Lime hydration systems

General reaction equations:
The chemical reactions describing the production of high calcium or dolomitic based lime hydrate are as follows:

**Hydrate From A High Calcium Lime**
\[ \text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{Heat} \]

**Hydrate From A Dolomitic Lime (Atmospheric Pressure)**
\[ \text{CaO} \cdot \text{MgO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 \cdot \text{MgO} + \text{Heat} \]

**Hydrate From A Dolomitic Lime (Under Pressure)**
\[ \text{CaO} \cdot \text{MgO} + 2\text{H}_2\text{O} \rightarrow \text{Pres Ca(OH)}_2 \cdot \text{Mg(OH)}_2 + \text{Heat} \]

The reaction between lime and water to form lime hydrate is exothermic and one in which a considerable amount of heat is released; e.g., when making lime hydrate from a high calcium lime, 497 BTU/lb of CaO is evolved. As a point of comparison, the exothermic heat evolved from the hydrating of 1,000 tons of high calcium lime equals the total heat value of approximately 35 tons of coal.

**Hydration and slaking:**
The chemical reactions describing the production of high calcium or dolomitic based lime hydrate are as follows:

Quite often these two terms are used interchangeably; however, there is a definite and distinct difference:

Hydration: may be defined as a process whereby approximately stoichiometric amounts of water and lime react to form a product, hydrate, which is a dry powder; i.e. it contains less than 1% free moisture and is handled as a powder.

Slaking: may be defined as a process whereby lime is reacted with an excess amount of water to form a lime slurry which is handled as a liquid.

**Properties:**
Lime hydrate – both high calcium and dolomitic hydrate – is normally a white powder consisting of micro-crystalline particles usually agglomerated to larger flakes. Properties which are to be considered for commercial hydrates are:

- Specific surface area
- Flow characteristics
- Plasticity
- Workability
- Yield and settling rate
- Settling volume
- Particle size

Most of these characteristics can be influenced to some degree by operational variations of the hydrating conditions or by further processing of the hydrate by grinding and air separation.

A hydrate BET surface area of approximately 14 to 20 m²/g can be expected. (BET stands for Borkland, Eyde and Teller, the individuals who developed the technique for determining surface area.)
### Table 1
#### Properties of lime components

<table>
<thead>
<tr>
<th>Properties</th>
<th>Quicklime Components</th>
<th>Hydrated Lime Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Name</td>
<td>Calcium Oxide</td>
<td>Calcium Hydroxide</td>
</tr>
<tr>
<td>Chemical Formula</td>
<td>CaO</td>
<td>Ca(OH)₂</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>56.08</td>
<td>74.096</td>
</tr>
<tr>
<td>Melting Point</td>
<td>2570°C (4658°F)</td>
<td>74.096</td>
</tr>
<tr>
<td>Decomposition Point</td>
<td>580°C (1076°F)</td>
<td>345°C (653°F)</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>2850°C (5162°F)</td>
<td>3600°C (6512°F)</td>
</tr>
<tr>
<td>Refractive Index</td>
<td>1.838</td>
<td>1.574 &amp; 1.545</td>
</tr>
<tr>
<td>Crystaline Form</td>
<td>cubic</td>
<td>hexagonal</td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>3.40</td>
<td>2.34</td>
</tr>
</tbody>
</table>

### Table 2
#### Properties of commercial lime components

<table>
<thead>
<tr>
<th>Properties</th>
<th>High Calcium</th>
<th>Dolomitic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Constituents</td>
<td>CaO</td>
<td>CaO &amp; MgO</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>3.2 – 3.4</td>
<td>3.5 – 3.6</td>
</tr>
<tr>
<td>Bulk Density (lb / cu ft)</td>
<td>55 - 75</td>
<td>55 - 75</td>
</tr>
<tr>
<td>Specific Heat @ 100°F, (Btu / lb)</td>
<td>0.19</td>
<td>0.21</td>
</tr>
<tr>
<td>Angle Of Repose *</td>
<td>55°</td>
<td>55°</td>
</tr>
</tbody>
</table>

#### Hydrates

<table>
<thead>
<tr>
<th>Properties</th>
<th>High Calcium</th>
<th>Normal Dolomitic</th>
<th>Pressure Dolomitic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Constituents</td>
<td>Ca(OH)₂</td>
<td>Ca(OH)₂ + MgO</td>
<td>Ca(OH)₂ + Mg(OH)₂</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.3 – 2.4</td>
<td>2.7 – 2.9</td>
<td>2.4 – 2.6</td>
</tr>
<tr>
<td>Bulk Density (lb / cu ft) * *</td>
<td>25 – 35</td>
<td>25 – 35</td>
<td>30 - 40</td>
</tr>
<tr>
<td>Specific Heat @ 100°F, (Btu / lb)</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>Angle Of Repose *</td>
<td>70°</td>
<td>70°</td>
<td>70°</td>
</tr>
</tbody>
</table>

* The angle of repose for both types of lime (hydrate in particular) varies considerably with mesh, moisture content, degree of aeration, and physical characteristics of the lime. (e.g. for quicklime it generally varies from 50° to 55° and for hydrated lime it may range as much as 15° to 80°.)

** In some instances these values may be extended. The Scott method is used for determining the bulk density values. In calculating bin volumes the lower figure should be used.
Metso lime hydration systems:
Metso markets both a non-pressure hydrator and pressure hydrator. The non-pressure hydrator was developed by KVS and the pressure hydrator was obtained from the Corson Company.

Metso Non-Pressure Hydrator
The Metso non pressure lime hydration system consists of a constant weight feeder, duplex mixer, seasoning chamber, vent duct, baghouse and the necessary control instrumentation. Quicklime feed to the duplex mixer is controlled by the constant weight feeder. Manual changes of the feed rate are made by varying the speed of the weigh feeder belt.

The crushed and weighed quicklime from the constant weight feeder enters the duplex mixer where water is mixed with the dry feed in the required proportions to achieve complete hydration. Addition of the water should be adjusted so that the chemical reaction in the material has started when the mixture of lime and water is ready to drop into the seasoning chamber and only a minimum of steam is developed in the duplex mixer itself. Therefore, hard burned limes with low reactivity will require longer retention time in the duplex mixer, and high activity lime require less retention time.

To control the amount of water required for the chemical reaction the fresh water flow is metered. The paste or slurry of quicklime and water enters the seasoning chamber where it is retained for the proper length of time to complete the hydration reaction. The seasoning chamber is a horizontal cylindrical vessel with a slowly revolving shaft and paddles to mix the mass of hydrate and advance it slowly towards the discharge end. Retention time in the seasoning chamber can be adjusted, to some extent, by a variable height overflow weir. The average retention time depends on the type of lime used, its reactivity, fineness, temperature, porosity, chemical analysis, etc.

Most quicklimes contain some hard burned particles or impurities which do not hydrate, or hydrate too slowly for the retention time provided. These heavy particles of grit sink to the bottom of the agitated mass and cannot overflow until they are either hydrated or finally removed periodically through a cleanout opening. Hydrated lime which overflows from the seasoning chamber into the discharge point is generally a finely divided powder, and water addition to the duplex mixer should be controlled so that both the moisture content and the temperature of the product are constant. High discharge temperature indicates a water deficiency; usually bone dry material contains unhydrated oxide. Low discharge temperatures indicate an excess of water with more than 1.5% free H₂O.

The normal operating temperature range for high calcium hydrate is 190o to 210 oF; this corresponds to approximately 0.5% free H₂O in the hydrate. It is advisable to operate with a small percentage of free water in the hydrate to assure complete hydration of any residual oxide. The end plate of the seasoning chamber has a quick opening discharge door to remove grit at regular intervals. Depending on the amount of unreactive material in the quick-lime feed, this cleaning should be done often enough to avoid accumulation; normally, it will be required once a week.

A typical Metso lime hydrator includes the following equipment:

Weigh Feeder – This is a continuous belt type unit and includes the belt, weighing mechanism, support frame, variable speed drive.

Duplex Mixer – This is the first system chamber into which the lime and water are introduced. The unit is of all-steel fabrication and equipped with a paddle arrangement to turn over the lime to facilitate the reaction. The unit is driven by a variable speed drive.

Seasoning Chamber – This is the second system chamber, into which the lime – water mixture discharges from the duplex mixer. The unit is of all-steel fabrication and equipped with a paddle arrangement to turn over and mix the lime and water in order to complete the reaction.

Dust Collector – A bag type dust collector with exhaust fan is used to handle the steam and dust which is evolved. The collected hydrate dust drops into the seasoning chamber, reentering the process stream. An electric preheat system provides supplemental hot air which is
introduced into the seasoning chamber vent hood is needed to prevent condensate from forming on the bags of the dust collector.

Water Metering System – This is an automated system whereby the supply of water is regulated. The control system checks thermocouples at the output of the duplex mixer and the seasoning chamber and makes adjustments to the water flow as required. For example, the temperature of the hydrate leaving the seasoning chamber should be in the range of 190°F to 210°F. If the temperature drops below 190°F, the water rate is reduced and if the temperature exceeds 210°F, the water rate is increased.

The control system will make incremental adjustments in the water flow rate as required.

### Sizes of non-pressure lime hydrators

<table>
<thead>
<tr>
<th>Hydrator Size</th>
<th>Nominal Feed Rate STPH Of Quicklime</th>
<th>Nominal Production STPH Of Hydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5 x 12</td>
<td>6.6</td>
<td>8.5</td>
</tr>
<tr>
<td>6.0 x 12</td>
<td>11.3</td>
<td>15</td>
</tr>
<tr>
<td>8.0 x 14</td>
<td>18.9</td>
<td>25</td>
</tr>
<tr>
<td>9.0 x 14</td>
<td>30.2</td>
<td>40</td>
</tr>
</tbody>
</table>

### Metso pressure hydrator

The Metso/Corson pressure hydration system is a commercially available, continuous unit to convert dolomitic quicklime to the fully hydrated compound of Ca(OH)$_2$, Mg(OH)$_2$. In this process, quicklime and water are fed continuously into a sealed vessel where the exothermic reaction of quicklime and water raises the system temperature and steam is formed. Only under these conditions of pressure, temperature and continuous mixing of the reacting mass is it possible to completely hydrate the magnesium oxide portion of dolomitic quicklime.

The application of pressure hydration is not limited to dolomitic quicklime; high calcium quicklimes can also be processed in the Metso/Corson Pressure Hydration System. Depending on the quicklime properties a fully hydrated Ca(OH)$_2$ of extremely fine particles size and high surface area results. Such hydrates have high chemical reactivity. Although the reaction mechanism of the hydration reactions is not thoroughly understood.

Sizes of Metso non-pressure lime hydrators

Metso lime hydrators are designed on the basis of processing a high calcium quicklime possessing an activity as defined in ASTM C-110: “A high reactive calcium lime will show a temperature rise of 40°C in three minutes or less and the reaction will be complete within 10 minutes. A medium reactive high calcium lime will show a temperature rise of 40°C in 3 to 6 minutes and the reaction will be complete in 10 to 20 minutes. A low reactive high calcium lime will require more than 6 minutes to show a temperature rise of 40°C and will require more than 20 minutes for the reaction to be completed.”
Hydrate From The Calcium Portion
\[ \text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{Heat} \]

Hydrate From The Magnesium Portion
\[ \text{MgO} + \text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 + \text{Heat} \]

Hydrate From Total Reaction Dolomitic Lime (Under Pressure)
\[ \text{CaO} \cdot \text{MgO} + 2\text{H}_2\text{O} \rightarrow \text{Pres} \ \text{Ca(OH)}_2 \cdot \text{Mg(OH)}_2 + \text{Heat} \]

(see above equations), it is generally preferred to conduct atmospheric, non pressure, hydration with liquid water rather than steam to obtain hydrates with commercially desirable properties of particle size / shape, bulk density, flow characteristics, plasticity and others. Dolomitic quicklimes processed in atmospheric hydration systems result in hydrates with appreciable amounts of unhydrated oxides, but when a fully hydrated product is required (without significant amounts of free, unreacted oxide) a pressure hydration system must be used. The pressure hydration system produces a submicron particle size hydrate with well defined commercially important chemical and physical properties. ASTM Type “S” (ASTM C207) hydrate can only be made in pressure type hydration systems.

Process advantages
Commerciably available process for producing dolomitic hydrated lime.

The design of the process with continuous discharge of hydrate through a small orifice assures submicron particle size and dry hydrate.

Both dolomitic and high calcium quicklime can be hydrated.

Process description:
Crushed quicklime is fed from a storage bin through a rotary feeder onto a continuous weigh feeder; the weighed quicklime is mixed with a metered amount of hydration water in a special premixer and the resulting thick slurry is forced by a special designed pump into the pressure hydration vessel.

In the pressure hydrator the quicklime is exposed to water and steam for a period from 10 to 30 minutes, depending upon the quality of the quicklime feed. The steam pressure generated within the hydration vessel is caused by the exothermic reaction of the quicklime with the water. The discharge orifice of the pressure hydration vessel releases the damp hydrated lime mass into a collector.

In a typical installation, steam pressure may reach 100 PSI (7.03 kg/cm² or 689 kPa) with a corresponding saturated steam temperature of 170°C (338°F). When this energy is released at the orifice, instantaneous flash drying and explosion of the particles occur. At this point the average resultant particle size is approximately 0.4 microns.

In the hydrate collector, lime particles drop out of the gas stream while steam is drawn upward to a bag type dust collector which removes any residual fine lime particles. The hydrate discharged from the dust collector is reintroduced into the product stream.

The process after the collector is dependent upon the usage of the final product:
For most uses the hydrated lime from the collector is fed directly to an air separator. Fines from the air separator are finished product while the tailings may be processed through a mill and then sent on to the finished product storage.

For those areas where construction practices require a greater plasticity, the entire output from the collector is fed to a ball mill, then air separated, with the tailings being recycled to the
ball mill. In this closed circuit processing a typical increase in plasticity for dolomitic lime is 100 to 125 units as measured on the Emley plasticity machine.

For agricultural or stabilization uses, where plasticity is not of importance, air separation and milling can be excluded.

**Basic system features**
Production rate: 10 to 15 TPH of hydrate, depending on quicklime feed quality.

Operator labor: One man per shift for the hydration system. Milling, bagging, and handling may require additional manpower.

Power requirement: Approximately 75 HP connected; actual consumption of KWh/T depends on quicklime quality, dust collection requirements, auxiliary equipment, etc.

Quicklime feed characteristics: Almost all quicklimes with more than 85% free oxide content can be handled. Laboratory evaluation by Metso is required.

Hydration water: Potable or industrial quality supply is sufficient; however, water analysis must be reviewed by Metso.

**Concept of the complete hydrate plant**
The lime hydrating equipment is only a portion of the total equipment required to produce and to process lime hydrate. Metso can design and supply not only the basic lime hydrating equipment, but also the complete hydrate plant which normally contains the following equipment.

1. Quicklime storage bin.
2. Hammermill to crush the quicklime to a nominal 1/4" size
3. Lime hydrating equipment
4. Ball mill, separator-classifier, or similar equipment to further process the hydrate.
5. Storage bins for the lime hydrate
6. Bulk load-out facilities
7. Bagging equipment
8. Dust collecting equipment
9. Structural supports and enclosures