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An innovative single-tier lime hydrator

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Hydrated lime is an industrial chemical deployed in a large number of manufacturing processes and products. The exothermic reaction of finely divided quicklime with water in a vessel triggers off excessive heat resulting in evaporation of water. The steam generated not only hydrates the reactant, but also causes the hydrated lime particles appear to behave like boiling fluids. This principle of fluidisation is employed in a single-tier lime-hydrating machine. The new machine has been designed on the above mentioned criterion and it consists of simply one hydration chamber, just preceded by a premixer. Another special feature of this machine is its capability of retaining the slowly-hydrating material over longer periods of time, while discharging soft burnt lime at a rapid pace. Design aspects like water and power consumption, power distribution to various components, elimination of impurities and economics of the plant are discussed in this paper. The new hydrator will be capable of producing quality lime along with cost-effectiveness.

Three tier lime hydrating machines of various types were designed and developed at CBRI in the recent past. This equipment was designed mainly for hydration of class 'C' lime. In the case of class 'B' and dolomitic lime, the period of hydration requires to be extended[1,2]. Some systems of hydration extensively employed earlier sought to extend this period by passing the material from the hydrator to a storage silo (also called ageing or maturing silo) for keeping it intact over a period of about 24 hours before air separation. However, this process involved practical difficulty for the extraction of the hydrate from inside of the silo[3].

Lime is a highly absorbent material especially when lightly burnt and it absorbs a little more than enough water to satisfy the stoichiometry of the hydration reaction with nothing in excess to dissipate the heat of reaction by its evaporation. The hard-burnt lime hydrates slowly and it absorbs less water than is required to satisfy the chemical reaction. In such a case, the material stored in the maturing silo will consist of substantially dry hydrate from the reactive lime, unhydrated lime from the less reactive variety and the excess water (unreacted or non-evaporated). Due to evaporation only some portion of the excess water will be absorbed by the residual unhydrated lime. Consequently the material coming into the maturing silo consists of dry hydrated lime mixed with pieces of quicklime containing a little water for complete hydration at 100°C. By that time lime already containing too little water for complete hydration will lose some of this water by evaporation due to the heat of reaction and in the static mass there is no means, other than slow diffusion, by which more water can reach it. Maturing silo thus does very little to assist the process of hydration[4,5].

In view of the aforesaid considerations, a mechanical lime hydrating machine to yield a continuous supply of about 5 T of dry hydrated lime per shift has been designed. This machine will automatically differentiate between slow and rapid slaking lime and will discharge the latter as soon as possible after the reaction, while retaining the former until it is hydrated. The rapid passage of the reacting lime balances the longer retention time of the slowly reactive constituent. Fortunately, the disintegration which accompanies the normal hydration of most limes provides a means of distinguishing between hydrated and unhydrated lime.

Fluidization with Selective Hydration[6]

A differentiating or selective hydrator has been designed for the continuous preparation of dry hydrated lime at atmospheric pressure. In this machine reaction is carried out in a horizontal trough of special design which is equipped with efficient agitation paddles. In such a short deep vessel the mixing of lime and water cannot be carried out efficiently so the hydration is preceded by a fast running premixer.

Qucklime of 1 cm size and preheated water are introduced into the premixer having agitation paddles to ensure rapid thorough mixing which is an essential first stage of good hydration. The mixture of

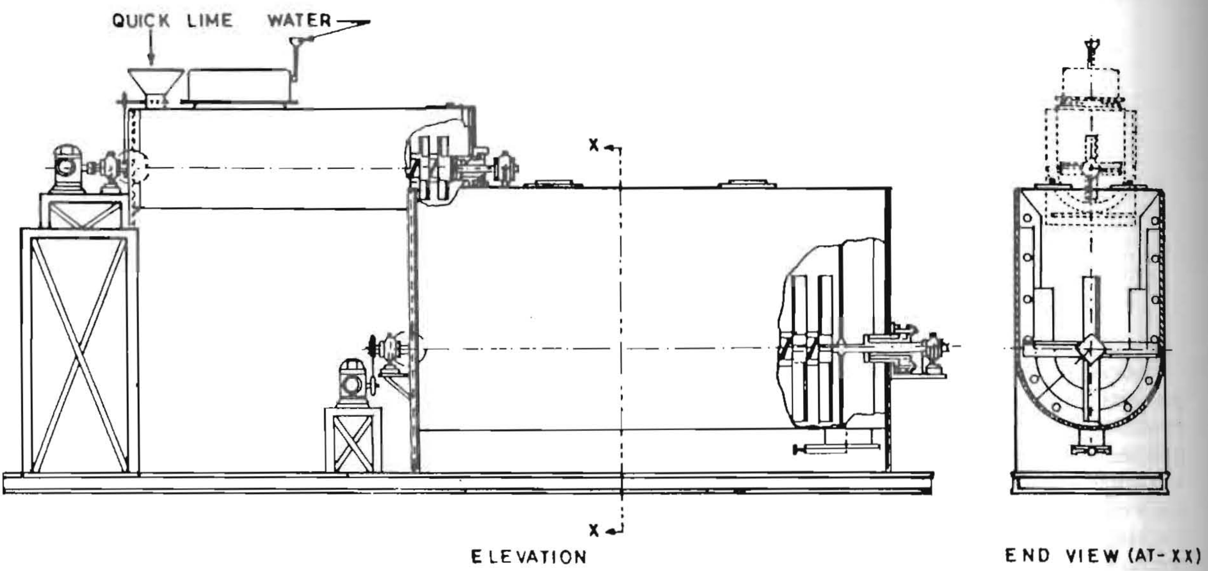

Fig. 1—Diagram of lime hydrating machine (single tier)

lime and water then passes into the main body of the hydrator fitted with slowly revolving stirrer arms. As the hydration is carried out in a deep bed the steam evolved fluidizes that bed and changes its whole character. The heavier slower slaking particles sink to the bottom while the fine hydrate rises to the surface and is discharged over a weir plate fitted in the end frame. Heavier particles are retained in the bottom of the hydrator until hydration takes place which then rises to the surface and is discharged. If the lime feed is free from unburnt stone and other unhydrated material the hydrator can continue indefinitely discharging by overflow, but in practice there is always some residue which accumulates in the machine and occupies useful space, reducing the retention time. It also increases the load on the stirring mechanism. The heavy residue is removed from the hydrator at regular intervals through a bottom valve. The selective hydrator utilizes fluidity and gravity to distinguish between fine hydrate and unhydrated lime.

Some limes are so highly reactive with water that preheating is unwarranted but the greater number of those treated in commercial hydrators are slow in commencing to react with cold water and efficient preheating makes an enormous difference to the rate; and thereby to the throughput of the plant. During hydration, a large quantity of heat is released due to the exothermic reaction taking place. The steam generated during the process of hydration is not allowed to escape to the atmosphere, but is utilised in preheating the water that affects hydration process. In practice the quality of water required for complete hydration of high calcium quicklime is about 60 per cent of the weight of solid lime.

Water and Power Requirement

An important feature of the selective fluidized hydrator is the way in which the power exerted to drive the stirring arms varies with conditions in the machine. It was found that the power required is minimal when conditions match appropriately for hydration, and that the requirement rises on either side of the correct conditions. The best conditions for hydration are those in which the maximum possible amount of water is used consistently with the discharge of substantially dry hydrate which involves a maximum amount of water vaporized in the hydrator. This in turn entails a high level of fluidization and it is the fluidization which decreases power consumption. A fully fluidized hydrator requires scarcely any more power than when the machine is running empty.

The rise in power consumption is sharper when too little or too much water is used. In the case of excessive water the degree of fluidization decreases and load on the system goes up. On the other hand if there is insufficient water to dissipate the excess heat by evaporation, the temperature in the hydrating mass rises above 100°C. At this temperature coherence of the hydrated particles and their adherence to the stirring mechanism take place, and all free moisture disappears. The cohering powder grows as a soft mass from the stirrers until it touches the side, at which point the load increases sharply.

Rate of Hydration

The extent of reaction between the lime and water depends upon the concentration and temperature of the reactants, besides the characteristics of quicklime. Even in limes of the same purity level, the rates of hydration can differ widely. It is, therefore, desirable that the rates of hydration and the optimum hydration conditions should be determined individually in each case. The rate of reaction can be affected markedly even by slight deviations in the conditions of hydration[7].

Increase in MgO content has a retarding effect on the rate of reaction. The greater the level of impurities, the slower is the rate of reaction. Pores are logged and the surface is partially coated with a slag formed by lime fluxing of such impurities as silica, alumina and iron, rendering it more impervious to water[8].

Provision for Hydration of Less Reactive Lime

This machine will distinguish between slow and rapid hydrating lime, and will discharge the latter as soon as possible after reaction while retaining the former until it is hydrated. Most limes, even those that are considered to be of the highest quality, contain a proportion of material which reacts slowly.

Assuming a lime containing 80 per cent active and 20 per cent relatively inactive is used in the selective hydrator which may have an average retention time of 30 minutes, i.e. the hydrator holds one half of its hourly output. If the output is 1 ton per hour then the hydrator holds half ton. The 80 per cent of rapidly reacting lime may complete its hydration (at about 100°C—the temperature inside the hydrator) in about 7.5 minutes (which is quite a normal figure) so that 800 kg of the 1 ton remains in the hydrator only for 7.5 minutes and the amount in the hydrator at any point of time is only $(800 \times 7.5)/60 = 100$ kg leaving the space for 400 kg of the less reactive lime. This lime (200 kg an hour) of the less reactive lime. This lime (200 kg an hour) can remain in the hydrator for an average of $400/200 = 2$ hr. Since some of the 20 per cent will need much longer retention of a very inactive lime.

Some of the salient features of this lime hydrator are:

1. It consists of a trough shaped deep and large horizontal vessel for hydration preceded by a fast running small paddle premixer.

2. A wet dust collector is provided with the lime hydrating machine to make the lime dust settle with the feed water. It has been seen that hot water (at 60-70°C) accelerates the slaking process. To raise the temperature to this level the steam and lime dust generated inside the troughs are brought in contact with the incoming water. The hot milk of lime thus obtained is passed to the premixer through the spraying jets for more uniform distribution.

3. Flexibility in the design-retention period available for the reaction between lime and water can be adjusted by changing the height of the weir plate. Retention time can vary automatically in the hydrator for different reactivities of quicklime.

4. The operation of the hydrator is dust-free.

5. Better quality control achieved.

6. The equipment is suitable for hydrating high calcium quicklime as well as dolomitic lime.

7. The machine is capable of being split into a number of subassemblies for ease of maintenance and transfer.

Power Distribution in the Machine

For hydrating machines of capacities ranging between 1 to 20 T/hr, the power requirement ranges between 5 and 40 H.P. This is made up of the total resistance such as friction of the material against the trough, surface of the paddles, bearings mixing and due to the hard crust on the trough wall.

An electric motor of 2 H.P. is connected by means of a flexible coupling to the speed reducer to obtain the required speed in the case of high speed mixer. For main hydrating chamber an induction motor of 3 H.P. is connected by means of a flexible coupling to the speed reducer (Worm & Worm Wheel type). The required speed is obtained by means of a pair of steel sprockets.

Equipment Specifications

Capacity of the hydrator	= 5T/shift (8 hrs)
Quicklime required	= 500 kg/hr (approx.)
Water required	= 300 litres/hr (approx.)
Feed size	= 1 cm
Retention time (average)	= 30 min.
Size of the mixer	
Length	= 1.7 m
Dia.	= 42 cm
Size of the hydrating chamber	
Length	= 2.75 m
Dia.	= 90 cm
Horse power	= 5
Weight of the machine	= 2.5 T (approx.)
Pressure	= Atmospheric

Elimination of Impurities[9]

Hydration of quick lime involves the conversion of calcium oxide into calcium hydroxide (and of magnesium oxide into magnesium hydroxide) the other impurities present in quicklime remain mostly unaffected. These impurities need to be eliminated from the hydrate. Vibratory sieves or mechanical air separator of the centrifugal type can be employed to eliminate the impurities and to classify the material to a fine state of sub-division. After milling, the finished hydrate is fed by gravity to storage silos, located above the automatic bag filling machines.

Conclusion

It is desirable that in order to produce standard quality lime, its production be brought in at par with an organised sector like cement, and some incentives be provided to this industry. The pattern proposed for the countrywide lime production could be based on quicklime produced in rural and semi-urban areas brought to central hydration plant to produce dry hydrated lime, packed and marketed like the portland cement. The size of the hydration plant could be suitably chosen to match the regional or subregional production of quicklime.

These plants can be widely distributed and located near the large construction activity centres like metropolitan cities, industrial and housing activity regions, etc. An added advantage of the small scale hydrated lime plants would be the closer proximity to the users, and the transportation expenses would be considerably reduced.

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