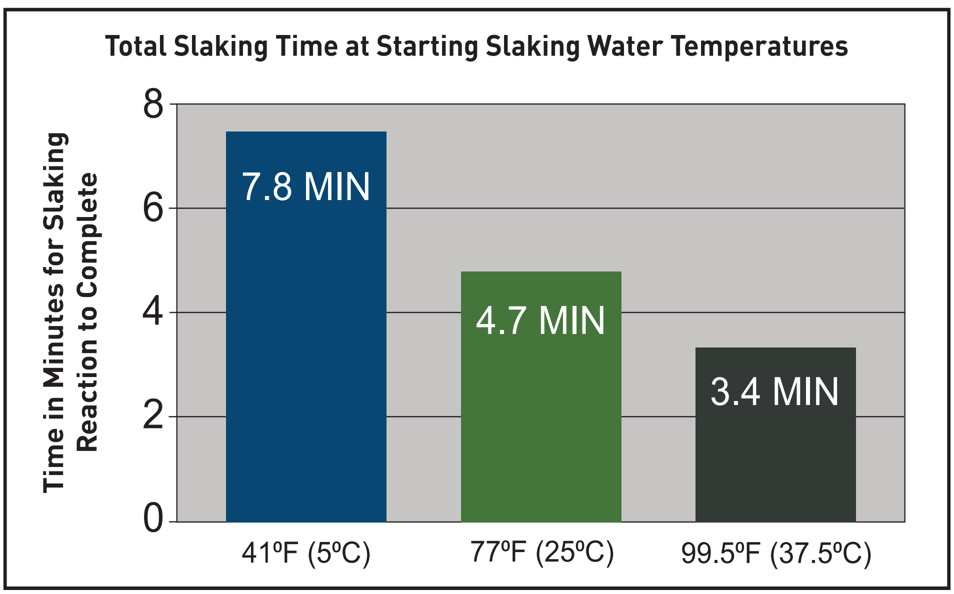
There are six main factors that impact the slaking process and, therefore the quality of the lime slurry:

1. Slaking temperature
2. Slaking water temperature
3. Slaking water chemistry
4. Slaking residence time
5. Slaking agitation
6. Steam control



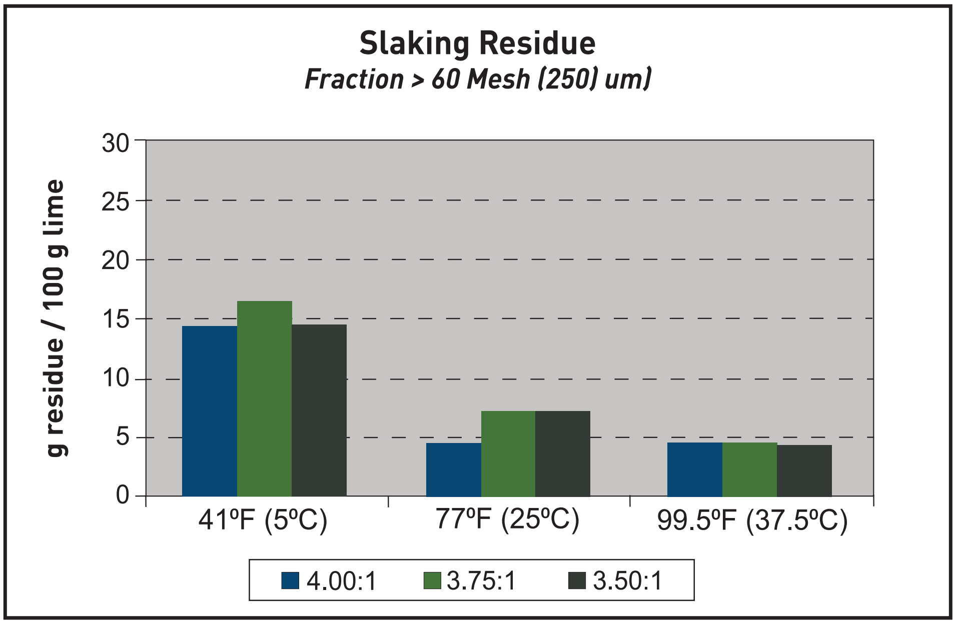
Of these, **slaking temperature** is perhaps the most important, as it directly influences the particle size of the hydrated lime—and, therefore the reactivity of the slurry. Simply put, the closer the slaking temperature is to the boiling point of water, 212°F (100.0°C), the finer the particle size, the greater the surface area, and the more reactive the slurry. Ideally, it should also not exceed this temperature so as to avoid boiling over the slaker. In detention and ball mill slakers, we would typically expect a slaking temperature between 175°F and 185°F (79.4°C and 85.0°C); in paste slakers, the slaking temperature is generally slightly hotter at between 185°F and 195°F (85.0°C and 90.6°C). Additionally, when using quicklime, hotter slaking temperatures can reduce the total time required to complete the slaking reaction as illustrated in Figure 1.

Figure 1



Slaking temperature itself is a function of the water-to-lime ratio, the quality of the quicklime, heat transfer efficiency within the slaker, and the **slaking water temperature**—the second fundamental factor of lime slaking. Particular challenges arise when using cold water (<70°F/21.1°C) in the slaker, as it makes it difficult to reach the required slaking temperature. This results in a less reactive slurry (due to coarser hydrated lime particles), as well as producing significantly more waste product (known as grit or residue). Figure 2 illustrates the increase in residue.

Figure 2



Not only must this additional grit be disposed of properly, it may also contain quicklime, resulting in the waste of valuable product. To avoid these issues, we typically recommend a slaking water temperature of between 70°F and 90°F (21.1°C and 32.2°C), and the use of a water preheater when the water falls below that.

The **chemistry of the slaking water** also has an impact. Water with a high concentration of sulfates and sulfites (>1000ppm) can cause delays in the slaking rate, as well as issues around the slaking temperature and wasted quicklime. High levels of phosphates can similarly impact the slaking process, although are generally less detrimental to the process. The third factor to watch in slaking water chemistry is hardness, which can result in scaling and may necessitate the use of a water softener.

When possible, we recommend using potable water, which typically contains low levels of the problematic chemistries. When water chemistry is an issue—for example, when process water needs to be recycled as part of zero liquid discharge regulations—the use of a ball mill slaker may be the most practical solution, since these are not as sensitive to the issues caused by high sulfate/sulfite and/or phosphate concentrations as other slaker types.

A final note about water chemistry: while the chemistries discussed above pose problems when slaking lime, other chemistries are more benign. For example, the pulp and paper industry benefits from high salt concentrations in its slaking water (particularly anions of chlorides and fluorides). These have a slight catalytic role on the slaking reaction, as well as increasing the boiling point, thereby allowing higher slaking temperatures.

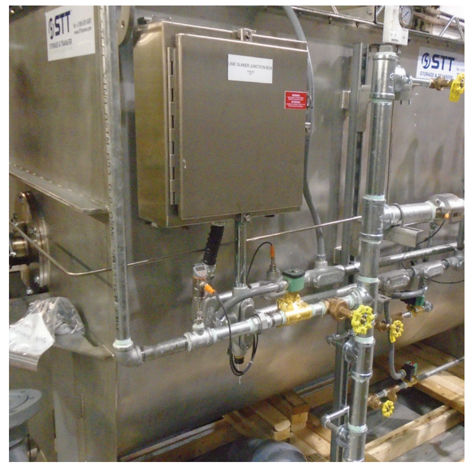
Slaking residence time is a factor to consider when using a continuous slaker (detention, ball mill and paste). As quicklime constantly moves through these types of slaker, it is important to ensure the quicklime spends enough time in the slaker to complete the slaking reaction. Typically, North American quicklimes will require at least three minutes of residency time to completely react, although some slower-reacting quicklimes may need double that time or longer. If the residency time is too short, the quicklime may continue to react as it passes through the grit removal system, which may cause safety issues and potential blockages (particularly when a grit removal screen is used)[1].

[1] It is important not to overload the slaker, as this reduces the effective residency time.

A related issue arises with improper **slaking agitation**. A poorly mixed slurry will not react well, reducing slaking speed and delaying the slaking reaction. To avoid this, regular, proactive maintenance is required on the agitation device, whether that be mixing paddles or agitators in the case of detention, paste and batch slakers, or the ball mill media in a ball mill slaker. In the case of paste slakers, proper mixing is also needed to mitigate against the risk that localized hotspots (i.e., above boiling point) will develop in the slurry.

The final factor to impact lime slaking is **steam control**. The slaking reaction will generate significant amounts of steam, which needs to be removed from the slaker in a controlled fashion. If not controlled effectively, steam will naturally migrate through the path of least resistance—which tends to be up the dry quicklime feed systems and into the silos. Here it will quickly degrade the quality of the quicklime, may cause handling issues—including blockages—and may result in significant scale build-up inside the silo. Steam that escapes into the surrounding work environment also poses a safety risk to personnel, as well as creating issues around cleanliness and housekeeping.

Current best practice is to use draft-induced scrubber boxes that use a water spray to quench the steam and scrub it of any lime dust. The water and lime dust are then returned to the process, helping to reduce lime waste and avoid environmental contamination.



A CAST OF FOUR: TYPES OF LIME SLAKER

As has been mentioned above, there are four general types of lime slakers: detention, paste, ball mill (both horizontal and vertical) and batch. The last is also known as a mix tank. This section will provide a brief description of each; a summary comparison can be found in the table below.

	Detention Slaker	Paste Slaker	Horizontal Ball Mill	Vertical Ball Mill	Mixtank / Batch Slaker
Capital Cost	Low	Moderate	High	High	Very Low
Max Size	26,000 kg/hr	3,600 kg/hr	50,000 kg/hr	50,000 kg/hr	500 kg/hr
Slaker Control	Temperature	Torque	Temperature (delayed)	Temperature	Measured Inputs
Grit Handling	Screen / Screw	Screen / Screw	Hydrocyclone	Separating Chamber	Screen / Screw
Ability to be Optimized	High	Low	Moderate	High	Low
Physical Size	Moderate	Small	Very Large	Large	Small

Requiring relatively low CAPEX, **detention slakers** are the most common type of slaker. They offer a relatively high residence time (6-12 minutes) compared to other types and can therefore process some slower-slaking quicklimes. Detention slakers control is based on the slaking temperature, adding more water if the reaction is too hot, and less if it is not hot enough. As a rule of thumb, however, the water-to-lime ratio will be about 4:1 and, we recommend slaking temperature be kept in a range between 175°F and 185°F (70.5°C and 85.0°C)

Slurry agitation is achieved by either a horizontally- or vertically-mounted impellor. After slaking, the slurry is most commonly degritted using a vibratory screen, before flowing either into a slurry holding tank (day tank) or directly to the end-use process. The grit is removed to a grit holding container for disposal. An incline rake or screw may also be used to degrit, although this is more usual for paste slakers.

Paste slakers are popular in the municipal water treatment market, as the higher slaking temperatures 185°F and 195°F (85°C and 90.6°C) can theoretically produce a more reactive slurry—although this also requires a very reactive quicklime. Residence time is shorter at 4-5 minutes, while the water-to-lime ratio is around 2.5:1 to 3:1.

The slurry is agitated by two horizontally-mounted paddle shafts, rotating in opposite directions. Once slaked, the slurry is diluted to roughly the same water-to-lime ratio as detention slakers (4:1) to facilitate grit removal. Both vibratory screens or inclined rakes/screws can be used to degrit, although, rakes/screws are more common here.

Requiring the highest capital investment, **ball mill slakers** are available in horizonal and vertical configurations. In terms of slaking temperature and residency time, ball mill slakers are similar to detention slakers; they are also controlled off of the temperature. The advantages of a ball mill slaker become most apparent, however, when dealing with slower-reacting quicklimes or cold and/or chemically-challenging slaking water.

At the heart of ball mill slaker operation is a pulverizing action produced by the movement of a grinding media (usually steel balls) against the process material —in this case, quicklime. This pulverizing action ensures adequate particle fineness, creating a highly-reactive slurry, from even the most challenging of feed materials. It also eliminates the need for degritting, as the grit is pulverized alongside the quicklime and incorporated into the slurry.[2]

The final slaker type is the **batch slaker**. These slakers are unique in that they do not offer continuous operation. Instead, batch slakers use weigh cells to control the amount of water and/or quicklime added to the tank, which is equipped with a vertical impeller for mixing. When the tank has been filled to the correct water-to-lime ratio, the entire mix is slaked before being pumped out and the process repeated, as necessary.

Batch slakers are cost effective for small-scale users of slurry, and offer a high degree of control over the variables. Residency time, for example, is unlimited by the constraints of a continuous process: you can effectively keep the slurry in the tank for as long as is needed (depending on output requirements). This makes batch slakers particularly effective at slaking low-reactivity quicklimes, providing users with broad flexibility when sourcing their raw material. Depending on the application, degritting is also not always necessary.[3] When included, it is typically a vibrating screen.

Batch slakers can also be equipped with a temperature probe to monitor slaking temperature as a way to refine the reaction. As with detention and ball mills, slaking temperature is managed by adding either more water (to lower the temperature) or more quicklime (to raise the temperature). This enables users to fine-tune the particle size of the hydrated lime and, therefore, better control the reactivity of the slurry. Meanwhile, users that have a particular sensitivity to the amount of dry product added to their process can accurately regulate the amount of quicklime added to the slurry.

[2] For this reason, ball mill slakers are not appropriate for processes that require higher-purity slurries, such as those used in alumina and lithium processing. Ball mills are also much noisier than other types; hearing protection is therefore mandated for personnel working in the vicinity of these slakers.
[3] For example, when the slurry is to be added to a solid process, such as for biosolid treatment.

THE IMPORTANCE OF GRIT REMOVAL IN LIME SLAKING

For most slaker types (the exception being ball mill slakers and some batch slakers, as discussed above), grit removal is recommended to reduce abrasion when pumping and piping the slurry, thereby extending equipment life.

In certain applications, grit removal can also improve the chemistry of the slurry. For example, the concentration of many of the common oxides that slurries are tested for can be greatly reduced by degritting. This is important in processes where high-purity slurries are required, such as lithium processing, and can also help to reduce the scaling in the pipes.

The two most common types of grit removal system are vibratory screens and inclined rakes/screws:

- **Vibratory screens** exclude particles by size. Grit particles—which tend to be coarser than hydrated lime particles—are therefore caught in the screen as the slurry flows through it and removed. Depending on how pure a slurry is required, degritting screens can range from 16 mesh down to 60 mesh, although 16 mesh to 30 mesh screens are most common.[4]
- **Inclined rakes/screws** are based on the principal that, in a liquid, larger solids will settle to the bottom, while finer particles remain in suspension. In practice, this means the slurry is pumped into a secondary, unmixed chamber after slaking, where the larger solids (the grit) are allowed to settle out of suspension. They are then elevated out of the tank by an inclined screw or rake. Although inclined rakes/screws are a lower maintenance option than screens, they do need to be replaced when sufficiently worn to maintain function. They also offer less precise control over what particles are removed.[5]

An examination of the grit removed from the slaker can help to shed light on any issues with the lime or the slaking process. Ideally, grit should be a loose, sandy material, damp but free of slurry, and cold (the same temperature as the grit spray water). A white pasty grit could indicate that too little dilution water is being added (in the case of inclined rakes/screws) or that the grit sprays are not functioning correctly.

A pasty grit could also indicate that the quicklime is not slaking to completion, especially if the grit is also warm. This is a potentially hazardous situation that should be investigated promptly to determine the root cause. Meanwhile, a significant increase in the size of the grit particles may indicate a change in the burn characteristics of the lime—specifically issues with underburned lime. In both situations, it may be necessary to involve an expert in the lime slaking process to ensure any issues are correctly identified and rectified.

On the other hand, a change in the color of the grit is unlikely to indicate any major issue. It most often simply reflects a change in the color of the original limestone, which can come in a range of shades—from the traditional white, beige and cream, to greys, browns, and even on toward black, depending on its exact chemical composition.

[4] Unless the slaking process is well optimized and carefully monitored, at finer meshes, screen blinding becomes a significant risk. It is therefore only advised when strictly necessary, most notably for the production of precipitated calcium carbonate (60 mesh) or in some flue gas treatment applications, e.g., where the process uses atomizers (40 mesh).

[5] Settling rates are a function of dilution. The more dilute the slurry the faster the particles will settle out of suspension, and the finer these particles will be. The principal is simple, but not so easy to control in practice.

DAY TANKS: WHAT ARE THEY FOR?

For the most part, regardless of the slaker type, a day tank will be installed after degritting (or directly after slaking in the case of ball mills). Day tanks are small, covered tanks, equipped with vertically-mounted impellers and baffles, and designed to hold between six and twelve hours of slurry. Their basic function is to provide continuity of slurry supply; their size will therefore reflect how critical it is that the end-process continue uninterrupted by any stoppage to the slaker.

In applications that see wide swings in slurry consumption, day tanks provide the ability to absorb peaks and troughs in demand, without continuously ramping the slaker up or down. This helps maintain an efficient slaking process, as slakers perform best when operating at a steady state. It may also potentially reduce the size of the slaker required by the application, as it is not necessary to engineer the equipment to cover extreme peaks in demand.

Day tanks are also the ideal place to dilute the slurry, as water chemistry has much less of an impact on the slurry at this stage of the process. For users with complex water chemistries, such as those bound by zero liquid discharge regulations, day tanks therefore offer the easiest way to incorporate water into the lime slaking process, while maintaining the quality of the lime slurry.

A final benefit provided by day tanks relates to the curing of the slurry. Simply put, slurry that is allowed to sit and mix for a while after slaking will become more reactive. In addition, any quicklime not slaked completely in the slurry will be allowed to finish its conversion to hydrated lime.

CONCLUSION

Unlike some chemical industrial processes, lime slaking is not particularly complicated. But that does not mean it is easy. There are a range of factors that influence both the choice of slaker and how to optimize that slaker to ensure the production of a high-quality slurry.

It is also true that slaking is almost always an intermediary process: the slurry produced is not an end product in itself but an additive to another, often more complex, process.[6] The production of on-spec slurry is therefore not an end to itself, but directly influences the quality of this end-process—whatever that might be.

Getting it right therefore has implications far beyond the slaker itself. As an expert in the use of lime products as well as the design and manufacture of lime slaking systems, STT, Member of the Carmeuse Group, is ideally positioned to help you get the most out of your lime slaking process. Whether it is helping to decide what slaker will work best for your application or troubleshooting and optimizing an existing process and equipment, we have the knowledge and experience to be your partner for lime slaking success.■

[6] The exception being the production of precipitated calcium carbonate.

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