A Review Of Lime Slakers
And Their Advantages And Disadvantages

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The question most often asked is "What is the best type of slaker?" The answer to this question is often complex and depends on factors such as:

- End use of produced lime slurry
- Type of quicklime used
- Quality of slaking water
- Quantity of lime slurry required
- Quality level of produced lime slurry required

To address the above, let us first review the types of slakers available in the marketplace today.

A. Detention or Slurry Slakers
B. Paste Slakers
C. Batch Slakers
D. Horizontal Ball Mill Slakers
E. Vertical Ball Mill Slakers

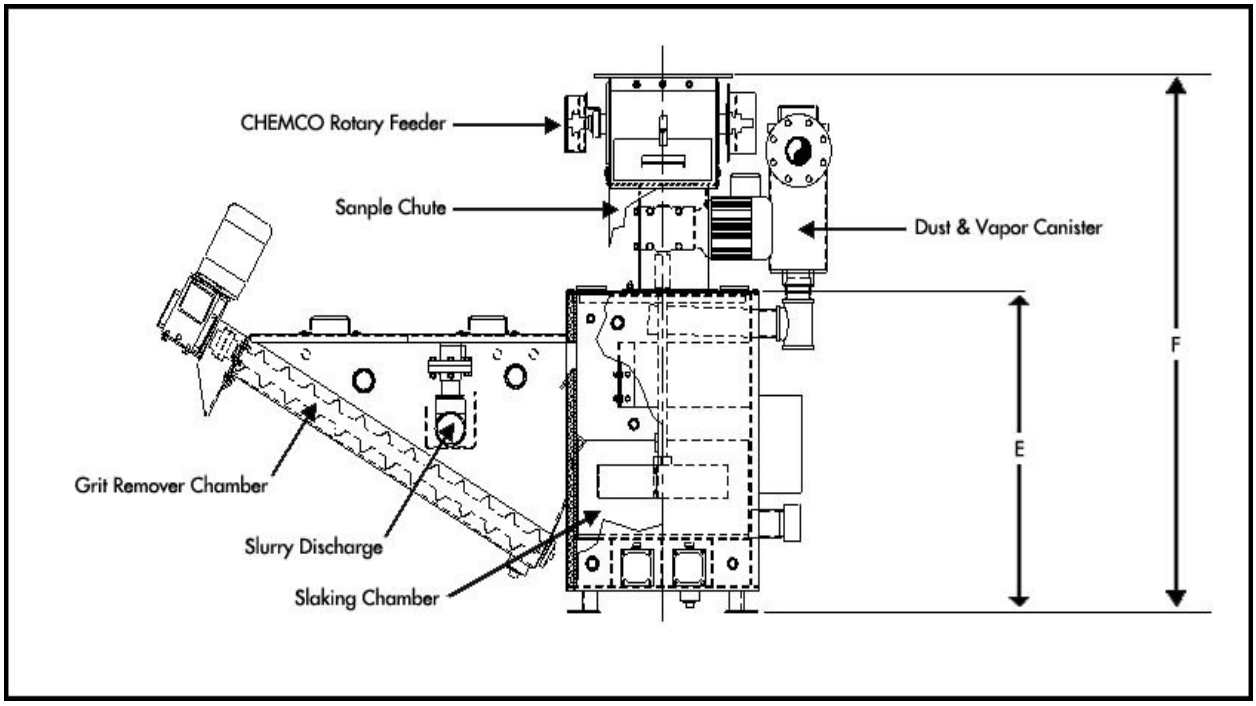
The following pages will describe each type of slaker with their advantages and disadvantages.

A. DETENTION OR SLURRY SLAKERS

A Detention slaker is composed of a cylindrical or square tank with an agitator to thoroughly mix water and lime to produce lime slurry.

The agitation must be vigorous and must prevent any dead zones in the mixing chamber. Furthermore, the tank must be baffled to prevent short circuiting of freshly added lime to the discharge.

(see sketch next page)



DETENTION SLAKER

Detention type slakers can operate continuously or in a batch mode.

The addition of water to lime in the Detention slaker is done either by a ratio method or temperature control method.

The ratio method is the old method adding lime and water to the mixing chamber base on a ratio of four to five parts water to one part lime by weight.

This type of slaker is simple and very easy to operate, however, to operate properly, it requires continuous operator adjustment to maintain a good quality slurry. Operator adjustments are required due to the variation of inputs to the slaker such as:

- lime reactivity (soft or hard burned lime)
- water temperature
- dry lime feed rate

The reactivity of lime changes from load to load, therefore, it is difficult for the operator to judge the reactivity unless the slaker is equipped with a slurry temperature indicator.

The temperature of water is easier to detect since temperature only changes with seasonal changes (assuming surface water is used). For the operator to detect these changes and make proper adjustments, he must very closely watch the slaker and make a regular temperature recording every two to three hours. This type of slaker will produce a variable quality of slurry and does not lend itself to processes where a close control of slurry quality is required.

The temperature-controlled slakers add lime and water based on the final temperature of the lime slurry. Under normal operation, the quicklime is fed at a constant rate and

variable quantity of water is added to maintain a constant slurry temperature within ± 2°F. Since temperature is the most critical factor that affects the quality of hydrate produced (finer particle sizes with larger surface area), maintaining a constant temperature is the logical method of control for slaking.

The final temperature of slurry is affected by the lime reactivity as well as changes in the slaking water temperature. The temperature-controlled slakers will automatically vary water feed to maintain a constant setpoint temperature.

The disadvantage of the temperature-controlled slaker is that the percentage of solid will vary as the reactivity of lime or temperature of water varies. In processes where a constant density slurry is required, a density control loop must be added after slurry is produced. Use of pebble lime where grit removal is necessary, limits the density of the final lime slurry to a maximum of 20% solid slurry. If a higher percentage of slurry is required, pulverized quicklime should be used.

Grit Removal in Detention Slakers
There are two types of grit removal available for the Detention slakers:

1. Integral Screw Grit Separator
2. External Vibratory Screen Separator

An integral grit separator is composed of a chamber with an inclined bottom channel in which an inclined screw rotates at a slow speed. There is little agitation in the grit separation chamber, therefore, the heavier material will settle in the inclined channel. The settled grit will be elevated by the grit elevator screw to above the surface of the slurry and discharged into a grit bin for disposal.

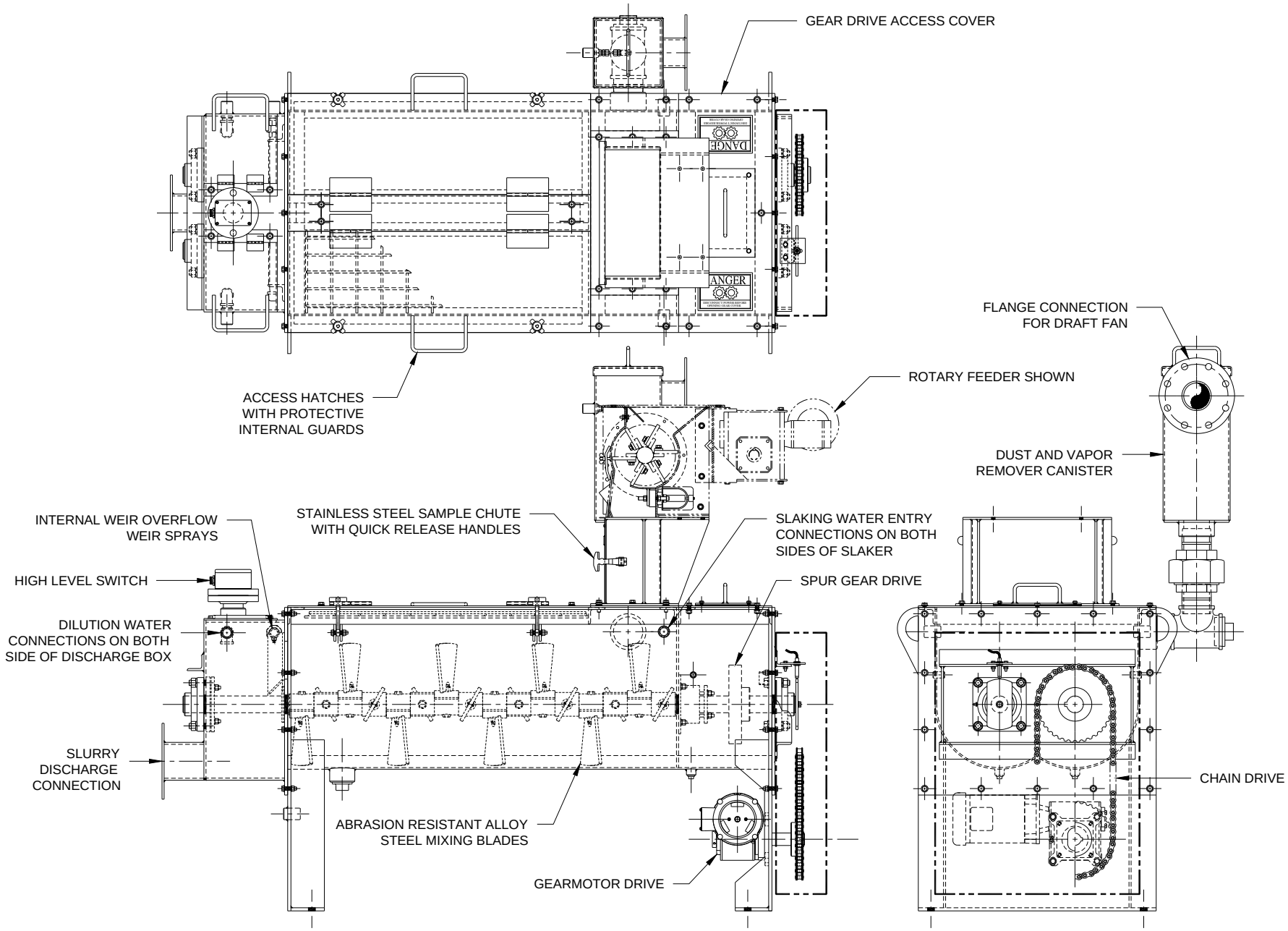
This system of grit separation works well but since it relies on gravity to settle the oversized, the slurry must be thinned to allow settling of grit in a relatively short period of two to three minutes.

The slurry produced and degritted by this method has a maximum solid content of 15% to 18% by weight. For higher slurry concentration, a vibratory screen separator should be used. Maximum slurry concentration degritted by the screen is 20%. The grit larger than 15 mesh can be easily separated by the screen. Finer screens will cause frequent blinding adding to maintenance down time.

B. PASTE SLAKERS

A Paste slaker is composed of a horizontal tub with two counter-rotating paddle shafts. The lime and water enter at one end and mix together to form a paste. The paddles move the paste forward where it exits the slaker into a dilution chamber. The paste is then diluted to form slurry similar to what is produced in a Detention slaker.

(see sketch of Paste Slaker – next page)



TYPICAL PASTE SLAKER

A Paste slaker operates based on the consistency of the paste. A torque sensor, mechanical or electronic, senses the torque required to drive the paddle shafts and compares this value with a pre-set value. If the torque is above the pre-set value (paste is too thick), it adds water to thin the paste. If the torque is below the set point (paste is too thin), it reduces the amount of water to thicken the paste.

The Paste slaker generally operates at a higher temperature than a typical Detention slaker, however, this higher temperature causes operational problems such as excessive steam and local hot spots.

Since the slurry at the inlet is very thick, when a pebble of lime falls into this thick slurry, it does not mix quickly. The local temperature in these spots reaches over 200°F thus forming hot spots. The hot spots will cause agglomeration of finer particles thus adversely affecting the quality of resultant hydrate. Paste slakers can be operated continuously or intermittently. A paste slaker operated properly will produce a good quality hydrate, but without operator interference a paste slaker cannot respond to changes due to the quality of lime or the temperature change of incoming water.

Paste slakers are very sensitive to the size of grits and inert in the incoming lime. Large grits and grit build-up at the bottom of the trough will be caught between the end of the paddles and the body of the slaker causing excessive torque on the drive. The control system interprets this extra torque as the paste being too thick and will add more water to dilute the paste. As more water is added and the paste gets thinner, more grit will settle to the bottom and more torque will be required to turn the shafts.

To avoid this problem, lime specifications must limit the upper size of particles (e.g., 100% < ½"). The size of the largest grit must be smaller than the clearance distance between the tip of the paddles and the body of the Paste slaker.

Typically, in a Paste slaker, the water to lime ratio is about 2.5 to 1. As paste exits the slaker, it is diluted to allow heavier particles to settle to the bottom of the grit chamber, so it can be removed from the grit chamber via grit elevator drag chain. The final slurry solid concentration after grit removal is 15% to 18% - same as the Detention slaker.

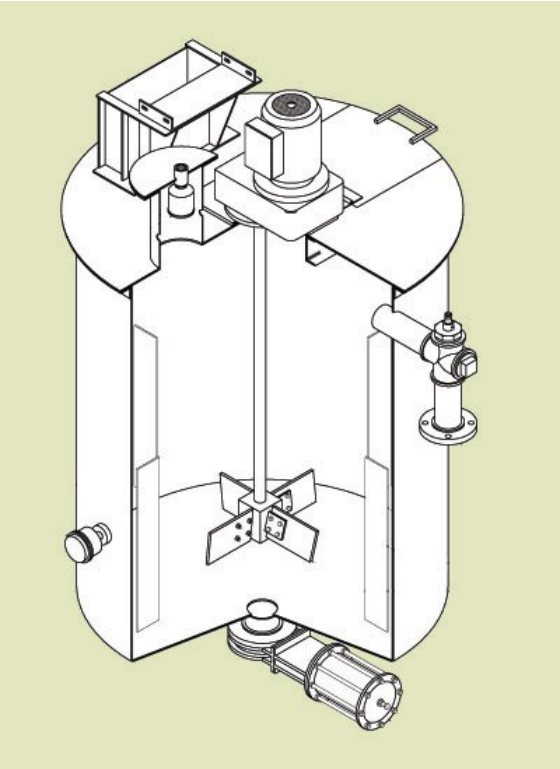
Paste Slaker Grit Separator
Similar to the Detention slaker, the Paste slaker has either an integral grit elevator or external vibratory screen. The final product for the grit removal point of view is very similar as described for the Detention slaker.

C. BATCH SLAKER

A Batch slaker is very similar to the Detention slaker except that the Batch slaker cannot run continuously. In addition, the method of control for the Batch slaker is slightly different than the Detention slaker.

A Batch slaker is a cylindrical tank with a high-energy mixer. First, water is added to the slaker by weight or volume. After the water feed is completed, the lime is added by weight or volume. The lime and water are mixed for a period of time until the desired temperature is reached. If the temperature exceeds the set point, additional cold water is added to lower the temperature to the set point. If the temperature does not reach the set point after a fixed period of time, more lime is added to raise the temperature.

Once the steady state is reached, the mixer stops and the batch of lime slurry is dumped. The controls will recalculate the amount of lime and water needed for the next batch. The Batch slaker is a good choice where lime consumption is low and a batch of a few hundred gallons of slurry is sufficient for a 24-hour use.



BATCH SLAKER

The Batch slaker requires minimum maintenance and housekeeping, therefore, requires very little operator attention.

The Batch slaker design does not lend itself to the integral grit removal systems.

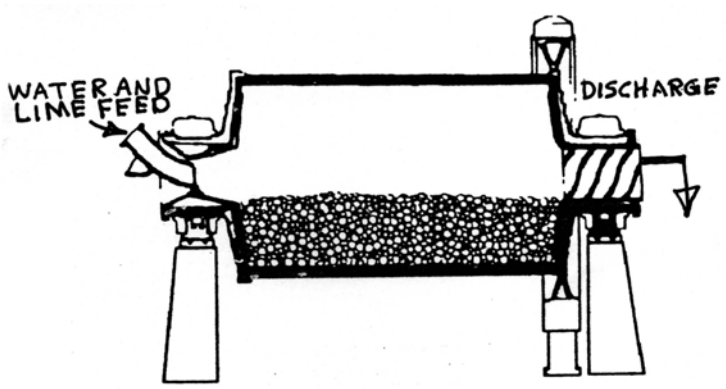
Existing Batch slakers are designed to use pulverized quicklime; therefore, no grit separation is necessary.

If pebble lime is to be used with the Batch slaker, the slurry must be degritted by using a vibratory screen or similar device.

D. HORIZONTAL BALL MILL SLAKERS

Standard Horizontal Ball Mills are sometimes used for lime slaking. Considering that Ball Mills are designed for grinding, and the slaking process is simply a chemical process, it is obvious that the use of a Ball Mill for slaking is not the best choice of equipment in most cases. However, there are a few cases where the use of a Ball Mill slaker is advantageous. These include:

1. Where the slaking water is high in sulphate or sulphite concentration (over 500 PPM).
2. Where grit disposal is not an available option.
3. Where dolomatic quicklime is used in place of calcium lime.
4. Where the required capacity is larger than the available size of Detention or Paste slakers.



HORIZONTAL BALL MILL

1. When the slaking water sulphates or sulphites content is more than 500 PPM, the sulphates or sulphites coat the pebbles of quicklime and prevent water from reacting with the lime. The only way this reaction can take place is the outer layer that is covered with the sulphate must be abraded away to allow water to penetrate lime pebbles. The only slaking equipment that can achieve this efficiently is a Ball Mill slaker.

2. In the case of the water with low sulphates or sulphites, the ball is used only to grind 5% of the total feed which is grit. This certainly is a very expensive way to get rid of 5% grit. In addition, since the entire body of the mill plus the media has to be rotated, it requires many times more power than the conventional Detention or Paste slakers.

3. In applications where magnesium lime is to be used in place of calcium lime, slaking this type of lime is very difficult in regular slakers if pebble dolomatic lime is used. With pebble dolomatic lime, slaking can take place only under high pressure and high temperature. In Detention type slakers, only pulverized dolomatic lime can be slaked at temperatures near 200°F and a residence time of about 30 minutes.

The Ball Mill slakers can be effectively used for slaking dolomatic pebble lime, since pebbles will be ground to a fine particle size. The mill temperature for slaking dolomatic pebble lime should be about 200°F. With this high temperature, special mill lining must be used. The normal mill rubber line will deteriorate at this temperature.

4. Detention type slakers are typically made with a maximum feed rate of 20 tons per hour. The Horizontal Ball Mills can handle capacities much larger than 20 tons per hour. However, from the economic point of view, using multiple Detention slakers to get the maximum capacity is generally much less expensive.

F. VERTICAL BALL MILL SLAKERS

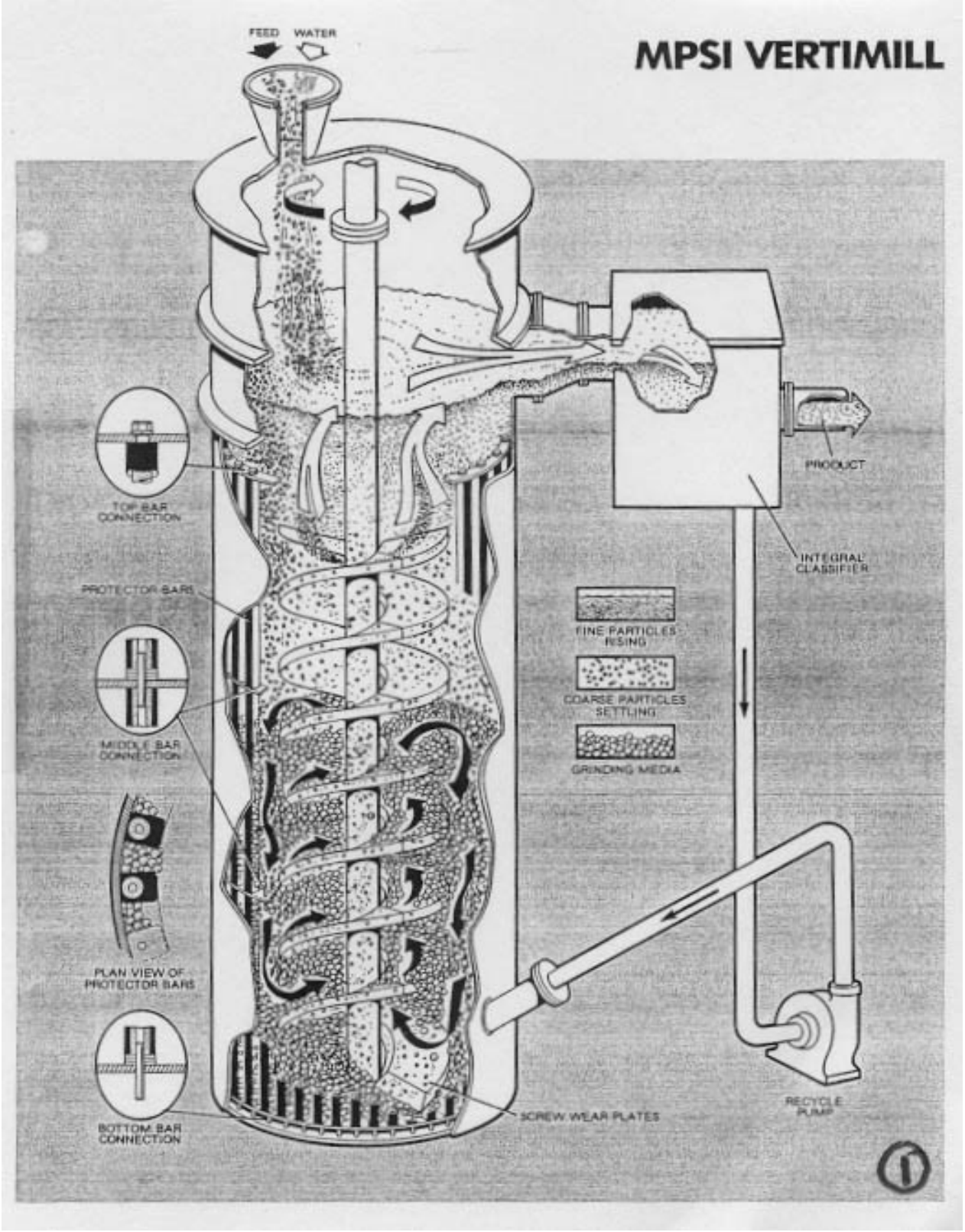
There are two types of Vertical Ball Mills on the market:

1. Vertimill
2. Attritor Ball Mill

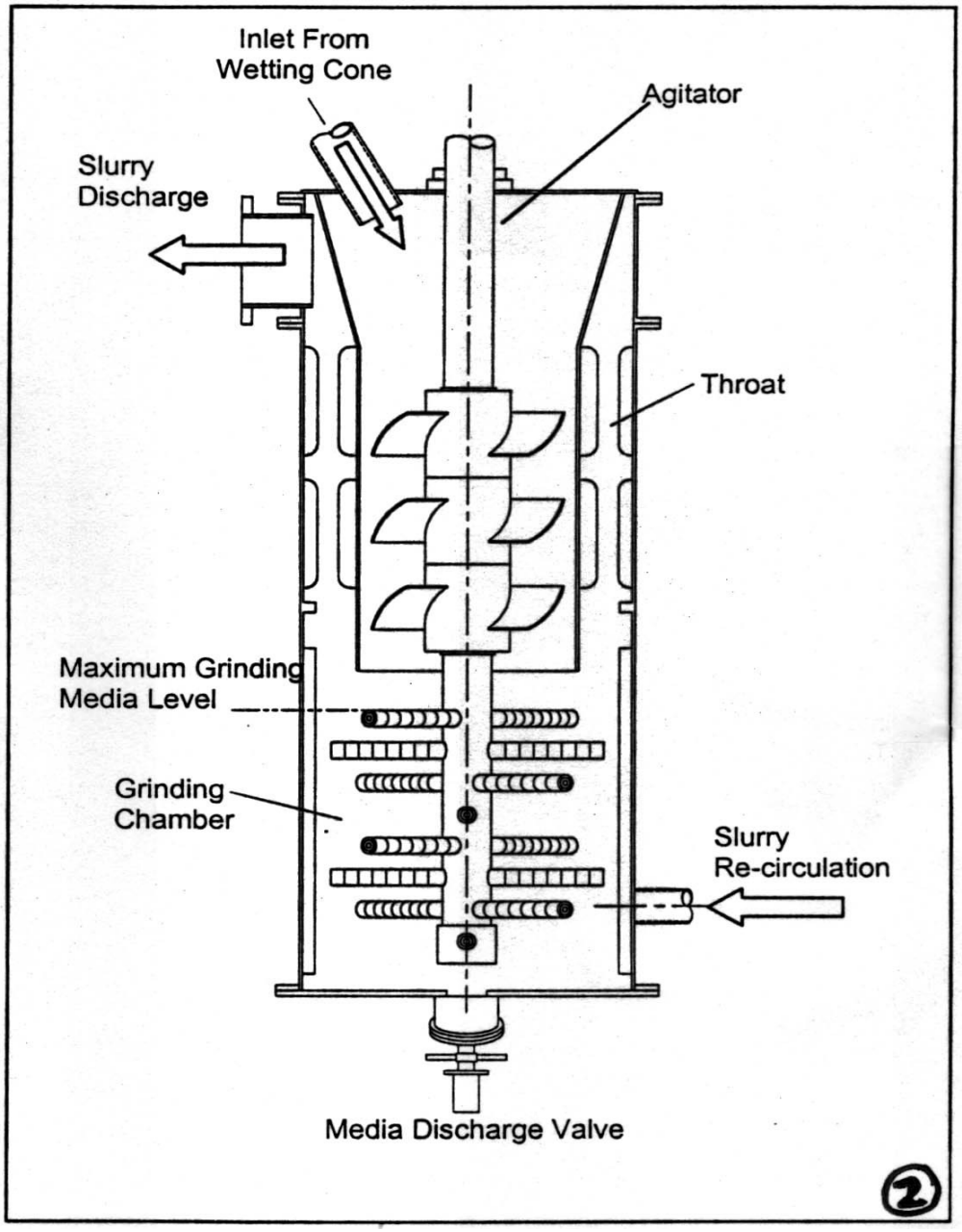
Both mills have stationary bodies and moving shaft and media. The difference is how the media is energized to move.

1. In the Vertimill[1] the media rises by a vertical screw and falls by gravity on the outer circumference of the screw. In this machine, the drive energy is used only to raise the media not to grind. The grinding is done by the gravity fall of the media and its impact to the other media during the gravity fall. Since media has to fall by gravity, the media has to be large enough in size to crush the lime particles as well as grit. Media in this mill is 1" and 1-1/2" diameter. The Vertimill sketch shown here is a Metso Mineral Vertimill.

[1] Vertimill is a trade name for a vertical mill marketed by Metso Mineral.



METSO VERTIMILL



2. In the Attritor Ball Mill, the media is agitated via a shaft with multiple arms. The shaft rotates at a speed to create an arm-tip speed of about 1,000 feet per minute. The agitated arms impact the media and throw the media in all directions in a random pattern. The lime and grit are impacted by energized media and are ground by a shear as well as impact. The media in this type of mill is generally 5/16" or ½".

DETENTION SLAKERS

Features	*Positive Impact*	*Negative Impact*
Capacity (thru put)	Available in sizes as small as 250# per hour with 10 – 1 turn down.	At this time, top size limited to 25 tons per hour.
Purity of Ca $(OH)_2$	Most grit and impurities are removed by the grit removal system.	Grits smaller than 20 mesh cannot easily be removed without the use of a hydrocyclone.
Particle Size of Ca $(OH)_2$	Very fine particles ranging in size 90% less than 20 microns, 100% less than 42 microns.	
Reactivity	Very high due to fine particle size achieved by chemical reaction of lime and water.	
Grit Carry Over		Due to the standard grit separation, available grits smaller than 20 mesh are carried over in the slurry (except when hydrocyclones are used).
Grit Separation Method Elevated Screw	This method is very simple, trouble-free and requires very little maintenance.	Since grit separation is done by the thinning of slurry to allow larger particles to settle, maximum slurry solid concentration is limited to 15%.
Vibratory Screen	With screen separation, slurry concentration can be up to 20% solid.	Upper limit of screen mesh is 16 mesh if frequent screen blinding is to be avoided.
Hydrocyclone	This method can produce slurry concentration up to 30% solid.	This system requires pumps and cyclones which increase cost and maintenance.
Preventative Maintenance Daily	Only ½-hour per day to inspect the slaker inlet and inside, and hose down of build-up with high-pressure water. Also cleaning dust and steam removal system.	On slakers with capacities less than 1,000# per hour, due to the small space within the slaker, a build-up of lime occurs above the slurry level. This build-up, if allowed to accumulate, could cause a potential safety hazard; therefore, requires frequent inspections and pressure water cleaning during the run.
Weekly	None if daily routine is done properly.	
Monthly	None if daily routine is done properly.	
Six Month	Drain slaking and grit removal chamber and check for any abnormal wear.	
Consumables or Wear Parts	Mixer impeller and wear plate at bottom and inner side of slaking chamber.	

DETENTION SLAKERS (CONTINUED)

Features	*Positive Impact*	*Negative Impact*
Safety	Three independent control loops monitor the operation of the slaker and act as back-up if one loop fails. A safety door latch and proximity switches prevent opening access doors while the slaker is running.	If the build-up of lime is not routinely cleaned off the walls of the slaker above the slurry level, it may form a bridge above the slurry. Should this bridge break, a quantity of dry lime will enter the slurry potentially causing an explosion-like reaction, which could damage equipment.
Initial Investment	Initial investment is relatively low compared to the Ball Mill slakers. Its price is about one quarter of the cost of a mill system of the same capacity.	
Power Consumption	As a rule of thumb, one hp per each 1,000# of slaker capacity.	
Grit Disposal		When the operating permit for the plant limits the disposal of grit, either pulverized lime or a small ball mill must be used to grind the grit small enough so the grit will pass through with the lime slurry.
Equipment Life	With proper maintenance, the life expectancy is 20 years.	

PASTE SLAKERS

Features	*Positive Impact*	*Negative Impact*
Capacity (thru put)	Available in sizes from 1,000# per hour with 10 – 1 turn down.	Maximum published size available is 10,000# per hour.
Purity of Ca $(OH)_2$	Similar to Detention slakers. Most grit and impurities are removed by the grit removal system.	Similar to Detention slakers. Grits smaller than 20 mesh cannot easily be removed without the use of a hydrocyclone.
Particle Size of Ca $(OH)_2$	Due to small physical size, it would be suitable for some retrofits - where space is very limited and final slurry quality is not critical.	Due to the lack of temperature control, the slaker temperature varies. Also, hot spots develop causing agglomeration of fine particles. Final product is not uniform.
Reactivity	Medium to high reactivity.	Reactivity somewhat changes from season to season due to the water temperature changes. Unless well water is used, operator adjustment is frequently required.
Grit Carry Over	Integral grit separation is simple and trouble free.	Due to the design of the grit elevator, grit particles smaller than 20 mesh cannot be separated from the lime slurry.
Grit Separation Method <u>Drag Chain</u>	This method of grit removal is a simple and compact design, maximum slurry concentration is 15%.	The wear of plastic scrapers attached to the chain.
<u>Vibratory Screen</u>	With a vibratory screen, higher solid slurry (up to 20%) can be achieved.	Maximum screen mesh - practical is 16 mesh. Finer screens will cause frequent screen blinding.
Preventative Maintenance <u>Daily</u>		When the unit is operated in Batch mode, at the end of each batch the paste must be thinned to slurry by adding water. This thinning will result in larger grit to settle at the bottom and, during the next batch run, rub against the paddle shaft and cause erratic operation of the torque valve.
<u>Weekly</u>		Must empty large grit accumulated at the bottom of the slaker by draining and flushing.
<u>Six Month</u>		Torque water valve needs adjustment every six months or so to keep the paste consistency correct.

PASTE SLAKERS (CONTINUED)

Features	*Positive Impact*	*Negative Impact*
Consumables or Wear Parts	Paddle shafts, torque valve and grit elevator plastic scapers.	Replacement parts cost are very high and long lead.
Safety	No major safety issues other than the fact that the slaker access doors do not have any provision for locking.	There is no safety back up for over temperature in this slaker. Temperature sensors are ineffective in Paste slakers because sensors cannot protrude in the active zones due to the interference with the paddles. Sensors that are uninstalled in inactive zones are not effective because of the delay in the sensing temperature. By the time the sensor senses high temperature it is too late.
Initial Investment	Initial investment is relatively low –similar to detention slakers.	
Power Consumption	Power consumption is low less than 1HP per each 1000# of slaker capacity.	Generally, the drive motor is undersized; therefore, the device does not have enough power to restart the paddle shaft with paste in the slaker after a long shut down due to a fault.
Grit Disposal		When the operating permit for the plant limits the disposal of grit, either pulverized lime or a small ball mill must be used to grind the grit small enough so the grit will pass through with the lime slurry.
Equipment Life	With proper maintenance, 20 years.	

BATCH SLAKERS

Features	***Positive Impact***	***Negative Impact***
Capacity (thru put)	Suitable for batch slaking of 2,000#/batch or less. Requires minimum operator attention and maintenance.	• Limited capacities are available. • Higher cost than continuous slakers. • Generally used with pulverized quicklime. • Grit removal not readily available.
Purity of Ca $(_{OH})_2$	The quality of hydrate is high with fine particles. No grit removal is required.	• Approximately 5% to 10% of total produced slurry is inert grit. • Higher raw material cost for pulverized quicklime in some areas.
Reactivity	Very high with particles of high surface areas.	
Grit Carry Over		100% of grit is carried over with the slurry.
Grit Separation Method		Typically not used. If required, it can be added by the addition of a tank and a vibratory screen separator. In this case, the slaker must be elevated approximately 10' to allow gravity feed.
Preventative Maintenance Monthly	Very little required. Inspection of slaker inside for build-up and cleaning by high pressure water.	
Consumables or Wear Parts	None	
Safety	Safest of all slakers with minimal attention.	

HORIZONTAL BALL MILL SLAKER

Features	*Positive Impact*	*Negative Impact*
Capacity (thru put)	Available with no practical upper limit for capacity.	Not available for capacities less than 1,000# per hour.
Purity of Ca $(OH)_2$		• Final product contains 5% to 10% inert grit. • Generally no temperature control used for process, therefore, slurry particle surfaces are not uniform.
Particle Size of Ca $(OH)_2$ and Water Chemistry	Water with high sulphate or sulphite content can be used for slaking.	Particle size of hydrate is coarse compared to Detention, Paste or Batch slaker.
Reactivity		Medium due to coarser particle size.
Grit Carry Over	No disposal permit required.	100%
Grit Separation Method		Generally none. In some cases, a hydrocyclone is used for separation of coarse grit. In this case, the final particle size of grit carried in the slurry will be finer than other types of slakers.
Preventative Maintenance <u>Yearly</u>	The mill lining wear must be checked once a year and replaced as need.	The lining of the mill is very costly and replacement is very labor and time intensive.
Consumables or Wear Parts		The media and mill lining are the major wear parts. Both materials are very costly.
Safety	Generally, mills are safe. Sudden steam release is minimal.	
Initial Investment		Initial investment for this type of slaker is very high. • Mill cost three to four times of a Detention slaker. • Space requirements five to six times of a Detention slaker. • Foundation cost is extremely expensive.
Power Consumption		Power consumption is very high. For example, a 10-ton per hour Detention slaker uses 25 HP per hour versus a Horizontal Ball Mill of the same capacity, which uses over 100 HP.
Grit Disposal	None required.	
Equipment Life	With proper maintenance and upkeep, 25 – 30 years.	

VERTICAL BALL MILL SLAKERS (VERTIMILL)

Features	*Positive Impact*	*Negative Impact*
Capacity (thru put)	Range from 1,000# per hour and up.	Sizes less than 1,000# per hour not available.
Purity of Ca $(_{OH})_2$		Coarse compared to Detention, Paste or Batch slaker.
Reactivity		Medium due to coarse particles.
Grit Carry Over and Water Chemistry	• Water with sulphate or sulphite content can be used. • No disposal permit required.	100%
Grit Separation Method	A separation tank at discharge of the mill allows some of the coarse, heavier particles to settle. The settled particles are pumped into the bottom of the mill for regrind.	
Preventative Maintenance Yearly	The mill lining wear must be checked once a year and replaced as need.	The double helical screw lining and mill lining are very costly to replace.
Consumables or Wear Parts		The media, mill and lift screw lining are the major wear parts. Media must be drained approximately every six months and screened. Undersized media removed and replaced with new media. Undersized media is removed as a waste product.
Safety	Generally, mills are safe. Caution must be used in operating as in any heavy equipment.	
Initial Investment		Initial investment for this type of slaker is high, but not as high as a Horizontal mill. Mills are tall, therefore, silos and feeders must be raised to accommodate feeding to the mill.
Power Consumption		Power consumption is high compared to Detention slakers. For example, a 10-ton per hour Detention slaker has 25 HP drive versus a Vertimill slaker of the same capacity has about 100 HP drive.
Grit Disposal	None required.	
Equipment Life	With proper maintenance and upkeep, 20 or more years.	

ATTRITOR BALL MILL SLAKERS

Features	*Positive Impact*	*Negative Impact*
Capacity (thru put)	½ ton to 30 tons per hour.	Must be custom designed for over 30-ton per hour units.
Particle Size of Ca $(_{OH})_2$	Fine due to temperature control of ± 2°F.	
Reactivity	High due to fine particle size and high surface area.	
Grit Carry Over and Water Chemistry	• Water with high sulphate or sulphite can be used for slaking. • No disposal permit required for grit disposal.	100%, but fine grit.
Grit Separation Method	A separation tank with two compartments located at the mill discharge will allow the heavier particles to settle to the bottom. From there, it is pumped back to the bottom of the mill for regrind. The lighter particles flow up into the second chamber and exit the tank as final product.	The slurry viscosity determines the size of the particles settled. The thinner the slurry, the finer the finished product particle size.
Preventative Maintenance Yearly	Since the mill typically does not require rubber lining, the body wear is negligible.	The agitation arms which mobilize the media is prone to wear and must be replaced once a year.
Consumables or Wear Parts	No media screening is required. The media is only added, therefore, reducing media waste.	The media and agitation arms are the major wear parts in this mill. Media has to be added in required quantity regularly. The arms based on the material of construction will last between eight months and two years.
Safety	Similar to all other mills.	Due to the small volume inside the mill, some build-up in the area of the mill top could cause operating problems.
Initial Investment	Initial cost is about 70% to 75% of the Vertimill and about 60% of the Horizontal mill and requires less real estate and foundation.	It costs about two to three times the cost of a Detention or Paste slaker.
Power Consumption	Less than 50% of the Horizontal mills.	Uses over 2-1/2 times the power compared to Detention slakers.
Grit Disposal	Not required.	
Equipment Life	With proper maintenance and upkeep, 20 years.	