In the Limelight

Narayana Jayaraman and Francisco Benavides, PEC Consulting, detail the configurations and deliberations behind the construction of a lime plant.

Introduction

The manufacture of quicklime (sometime referred to as lime or CaO) involves a simple chemical process, involving the calcination of high-grade calcium carbonate ($CaCO_3$) at a temperature ranging from 950 – 1150 C. However, there are challenges associated with the choice of appropriate technology and design, based on the following factors.

Lime plant design factors

Production capacity

The plant's production capacity acts as the first filter in determining the type of kiln. The available options for various capacities are as follows:

Capacity >900 tpd

Single kiln large capacities are best produced by rotary kilns, long rotary kilns, or rotary kilns with preheaters. The choice of a kiln with or without a preheater depends on the raw material and fuel characteristics, and the specific needs of the product. Long kilns have a specific heat consumption in the range of 1400 – 1600 kcal/kg-lime. Preheater kilns have a better specific heat consumption of 1200 – 1400 kcal/kg of lime. For low sulfur lime, rotary kilns without preheaters are commonly used. A waste heat recovery system may be employed to increase energy efficiency.

Capacity <250 tpd

Typically, single shaft kilns are suited for small capacities, as they are compact and economical to build. Their specific heat consumption is in the range of 1000 – 1200 kcal/kg of lime.

Capacity 250 – 900 tpd

This is the most common range and presents the widest choice of kiln system. The parallel flow regenerative (PFR) kilns are by far the most efficient in fuel consumption (approximately 800 kcal/kg of lime). Single shaft kilns can be chosen at the lower end of the range and rotary kilns at the higher end.

Lime kilns are very sensitive to the feed size of limestone. To ensure uniform calcination, the ratio of the largest to the smallest stone is limited to 2 – 2.5 in the case of vertical kilns (both single shaft and PFR kilns). It is slightly higher for rotary kilns where the ratio can be up to 4.

Stone size limitation is an important factor that determines the yield of usable limestone from the run-of-mine (ROM) material. Despite good chemical composition, the fines cannot be used in the kiln and would have to be rejected.

If the total capacity requirement is high, using two kilns should be considered, one with coarser and the other with finer feed fractions, each still conforming to the size ratio.

Chemical and physical characteristics of limestone

The chemical and physical characteristics of the raw material determine the choices of the kiln technology that could be used. Vertical kilns are more sensitive to the physical properties than a rotary kiln. Limestone (or other raw material) that breaks easily in the raw form (shatter) or during calcination (decrepitation) disturbs the desired ratio of maximum to minimum feed size and the permeability of the material column for the gas flow.

The raw materials need to be tested before the bid documents are prepared, specifying the kiln type. As part of the bid process, the kiln manufacturers need to do their independent testing of the chemical and physical properties of the raw materials, and provide their warranties accordingly.

The nature of limestone and the feed size requirements dictates the crushing and screening system.

Type of fuel

Oil and gas firing has optimum handling in a shaft kiln. Using pulverised coal, or petcoke, as a fuel is equally common. Coal firing requires coal handling equipment, a grinding installation, and pulverised coal distribution system.

Coal firing in a rotary kiln is relatively easier than in a shaft kiln, since there is a single point of firing versus multiple burners for the vertical kilns.

Figure 1. Metso preheater kiln.

Logistics for ingoing and outgoing materials

The unloading of incoming material and loading of outgoing products need special consideration in the layout and handling system, depending on the mode of transportation (be it truck, rail or, barge). Each mode of transport calls for its own space and facilities, which is vital information before the plant concepts are developed.

Market requirements for lime quality

The market dictates the product's granulometry and whether it will be packed in bags or bulk. The choice of equipment will depend on how the product will be dispatched.

Product mix: hydrates or other products, such as precipitated calcium carbonate (PCC)

Another factor that impacts the design of the lime plant is the product mix. If the end products include hydrated lime, the hydrating plant and all intermediate storages become an important part of the project. If PCC is also one of the end products, the equipment will need to be more elaborate (slaker, CO_2 capture system, carbonation unit, dryer, and packing units, etc). Typically, the percentage of these products is low, but it fetches a good price, assuming there are accessible markets. Transportation costs are a consideration in the design, as it may be more economical to place the hydrating plant closer to the market.

Overview of a lime plant

Quarry and mining

Good quality raw material deposits need to be identified and earmarked for mining and utilisation for the lime production. Due to the nature of the quarry, selective mining will need to be adopted to segregate the lime quality raw material. Due to the requirement of fines-free raw materials for lime production, the blasting, crushing, and screening need to be designed to generate the minimum amounts of fines.

Considering the high level of investment required for the facility, it is important to ensure that the plant will have adequate, quality proven raw material resources to last at least 30 years. Very often, the owner tends to neglect the importance of a scientific determination of the raw material quality and quantity before ordering the equipment. There have been cases where investors discover the inadequacy of the raw materials after the plant is built.

Industry-experienced geological and mining consultants are essential participants in selecting and designing the mine plan in cooperation with the process engineer.

Crushing and screening

The crushing and screening of limestone in a lime plant is an important component to the plant configuration. The limestone needs to be segregated into a usable feed size. If there are many kilns, each using different stone

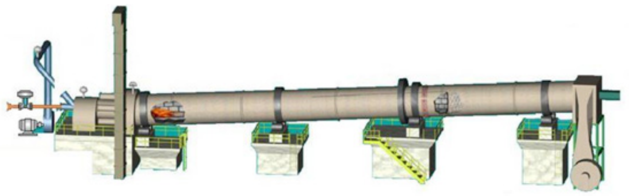

Figure 2. Long rotary kiln

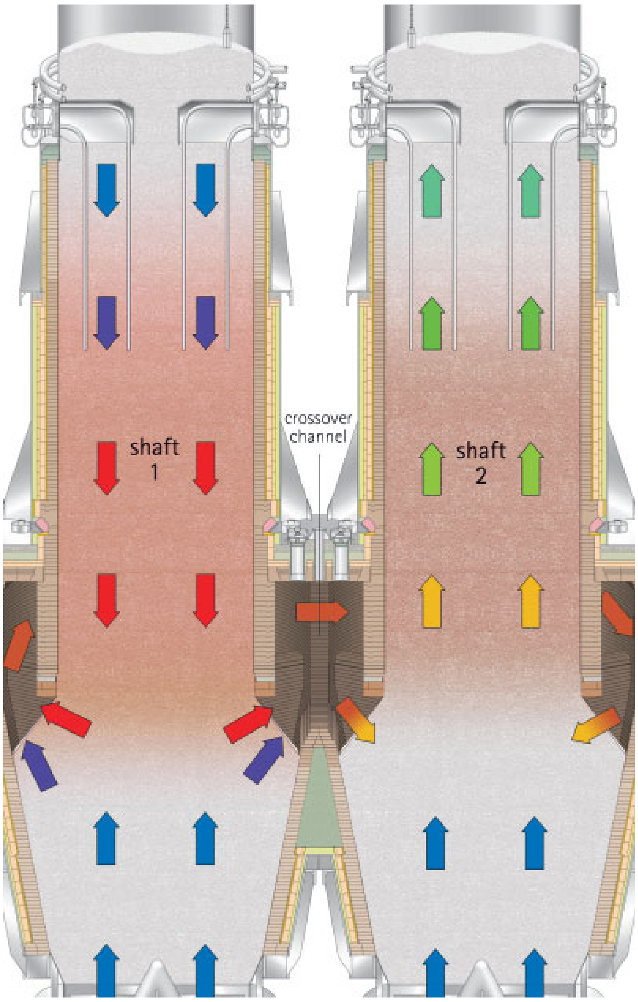

Figure 3. PFR kiln.

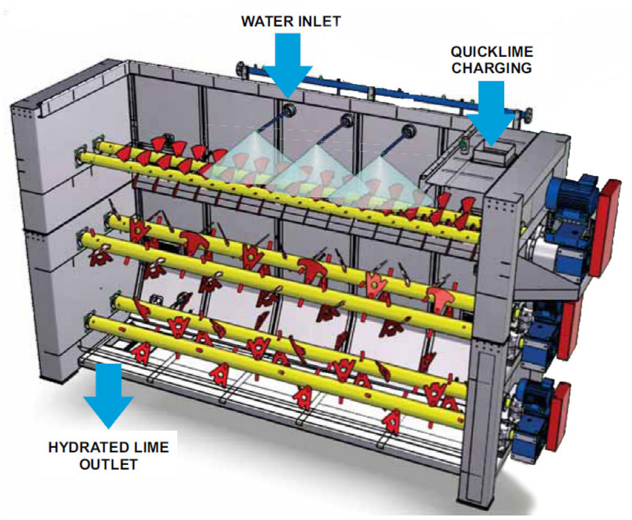

Figure 4. Cimprogretti's hydrator.

fractions, the screening needs to be designed to create individual feed sizes with a reject pile for undersize rock.

A scalping screen is placed in front of each kiln feed to remove the fines generated during handling. The shaft kiln operation is impacted negatively by the presence of fines. It is therefore important to screen off all the fines, before they are fed to the kiln.

Limestone storage and handling

The limestone storage and handling system is designed to ensure minimum relative movement of limestone to reduce the generation of dust that needs to be avoided.

Limestone feeding arrangement

If the layout permits, limestone fed through belt conveyors provides the best arrangement in terms of minimum material movement and lowest maintenance issues. However, the layout sometimes limits the use of a belt conveyor; a steep angle skip-hoist is therefore chosen instead. The skip-hoist arrangement is compact, but it comes with some maintenance and control issues.

Calcining system

There are several options for the kiln systems; however, other factors, such as capacity, limestone, and fuel characteristics restrict the choice of kiln type.

The specific heat consumption of the process varies with the type of kiln, from the lowest for PFR kilns to the highest for long rotary kilns. Conceptual pictures of the various lime kilns are in Figures 1, 2, and 3.

There are other special design kilns, such as Polysius' suspension calciner or cyclone preheater kilns for fine materials, such as sea shells used as raw materials. Although there are very few calcining systems of this kind operating in the world, it is mentioned here as an available option for fine raw materials.

Cooler

Vertical shaft kilns do not need a separate cooler, and the kiln itself has a cooling zone for cooling the lime and returning the recuperated heat to the process improving the efficiency of operation.

Rotary kilns have contact coolers for the same function described above, but as a separate unit. All the cooling air is used for combustion or the coal mill operation. No part of the cooler air is vented out to the atmosphere.

Gas handling system

All kilns require a dedicated gas handling system for dedusting the kiln gases and creating the necessary draft for the gas flow. The gas is vented out after dedusting in a baghouse, ensuring compliance with prevalent emission rules. The dust is recycled or disposed of as waste. The kiln fan is the biggest electrical consumer in the system.

Lime crushing/screening and storage

The product is typically the same size as the limestone, which can be crushed and screened per market requirement. If there is a downstream processing requirement, the lime, after conversion to hydrates, is ground in a ball mill and screened, if necessary, for further dispatch.

Hydrator

If hydrated lime is one of the products, the quicklime is mixed with water to form $Ca(OH)_2$. Cimprogetti's hydration system is illustrated in Figure 4.

Storage and loadout

The products from the lime plant are graded and stored in silos for loading on to trucks, rail, or barge. Due to the reactive nature of quick lime, it needs to be stored in closed silos or domes, avoiding contact with personnel and moisture.

Plant configuration

In addition to the various factors that affect the design of a lime plant, whether the plant is a stand-alone unit or part of other systems is also another consideration. Potential combinations include the following:

- Lime plant and a cement plant: this combination provides the best utilisation of the limestone reserves. Better-quality limestone is used for lime production and the limestones with lower CaO content can be used for cement production. Furthermore, the fines from the screening section of the lime plant can act as a sweetener for the cement plant.
- A vertical shaft kiln and a rotary kiln, both for manufacture of quicklime, provide a better utilisation of the limestone reserves, with the coarser fractions used for the shaft kiln and the fines for the rotary kiln. With two types of kilns, different product specifications can be obtained, such as reactivity.
- A captive unit to other mainstream products will be specifically tailored for the main product. Special quality requirements for captive consumption are considered in the plant design.

Conclusion

The lime plant configuration is thus a product of many design factors. It is important to review all the factors and situations, while developing the concepts for the lime plant.

About the authors

Narayana Jayaraman, Director-Technical Services, has over 50 years of experience in the cement and lime industries in various capacities with a major focus on process and technology.

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