CHENEY LIME & CEMENT COMPANY

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FAQS - Frequently Asked Questions - 51

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differ? (ASTM C25 and AWWA B202 standard tests)

3. **Why is sugar added when running the standard titration for the percent of available lime (CaO%)? (ASTM C25 and AWWA B202 standard tests)**

4. **When I take a sample of quicklime from a truck or railcar for testing for the percent of available lime (CaO%), do I need to seal the container?**

5. **What are the CAS Numbers for quicklime and hydrated lime, and what does CAS mean?**

6. **What is meant by quicklime that has been *"drowned"*?**

7. **What are the STCC, CAS and EPA reference numbers for quicklime (Calcium Oxide-CaO) and hydrated lime Calcium Hydroxide-$Ca(OH)_2$)?**

8. **I have completed the available lime test for CaO% and am concerned about a low test percentage. How can I tell if my quicklime sample has undergone air slaking?**

9. **What is the correlation between the *Available CaO%* in Quicklime, CaO and the *CaO% Equivalent* in Hydrated Lime, $Ca(OH)_2$?**

10. **As I understand it, hydrated lime is only slightly soluble in water and the solubility is inversely proportional with temperature. What is the actual solubility of hydrated lime in water with temperature? Also, how is the solubility of quicklime determined since quicklime reacts with water to form hydrated lime and is not in its original form in a water solution?**

11. **Since magnesium carbonate is chemically very similar to calcium carbonate why doesn't magnesium oxide and magnesium hydroxide have the exact same chemical properties as calcium oxide (Quicklime) and calcium hydroxide (Hydrated Lime)?**

12. **What is the ASTM Standard C-977 and does the lime produced by Cheney Lime & Cement Company meet this specification?**

13. **Lime companies refer to a "Typical Chemical Analysis". What does this mean and why is it not referred to as a specific chemical analysis like the reagent grade chemicals I buy?**

14. **With regard to the NAFTA Certificate of Origin, what does the *HS Tariff Classification Number* mean and what are the HS Tariff Classification Numbers for quicklime and and hydrated lime? Also, what does the *Preference Criterion* mean?**

15. **What is the difference between the temperature scales of Celsius/Centigrade (^oC), Fahrenheit (^oF) and Kelvin (^oK) and how do I convert between the these?**

16. **When in contact with metal equipment does lime have any affect on iron or steel? Also, is there any affect on aluminum, lead, tin, brass or zinc?**

17. **I understand that limestone (calcium carbonate and/or magnesium carbonate can be used to neutralize a strong acid. Why can't I simply use limestone to raise the pH above 7.0 (neutral)?**

SIZE:

1. **We are going to build a plant that will use quicklime and need to know which is the best quicklime size to use in the design of our plant.**

2. **When I buy quicklime from different suppliers I sometimes have to adjust my system, even though the size of the quicklime is the same. Why are there variations in quicklime from different suppliers?**

SILOS:

1. **With regard to deliveries by truck or rail car, how large of a silo should we plan for in the design of our plant?**

2. **I am in the final planning stages for our lime silo and want to make sure that I have covered all key points. Is there something I need to be sure to check before ordering the silo?**

3. **I need to remove some lime that is currently in my silo. Does anyone do this and what are the type of charges that I can expect?**

4. How can I do a quick calculation of the cubic feet capacity of a silo? Also, how much quicklime, or hydrated lime, can go in the silo?

SLAKERS & MIXERS:

1. What is a "slaker" and why can I not simply mix quicklime in a simple mixing tank?
2. Why does hydrated lime settle when the agitation stops? Why doesn't it all go into solution?
3. I have a slaker, or other type of lime handling equipment, that requires a part that is no longer available or manufactured. Is there a company who can make this part for me if I have the drawings/specifications, or if all I have is the broken part(s)?
4. What is a *Lime Slurry* and are there other physical forms of hydrated lime and water? Also, is there a formula that can be used in calculating the amount of lime and water to produce a certain percent slurry?

TRANSPORTATION:

1. When I receive a shipment of lime, by truck or rail, how long do I have to unload it? Is there a penalty if I exceed the time allowed, and what is meant my the term *Demurrage* ?
2. When I called to place an order for lime by truck I was told there was a *shortage* of trucks. All of the lime companies I talked with also confirmed this. Why does this happen? Also, how do the trucking companies maintain enough trucks to serve the lime market and what can I do to help avoid these truck shortage situations?
3. I am considering comparing getting my lime by rail vs. truck. What are some of the pros and cons regarding these two modes of lime delivery?
4. I am considering using a *Pressure Differential* railcar (*PD Car*) for lime delivery by rail. What kind of railcar is this and is there any reason why I would not want to use this type of car?
5. I am planning to starting ordering truckloads of bagged hydrated lime. Should I have the lime delivered by a flatbed or van type of truck?
6. When I order truck shipments of lime my lime supplier sets up the trucking. Should I consider having my company handle the transportation arrangements or should I continue to have my lime supplier handle this?
7. What is the difference between *Short Miles* and *Practical Miles* in determining freight rates and why can there be differences between the two mileages when going to the same location?

USING THE WEBSITE:

1. When I try to view a PDF file in my browser it does not appear. All I get is a small icon on a blank page. Why does this happen and how do I correct it?
2. Why are all the Questions and Answers on the FAQS (Frequently Asked Questions) web page displayed on single page, rather than on multiple pages of the website?

PRODUCT:

1. There are limestone deposits all around my location. Why isn't there any high calcium lime available locally?

The term *limestone* can refer to both *dolomitic limestone* or *high calcium limestone*. Most limestone deposits are dolomitic limestone, which is a mixture of calcium carbonate and magnesium carbonate in a general ratio of 40-60%. High calcium limestone is generally considered to be in excess of 90% calcium carbonate. Nature does create predominantly limestone deposits composed of predominantly calcium carbonate, however, these locations are considerably fewer than those of dolomitic limestone. Although both carbonates undergo the conversion to oxide in the kiln (CaO and MgO) there is an important, fundamental difference in their reactivity with water. Calcium oxide will react readily with water at normal temperatures to produce calcium hydroxide and an excess of heat (exothermic) whereas magnesium oxide requires special conditions to convert to magnesium hydroxide. Any magnesium oxide will remain unreacted in water, resulting in additional grit. If kilns were set up to process dolomitic limestone into "quicklime", approximately 40% of the product (the MgO portion) will not react with water significantly, resulting in

about 40% grit.

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2. **What is "Hot Lime"?**

This is quicklime, which is chemically known as calcium oxide. Because quicklime generates a lot of heat (exothermic) when reacting with water to form hydrated lime (calcium hydroxide) it has been commonly known as "hot lime". Hydrated lime will not generate heat when mixed with water since it has already been converted to the hydrated form.

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3. **Why does the tint (color) of quicklime vary?**

This is because of the different fuels used to heat the limestone (calcium carbonate) to convert it to quicklime (calcium oxide). Many suppliers use pulverized coal and a mixture of pet coke which can result in a slight grayish color to the quicklime due to the exposure to the fuel. You'll notice that a pebble of quicklime, when split, will appear white inside since this area has not been exposed to the burning fuel directly. Generally, The tint of the quicklime has no significant bearing upon the reaction of the quicklime with water. This is because the amount of material associated with the color is insignificant. The exception would be if the quicklime were "overburned", which could decrease the reactivity.

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4. **What does the term "Overburned Quicklime" mean?**

This term refers to quicklime that has been subjected to excessive heat. The term really means "over heated quicklime". The term "burning" generally refers to oxidation, which is the process of a material chemically reacting with oxygen (combustion, rusting, etc). In the kiln, the limestone is simply subjected to a high temperature (ranging from 1850 to 2450º F for high calcium limestone) which results in the dissociation of the limestone into calcium oxide and carbon dioxide. For the most part, the limestone going into the kiln is in pebble form. Since the pebbles are the result of the crushing of the limestone rock, they are irregular to a degree and vary in sizes. In heating the limestone pebbles a compromise has to be reached between heating the larger pebbles enough to convert them entirely, and not overheating the smaller pebbles. Limestone is a porous rock, so the carbon dioxide gas escapes through the pores of the rock. If the pebble is subjected to too much heat, the surface can tend to shrink, which results in a delay in the conversion from calcium carbonate to calcium oxide. Overburned quicklime tends to react at a slower rate than ideally burned quicklime.

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5. **Which type of lime should I use, Quicklime or Hydrated Lime?**

This is generally determined by the volume (tonnage) of lime used. A good way to think of quicklime is that it is hydrated lime without the water. It's important to understand that when water is added to quicklime it chemically combines with it to form two products: calcium oxide (quicklime) and carbon dioxide. The weight ratio is that 100 tons of pure calcium carbonate would ideally produce 56 tons of calcium oxide (quicklime). To produce a dry hydrated lime you would then add 18 tons of water to the 56 tons of quicklime to produce 74 tons of hydrated lime. When companies buy quicklime they are using a fairly large volume of lime, so they form their own hydrated lime by reacting it with water at their plant. If the usage is relatively small they will buy the hydrated lime, which is quicklime already reacted. For calculation purposes you can consider a truck of quicklime equals 1.32 trucks of hydrated lime. Another important consideration is that, generally, using quicklime requires that you use a slaker, whereas you can use a simple mixing tank with agitators to use hydrated lime. The cost of a lime slaker is generally higher than that of a lime mixer.

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6. **Why would I not want to simply buy lime slurry, rather than buying quicklime or dry hydrated lime (in bulk or bags) to make my own slurry?**

For some purposes using a lime slurry is fine. However, there are a number of considerations to be aware of. First, consider that it takes 1.32 trucks of hydrated lime to equal a truck of quicklime (weight ratios). If the slurry were 20% solids, it would take 5.0 trucks of slurry to equal one truck of dry hydrated lime, or 6.6 trucks of slurry to equal one

truck of quicklime. In addition, you will have to factor in the freight cost for hauling a truck with 80% water in it. Quicklime and dry hydrated lime arrive in pneumatic trucks, and the lime is pumped into silos. Slurry comes in a slurry truck, which is then pumped into an on site portable slurry tank, or slurry tank in the plant. The slurry has to be constantly agitated to avoid the settling of the lime. Another consideration involves the availability of slurry. All of the major lime companies produce quicklime and most produce dry hydrated lime. Only a few are involved with lime slurry, which limits the sources available. All of these things have to be taken into account in considering slurry rather than quicklime or dry hydrated lime.

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7. Lime is used to neutralize acids, which raises the pH. How does this take place?

Most quicklime is converted to hydrated lime before using. Hydrated lime is chemically known as "calcium hydroxide" and is a strong base. The reaction of an acid and a base produces a "salt" and water, so a base "neutralizes" an acid. Simple examples of this are the reactions of hydrochloric acid (HCl) with sodium hydroxide (NaOH) and with calcium hydroxide ($Ca(OH)_2$):

Typical Acid-Base Reactions

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

$$2HCl + Ca(OH)_2 \longrightarrow CaCl_2 + 2H_2O$$

The products of this reaction are water (H_20) plus the salts: sodium chloride NaCl) or calcium chloride ($CaCl_2$). To those less familiar with chemistry, the term "salt" is generally thought of as NaCl (table salt), however, a "salt" should be thought of as the product of an acid-base reaction. When an acid is in a water solution it dissociates into a cation (H^+) and an anion (Cl^-). The term pH refers to the concentration of hydrogen ions (H^+). As these ions are combined with the (OH^-) from the base, the number of hydrogen ions (H^+) decrease which results in the neutralization of the acid. The pH of a solution can range from 0 to 14. A pH of 7.0 is considered to be completely neutral (deionized water). So a solution that is acidic has a pH of less than 7.0 and a solution that is basic has a pH above 7.0. Lime is a strong base and an excess of lime can quickly produce a pH above 12. It can also be seen, as shown in the reactions above, that a molecule of calcium hydroxide ($Ca(OH)_2$) will react with twice (2x) as many molecules of hydrochloric acid (HCl) than sodium hydroxide (NaOH) does.

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8. I keep hearing the term *Pebble Quicklime* and sometimes see the letters *QL* and *PBQL*. Why is this terminology used and what does it mean?

Commercial quicklime is commonly produced in rotary kilns where pebbles of high calcium limestone are transported through the kiln and converted into quicklime (calcium oxide). Initially, the limestone is quarried into boulders, which are then broken down further and taken to a crusher. After the crushing process, and a further sizing process, the pebbles go into the kiln. When they exit the kiln they may be crushed further and sized, but in any case, the *pebbles* of quicklime are produced in generally two size ranges that have the trade names of *Rice* and *Medium* size quicklime. Pebbles that are too large go back to the crusher while quicklime that is too small to be sold as *Rice* size quicklime is either sold as *Granular* size quicklime or is used to make hydrated lime in a plant that is usually found adjacent to the kiln operation. (The general designation *QL* is commonly used for quicklime as the designation of *HY* for hydrated lime. The designation of *PBQL* is often used for pebble quicklime as opposed to *Granular* or *Pulverized* sized quicklime.)

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9. How much less lime will I use if I use quicklime rather than bulk hydrated lime, and at what point is this practical?

This is easy to determine. When hydrated lime is produced from quicklime it is a "complete" reaction in that all of the water chemically combines with the quicklime:

$$CaO + H_20 \longrightarrow Ca(OH)_2 + Heat$$

The molecular weight of quicklime, CaO is 56 and that of hydrated lime, $Ca(OH)_2$ is 74.
(Calcium, Ca=40, Oxygen, O=16 and Hydrogen, H=1)

The best way to think of "molecular weight" is a "weight ratio". Once quicklime is added to water it converts to hydrated lime so you are essentially comparing the same product in different forms. In the simplest form 56 lbs of quicklime is equivalent to 74 lbs of hydrated lime. Another way to view this is to take your current hydrated lime usage (tons) and multiply it by 0.757 to come up with the approximate usage of quicklime equivalent to your hydrated lime usage. This factor comes from dividing the molecular weight of quicklime (56) by that of hydrated lime (74), which equals 0.757, or 75.7%.

Whether or not it is practical to switch from using bulk hydrated lime to using quicklime generally depends upon the amount of lime you're using and your willingness to purchase a slaker. (Slakers insure that you have complete, intimate mixing/reacting of water with the quicklime, which is very important since the reaction is exothermic and produces steam). If you're currently using bulk hydrated lime you already have a storage silo so purchasing a silo won't be an issue unless you want to increase your storage capacity. If you're producing a lime slurry it's likely that you'll require a slaker rather than the current mixer you've been using. As a general rule bulk hydrate seems to be used for requirements of up to 1-2 trucks a month (300 to 600 tons/year, a truck holds approximately 25 tons). Some customers will use quicklime if they're using only 100-200 tons/year, but generally quicklime is not considered until somewhere in the 300-600 tons/year range. In any case, the costs vs. savings factors need to be carefully evaluated prior to making the decision to switch from bulk hydrated lime to quicklime, and each customer's requirements will be different.

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10. I need to use hydrated lime but am not sure whether I should get it in bags or in bulk. What are some of the advantages and disadvantages of bags vs. bulk?

This primarily depends upon how much hydrated lime you intend to use, and whether or not it will be used in multiple locations. Both bagged and bulk hydrated lime serve a purpose, so it's important that you have a clear idea of your long-term plans with lime.

BAGGED: If your are a distributor of hydrated lime you will almost always require only bagged hydrated lime. If you are a lime user, and require a sizeable amount of lime, but have to transport it to multiple locations (such as individual well sites, etc.) your only option is probably hydrated lime in bags. Generally, customers who are currently using bagged hydrated lime in their process do not require a lot of lime. In some cases bagged hydrated lime has an advantage because each bag is 50 lbs which allows it to be used in batch preparations where a certain number of bags of hydrated lime are added to the mix/batch. *Advantages:* You only require storage space and a mixing tank to prepare the slurry. *Disadvantages:* the price (bagged hydrated lime is more expensive), the unloading (pallets of lime have to be removed from the truck by a forklift) and the handling (each bag has to be handled by a worker).

BULK: Bulk hydrated lime is usually used by customers who have a higher usage requirement. Your longterm projected usage of hydrated lime needs to be taken into account in considering bulk hydrated lime. If the usage is expected to increase, it may pay to invest in the capital equipment to use bulk hydrated lime right at the start. Some customers, who are in the process of implementing a new lime slurry operation, will start with bagged hydrated lime, then switch to bulk once the operation gets going. *Advantages:* the price (bulk hydrated lime costs less than bagged hydrated lime), the unloading (the lime is delivered via a pneumatic tank truck which blows the product into the silo, so the customer has no labor in unloading), and the handling (the lime is automatically handled from the silo to the slurry preparation). *Disadvantages:* Initial capital investment (you will require a lime silo, feeder and metering equipment to control the feed of the hydrated lime to the mixing tank).

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11. What is the difference between *Limestone* and *Lime*? Also, I hear the terms *Aglime* and *Dolomitic Lime* used a lot. How do they differ from limestone and lime?

This question comes up quite frequently and is caused by a popular use of the term *LIME* interchangeably for "limestone" and "lime" especially in the agricultural market. From a practical standpoint it's likely that this will continue in the future, so it's very important to know when a person says they use "lime", whether they mean "limestone", which is rock, or do they really mean "lime", which is a chemical in the form of the oxide or hydroxide. (From a chemistry standpoint, lime is a *chemical base*.)

Limestone: Although limestone is often referred to as "lime" it is actually a "stone or rock", either naturally occurring in mineral deposits or, when physically processed, in various size pebbles, crushed, ground or pulverized. The term limestone generally refers to calcium carbonate, $CaCO_3$ and magnesium carbonate, $MgCO_3$, which are usually found together, to some degree, in various proportions. The term Dolomitic Limestone general refers to

limestone deposits with a much higher percentage of $MgCO_3$ than is found in high calcium limestone deposits. (Cheney Lime & Cement Company produces quicklime, CaO from the calcination of deposits of high calcium limestone in Shelby County, AL. This quality of limestone is required to produce the high calcium quicklime and high calcium hydrated lime products we supply.)

Lime: In the correct use of the term, lime is actually a "chemical" which is in the form of calcium oxide, CaO (quicklime) and/or magnesium oxide, MgO which is produced from the high temperature process of calcination which takes place in a lime kiln. Lime also refers to calcium hydroxide, $Ca(OH)_2$ and magnesium hydroxide, $Mg(OH)_2$ which are the hydroxides produced from the reaction of the oxide and water. In the case of calcium oxide, CaO the reaction occurs readily and is highly exothermic. Both $Ca(OH)_2$ and $Mg(OH)_2$ are chemical bases.

Aglime: Generally, Aglime (sometimes referred to as Agstone) is a dolomitic or high calcium limestone that is finely ground to enable it to neutralize soils that are acidic. Although limestone is considered relatively inert, it can be attacked by a strong acid, or a weak acid over time, and will neutralize the acid. If the acidity is quite high, then either quicklime or hydrated lime is usually used.

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12. What is the difference between *Hydrated Lime* and *Hydraulic Lime?*

***Hydraulic Lime* and *Hydrated Lime* have basically the same chemical composition, however, hydraulic lime has its initial setting with water (similar to cement) and a second setting with recarbonation (the absorption of CO_2). Hydrated lime does not set with water and only undergoes recarbonation. Cheney Lime & Cement Company produces a type N hydrated lime, which is used chiefly for its chemical characteristics. Hydrated lime that is used for construction purposes (stucco, etc.) represents only modest quantities compared to the chemical uses.**

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PRICES:

1. Why does the price of quicklime increase when I know that there are still enormous deposits of high calcium limestone available to be produced into quicklime?

It's true that there are huge supplies of high calcium limestone in the quarries that lime producers own. The supply of limestone, however, is not the primary determining factor in what the market price of lime will be. To understand this, keep in mind that all of the quicklime that is in the lime market (hydrated lime is produced from quicklime) came from high calcium limestone that had to go through kilns to be converted to quicklime. A new kiln is a major undertaking for a lime company, both financially and with regard to state and federal regulations. As a result, lime companies try to anticipate the lime market to make certain the new kiln will either meet existing demands, or those anticipated in the reasonably foreseeable future. If the lime market is "soft", and future prospects for the economy uncertain, it's unlikely that a new kiln will be brought online until things have improved. Eventually, the demand will grow to meet the existing lime production capacity, yet a new lime kiln may still not be brought online. In fact, during periods when lime demand is very slow, existing kilns may be idled to bring production more in line with existing demand. In any case, the critical path is that the number of "kilns in operation" determines the market; not the supplies of high calcium limestone.

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2. How does the availability and quality of high calcium limestone deposits affect the price of quicklime?

Although the number of kilns in operation is a major determining factor in lime price, the limestone deposits and quarrying operations play a very significant part, principally due to their effect on bottom line production costs. If the limestone in the quarry is found in a deposit of consistent quality, and is relatively easy to reach, the quarry costs are lower. If the quality of the deposit is inconsistent, there is an increase in the amount of selective quarrying that has to be performed. Also, if the limestone deposit has to be mined underground, as opposed to an open quarry, the costs increase. As the limestone that is located closest to the kilns is depleted, limestone has be to be brought in from further distances, which results in an increase in transportation costs. All of the factors in limestone deposits and quarrying have a direct impact on the bottom line cost to produce quicklime. This has a significant effect on the quicklime price the lime producer can offer to the market and still expect to realize a reasonable profit.

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3. **Will forming a buying cooperative, or buying from an existing one, always guarantee that I'm paying the lowest price for lime?**

Forming a cooperative does clearly offer some advantages. (1) Having a single cooperative member's purchasing department handle all of the bids for all of the members provides a savings in both time and personnel. (2) Buying as a cooperative group does increase the total volume of lime used, increasing the purchasing power of the members and can result in a reduction in the lime price. (3) Also, buying within the cooperative enables the smaller members to increase their market share and purchasing power. However, there are a number of reasons why cooperatively buying may not provide the best price despite the higher total market share.

1. ***The assumption is that increasing the market share will always provide the best price.* This works to a point, however, when a cooperative begins to get too large the number of lime suppliers able to supply the high volume decreases, thus competition is actually reduced. Eventually, a cooperative can reach a point where only one lime supplier can supply them, which leaves them in a somewhat vulnerable position.**

2. ***All price increase projections for the year have to be given to all of the members at the same time.* When cooperative members (especially municipalities) are bidding individually throughout the year a lime supplier has the opportunity to "sharpen their pencil" on the next bid, if they lose the current bid. When bidding on a cooperative, the approach is "all or none", consequently, a lime supplier has to factor in any potential price increases and lock them in for a year.**

3. ***Large cooperatives tend to discourage the introduction of new lime competitors because all of the business is "locked up".* If a potential lime supplier does enter the market and is able to win the cooperative bid, they have no assurance that they will have the bid the next year, even if there are optional extensions to the contract.**

Generally, moderately sized market share cooperatives appear to successfully gain pricing advantages and do not seriously deter competition. Extremely large cooperatives, on the other hand, appear to offset the cooperative advantages by deterring competition and the introduction of new lime competitors.

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4. **We are trying to determine if it would be better for us to go with a multiple year contract for our lime requirements, rather than a single year. What are the advantages and disadvantages?**

Many industries and municipalities have an annual contract for lime. One of the advantages of this type of contract is that it forces a lime user's purchasing department to review the current market for lime in a one year cycle. Another important advantage is that it keeps all of the lime companies interested since they have an opportunity each year to go after the business.

***Contract Extensions*: Municipalities, and some industries, will provide for annual extensions, sometimes up to three years, if both parties are in agreement. The general assumption is that holding the price for another year is always good for the organization. This is not always the case. In some instances, a lime company has recently lost a contract and needs to replace that lost tonnage. In those cases they may bid more competitively to replace the lost business. Also, the prices in the lime market do follow cyclical patterns as a result of changes in the economy, as well as the introduction of new kilns. Those industries and municipalities, who have nearly automatic contract extensions, often miss out when the market price does decline.**

***Multiple Year Contracts*: When considering the duration of a lime contract it's often appealing to try to lock in a price for two or three years, with limited escalations in price being allowed on an annual basis. In addition to the price advantages, the purchasing department reduces the number of RFQs (request for quotes) that it has to be involved with. The lime user feels that they've locked in a supply of lime at a predictable price, however, what often happens is that the lime users, with the three year contract, are "out of the loop", with regard to market changes. Since they tend to become identified with a particular lime supplier they may find themselves removed from the "active prospects" list of other lime companies, which indirectly tends to reduce competition. Some companies, who have two and three year contracts, may also find themselves in a difficult situation in a tight lime market since a lime company is less interested in helping out a lime user who offers little or no opportunity for future business.**

***Recommendation*: Whenever possible, an annual (twelve month) time frame will often provide the best contract period**

for many businesses. The lime user will be monitoring the market for lime, at least on an annual basis, and the current lime supplier will always have to "be on their toes" with regard to price, service and the lime market. Most successful lime users want to make certain they're paying a fair price for their lime to insure that they have good, dependable suppliers. If an option for multiple years is needed it's generally best to have annual extensions, subject to approval by both parties. This allows the lime user to avoid multiple years of a high priced lime in a declining market, and allows the lime supplier to limit their exposure to a low price in a rising market. The downside to an annual contract is that it does require that the purchasing department monitor the price of lime more frequently.

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CHEMICAL & TESTING:

1. Lime companies refer to a "Typical Chemical Analysis". What does this mean and why is it not referred to as a specific chemical analysis like the reagent grade chemicals I buy?

All industrial lime is produced from quarried limestone (or in some cases oyster shells), which has naturally occurring impurities in it. Many companies wash the stone before in goes into the kiln, however, any impurities in the limestone itself will appear in the quicklime. Much of the control of the quality of the quicklime can be affected by how well the material is quarried. The vein of limestone being quarried is constantly monitored to insure that only the highest purity is selected for the kiln. The quicklime produced is chemically analyzed, based upon standard statistical sampling procedures, but the chemical analysis will vary to a degree according to the way nature left the limestone deposit. This is why most companies refer to a "typical chemical analysis." There are minimum and maximum chemical limits to the various components of the lime, but within these limitations the chemical analysis will always vary to some degree. (Note: Lime can be produced from oyster shells, which have a very high purity of calcium carbonate, however, this source of kiln material is declining, having been almost completely replaced by quarried limestone.)

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2. What are the standard tests used to determine the percent of available lime (CaO%) of quicklime and how do they differ? (ASTM C25 and AWWA B202)

The two most widely used standard tests for available lime, used in both the private and public sectors, are the ASTM C25 (American Society for Testing and Materials standard) and AWWA B202 (American Water Works Association) tests. Both of these tests use the *Rapid Sugar Method* with the only significant difference between them being the normality of the acid solution and the sample weight. Both tests require a specified sample weight and specified acid normality such that 1 ml of the volume of acid used equals 1% CaO. This makes it convenient for lab personnel since they can simply read the number of milliliters (ml) of acid used from the burette, which is then equal to the available lime percentage (CaO%). (Lime users and producers may modify the test slightly with regard to the sample size and acid normalities. In those cases the available lime percentage is determined by simple calculations. See *Modified Procedures* shown below.)

***Acid Normality and Sample Size:* In the case of the ASTM C25 test, a 1.000 N HCl is used, which results in a requirement of exactly 2.804 grams of the sample of calcium oxide (CaO). In the case of the AWWA B202 test, 0.1782 N HCl acid is required and the sample must be exactly 0.500 grams. (The acid solution for the AWWA B202 test is usually prepared by the lab personnel since a commercial, standard solution at 0.1782 N is not readily available.) Care must always be taken in preparing any standard solution to insure that it is as accurate as possible since an incorrect acid normality will result in inaccurate CaO% determinations. Both the purchased and prepared standard solutions should be periodically checked to insure that they are accurate.**

***Generalized Test Procedure*: The laboratory steps in the two tests are very similar. The sample of quicklime (CaO-Calcium Oxide) is pulverized, then the desired weight is measured into a flask which contains a specified amount of water. The flask is placed on a hot plate and a specified amount of additional boiling water is added. The flask is swirled and boiled for a minute, then removed from the hotplate. The flask is placed in a cold water bath to cool it to room temperature. (The solubility of lime is inversely proportional to temperature.) Sugar is added, then the flask is swirled and allowed to stand for 15 minutes, with periodic additional swirling to allow the sugar and lime reaction to take place. Phenolphthalein solution is added as an indicator, and the sample is titrated until the first disappearance of the pink color that lasts for at least three seconds. The burette is then read to determine the available calcium oxide percentage. (CaO%).**

***Modified Procedures*: *Are these test procedures ever modified by lime users and producers?* The answer is yes, however, the only thing that is usually changed is the sample size and/or the normality of the acid. The lab procedures,**

including the addition of sugar to increase the solubility of calcium hydroxide, are not changed. Keep in mind that both the ASTM C25 and AWWA B202 tests are designed to enable the lab personnel to read the available lime percentage from the burette. The drawback to this is that the sample must be weighed to a very specific weight. All forms of quicklime (pebble, granular or pulverized) immediately begin to undergo *air slaking* when exposed to any moisture in the air. This simply means that the moisture in the air reacts with the quicklime to form calcium hydroxide. This process occurs all the time, but has its greatest effect when the sample has been pulverized to a powder. The surface area of the quicklime is increased dramatically, which increases the rate of air slaking. Weighing the sample to a very specific, designated weight requires the lab personnel to take extra time in weighing, during which air slaking of the sample is occurring. Dependent upon the extra time required, the sample weight can change. Care should always be taken to insure the sample is weighed as quickly as possible. To minimize air slaking, a sample can be weighed exactly, at a weight close to the "targeted weight", then titrated with a commercially available, standard solution. The lab test procedures will be the same, however the available lime (CaO%) will need to be determined by calculation, using the amount of acid used and the exact weight of the sample. Lime users and producers will often modify the test in this way since it will generally produce more accurate results, however, you do lose the convenience of simply reading the available lime percentage (CaO%) as the milliliters of acid used.

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3. Why is sugar added when running the standard titration for the percent of available lime (CaO%) in quicklime? (ASTM C25 and AWWA B202)

The reason that sugar is added to the sample of quicklime after it has been added to water, is to increase the solubility of calcium hydroxide that was formed from the reaction of water and quicklime. This allows the lab technician to titrate quickly and is the reason the test is referred to as the *Rapid Sugar Test for Available Lime*.

The solubility of calcium hydroxide in water is quite low, with a range of 0.185 grams per 100 grams saturated solution at 0º C to 0.071 grams at 100º C. (Note that the solubility decreases with an increase in temperature.) As the sample is stirred, a suspension of calcium hydroxide is maintained (milk of lime). As you titrate the calcium hydroxide in solution, more will dissolve. Since most of the calcium hydroxide exists as a solid in suspension, it cannot be titrated until it has dissolved (gone into solution.) The titration process itself involves a reaction of the acid with calcium hydroxide in solution and will consume lime, allowing more lime to go into solution. However, this process can be speeded up significantly by the addition of sugar. When sugar is added, an intermediate product is formed, calcium sucrate (calcium hydroxide saccharate) which is significantly more soluble than calcium hydroxide. For example; the addition of 35 grams of sugar will increase the solubility of the calcium hydroxide from 0.159 to 13.332 grams per 100 grams of saturated solution at 25ºC; which is a solubility factor increase of 84.

***What happens if you don't add the sugar as prescribed in the test?* The acid has to be added relatively slowly to allow the calcium hydroxide that is still in suspension as a solid, to dissolve as calcium hydroxide that is in solution is neutralized. The titration procedure requires that you add acid until the first disappearance of color that lasts for three seconds. If you've inadvertently added too much acid you've effectively created a chemical "buffer". With excess acid introduced, the phenolphthalein pink color will disappear, and the excess acid will react with any calcium hydroxide going into solution with the result that the disappearance of color can persist for three seconds, indicating an incorrect end to the titration. The amount of acid used may be determined to be less than it should be and the resultant calculation (or reading from the burette) will indicate an available lime percent lower than the true value.**

A number of companies titrate the calcium hydroxide without adding sugar and are comfortable with this. The addition of sugar in the standard test procedure was developed to insure that the endpoint of the titration could be reached as quickly and accurately as possible, thus providing the greatest accuracy in the available lime determination. Those industries who currently do not add sugar in the test for available lime, and who have processes that can be significantly affected by fluctuations in the available lime determinations, may want to consider the addition of sugar to their testing procedure. Both ASTM and AWWA provide very detailed procedures and equipment requirements for testing both quicklime and hydrated lime. Please contact them directly for their industry recogized and accepted standard test procedures: (ASTM C25 - AWWA B202.)

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4. When I obtain a sample of quicklime from a truck or railcar for testing for the percent of available lime (CaO%) do I need to seal the container?

Yes, it's very important to place the quicklime sample in a sealed container. Quicklime is highly reactive with water and, when exposed to air that has moisture in it, will undergo *air slaking*, which means that the quicklime (calcium oxide)is reacting with moisture in the air to form hydrated lime. Any portion of the quicklime sample that has reacted

with moisture in the air (water) will be converted to hydrated lime, which has a weight that is 1.32 times as heavy as it was as quicklime. The overall weight of the sample will be increased, which will tend to reduce the available lime percent determination. The degree to which the sample is affected is a result of the moisture in the air. To avoid the possibility of the sample being affected by air slaking, the sample should be sealed until it is to be tested.

When obtaining a sample of hydrated lime the sample should also be sealed, primarily to keep the sample clean and free of debris. The hydrated lime does not react with moisture in the air since it has already been converted from quicklime to hydrated lime. Over an extended period of time, however, the hydrated lime (calcium hydroxide) will react with carbon dioxide in the air to form calcium carbonate. As a general rule then, all lime samples, whether quicklime or hydrated lime, should be in sealed containers.

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5. What are the CAS numbers for quicklime and hydrated lime, and what does CAS mean?

The CAS number for quicklime is 1305-78-8 and the number for hydrated lime is 1305-62-0. A CAS number refers to *Chemical Abstracts Service Registry Number* and identifies a chemical. For example, the same CAS number would be used for quicklime and calcium oxide, since they are the same compound. The CAS number, however, tells nothing about the concentration of the chemical. (The *Chemical Abstracts Service* is a division of the *American Chemical Society*.)

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6. What is meant by quicklime that has been *"drowned"*?

To understand this it's important to keep in mind that then when quicklime (CaO) reacts with water it forms hydrated lime (calcium hydroxide) which is only slightly soluble in water. (0.159 grams per 100 grams of saturated solution at 25º C.) A "pebble" of quicklime, when exposed to water, will readily react and break apart due to the swelling that occurs as a result of the larger sized crystals of calcium hydroxide that are formed. As this occurs, more water enters the pebble, producing more hydrated lime, and so on. If the quicklime "pebble" is in the presence of too much water a phenomenon known as "drowning" can occur.

What happens is that, although the quicklime (calcium oxide) on the surface of the pebble converts to calcium hydroxide (hydrated lime), the excess water can absorb the heat generated in the reaction and result in a delay in the hydration process. In addition, the calcium hydroxide on the surface, because of it's limited solubility in water, will tend to block the exposure of additional water to the quicklime within the pebble, resulting in a delay or cessation of the hydration reaction. Quite often, the "drowned" quicklime will be removed from the slaker as "grit", which will later undergo hydration in the grit pile. To avoid "drowning the quicklime" it is important to operate the slaker at both the correct water to lime ratio, and at the optimum water temperature. A lime user who notices an increase in the amount of grit, which appears to react later in the grit pile, may find that they're experiencing the phenomenon of "drowning" the quicklime.

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7. What are the STCC, CAS and EPA reference numbers for quicklime (Calcium Oxide-CaO) and hydrated lime (Calcium Hydroxide-$Ca(OH)_2$)?

All of these numbers are needed at one time or another. The STCC refers to *Standard Transportation Commodity Code*, the CAS refers to *Chemical Abstract Service* and the EPA refers to the *Environmental Protection Agency*. For your reference the numbers are as follows:

Reference	Quicklime	Hydrated Lime
STCC	32-741-10	32-741-11
CAS#	1305-78-8	1305-62-0
EPA#	A350-2789	S349-3522
Chemical Name	calcium oxide	calcium hydroxide
Formula	CaO	$Ca(OH)_2$

Molecular Wgt	56.08	74.09
Mol. Wgt. Ratio	1	1.32

Note: Included in the table above are the molecular weights for both quicklime and hydrated lime. Hydrated lime is produced from quicklime by a reaction with water. Using the molecular weights as a ratio, 56.08 tons of calcium oxide will react with 18.01 tons of water (molecular weight) to produce 74.09 tons of hydrated lime. The ratio of calcium oxide to calcium hydroxide is 1:1.32, so a truck of quicklime is equivalent to 1.32 trucks of hydrated lime. This information is useful in determining the cost benefits of quicklime vs. hydrated lime, and whether the savings warrant going to quicklime.

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8. I have completed the available lime test for CaO% and am concerned about a low test percentage. How can I tell if my quicklime sample has undergone air slaking?

When a quicklime sample is taken from a truck or railcar it's important that the sample be obtained from beneath the surface. Quicklime is very reactive with water and will readily react with moisture in the air. Depending on how long the top hatches were open during the loading process, as well as the humidity, the surface of the quicklime will become air slaked, or converted to calcium hydroxide from moisture in the air. The amount of quicklime that air slakes is very minimal compared to the total amount of quicklime in the truck or railcar, however, if a sample of quicklime is taken from the top surface, then the amount of air slaked quicklime could be high relative to the sample size.

An unusually Low CaO% may indicate air slaking: **A theoretically pure quicklime, CaO (56 lbs.) will react with water H_2O (18 lbs.) to produce calcium hydroxide, $Ca(OH)_2$ (74 lbs.). If the sample were absolutely pure quicklime, then the available CaO% would be 100%. If the same sample were to be completely air slaked, then the available lime would ideally be 75.7% (56/74). Percent readings near this range can be an indication that the sample may have become air slaked. A sample taken should be sealed, and tested relatively soon to avoid issues of air slaking. Also, once a sample is pulverized for testing, the sample is very prone to air slaking so the weighing of the sample should be completed quickly to avoid air slaking. Air slaking adds weight (water chemically reacts with quicklime) to the sample, and steadily causes a reduction in the available lime CaO% values.**

If the available lime percent readings are unusually out of line with what you normally receive a re-test is advised. To be sure the sample is not the issue you will want to obtain another sample from the truck or railcar, underneath the surface, otherwise you find that you are just be re-testing a compromised sample. Also, it's important to be certain that the acid used in the titration is correct. Because these are prepared locally, it's important to make sure that an error has not occurred.

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9. What is the correlation between the *Available CaO%* in Quicklime, CaO and the *CaO% Equivalent* in Hydrated Lime, $Ca(OH)_2$?

The term *Available Lime* refers to the percent of CaO in a sample that is available as CaO. Because quicklime is produced from the heating of calcium carbonate that occurs in nature, it will have some impurities that are dictated by the nature of the geological deposit. Also, in the process of producing quicklime there will always be some calcium carbonate core due to having to heat irregularly shaped and varying sized rocks of limestone. In some chemical testing of lime the CaO in the calcium carbonate core is included and is referred to as the *Total CaO*. This percentage is generally higher than the *Available CaO* since it includes the CaO that is chemically bonded in the calcium carbonate core.

The "Rapid Sugar Test" for available lime, either the ASTM C-25 or AWWA B202 version, is usually the chemical test that is used to determine the available lime in a sample of quicklime or hydrated lime. In a theoretically pure sample of quicklime, devoid of all naturally occurring impurities, and with an unrestricted time period to convert the limestone to quicklime with heat, you would have an ideal available lime of 100%. The available lime percentages generally experienced in the commercial market for high calcium quicklime typically require a minimum of either 90% or 92%, depending on the industry. Most lime companies have available lime values higher than 92%.

In the reaction to convert quicklime to hydrated lime; $CaO + H_2O \rightarrow Ca(OH)_2$ you are essentially doing the equivalent of taking 56.08 lbs of CaO (mw-molecular weight) and 18.00 lbs of water (mw), and reacting them to produce 74.08 lbs. (mw) of calcium hydroxide. Based upon the purity of the sample, an approximate comparison can

be made between the available CaO% of the quicklime and the expected CaO% equivalent in the hydrated lime. It can be seen from the chart below that the highest CaO equivalent possible in a 100% pure sample of calcium hydroxide would be 75.7%.

Quicklime Available CaO% vs CaO Equivalent in Hydrated Lime

Quicklime Avail. CaO%	Hydrated Lime, CaO Equiv.	**Quicklime Avail. CaO%**	Hydrated Lime, CaO Equiv.
100%	75.7%	**92%**	69.6%
99%	74.9%	**91%**	68.9%
98%	74.2%	**90%**	68.1%
97%	73.4%	**89%**	67.4%
96%	72.7%	**88%**	66.6%
95%	71.9%	**87%**	65.8%
94%	71.1%	**86%**	65.1%
93%	70.4%	**85%**	64.3%

Is using this table it's important to keep in mind that the process of hydration is not perfect, so that some loss of available CaO% can occur. Because of this the table should be viewed only as a general guideline.

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10. As I understand it, hydrated lime is only slightly soluble in water and the solubility is inversely proportional with temperature. What is the actual solubility of hydrated lime in water with temperature? Also, how is the solubility of quicklime determined since quicklime reacts with water to form hydrated lime and is not in its original form in a water solution?

Although hydrated lime is only slightly soluble in water, as can be seen in the chart below, the *effectiveness* of the solubility is increased by the suspension in water of the very small particles of hydrated lime that were formed during the hydration process. This suspension (slurry) of lime dramatically increases the dissolving process. Also, the solubility of lime in water is inversely proportional with temperature. The chart below shows this temperature/solubility relationship and it's apparent that the highest solubility of lime is at the freezing point of water and the lowest is at the boiling point water.

Solubility of Lime in Water

Saturated Solution - grams per 100 gms of solution

T^{o}C	**$Ca(OH)_2$**	**CaO**	**T^{o}C**	**$Ca(OH)_2$**	**CaO**
0	0.185	0.140	**50**	0.128	0.097
10	0.176	0.133	**60**	0.116	0.088
20	0.165	0.125	**70**	0.104	0.079
25	0.159	0.120	**80**	0.092	0.070
30	0.153	0.116	**90**	0.081	0.061
40	0.140	0.106	**100**	0.071	0.054

***Determination of Solubility of Quicklime in Water*: Since quicklime calcium oxide (CaO) cannot exist in water in the oxide form, the solubility of CaO in water is based on the *calcium oxide equivalent* of CaO in $Ca(OH)_2$. The values for the solubility of CaO in water, shown in the chart above, represent the amount of CaO that is within the dissolved $Ca(OH)_2$. The calculation for the ratio of CaO in $Ca(OH)_2$ appears below:**

$$\frac{CaO}{Ca(OH)_2} = \frac{56.08\ mw}{74.08\ mw} = 0.757$$

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11. Since magnesium carbonate is chemically very similar to calcium carbonate why doesn't

magnesium oxide and magnesium hydroxide have the exact same chemical properties as calcium oxide (Quicklime) and calcium hydroxide (Hydrated Lime)?

Magnesium appears above calcium on the *Periodic Table of Elements* (see below) and has an atomic number of 12 and a molecular weight of 24.32, whereas calcium has an atomic number of 20 and a molecular weight of 40.08. Both have a charge of +2 as an ion after two electrons have been removed from their s-orbits. This is the maximum number of electrons that can be removed from their s-orbital, which can hold can hold only two electrons, so both undergo similar reactions with other elements and chemical groups. Even though the charge appears to be identical, the "effective charge" is somewhat different and accounts for the difference in reactivity, as is described in the following paragraphs.(For additional on the energy levels, sublevels and orbitals of atoms see the *Chemistry Reference Note* section that appears just below the partial Periodic Table of Elements at the end of this section.)

There are two factors that come into play with regard to the "effective charge" of the Ca^{+2} and Mg^{+2} ions:

(1) Although both calcium and magnesium ions have a +2 charge, the distance from the ionic extremity (border) to the +2 charge at the nucleus is different. In the case of magnesium, the size (radius) of the ion is smaller (0.66 Anstrom units) than that of calcium (0.99 Anstrom units). The increase in the size of the calcium ion is due to the addition of another energy level. Consequently, the distance from the +2 charge to the extremity of the ion in the magnesium ion is shorter by about 33% then the distance in calcium. The shorter distance means that the electrostatic attraction between the magnesium ion (+2) and the oxygen ion (-2) is stronger than that of the bond between the calcium ion (+2) and the oxygen ion (-2). Note that, in both cases, the +2 charge offsets the -2 charge and results in the neutral compounds of CaO and MgO. However, the inherent elemental differences *(number of protons and electrons)* between the elements of calcium and magnesium, result in a difference in their ease of ionization *(removal of electrons)* and their ability to chemically combine *(strength of their electrostatic forces)* with other elements and compounds in reactions.

(2) Also, in the case of the calcium ion, even though the charge is the same as that of magnesium, the +2 charge at the nucleus of the calcium ion has to go through more electrons, eighteen (-18), compared to the magnesium ion which has a +2 charge, but only has to go through ten (-10) electrons. This reduces the overall attraction (strength) that the calcium ion (+2) has for other elements and chemical groups as compared to magnesium.

***Effects on Solubility:* Because of this effectively "weaker" +2 charge, the solubility of calcium hydroxide is greater than magnesium hydroxide. The water molecules clustering around the calcium hydroxide compound have enough force (Van der Waals force) to dissociate the compound into a calcium (+2) ion and two hydroxyl (-1) ions, although not to a great degree, which accounts for the limited solubility of calcium hydroxide in water. In the case of magnesium hydroxide, the attraction of the magnesium +2 ion and the hydroxyl -1 ion is too great for the water molecules to overcome, and the magnesium hydroxide remains mostly out of solution.**

The difference between calcium and magnesium can be readily seen on the *Periodic Table of Elements*. Although calcium is just below magnesium vertically, there are six elements between them horizontally. Nature does favor calcium carbonate and magnesium carbonate occurring together, so even deposits of high calcium limestone will have some magnesium carbonate mixed in, which is considered a "naturally occuring impurity."

For comparative purposes, $Mg(OH)_2$ has a solubility of 0.0042 grams per saturated solution, which can be considered insoluble in water. Furthermore, the reaction of MgO with water is not highly exothermic, so MgO will stay in water as "grit". CaO, however, will quickly convert to the hydrated lime form in a dramatic exothermic reaction. MgO can be forced to react more quickly with increased pressures and temperatures. For reference, a partial *Periodic Table of Elements* appears below:

Periodic Table of Elements (Partial)
Elements 1-109

1	1 **H** 1.008																	2 **He** 4.08
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95

4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.5	38 **Sr** 87.6	39 **Y** 88.9	40 **Zr** 91.2	41 **Nb** 92.9	42 **Mo** 95.9	43 **Tc** (99)	44 **Ru** 101.0	45 **Rh** 103.0	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57* **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Ti** 204.4	82 **Pb** 207.2	83 **Bi** 209.9	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89+ **Ac** (227)	104 **Rf** (261)	105 **Ha** (262)	106 **Sg** (263)	107 **Ns** (262)	108 **Hs** (265)	109 **Mt** (267)									
The Lanthanide and Actinide Series are shown below:																		
Lanthanide Series*					58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
Actinide Series+					90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (254)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Element

Atomic No. **Element Symbol** Atomic Wgt.

Reference

Alkali Metals	Metalloids
Alkaline-Earth Metals	Nonmetals
Transition Metals	Holgens
Post Transition Metals	Noble Gases

At 25ºC

Solid
Gas
Liquid

For comparative purposes, $Mg(OH)_2$ has a solubility of 0.0042 grams per saturated solution, which can be considered insoluble in water. Furthermore, the reaction of MgO with water is not highly exothermic, so MgO will stay in water as "grit". CaO, however, will quickly convert to the hydrated lime form in a dramatic exothermic reaction. MgO can be forced to react more quickly with increased pressures and temperatures.

Chemistry Reference Note

PRINCIPLE ENERGY LEVELS, SUBLEVELS AND ORBITALS

Calium and Magnesium Ions:

Both calcium and magnesium have two electrons in an s-orbital. In the case of magnesium, the two electrons are in its 3s orbital (3rd energy level, 3s orbital). For calcium, the two electrons are in its 4s orbital (4th energy level, 4s orbital). Only the electrons that are in the outermost Principle Energy Level of an element are available for chemical reactions (chemical bond formation). Electrons in energy levels lower than the outermost energy levels have the electron configurations (energy level structures) of noble gases, which are completely stable and do not chemically react under normal circumstances.

Principle Energy Levels, Sublevels & Orbitals:

There are seven Principle Energy Levels which correspond to the horizontal rows on the Periodic Table of Elements. At the end of each row is a noble gas. The noble gases are He-Helium, Ne-Neon, Ar-Argon, Kr-Krypton, Xe-Xenon, and Rn-Radon. (Although Radon does not react chemically, it's nucleus is unstable so it is radioactive. It is formed by the natural breakdown of uranium in soil, rock and water.) Within each Principle Energy Level are sublevels designated as s,p,d,f. Within each of these sublevels are orbitals, and each orbital can contain two electrons. Note that not all Principle Energy Levels have all of the sublevels. The number of orbitals in each sublevel increases from s,p, d through f. The orbitals represent a three dimensional space in which the two electrons exist.The s sublevel has a single spherical orbital and the p,d and f sublevels have dumbbell shaped orbitals in which each of the two electrons occupy opposite ends of the dumbbell. This is somewhat of an oversimplication, but it helps in visualizing orbitals. The p, d and f orbitals are what gives structure and shape to molecules (compounds).

Energy Level - Possible Sublevels:
7 - sp
6 - spd
5 - spdf
4 - spdf
3 - spd
2 - sp
1 - s

Max number of electrons in sublevels:
s = 1 orbital x 2 electrons = 2 total
p = 3 orbitals x 2 electrons = 6 total
d = 5 orbitals x 2 electrons = 10 total
f = 7 orbitals x 2 electrons = 14 total

Energy Level - Sublevels - Theoretical & Actual Electron Configurations:

The order of the orbitals shown below is not necessarily the order in which they actually appear in elements due to differences in the energies of orbitals. However,it useful to view them in this simplified way for reference purposes.

Long Form:
Period 1: $1s^2$ = [He]
Period 2: $1s^2$ - $2s^2p^6$ = [Ne]
Period 3: $1s^2$ - $2s^2p^6$ - $3s^2p^6d^{10}$ = [Ar]
Period 4: $1s^2$ - $2s^2p^6$ - $3s^2p^6d^{10}$ - $4s^2p^6d^{10}f^{14}$ = [Kr]
Period 5: $1s^2$ - $2s^2p^6$ - $3s^2p^6d^{10}$ - $4s^2p^6d^{10}f^{14}$ - $5s^2p^6d^{10}f^{14}$ = [Xe]
Period 6: $1s^2$ - $2s^2p^6$ - $3s^2p^6d^{10}$ - $4s^2p^6d^{10}f^{14}$ - $5s^2p^6d^{10}f^{14}$ - $6s^2p^6d^{10}$ = [Rn]
Period 7: $1s^2$ - $2s^2p^6$ - $3s^2p^6d^{10}$ - $4s^2p^6d^{10}f^{14}$ - $5s^2p^6d^{10}f^{14}$ - $6s^2p^6d^{10}$ - $7s^2p^6$

The following *Short Form* of indicating electron configurations helps to highlight why only the outermost energy level participates in chemical reactions. Note that the inner energy levels are identical to the noble gas electron configurations and are completely stable.

Short Form:
Period 1: $1s^2$ = [He]
Period 2: [He] + $2s^2p^6$ = [Ne]
Period 3: [Ne] + $3s^2p^6d^{10}$ = [Ar]
Period 4: [Ar] + $4s^2p^6d^{10}f^{14}$ = [Kr]
Period 5: [Kr] + $5s^2p^6d^{10}f^{14}$ = [Xe]
Period 6: [Xe] + $6s^2p^6d^{10}$ = [Rn]
Period 7: [Rn] + $7s^2p^6$

Theoretical order of electrons filling sublevels: *(Increasing Energy)*
1s - 2sp - 3spd - 4spdf - 5spdf - 6spd - 7sp

Actual order of electrons filling sublevels: *(Increasing Energy)*
1s - 2sp - 3sp - 4s - 3d - 4p - 5s - 4d - 5p - 6s - 4f - 5d - 6p - 7s - 5f - 6d - 7p

Building the Periodic Table of Elements: **The Periodic Table of Elements can be built by starting with Hydrogen and adding one proton and electron, and continuing on through the elments. As the elements get larger, more neutrons are required to stabilize the nucleus, which will increase the weight of the element, however, the identity of element is determined only by the number of protons. The neutrons are not involved with normal chemical reactions. In viewing the *Actual* order of electronic configurations, it can be seen that the s orbitals are more stable than the d and f and will fill earlier than the d and f sublevels of lower energy levels.**

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12. What is the ASTM Standard C-977 and does the lime produced by Cheney Lime & Cement Company meet this specification?

The ASTM C-977 is the ASTM standard specification for quicklime and hydrated lime used in soil stabilization. The quicklime and hydrated lime produced by Cheney Lime & Cement Company meets the specifications of ASTM Standard C-977.

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13. Lime companies refer to a "Typical Chemical Analysis". What does this mean and why is it not referred to as a specific chemical analysis like the reagent grade chemicals I buy?

All industrial lime is produced from quarried limestone (or in some cases oyster shells), which has naturally occurring impurities in it. Many companies wash the stone before in goes into the kiln, however, any impurities in the limestone itself will appear in the quicklime. Much of the control of the quality of the quicklime can be affected by how well the material is quarried. The vein of limestone being quarried is constantly monitored to insure that only the highest purity is selected for the kiln. The quicklime produced is chemically analyzed, based upon standard statistical sampling procedures, but the chemical analysis will vary to a degree according to the way nature left the limestone deposit. This is why most companies refer to a "typical chemical analysis." There are minimum and maximum chemical limits to the various components of the lime, but within these limitations the chemical analysis will always vary to some degree. (Note: Lime can be produced from oyster shells, which have a very high purity of calcium carbonate, however, this source of kiln material is declining, having been almost completely replaced by quarried limestone.)

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14. With regard to the NAFTA Certificate of Origin, what does the *HS Tariff Classification Number* mean and what are the HS Tariff Classification Numbers for quicklime and and hydrated lime? Also, what does the *Preference Criterion* mean?

The "HS" in *HS Tariff Classification Number* refers to "Harmonized System" which is short for *Harmonized Commodity Description and Coding System*. This is a system for classifying goods in international trade. In the case of quicklime the number is 2522.10 *("calcium oxide, obtained from the product of calcining natural materials")*, and for hydrated lime/slaked lime) it's 2522.20 *("calcium hydroxide obtained from the product of calcining natural materials")*. For calcium oxide and calcium hydroxide that is not obtained from calcining natural materials, the HS code is the same for both products; 2825.90. *("calcium oxide and hydrated lime in the pure state")*. The 2825.90 products can be considered to be "reagent-grade" lime products rather than "commercial-grade" lime products. *Reading the HS number:* (Example: quicklime 2522.10) The first two digits are the chapter 2522.10, the third and fourth digits 2522.10 are the header, and the fifth and sixth digits 2522.10 are the subheader.

The *Preference Criterion* refers to a code designating the degree to which the products are coming from the country of origin. In the case of quicklime and hydrated lime from Cheney Lime & Cement Company, all of the components are USA based, so the designation would be "C". More specifically, from the NAFTA Certificate of Origin Instructions, a Preference Criteria "C" refers to *"The good is produced entirely in the territory of one or more of the NAFTA countries exclusively from originating materials."*

Slaked Lime: In the description of calcium hydroxide products in the HS Tariff Classification System, it can be a bit confusing. In one instance it will refer to calcium hydroxide as "hydrated lime", then another time as "slaked lime". Hydrated lime produced from calined limestone (quicklime) can be thought of as simply a reaction of the quicklime (calcium oxide, CaO) with the exact amount of water (H_20) to produce a dry hydrated lime (calcium hydroxide, $Ca(OH)_2$). The term "slaked lime" refers to the reaction of quicklime with water to a dry powder, as well as the addition of excess water to produce a *paste, slurry* or *milk of lime*. Technically then, dry hydrated lime is also considered to be slaked lime.

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15. What is the difference between the temperature scales of Celsius/Centigrade (ºC), Fahrenheit (ºF) and Kelvin (ºK) and how do I convert between these?

Kelvin & Celsius	Ceslius & Fahrenheit	
K = C + 273	C = 5/9 x (F - 32)	C = (0.556 x F) - 32
C = K - 273	F = (9/5 x C) + 32	F = (1.8 x C) + 32

Fahrenheit - The Fahrenheit temperature scale is based upon 32 ºF as the freezing point of water and 212 ºF as the

boiling point of water. (The Fahrenheit scale was devised by Gabriel Daniel Fahrenheit (1686-1736), a natural philosopher who invented the mercury thermometer in 1714.)

Celsius (Centigrade) - The Celsius (Centigrade) temperature scale is based upon 0 ºC as the freezing point of water and 100 ºC as the boiling point of water. The formulas to convert between Fahrenheit and Celsius (Centigrade) come from the fact that there are 180 degrees (212-32) between freezing and boiling in the Fahrenheit temperature scale, so each degree in the Fahrenheit scale is equal to 100/180 (or 5/9) of the Celsius/Centigrade scale. (The Celsius scale was devised in 1742 by Anders Celsius (1701-1744), a Swedish professor of astronomy.)

Kelvin - The Kelvin temperature scale is based upon the physics of cooling a gas and represents an extrapolation of the Centigrade temperature scale to -273 ºC (or more accurately, -273.15 ºC) at which point there is no longer any motion of atoms or molecules; or put in the simplest way, "there is no heat". This point in the Kelvin temperature scale is assigned a value of 0ºK. For the Celsius (Centrigrade) temperature scale the freezing point of water would be 273ºK and the boiling point would be 373ºK. (The Kelvin temperature scale was developed by Lord Kelvin (1824-1907), a British physicist.)

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16. When in contact with metal equipment does lime have any affect on iron or steel? Also, is there any affect on aluminum, lead, tin, brass or zinc?

Without water (H_2O) being present, neither *quicklime* (CaO, calcium oxide) nor *hydrated lime* ($Ca(OH)_2$, calcium hydroxide) react with metals. If water and quicklime are both present the water will first react with the calcium oxide, converting it to calcium hydroxide (hydrated lime). When water is present in excess of the amount required to convert quicklime (CaO) to hydrated lime, or the hydrated lime is moist or in a slurry, it is in a form that can attack metals. Lime (quicklime or hydrated) does not react with (attack) either iron or steel. However, lime does react with (attack) aluminum, lead, brass and zinc. Since lime does not attack iron and steel these metals are generally used for lime handling equipment.

Since the pneumatic trucks hauling lime (calcium oxide or calcium hydroxide) are made of aluminum alloy, the lime does not have the same capacity to attack the metal as it would if they were made of aluminum. In addition, quicklime acts as a *desiccant* in that it will react with any moisture in the tank preventing the lime from going into solution. In the case of calcium hydroxide, any moderate amount of water will be electrostatically attracted to the hydrated lime, which will also help prevent a solution of any sort forming. One of the best sources for information on the effect of lime on metals comes from Robert S. Boynton's book the *"Chemistry and Technology of Lime and Limestone"*, 2nd edition, 1980, page 223, where he states the following:

"Effect on Metals. When in contact with metal equipment, lime does not affect steel or cast iron to the slightest extend. In fact, by coating these metals with a lime whitewash, it acts as a conservation agent by protecting the metals from oxidation. However, any form of lime or strong alkalin will disastrously attack and destroy *aluminum*, except special alkaline resistant alloys of this metal. *Lead and* and *brass* are also readily attacked, and under some circumstances lime will literally dissolve lead."

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17. I understand that limestone (calcium carbonate and/or magnesium carbonate can be used to neutralize a strong acid. Why can't I simply use limestone to raise the pH above 7.0 (neutral)?

A strong acid, such as hydrochloric acid (HCl), can react directly with various forms of limestone, ($CaCO_3$, $MgCO_3$ or $CaCO_3$•$MgCO_3$). For example, the reaction of $CaCO_3$ with HCl is: $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2CO_3$. The carbonic acid produced is unstable and breaks down into carbon dioxide (gas) and water: $H_2CO_3 \rightarrow CO_2 + H_2O$. However, CO_2 is soluble in water and produces a weak carbonic acid, so you ultimately find that the neutralization of a strong acid with limestone results in the generation of a weak acid. Consequently, you can never reach a point above a pH of 7.0.

Note: Carbon dioxide (CO_2) which is a component of the atmosphere will combine with rainwater to produce carbonic acid, H_2CO_3, which can dissolve limestone over time. Also, sulfur dioxide (SO_2) in the air can also dissolve in the water, which produces a strong acidic solution of H_2SO_4 (sulfuric acid). This result of this process is referred to as *acid rain*.

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SIZE:

1. **We are going to build a plant that will use quicklime and need to know which is the best quicklime size to use in the design of our plant.**

Quicklime Sizes: In the lime market that Cheney Lime & Cement Company serves, quicklime generally falls into one of the following two size classifications: *Pebble Quicklime* and *Granular Quicklime*. Although lime suppliers have various gradations of these two classifications it is helpful to view pebble quicklime as a size that generally ranges from about 1 to 1/4 inch, and granular quicklime from about 1/4 inch down. For the most part, the size quicklime that dominates the market is pebble quicklime, and granular quicklime can be considered as available in relatively limited supply. Most lime companies further divide the pebble quicklime sizes into subcategories: *medium* and *rice* quicklime. Although there are slight differences in the specific sizes between suppliers, you can consider the medium size to generally be from about 1 to 1/2 inch, and the rice size from about 1/2 to 1/4 inch. (Individual lime producers can tell you their specific size ranges.)

Best Quicklime Size: In some situations the size is very clearly defined and the plant designer has no option. Usually this involves the major classifications of *pebble* and *granular* quicklime. However, within the sizes of *medium* and *rice* size pebble quicklime, the plant designer has options to consider. From a product availability standpoint the best design choice is to make certain that the plant can run either medium or rice quicklime, and if possible also granular. This is especially important if there is a high demand for quicklime, whether on a continuous or emergency basis. The following paragraph explains this further.

Product Availability Factor: The cost of quicklime is very freight intensive, so quicklime is usually considered a regional product. Because of this all of the quicklime used at a specific plant comes from a relatively close geographical area. Whether that area has one producer, or multiple producers, all of the quicklime has to be processed through kilns. In most lime production areas there are often multiple kilns in production. During processing, the quicklime is crushed and screened to generate the various sizes. If the available pebble quicklime sizes in an area were evenly split between medium and rice, and your plant can only use medium, your available supply of quicklime from producers would only be half of what is actually produced. If you require a granular size quicklime the situation becomes even more difficult since this is considered to be a minor size in the lime market.

Recommendation: It is recommended that a new plant be designed to at least be able to run either medium or rice. The plant may not be able to alternate between truckloads of the medium and rice sizes, but in the event of a lime shortage, the plant would be able to switch sizes. It is not recommended that a granular size be used for a high volume user, unless this size is mandatory for the process, since this could severely limit product availability, especially during peak demand periods.

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2. **When I buy quicklime from different suppliers I sometimes have to adjust my system, even though the size of the quicklime is the same. Why are there variations in quicklime from different suppliers?**

Although the high calcium quicklime received from different lime suppliers is essentially the same chemical (calcium oxide), each deposit of limestone from which the quicklime is produced has naturally occurring impurities. These can vary between suppliers because of different geological deposits, as well as from different parts of the same quarry of a single company. Because of this, there are inherent differences between the quicklime from various lime suppliers. Also, both the kiln operating characteristics and the type of fuel mixture used can be a factor. If each lime supplier uses a slightly different mixture of fuel (i.e. pet coke and pulverized coal) the effect on the quicklime produced can vary slightly. In addition, there are different types of kilns used in the production of quicklime, each of which can produce a quicklime with slight differences. Most users of quicklime in the market will not be aware of any of these slight differences, however, occasionally there is a lime user who finds that their lime system is sensitive to these. From a marketing standpoint, it is in a lime user's best interest to design their lime system to be able to use any good quality high calcium quicklime, without regard to the factors of quarry source, kiln type, etc., since this will prevent them being limited to only one supplier, or to one particular plant or kiln within a specific company.

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SILOS:

1. **With regard to deliveries by truck or rail, how large a lime silo should we plan for in the design of our plant?**

   As would be expected, the lime silo capacity is greatly affected by the specific needs of a company which will need to be taken into account, along with the daily lime demands. From a transportation delivery standpoint there are some things that can be useful to keep in mind. (Please be aware that the suggestions for silo capacities shown in the following paragraphs are approximate and are provided only to help you get an idea of the requirements for lime delivery by truck and rail, and to see the differences between the two. Each plant design has its own unique requirements which should be carefully considered before the investment in storage capacity is undertaken.)

   Truck Delivery: A truck can generally be considered to hold about 25-30 tons of quicklime. The minimum freight weight requirements are usually 25 tons for quicklime (50,000 lbs) and 22 tons for bulk hydrated lime (44,000 lbs); bulk hydrated lime is lighter than quicklime. A weight of 25 tons/truck is useful to use as a general guideline since it will cover most shipments. Generally, you are allowed one to two hours for unloading a truck before a demurrage charge is applied, based upon the individual carrier's policy. Depending upon your demand for lime, any silo you design should be able to hold no less than 2 trucks of lime (50 tons). If a truck is ordered when the silo gets to the point where it can hold a full truck, you avoid problems associated with demurrage. This is quite a small silo, so it is recommended that, dependent upon your requirements, you have a silo that can hold 4-5 trucks (100-125 tons) of lime. The additional silo capacity will give you an added buffer in the event of unforeseen truck delivery problems.

   Rail Delivery: A railcar can generally be considered to hold about 100 tons of lime. In our market area bulk hydrated lime is usually not shipped in rail cars aside from PD cars (Pressure Differential cars), which are owned by the lime user or lime supplier. Usually the railroad will allow you two days to unload a railcar. Depending upon your demand for lime, the silo should be able to hold no less than 1-1/2 rail cars of lime (150 tons). Rail delivery times are not as specific as truck, so it's important to consider having additional silo capacity. A silo with 250 tons will enable you to unload two cars into a silo when less than 50 tons are remaining in the silo. Although your lime demands may dictate your silo requirements, a silo with 500 tons capacity would enable you to have an added buffer for unforeseen rail delivery problems. (i.e. a rail car enroute is set aside for a day to be repaired, etc.)

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2. **I am in the final planning stages for our lime silo and want to make sure that I've have covered all key points. Is there something I need to be sure to check before ordering the silo?**

   The answer to this is yes. It's very important that the silo have enough product capacity. Quite often a silo is designed to hold only one truckload of lime. This presents a problem because the lime user has to wait until they're almost out of lime to order so that they can fit all of the lime into the silo. A lime company generally processes an order as "a truckload of lime". Dependent upon whether it's quicklime or hydrated lime, the weight will vary due to the density of the lime and/or the capacity of the pneumatic truck. In any case, it's a wise decision for the lime user to have additional capacity available in the silo so that a truck can be ordered and received without having to have the silo completely empty.

   One other very important point to be careful of involves the density used in the calculation of silo size. The term "lime" refers to both quicklime/calcium oxide and hydrated lime/calcium hydroxide, however the density of the two materials are significantly different. Generally, quicklime is shipped as "pebble quicklime" whereas hydrated lime is a fine, white powder similar in consistency to "flour". It's important to be sure to know exactly which product will be going into the silo. Some lime users have used the density of quicklime in their calculations when they were actually going to be using bulk hydrated lime. The result is a silo which will not hold a full truck of hydrated lime.

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3. **I need to remove some lime that is currently in my silo. Does anyone do this and what are the type of charges that I can expect?**

   Unless it's not possible, the least expensive way to remove the lime from the silo is to run it through the system, even if this has to be done at a slower pace. If it's determined that the lime must be removed from the silo there are companies who have trucks called *self loading vacuum trucks* which can vacuum out the dry product and then take it to another location. To accomplish this a fitting (approx. 4") has to be placed on the opening at the bottom of the silo so that the truck's vacuum system can be attached. Some of the charges associated with this type of operation are:

   1. **Charge per mile to and from the site of the silo.**

2. **Charge to clean the truck before and after handling the lime.**
3. **Cost per hour for the actual operation.**

Here are two companies we are aware of that can provide this type of service:
(1) Bulkmatic Transport, at Jacksonville, FL, 904-783-3500, Mobile, AL, 251-694-0900, and (2) Fenn-Vac, Inc, at North Charleston, SC, 843-552-8306. For pricing and availability of equipment please contact these companies directly. If either of these companies are not able to provide this service in your area, they should be able to direct you to a company near you. (Other companies that can provide the service of removing dry lime from a silo may contact us at sales@cheneylime.com. We would be pleased to include their name and phone numbers here as a service to our customers and other lime users.)

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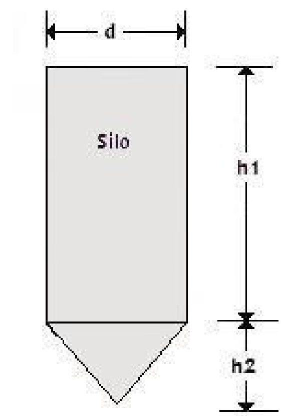
4. How can I do a quick calculation of the cubic feet capacity of a silo? Also, how much quicklime, or hydrated lime, can go in the silo?

When determining the size of the silo that you require it's important to make certain that you use the correct density for the product required. As you can see below, the density difference between quicklime and hydrated lime is very significant.

***Example*: The following calculations apply to a circular silo with a single cone at the bottom. The cylinder part of the silo is 20 ft. high and the cone part of the silo is 5 ft. high. The diameter of the cone is the same as the cylinder. The diameter of the silo is 12 ft., so the radius is 6 ft. (For silos having multiple cones, each cone would be calculated individually based upon its diameter. The volume of all the cones would be combined with the volume of the cylinder.)**

Formula for the Volume of a Cylinder **$v1 = \pi r^2 h$**	Formula for the Volume of a Cone **$v2 = 1/3 \pi r^2 h$**	
π = 3.14 **h1** = 20 ft (cylinder height) **d** = 12 ft (diameter) **r** = 6 ft (radius r = d/2)	**π** = 3.14 **h2** = 5 ft (cone height) **d** = 12 ft (diameter) **r** = 6 ft (radius r = d/2)	
v1 = 3.14 x 36 x 20 **v1** = 2,261 sq. ft.	**v2** = 1/3 x 3.14 x 36 x 5 **v2** = 188 sq. ft.	
v3 = silo volume **v3** = **v1** + **v2** **v3** = 2,261 + 188		
v3 = 2,449 sq. ft (silo volume)		

Silo Product Capacity in Tons of Lime: To estimate the number of tons of quicklime, or hydrated lime, that a silo can hold simply multiply the silo volume times the average anticipated lbs./sq. ft and divide by 2,000 lbs. Since both lime products can vary in density, an approximate range can be used:

Approximate Densities of Limes

Pebble Quicklime = 65 to 70 lbs./cu.ft.

Hydrated Lime = 25 to 35 lbs./cu.ft.

For reference: **π** (called "pi") is the ratio of the circumference to the diameter of a circle and is the same for all circles. It is approximately equal to 3.14159... *(The decimal expansion never ends and does not repeat.)*

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SLAKERS:

1. **What is a "slaker" and why can I not simply mix quicklime in a simple mixing tank?**

As a general rule "pebble quicklime" requires the use of a slaker whereas "hydrated lime" can be mixed with a standard mixer. To understand this it helps to visualize the pebble quicklime as identical to the original limestone pebbles that it was created from, except that it's about 44% lighter. (The carbon dioxide, produced during the dissociation of calcium carbonate into calcium oxide and carbon dioxide, escapes through the porous limestone.) When these pebbles drop into a simple mixer they go immediately to the bottom of the container, reacting as they go. A layer of "reacting rocks" builds up on the bottom of the tank and consumes the water in the surrounding layer of quicklime. The result is that all of the quicklime may not react. Un-reacted quicklime that gets into a pipe can cause problems because of the steam emitted as it converts to the hydrated form. To avoid this problem, a slaker is used which can be thought of as a "specialized mixer". The quicklime pebbles encounter a screw or paddles at the bottom of the tank which insure that all of the quicklime comes into intimate contact with the water and completely converts to the hydrated lime. A slurry is produced, similar to that used in a hydrated lime mixing tank, but it's essential that all of the quicklime gets completely converted.

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2. **Why does hydrated lime settle when the agitation stops? Why doesn't it all go into solution?**

Hydrated lime (calcium hydroxide) is only slightly soluble in water. The particle size is very small, so agitation of the solution will keep the particles suspended until the agitation is stopped. The small size of the particle in suspension is responsible for the reactivity of hydrated lime. Since the particle size is so small, the surface area of the hydrated lime exposed to water increases dramatically. As hydrated lime (calcium hydroxide) in solution is used up in reactions, additional lime goes in solution to replace it.

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3. **I have a slaker, or other type of lime handling equipment, that requires a part that is no longer available or manufactured. Is there a company who can make this part for me if I have the drawings/specifications, or if all I have is the broken part(s)?**

A company may have lime handling equipment that requires a part that is no longer made. The equipment may still be in reasonably good shape, but the part is not available anymore; possibly due to being obsolete, or no longer supported by the manufacturer. A company by the name of Anthoine Machines Works, Inc. in Fort Valley, GA (USA) can reproduce the part from drawings or from the damaged part(s). The company was established in 1885 and has been providing this service to companies throughout the world. Their phone number is 478-825-5613. They should be able to help you. If it is a type of work that they are not able to do they should be able to help direct you to someone who can help you. (Generally stated, this company produces parts for equipment, both current and obsolete; custom parts.)

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4. **What is a *Lime Slurry* and are there other physical forms of hydrated lime and water? Also, is there a formula that can be used in calculating the amount of lime and water to produce a certain percent slurry?**

There are generally six physical states of hydrated lime that are used in industry. Other than the dry forms, the differences involve amount of water mixed with the hydated lime. These six forms are:

Type of Lime	Solids	Water
Dry Hydrated Lime	100%	0%
Lime Putty	70 - 55%	30-45%
Lime Slurry	35 - 25%	65-75%
Milk of Lime	20 - 1%	80-99%
Lime Water	0%	100%
Air-Slaked Lime	100%	0%

When the exact amount of water is reacted with quicklime (CaO) it will chemically combine completely leaving a *Dry Hydrated Lime* which is sold in bulk or 50 lb. bags. Whether a customer orders quicklime or hydrated lime, in most cases, they will ultimately be forming a colloidal suspension of hydrated lime in the form of either a *Lime Slurry* or

***Milk of Lime*.** **(Quicklime can be thought of as an intermediate product which will ultimately be converted to hydrated lime.) From an industrial standpoint lime is generally received by the customers in either bulk or bags as a dry product (quicklime or hydrated lime). If quicklime is used it goes through a slaker to be converted to hydrated lime and then slurried. If hydrated lime is used it goes into a mixture which produces the slurry. In either case the customer transports the lime within their plant as either a *Lime Slurry* or as a *Milk of Lime*.**

It is important to have lime in suspension (slurry) because of the low solubility of hydrated lime in water. *Lime Water* is a lime solution without solids, with the result that, when the hydrated lime that is in solution is depleted, there aren't any solid particles to go into solution to replace the lime that has been used up. There is some transportation of slurry directly to customers by some lime companies, however, this is a relatively small part of the lime business. Since a large portion of slurry is water, the customer ends up having to pay for the transportation of water, which may offset other savings associated with not having to make the lime slurry themselves. Also, more trucks are required to deliver the same effective amount of lime that can be delivered as dry hydrated lime. A standard formula (guideline) is used to prepare suspensions of lime (*Lime Slurries* and *Milk of Limes*) as follows:

Weight of Slurry Calculation

$$\mathbf{X} = \frac{6237\mathbf{z}}{100 - \mathbf{y} + \mathbf{zy}}$$

X = Lbs. of lime slurry per cubic ft.
z = Specific gravity of dry lime solids
y = Percent(%) water in slurry.

***Air-Slaked Lime* is the reaction of moisture in the air with quicklime (CaO). Quicklime is very hydroscopic and can be considered a desicant. It will absorb and react with moisture in the area to convert to hydrated lime. Although this reaction is exothermic, air-slaking does not generate much heat because the reaction takes place over an extended period of time. The biggest problem from air-slaking comes from the effect on samples of quicklime. The reacted water adds weight to the sample and decreases the percentage of *available lime*. Samples of quicklime should always be sealed and tested rather quickly. *Lime Putty* can be thought of as a thick, paste form of lime and water. Usually it is prepared by customers and homeowners who need the use of lime in this form.**

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TRANSPORTATION:

1. **When I receive a shipment of lime, by truck or rail, how long do I have to unload it? Is there a penalty if I exceed the time allowed, and what is meant by the term *Demurrage*?**

***Truck Delivery*:**
The time allowed to unload a truck, without penalty, varies with each carrier. Generally, you are allowed one to two free hours to unload a truck, depending on the carrier's policy. This time usually starts from the designated delivery time, if there was a time specified. Otherwise, it is from the time the product was delivered to the plant. The penalty is a per hour (or portion of hour) charge.

***Rail Delivery*:**
In the case of hopper cars (rail delivery), you are usually allowed two days for unloading. There is a per day charge, which begins to escalate each day the car is held from service. Each rail carrier has their own penalty time periods and charges, so you will need to verify these with each rail carrier, as you do with each of the truck carriers.

Demurrage:
In the trucking and rail shipment modes The term *demurrage* refers to the penalty charge applied to the time period beyond the free unloading time during which a penalty is applicable. This penalty is assessed because the truck, or hoppercar, is withheld from transit to its next destination or from the pool of available trucks or hoppercars.

***Impact of Holding up a Truck:* Although applicable to both truck and rail shipments, holding up a truck can have a significant, immediate impact. The reason for this has to do with the availability of trucks. Often, a customer will have a requirement for multiple daily truck shipments to their plant. Depending on the shipment distance, and driver hours, the morning truck may make a *turn around* and deliver another load in the afternoon. If the morning truck is**

held up, it can result in a delay of the later shipment, since it may be the same truck making that delivery. Trucking companies assess a demurrage charge/penalty to get trucks back into service quickly, as well as to help offset the expense of driver wages, since the truck has been removed from service until it is unloaded. In reality, the trucking companies, as well as the railroad companies, do not want to have to charge demurrage and would prefer to get their truck or hoppercar back into service, since this is how their revenue is generated. The demurrage charge does little to offset the lost revenue.

Historical origin and definition of the term "Demurrage": **This word originally came transportation by ships. The following description of demurrage came from the *'Lectric Law Library Lexicon on Demurrage* - "The freighter of a ship is bound not to detain it, beyond the stipulated or usual time, to load or deliver the cargo, or to sail. The extra days beyond the lay days (being the days allowed to load and unload the cargo), are called the days of demurrage. The term is likewise applied to the payment for such delay, and it may become due, either by the ship's detention, for the purpose of loading or unloading the cargo, either before, during or after the voyage, or in waiting for convoy."**

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2. When I called to place an order for lime by truck I was told there was a *shortage of trucks*. All of the lime companies I talked with also confirmed this. Why does this happen? Also, how do the trucking companies maintain enough trucks to serve the lime market and what can I do to help avoid these truck shortage situations?

Lime is usually shipped in a *pneumatic trailer*, which is a specialized tank truck with a blower that can blow the lime from the truck into the silo of the customer. Because of the freight cost factor in shipping lime, the lime market is generally a regional one, with most shipments destined to customers in the state where the lime plant is, and/or the adjoining states. A number of trucking companies include the lime market in their transportation business, and acquire enough pneumatic trucks to serve this market. The combined number of trucks available continually adjusts to general market conditions, and can change, but generally this involves assigning new equipment to the market area, which can involve some delay. Also, any equipment moved to meet the demands of the local market has to be withdrawn from another competing market area. In any case, the number of trucks within a geographical lime market area can be viewed as somewhat fixed over the short-term.

When a lime customer calls a lime producer for orders, that lime company will call one of more of the truck carriers that handle the local lime market, and set up a shipment schedule(s). For the most part, all of the lime companies use the same commercial truck carriers, though some carriers may be designated as the primary carrier for a customer. Throughout any day the availability of trucks can vary, dependent upon the demands of the lime market. Also, there are a number of industries that can place tremendous, short-term demands on both the lime producers and the trucking companies as a result of customer equipment problems, production problems, unusual weather, plant startups, etc. In arranging for trucks, it's not unusual to find that there are *short-term* shortages of trucks throughout the day. But this can, and often does, dramatically change during the day. Another key factor in truck availability involves the *Driver Time*. Recent changes in the law require that drivers can only drive for a specific period of time, after which they must rest for a minimum number of hours. This becomes a factor since there are only a number of total drivers serving a specific lime market area. The trucking companies do their very best to try and maintain enough drivers and pneumatic trucks to serve the local lime market without having their drivers or trucks inactive.

Placing orders with a lime company as early as possible helps a customer avoid many of the unanticipated problems associated with truck shortages. However, much of the lime market involves servicing those industries who have enormous short-term demands, which is a very important and much appreciated business for lime companies. Those customers who experience a short-term truck shortage may find solace in knowing that the availability of trucks in the market is quite fluid and changes frequently. For the most part, the lime companies are able to meet the daily demands of the lime market during truck shortages through the patience and understanding of the valued customer.

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3. I am considering comparing getting my lime by rail vs. truck. What are some of the pros and cons regarding these two modes of lime delivery?

Both modes of receiving lime have advantages and disadvantages. Following is a list of points to consider:

1. ***Do you have a rail siding coming into the plant?*** **If you do not have a rail siding coming into your existing plant then the option to receive lime shipments by rail is not available to you, unless you are willing to provide rail access to the plant. In the planning of a new plant it's important to address the issue of potential rail delivery of lime during the early design stages. This is because rail delivery of quicklime will require a railroad spur to the**

lime unloading site, an unloading system of some type and adequate silo storage, usually at least a 150 tons. (For reference, a hopper car of quicklime weighs approximately 100 tons.)

2. ***Are you using quicklime or hydrated lime?*** **Pebble quicklime is often carried via covered rail hoppercars while hydrated lime generally is not carried via rail. Hydrated lime is a fine powder which would require a special PD railcar (pressure differential). This type of railcar could also handle a granular or pulverized quicklime. For the most part, unless the volume of hydrated lime used is significantly high, it is usually carried via pneumatic trucks. (As a general guideline you can consider that pebble quicklime can be carried by pneumatic trucks or bottom drop rail hoppercars, whereas hydrated lime is usually carried pneumatic trucks. Please be aware, however, that there are exceptions to this.)**

3. ***Truck Delivery Advantages and Disadvantages:*** **Receiving lime by truck offers an excellent and quick way to meet your lime requirements. Assuming that the lime supplier has product available, the only time delay is that of the setting up of the trucks and the travel time to your plant. The lime is delivered from the pneumatic truck by blowing the lime into your silo. The silo should be able to hold at least a full truck of lime, however, it's better to have a silo capable of holding about two trucks of quicklime (50 tons) lime to provide room for a recent truck order and to provide a cushion in the event of a truck delay, or product availability issue. Because a truck only holds about 1/4 of a railcar, you will have about four trucks to every rail car. Also, if you are receiving lime from a transloading terminal, you will be paying the cost of the transferring the lime from a railcar to a truck, plus the cost of the truck freight to your silo.**

4. ***Rail Delivery Advantages and Disadvantages:*** **Assuming that you have a rail siding that is accessible to your plant, rail delivery offers an excellent way to receive pebble quicklime. The freight rate is generally lower than the truck rate, especially the further your are from the lime source. Also, each railcar, which holds about 100 tons, is about equivalent to four trucks of 25 tons each. As with truck delivery, there are disadvantages to consider. There are initial costs involved with extending existing rail sidings to allow access to the lime silo location. A railroad switch has to be installed, as well as a rail unloading system and adequate silo storage. Since most railcars hold about 100 tons, the silo should be at least 150 tons in capacity; preferably larger. Also, rail delivery requires planning. As a guideline, a delivery time of seven to ten days is useful to use, though often it's closer to five to seven days. As a result of the days required for rail delivery, planning of lime usage is required. Since planning is an integral aspect of most plant operations, this should not be an issue where lime usage is consistent and relatively predictable.**

5. ***Is Truck Delivery Best For Me?*** **This is a question only you can answer, however, there are some thing to keep in mind in considering rail delivery. As a general rule truck delivery is most often considered when (a) lime usage is very unpredictable (b) there is no rail access to the plant, (b) the volume of lime used is relatively low, (c) no rail siding, switch, rail unloading equipment adequate silo capacity is available nor is the company willing to commit to the capitial expenditures to provide for these. (If only hydrate is used, only truck delivery is usually considered.)**

6. ***Is Rail Delivery Best For Me?*** **As with truck delivery, this is one that only you can answer, however, in considering rail delivery there are some things to keep in mind. As a general rule, rail delivery is most often considered when (a.) a relative high volume quicklime is being used, (b.) the plant already has rail access to some degree, (c) and the company has an existing rail siding, switch, rail unloading equipment and adequate silo capacity in place or is willing to commit to the capital expenditures required to provide these. (All plants have the capability to receive lime by rail should be able to receive lime by trucks as well, which will enable the plant to obtain quicklime on short notice when the usage cannot be anticipated.)**

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4. I am considering using a *Pressure Differential* railcar (*PD Car*) for lime delivery by rail. What kind of railcar is this and is there any reason why I would not want to use this type of car?

The *Pressure Differential (PD)* railcar is a specialized railcar that has the capability of blowing lime directly from the railcar to the silo, in the same way that a pneumatic truck can blow lime from the truck to the silo. It can be used for both hydrated lime and quicklime. For the most part, quicklime is carried by bottom drop covered hoppers that require that the lime drop into a pan under the car where it is then drawn into an unloading system that then blows the quicklime into the silo. The PD car appears to be a great alternative to using the bottom drop cars, however, there are issues to keep in mind when considering this type of railcar.

The railcars used for quicklime are part of a *Car Pool* of railcars designated by the railroad for lime. Lime suppliers

request a specific number of cars to be dropped off for loading. The quicklime is then loaded into these cars and then shipped to the customers. Generally, the railroads do not have PD cars in this pool of cars. PD cars are owned by either the lime company or the customer. Even if the PD cars were available for customer use, because the lime company owned some, or the customer owned them, there can be a monumental logistical problem involved with using PD cars. A customer that specifies the use of PD cars would have to be certain the car had made it back to the lime plant in a timely fashion. When they placed their order for quicklime the timeliness of the delivery of their product would be dependent upon whether the PD car was available. With bottom drop cars the lime company simply takes the order for the car load and ships it as soon as car is available which may very well be that day, or within a day or so (usually). With the PD car there may be a considerably delay waiting for the PD car to be returned, or made available (brought in) by the railroad.

In summary, using PD cars is not out of the question, but any company that wants to consider them needs to keep in mind that these cars are not usually part of the car pool and are not often used lime companies. They also need to be aware of the significant logistical issues in using a very specific car that must transit between the lime plant and the customer.

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5. I am planning to starting ordering truckloads of bagged hydrated lime. Should I have the lime delivered by a flatbed or van type of truck?

Generally, you only order bagged hydrated lime by a van truck (box) if you have an unloading dock. Flatbed trucks are primarily used when there is no loading dock available. A flatbed truck can be easily unloaded from the side of the truck with a fork lift. (Unloading a van truck without a loading dock is difficult and time-consuming. Each of the pallets would have to be pulled to the end of the truck with a pallet jack and then removed with the fork lift. Unloading a flatbed truck from a dock is dangerous because the forklift driver runs the risk of driving off the open side of the flatbed.)

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6. When I order truck shipments of lime my lime supplier sets up the trucking. Should I consider having my company handle the transportation arrangements or should I continue to have my lime supplier handle this?

At various times lime users are faced with deciding whether to set up their own trucks or have their supplier to do. Answering this questions requires careful consideration of a number of key issues. Listed below are some of the issues that need to be kept in mind:

1. ***Lime companies do not mind if a customer sets up their own trucks:* Setting up trucks for customers is a very important and integral part of the lime supplier's business, however, any customer who handles their own transportation frees the lime supplier from the scheduling of trucks, which is always welcomed.**

   ***Advantage:* Those lime users who set up their own trucks do have an advantage in that they can have their trucking company send in a trucks to pick up lime as needed. Often, the delay the lime supplier experiences in not getting trucks out to their customers right away is the result of trucks not being available. Having the lime customer handle the transportation avoids this problem, however, those companies that do set up their trucks need to be certain that product is available before sending their truck in to load.**

   ***Disadvantage:* The logistical issues of a lime user arranging a large number of trucks from different trucking companies, however, may be a difficult undertaking and they will need to make certain that trucks they scheduled actually do arrive at the lime supplier's plant.**

2. ***Lime suppliers have established relationships with multiple trucking companies:* Some lime users, such as those in the pulp and paper industry, have unplanned, high volume needs for quicklime. During these periods of high demand all of the regular lime carriers in a particular area are required. Most lime suppliers already have established, ongoing relationships with the carriers that are able to serve their plants. Because of this, it may often be much more practical for the lime customer to allow the lime supplier to handle all lime shipments.**

3. ***A lime user may be able to negotiate a freight cost savings:* In some cases a lime user may be able to negotiate a better freight rate by dealing directly with the freight company. A rate can be established with a particular carrier for the routine shipments. During periods of high demand (planned or unplanned outages) all of the**

other truck carriers can be used.

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7. What is the difference between *Short Miles* and *Practical Miles* in determining freight rates and why can there be differences between the two mileages when going to the same location?

Short Miles and Practical Miles Defined: **Short miles represent the shortest distance between the origin and destination that a commercial truck can travel. Practical miles represent the fastest distance between the origin and destination and may be longer than the short miles. Since truck lime freight rates are based upon the shipment (product weight times freight rate), and not trip time, short miles represent the lowest overall freight cost for the customer.**

Historically: **The lime freight rates were based upon *Rand McNally* short miles. In recent years a number of the truck companies have gone to an alternative mileage source; *PC-Miler*. In comparing short miles for the two mileage sources you will find them nearly identical since, assuming the road information is up-to-date, the shortest commercial truck distance between the origin and destination is simply a matter of adding the distance of each segment of the trip; which is a fundamentally simple algorithm to compute.**

Conversion to PC-Miler: **In the conversion to *PC-Miler* some of the trucking companies have made the decision to use practical miles rather than short miles. This presents the customer with a dilemma. To see the problem envision four truck carriers with nearly the same scale tariff rates, with two of the carriers using short miles and two using practical miles. On the surface they would all appear to have nearly the same scale rates, however, since two of the carriers use practical miles there are often instances when there is significant difference in total truck cost due to the difference in short and practical mileages.**

Analogy for Short and Practical Miles: **A lifeguard rescuing a swimmer offers a good overview of short vs. practical miles. A lifeguard watching over swimmers knows that he can run much faster on the beach than he can swim in the water, so he takes this into account in his rescue plans. If the person to be rescued is in the water directly in front of his lifeguard chair he simply runs to the edge of the water and swims directly to the swimmer. (In this case the shortest and fastest distance are equal.) As the position of the swimmer moves further and further up or down the beach the difference between the shortest and fastest options begin to increase. Generally, the lifeguard would run down the beach to a point where the swimming distance is minimized then enter the water and swim the shortest distance in the water to the person. Often, in these cases, the quickest distance is longer, although faster.**

Factors for a Carrier to Elect to go to Practical Mile: **Because of the change in the hours of operation for a driver, going the quickest route, rather than the shortest would appear to help preserve driver hours. However, the extra distance requires more fuel, which offers an offsetting disadvantage. Also, the algorithm used in determining practical miles is more complicated and subjective than short miles algorithms since they involve driving speeds, traffic congestion and road construction. These can vary far more frequently than the simple short distance to the destination. Also, the discrepancy between short and practical miles makes it difficult to compare carrier rates. As a final note, it is unlikely that the truck drivers would not elect to take the shortest route, even if it were longer than the practical miles route.**

What is a Carrier Solution to the Problem? **All truck carriers would be far better served to use the traditional standard short miles (*Rand McNally*, *PC-Miler* or alternative mileage sources) so that significant mileage differences are no longer an issue. If the carrier believes that the short miles do not provide enough truck revenue for the haul then they can simply increase their tariff scales rates to offset this.**

What is a Customer Solution to the problem? **There is a relatively simple method to solve this problem. If the largest carrier uses short miles, then all shipments by all carriers are based upon short miles. Rates of carriers continuing to use non-short miles would find that all of their rates are now determined on a point-to-point basis, and ultimately then end up with all point-to-point rates.**

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USING THE WEBSITE:

1. When I try to view a PDF file in my browser it does not appear. All I get is a small icon on a blank page. Why does this happen and how do I correct it?

Many people use *Adobe Acrobat* to view PDF files while using their browsers. The PDF file is automatically loading into the browser as as a web page. Sometimes a problem can arise in viewing PDF files this way because of issues

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2. **Why are all the Questions and Answers on the FAQ's (Frequently Asked Questions) web page displayed on single page, rather than on multiple pages of the website?**

   By having all of the FAQ's, (and answer sections) on one page, a person wanting a hard copy of all of the information, without using the PDF file provided, can simply print the entire FAQ's web page and place it in a file for reference. Having the information on multiple web pages would require the person to go to each specific page of interest, and print that one particular page, then go on to another pages. Individuals wanting just a limited amount of information from the FAQ's web page can cut and paste that information into a word processor, or simply print the pages of interest from the PDF file provided.

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