A Techno-Economic Study of Lime Manufacture

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ABSTRACT

Lime is a basic industrial chemical used in a large number of manufacturing processes and products. Several lime kilns and hydraters of efficient designs have been evolved at the Central Building Research Institute, Roorkee, in the recent decade and a host of lime plants have been established in various parts of the country. This paper reviews the manufacturing processes, detailed features of the process plant and equipment, layout of the envisaged plant, capital outlays, economic estimates and viability analysis of a lime plant based on optimal considerations of fixed and variable costs. The production of building lime is a small scale labour intensive industry and its units for capacities of 10-20 tonnes per day should be established in the outskirts of metropolitan towns of the country based on the know how provided by the Institute.

Introduction

Quick lime (Ca O) is an industrial chemical of significant importance in the building, chemical and a large number of allied process industries. It is obtained from the endothermic process of calcination of limestone at elevated temperatures according to the reaction.

$$\underset{\text{(Calcium carbonate)}}{CaCo_3} \rightarrow \underset{\text{(Quick lime)}}{CaO} + \underset{\text{(Carbon dioxide)}}{CO_2}$$

The decomposition of calcium carbonate is effected in a kiln of appropriate design using solid, liquid or gaseous fuels. The hydrated lime, $Ca(OH)_2$, is produced by the exothermic process of hydration of quick lime at nearly room temperatures and atmospheric pressure. The reaction can be represented as

$$\underset{\text{(Quick lime)}}{CaO} + \underset{\text{(Water)}}{H_2O} \rightarrow \underset{\text{(Hydrated lime)}}{Ca(OH)_3}$$

The hydrated lime is a fine powder and the process of hydration is brought about in a mechanical hydrator of suitable design. Hardly a few process industries could be identified where the lime or lime-stone do not find applications in the direct or indirect forms.

Manufacture of Quick Lime

Significant developments have been made in the manufacture of quick lime in the past decade at the Central Building Research Institute, Roorkee. Extensive field surveys and laboratory studies were undertaken to investigate and improve upon the design and performance characteristics of the existing lime burning kilns in the country. Based on the feed back studies and scientific analysis of the available data, improved designs of the vertical mixed feed coal-fired lime shaft kilns were developed and perfected in the field for production capacities of 5, 10 and 15 tonnes of quick lime per day. Some of the salient technical features of the kilns are as follows :—

(i) Vertical masonry shaft lined inside with firebricks
(ii) Kiln loading at the top with mixed feed of limestone and steam coal
(iii) Uniformity of natural draft
(iv) Suitable for dolomitic and calcitic limestones
(v) Continuous operation in 2 to 3 shifts per day
(vi) Fuel economy 5-15 percent over conventional kilns
(vii) Amenable to a fair degree of instrumentation
(viii) Manual as well as mechanized charging
(ix) Good quality product output
(x) M.S. rings and angle iron casing provided for 5 tpd kilns
(xi) R.C.C. ring beams and columns casing provided for 10 and 15 tpd kilns.

The kilns operate continuously in three zones, namely, the preheating zone at the top, the calcining zone at the middle, and the cooling zone at the bottom. The calcination zone operates at a temperature level of 900—1200°C with steam coal firing. The shaft of the kiln may be constructed with burnt clay bricks or building stones generally laid in lime-surkhi mortars. The kilns are basically cylindroconical structures with a view to providing uniformity of draft vis-a-vis obtaining higher productivity. The lime kilns of improved design have been installed by entrepreneurs at several places in the country.

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Manufacture of Dry Hydrated Lime

The machine for the hydration of lime has been designed and fabricated for capacities of 10 and 20 tonnes per shift. Extensive field trials have been conducted and the performance of these machines has been found to be satisfactory.

In this machine reaction is carried out in three horizontal troughs which are equipped with efficient agitation paddles. These chambers are positioned one above the other. The free space and holding capacity provided in each chamber are in proportion to the increase in volume of the hydrate during the hydrating process.

Some of the salient features of the lime hydrator are as follows :

(i) 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.

(ii) Water is sprayed by jets for more uniform distribution.

(iii) Retention period available for the reaction between lime and water can be adjusted by varying the height of the weirplates.

(iv) The operation of the hydrator is completely dust-free.

(v) Better quality control is achieved.

(vi) The hydrator is suitable for hydrating high calcium quick lime as well as soft burnt dolomitic lime.

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

Process Description

A process flow chart of a lime plant is outlined in Fig. 1. Limestone is calcined in the shaft kiln (1) and the product, quick lime, lumps are transferred to the hammer mill (2) through a belt conveyor (3). The 75-125 mm lumps of quick lime are reduced to the size range of 10-20 mm in the hammer mill. The hammer mill discharges the product into the boot of bucket elevator (4) which feeds the material at the top of the hydrating machine (5) where a regulated flow of water is also fed into the top tier. The quick lime and water are premixed in the first tier. The hydration takes place in the middle tier and the finishing of the product is effected in the third tier at the bottom. The hydrated lime powder discharged from the hydrator is conveyed to the curing bin (6) through a screw conveyor (7) and bucket elevator (8). The cured product is screened through a vibrating screen and the fine hydrated lime product is packed in polyethene lined bags and stored for marketing. Further size classification is required for chemical grade of hydrated lime only which is not considered necessary for building grades. A layout of the proposed hydrated lime plant as envisaged is shown in Fig. 2.

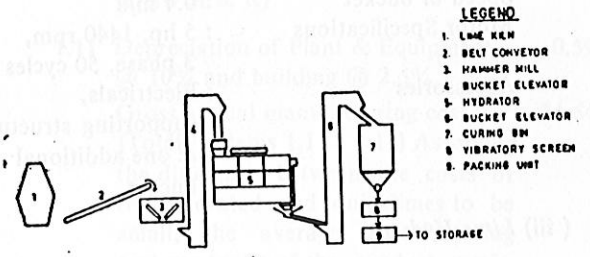
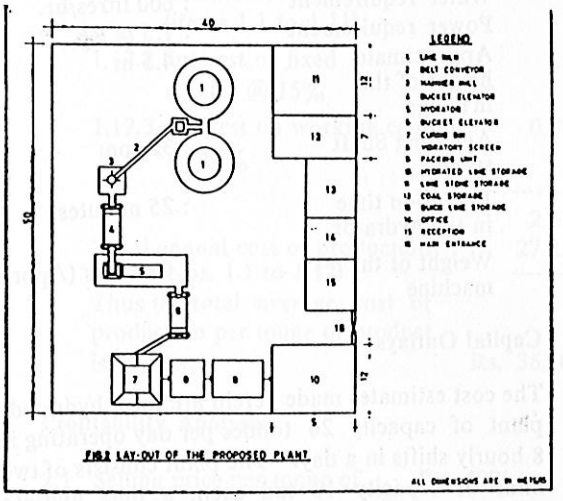


FIG.1 PROCESS FLOW CHART FOR THE MANUFACTURE OF HYDRATED LIME



Major Specifications of Plant and Equipment

(i) *Lime Kiln*

Capacity	:	10 tpd
Effective height of the kiln	:	11.00 m
I.D. at top of kiln	:	2.30 m
I.D. at 6.90 m height from GL	:	3.00 m
I.D. at bottom of kiln	:	1.80 m
Height of preheating zone	:	4.10 m

Height of burning & cooling zone	:	6.90 m
Wall thickness of masonry shaft	:	95 cm
Fire brick lining thickness	:	23 cm

(ii) *Charging Device for Lime Kiln*

Type	: Single bucket encounter weighted hoist type
Capacity	: 10 tpd
Size of bucket	: 687×782×831 mm
Bucket charge	: 500 kg.
Speed of bucket	: 0.4 m/s
Motor Specifications	: 5 hp, 1440 rpm, 3 phase, 50 cycles
Accessories	: Electricals, supporting structures & one additional bucket

(iii) *Lime Hydrator*

Capacity	: 10 tonnes of hydrated lime per shift
Pressure	: Atmospheric
Quickline required	: 8 tonnes/shift (Approx)
Water requirement	: 600 litres/hr.
Power requirement	: 7.5 ~~m~~ Rp
Approximate height of the machine	: 4.5 m
Agitating Shaft speed	: 32 rpm
Retention time in the hydrator	: 25 minutes
Weight of the machine	: 4 tonnes (Approx).

Capital Outlays

The cost estimates made herein are for a hydrated lime plant of capacity 20 tonnes per day operating in two 8 hourly shifts in a day. The plant consists of two lime kilns of capacity 10 tpd each, a lime hydrator of capacity 10 tonnes per shift, mechanical charging devices for the lime kilns, and the related plant and equipment for the hydration unit. The estimates given herein form a basis for the setting up of a lime plant with an idea of overall investment that may be required. The cost figures are based on the countrywide averaged values and do not take into account the local and wide ranging fluctuations in typical lime producing zones of the country. This has been done with a view to studying the econimic feasibility of this process. The actual returns on investment could be worked out by a prospective entrepreneur from a knowledge of the specific site, exact nature and source of financing, and the costs of locally available materials.

1. Fixed Capital Investment

	Rs. (Lakhs)
(A) Land and Buildings	
A1. Industrial land 2000 m² @ Rs. 25/- per m²	0.50
A2. Factory building/sheds 250 m² @ Rs. 500/- per m²	1.25
A3. Office building 40 m² @ Rs. 1000/- per m²	0.40
A4. Site development, yard improvement, boundary wall, fencing, etc.	0.10
Total (A)	2.25
(B) Plant and Equipment	
B1. Purchased equipment (PE), delivered.	
(i) Lime kilns (Constn. materials) 2 Nos. @ Rs. 1,00,000/- per kiln	: 2.0
(ii) Common staircase for the kilns (materials)	: 0.25
(iii) Charging devices for the kilns. 2 Nos. @ Rs. 25,000/-	: 0.50
(iv) Belt conveyor	: 0.10
(v) Jaw crusher for quick lime	: 0.28
(vi) Lime hydrator, 1 No.	: 0.80
(vii) Chain bucket elevator	: 0.50
(viii) Bucket elevator (Belt)	: 0.50
(ix) Vibrating screen	: 0.10
(x) Storage bins, 2 Nos. of 8 tonnes capacity each	: 0.30
Table (1)-PE cost	5.33
B.2. Equipment erection cost @ 10 % of PE	: 0.53
B.3. Electrical installation @ 10 % of PE	: 0.53
B.4. Instruments & controls (L.S.)	: 0.10
B.5. Water services & drainage @ 5% of PE	: 0.26
B.6. Laboratory, workshop etc. @ 5% of PE	: 0.26
B.7. Engg., supervision, premium & consultancy @ 10% of PE	: 0.53
B.8. Contingencies (L.S.)	: 0.50
Total (B)	8.04

Fixed capital investment (A+B) Rs. 10.29 Lakhs

Working Capital

The criterion recommended for estimation of the working capital amounts to 25 per cent of the total capital investment for smooth running of the plant for one month.

Total capital Investment = Fixed capital + Working Capital

(TC I) (FC) (WC)

Or TCI = FC + .25 TCI

Or $TCI = \frac{FC}{0.75} = 13.72$

Thus working capital = Rs. 3.43 Lakhs

3. **Total capital investment = Rs. 13.72 Lakhs**

Economic Evaluation

The economic estimates have been made on the basis of 300 working days per annum. An annual capacity of 6000 tonnes of hydrated lime as major product and about 1500 tonnes of building grade quick lime as bye-product has been envisaged. The production cost includes all the expenses directly connected with the manufacturing operation.

1. **Cost of Production**

		Rs. (Lakhs)
1.1	Limestone 12,000 tonnes @ Rs. 50/- per tonne	6.00
1.2	Fuel 2,400 tonnes @ Rs. 500/- per tonne	12.00
1.3	Electric Power, 1,50,000 kwh @ Rs. 0.30 per kwh	0.45
1.4	Water 10,000 KL @ Rs. 0.10 per KL	0.01
1.5	Packing bags 6,000 tonnes @ Rs. 37.50 per tonne	2.25
1.6	Labour and Supervision (L.S.)	
1.6.1	Plant supervisor—cum—manager—one @ Rs. 2,000/— per month	0 24
1.6.2	Chemist—cum—analyst—one @ Rs. 1,000/- per month	0.12
1.6.3	Plant operators, 4 Nos. @ Rs. 1,000/- per month	0.48
1.6.4	Electrician—cum—mechanic—2 @ Rs. 500/- per month	0.12
1.6.5	Storekeeper—one @ Rs. 500/- per month	0.06
1.6.6	Clerk—cum—typist—one @ Rs. 500/- per month	0.06
1.6.7	Semi—skilled labourers—12 @ Rs. 15/- per day	0.54
1.6.8	Mazdoors— @ Rs. 12/- per day	0.72
1.6.9	Watch and Ward - 2 @ Rs. 400/- per month	0.096
	Total (L & S)	23.146
1.7	Maintenance & Repairs (MR) Plant & Building @ 2% of the fixed capital	0.206
1.8	Operating supplies @ 10% of M & R	0.020
1.9	Taxes and Insurance @ 2% on the fixed capital	0.206
1.10	Plant overheads @ 20% of (L S+M & R)	0.467
1.11	Depreciation of Plant & Equipment @ 10% and building @ 2.5%	0.599
	Gross annual manufacturing cost (Total of items 1.1 to 1.11) Assuming the difference between the costs of the hydrated and quicklimes to be small, the average manufacturiug cost per tonne of the product works out to	24.644 328.50
1.12	General Expenses	
1.12.1	Administrative, distribution and selling costs @ 2% of manufacturing cost (items 1.1 to 1.11)	0.492
1.12.2	Interest on fixed capital @ 15%	1.54
1.12.3	Interest on working capital @ 17%	0.583
		2.615
	Total annual cost of production (Items Nos. 1.1 to 1.12)	27.259
	Thus the total average cost of production per tonne of product is approx.	Rs. 363.00

2. **Profitability Analysis**

2.1	Selling price per tonne of good quality lime (proposed)	Rs. 400/-
2.2	Gross annual income from sales	Rs. 30.00 Lakhs
2.3	Gross annual cost of production (Approx.)	Rs. 27.259 ,,
2.4	Annual return (Profit)	Rs. 2.741 ,,
2.5	Return on Investment (2.74 × 100/13.72) Say 20%	19.978 %

Concluding Remarks

The processes of lime manufacture and the designs of the related plant and machinery evolved at the Central Building Research Institute, Rookee, are technically sound and economically feasible. A large number of lime kilns of improved design and lime hydrating machines have been installed by various entrepreneurs and licensees at several different places in the country. The plants are in operation and the equipment are working satisfactorily. It is recommended that the lime plants be established on much larger scales of production based on the know-how developed at the Institute.

Acknowledgement

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