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TECHNOLOGY PROFILE ON MINI CEMENT PLANTS**

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by

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C O N T E N T S

TECHNOLOGICAL PROFILE ON MINI CEMENT PLANTS

0 INTRODUCTION

Cement is one of the most important building materials. The total cement production in the world reached 900 million tonnes in 1984. A major percentage of this total production is in large scale plants with capacities ranging from 2000 to 20,000 tpd and transported to the place of use in bulk or bags.

Large capacity plants are appropriate for deriving the benefits from economies of scale in locations where:

- large enough deposits of the basic raw material i.e limestone is available.
- infrastructural needs such as power and transportation system are sufficient.
- cement consumption is substantially concentrated.
- transportation costs are low
- capital intensive technology is preferable from socio-economic considerations

Mini cement plants are appropriate for other areas particularly in cases like:

- Small countries which intend to develop their own cement industry to cater to their limited needs, thus becoming independent of imports.

- Large countries with low population density and/or low per capita cement consumption.

- Only scattered limestone deposits, which cannot sustain large scale cement plants, are available.

- Large cement plants cannot be set-up due to infrastructural constraints - specially hilly and remote regions.

- Areas where local and regional market will absorb the production of a mini cement plant only and that industrial size plants could not operate at economic production rates.

- Socio-economic considerations justify a Labour intensive technology rather than a capital intensive one.

1.0 DEFINITION OF MINI CEMENT PLANT

Although there is no rigid definition of mini cement plant vis-a-vis their maximum size since the same depends upon the various technical, social, political and economic considerations as enumerated above and also in the following sections, normally the mini cement plant technology relates to plants with maximum capacity ranging between 200 - 400 tonnes per day. For example, in India, the maximum size for a mini cement plant which is encouraged by the Government based upon the various socio-economic considerations, has presently been fixed at 200 tpd.

2.0 ADVANTAGES OF MINI CEMENT PLANTS

The mini cement plant

1. Lowers capital investment per unit production without sacrificing quality of either the plant or the product.
2. Helps realise quicker returns on capital invested because of lower gestation periods.
3. Brings cement industry within the financial access of smaller entrepreneur and thus enlarge entrepreneurship in the country.
4. Contributes to uplifting local economy and development as well as to formation of rural cooperatives as owners of cement plant.
5. Creates employment oppertunities in rural areas on a well dispersed basis.
6. Enables development of cement industry in terrains where movement of heavy machinery and cement are difficult.
7. Makes it possible to exploit small deposits of limestone as well as limited quantities of calcareous industrial wastes.
8. Avoids wasteful movement and thus helps to bring down the average unit cost of transportation of cement in the country as well as strain on Nation's transportation system.
9. Eliminates packing charges where the utilisation point is localised by resorting to bulk supply.

3.0 COMPARISON OF VARIOUS TYPES OF MINI CEMENT PLANTS

The various technologies which have been tried for adoption in mini cement plant are:

a/ The Fuller Pyzel fluidized bed process.
b/ Reba Process.
c/ Travelling grate (Lurgi sinter grate)
d/ Rotary kiln and
e/ Vertical Shaft Kiln

In a nutshell, in all these five alternative schemes of technological lines, there is an upper and lower threshold of size beyond which either it is technically not feasible or economically not viable. Down scaling of plants under any particular technology even within these threshold results in

- increase in investment per annual tonne of installed capacity
- increase in the cost of production per tonne.

So when the technical and economical threshold is reached for any given technology line, other technology lines may still give technically feasible and economically viable results.

The conventional rotary kiln is normally uneconomical below 300 to 600 tpd and so the technology lines like Sintergrate and Reba were evolved, but they could not succeed due to inherent defects.

A brief process description for all these technological lines which were tried or adopted for manufacture of cement in small scale are given in the following sections:

3.1 Fluidised Bed Process

Of these the fluidised bed or Pyzel process is the least popular because the number of plants working on this process are extremely few even on global basis and not much is known except for some broad principles of working. This process, invented by Robert Pyzel, has been developed in USA by Fuller. A 100 tpd pilot plant based on this technology is reported to be in operation on experimental basis for the last six years with M/s Scientific Design Company, New York, USA.

3.1.1 Process Details

The plant consists of a fluidised bed reactor; raw meal consisting of finely ground feed mixture is pneumatically conveyed to the fluidised bed alongwith fuel and preheated air. The temperature of the fluidised bed is maintained at approximately 1315°C by introducing the fuel directly into the fluidised bed.

Cement clinker being almost refractory, coarse clinker particles of 0.8 to 8 mm can be maintained in granular form in suspension, when finely ground raw mix is pneumatically blown in, raw cement phases are formed on the hot surface of characteristically round clinker particles, so that they grow in size continuously.

The specific heat consumption reported without any heat recovery system is 2600 kcal/kg of clinker and with heat recovery system 1046 kcal/kg of clinker. Energy requirement for production of clinker alone by the fluidised bed reactor is 55 kWh/t as against 20-25 kWh/t of clinker in case of rotary or shaft kilns.

Fuels like gas, oil, coal, anthracite and coke could be used in this process.

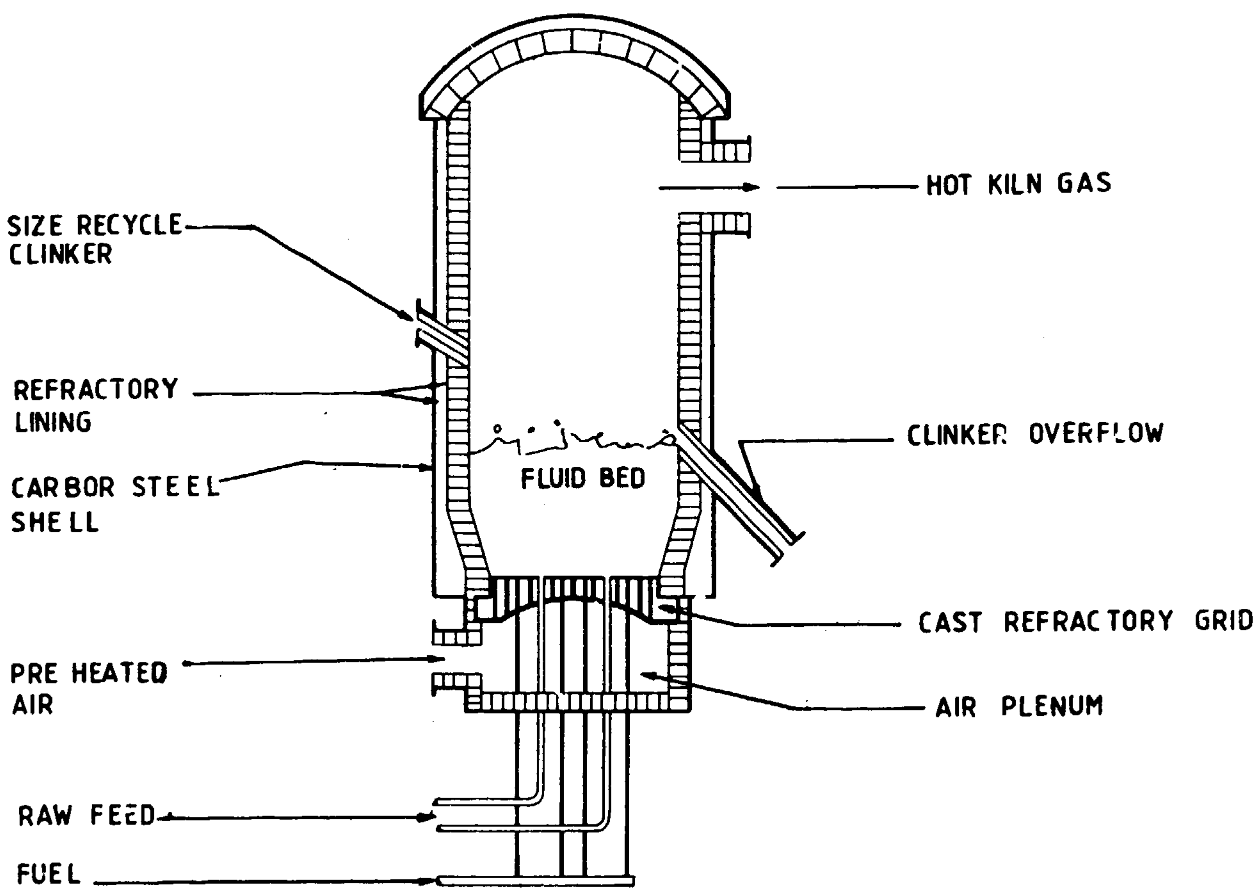


Fig. 1 FLUID BED PROCESS

This process stands a good chance for a promising market in USA as there are very strict environmental protection specifications regarding oxides of sulphur and nitrogen. At the same time special 'low alkali' cement specifications necessitate the rejection of large quantity of dust in rotary kiln burning operation. This dust with high alkali content can be used as a cement raw mix in the Pyzel reactor.

The specific advantages of Pyzel process have been claimed where there is (a) high alkali problem; (b) strict environmental protection regulations regarding oxides of sulphur and nitrogen from exit gases; (c) disposal problem of kiln dust with high alkali content; and (d) using different fuels like gas, oil, coal, anthracite and coke.

The high investment cost for the heat recovery systems and stringent controls through an elaborate instrumentation and automation and non-availability of highly skilled personnel for the operation of the reactor, go against the very philosophy of mini cement plant. Due to the inherent technological problems in stabilising the operation of plants based on the above process and also due to the reported high investment cost per annual tonne of installed capacity, mini cement plants based on the above technology have not been reported to be a commercial success anywhere in the world.

3.2 Reba Process

In this process, the feed operation requires crushing of limestone to -15 mm size, storing in bays/bins, proportioning of raw materials and final grinding in a roller/ball mill, homogenisation of raw meal and storage.

The fuel used is oil or gas. The homogenised raw meal is fed to a noduliser where nodules are formed with addition of water and are then fed to a combustion chamber. The nodules are dried in the preheating zone and heated in the calcining zone to

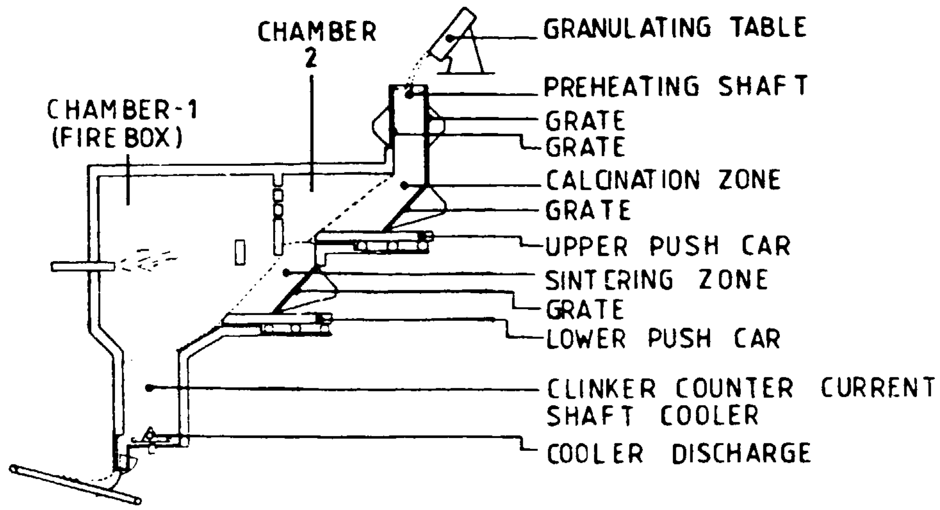


Fig 2(a) MATERIAL FLOW IN REBA PROCESS

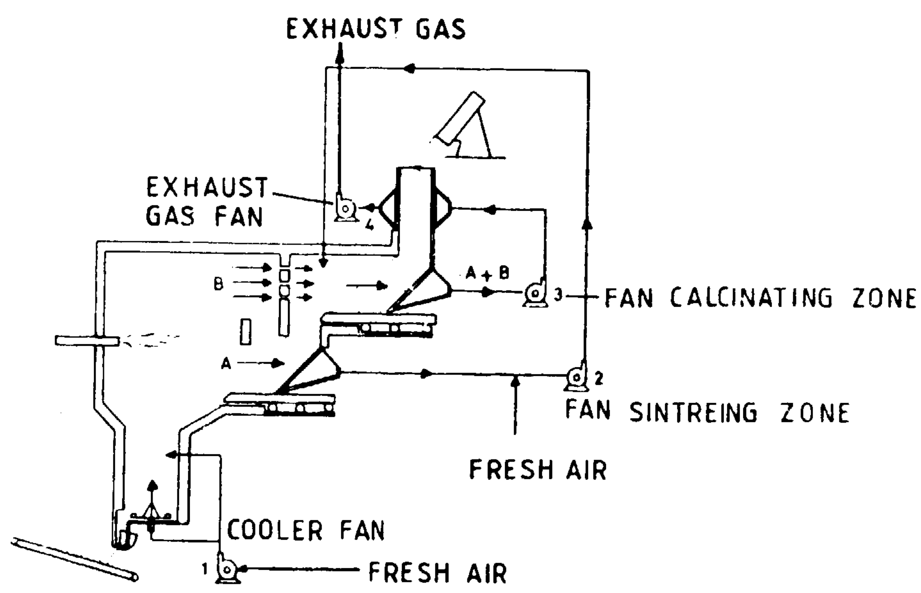


Fig 2 (b) GAS FLOW IN REBA PROCESS

about 1100°C. The granulated material is then sintered at about 1450°C and cooled in the shaft cooler. The flow of gases is in opposite direction to flow of material and thus air used to cool the clinker heats up and is used as secondary air together with primary air when burning the fuel.

Reba process has not so far been operated on solid fuel, i.e. coal and as such no operational data are available on such applications.

It was claimed by the firm M/s Ready Mix Cement Engineering of FRG that the Reba kiln installations for production of cement in the range of 50-200 tpd still have low investment costs and less energy consumption. The heat consumption is estimated to be approximately 730 kcal/kg of clinker. Furthermore, the electrical energy consumption should correspond to that of rotary kilns. The energy consumption for burning of materials alone is claimed to be 14 kWh/t.

It is understood that the Reba process has been tried successfully only for burning of lime and the firm is yet to establish the technology for burning of cement clinker on a commercial basis. Further, the quality of limestone and fuel tried are of very rich quality, i.e., very high percentage of lime in limestone of the order of above 52% and coal with very low ash content (10%) and high calorific value and till date the technology has not been proved using cement grade limestone and coals with high ash content. No commercial plants are known to be in operation in the world on this technology.

3.3 Travelling Grate (Lurgi Sinter Grate)

In this process, the feed operation requires crushing of limestone to -15 mm size in a crusher/mill, storing the materials of -15 mm size in gantry/storage bins, proportioning of raw materials and final grinding in closed circuit ball mill/roller mill, homogenisation of raw meal and storage,

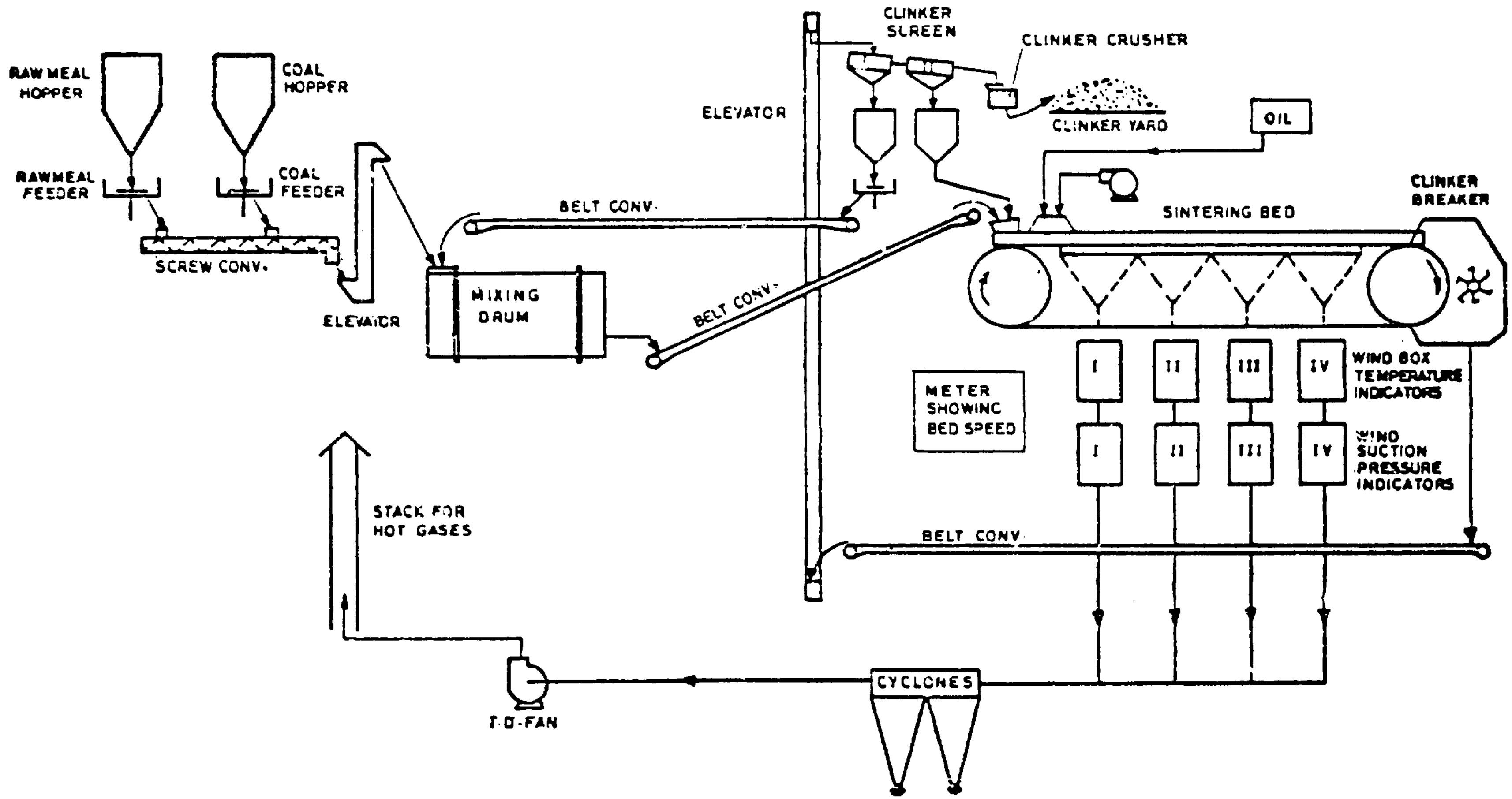


Fig. 3 LURGI SINTER GRATE

crushing and screening of coal to -5 mm size in closed circuit operation and storing of crushed coal in bin.

The raw meal and crushed coal are then extracted from respective bins according to requirement and conveyed to a drum type noduliser. In addition, the noduliser is also fed with 15% of -5 mm size burnt clinker to form core of nodules and 15% water spray. The nodules are conveyed by a belt conveyor to moving sinter bed made of cast iron grate base. A 75 mm thick layer of +5 mm and -10 mm burnt clinker is first spread over this bed and then the fresh nodules fall over this. The sinter bed passes through various zones over some distance where suction is maintained through ID fan. Light diesel oil is fired over the bed in hood fixed about 200 mm above the bed height and the resulting clinker is discharged through a rotating arm type breaker in red hot condition over an open pan type horizontal conveyor where it undergoes cooling.

3.4 Small Rotary Kiln

Here, the kiln feed and fuel preparation requires crushing and grinding operations, like:

- Crushing of limestone and additives in a hammer mill or 2-stage, viz., jaw crusher and hammer mill to -15 mm size.
- Storing the crushed raw materials in storage yard/bins.
- Proportioning and grinding the raw materials in a roller/ball mill.
- Homogenising and storage of raw meal in blending and storage sections.
- Fuel, viz, coal (VM 25-30%) is pulverised in a separate section (combined coal drying-cum-grinding section).

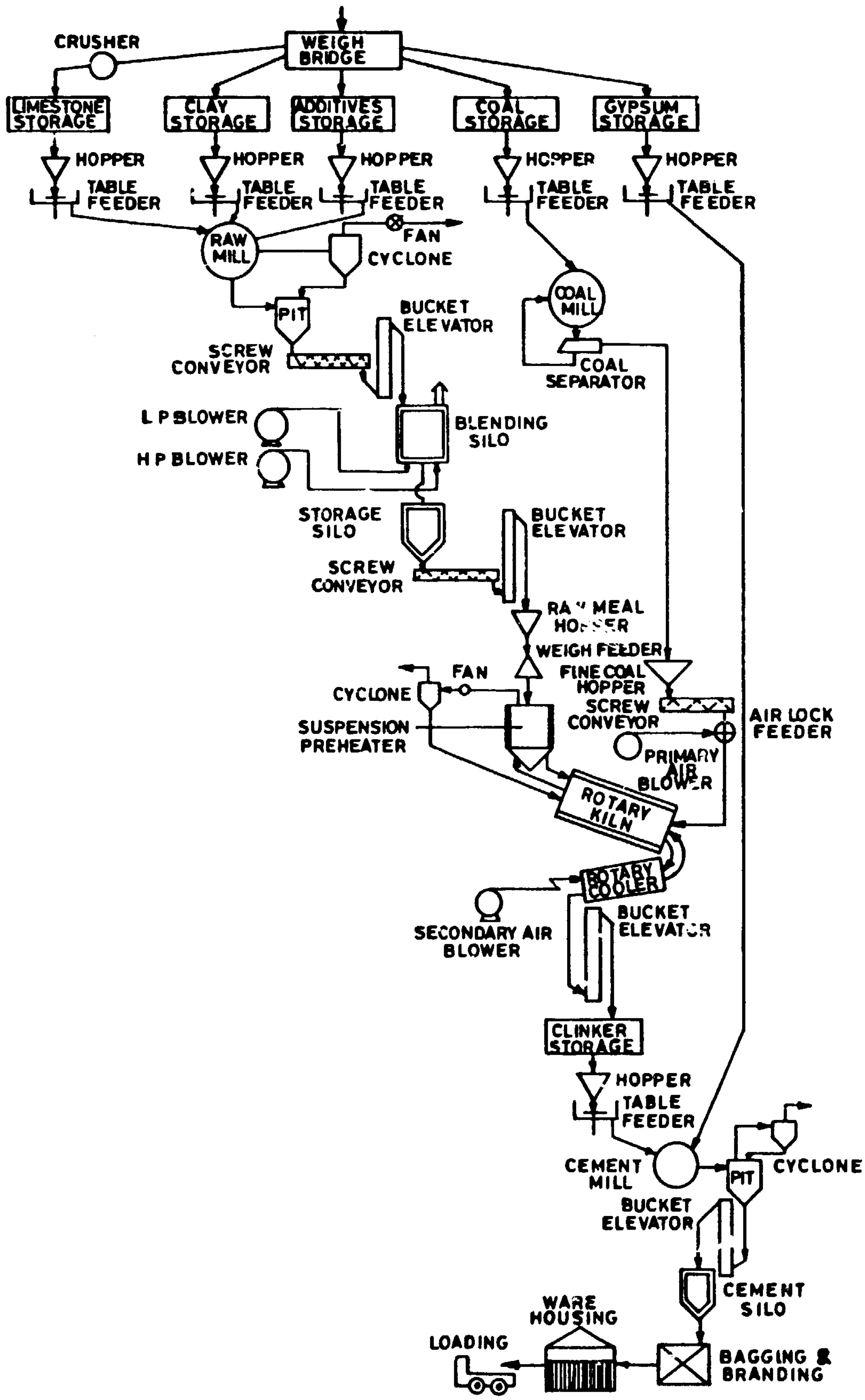


FIG. 4 FLOW SHEET OF DRY PROCESS ROTARY KILN CEMENT PLANT

Blended and homogenised raw meal is then fed to the suspension preheater of counter current type, where it is preheated and partially calcined by the kiln hot gases passing in counter current. Raw meal enters the kiln at a temperature of 700° - 800°C. The exit gases from the preheater are then passed through the dust collection system and discharged to atmosphere. Dust collected is recycled.

Pulverised coal mixed with primary air is fired from the lower end of the rotary kiln through coal burners. Secondary air is supplied through clinker cooler to make up for the combustion air. A flame at around 1660°C is maintained. This heats the material as the kiln rotates at 1 to 2 rpm. Various chemical reactions (calcination, sintering, cooling) take place as the material temperature goes upto 1440°C. Hot gases having transferred the heat to material escape in counter flow i.e. from lower end to upper end through suspension preheater and dust collectors to atmosphere. Clinker is discharged into clinker cooler which may be rotary, planetory or moving grate type. Clinker is then transported to storage yard and finally ground with gypsum. Control is maintained through various control instruments and inspection of burning conditions.

3.5 Vertical Shaft Kiln

The use of vertical shaft kiln process for cement manufacture dates back to the year 1824 when Portland Cement was invented. However, because of its non-continuous operation, this process was found uneconomical and produced clinker of non-uniform quality.

Later after the development of continuous pan type noduliser, a significant advance was achieved and the shaft kiln performance improved considerably thus permitting its adoption and production of uniform quality of clinker on a continuous basis. Cement manufacture by using Modern Vertical Shaft Kiln is reportedly being carried out in different countries like China,

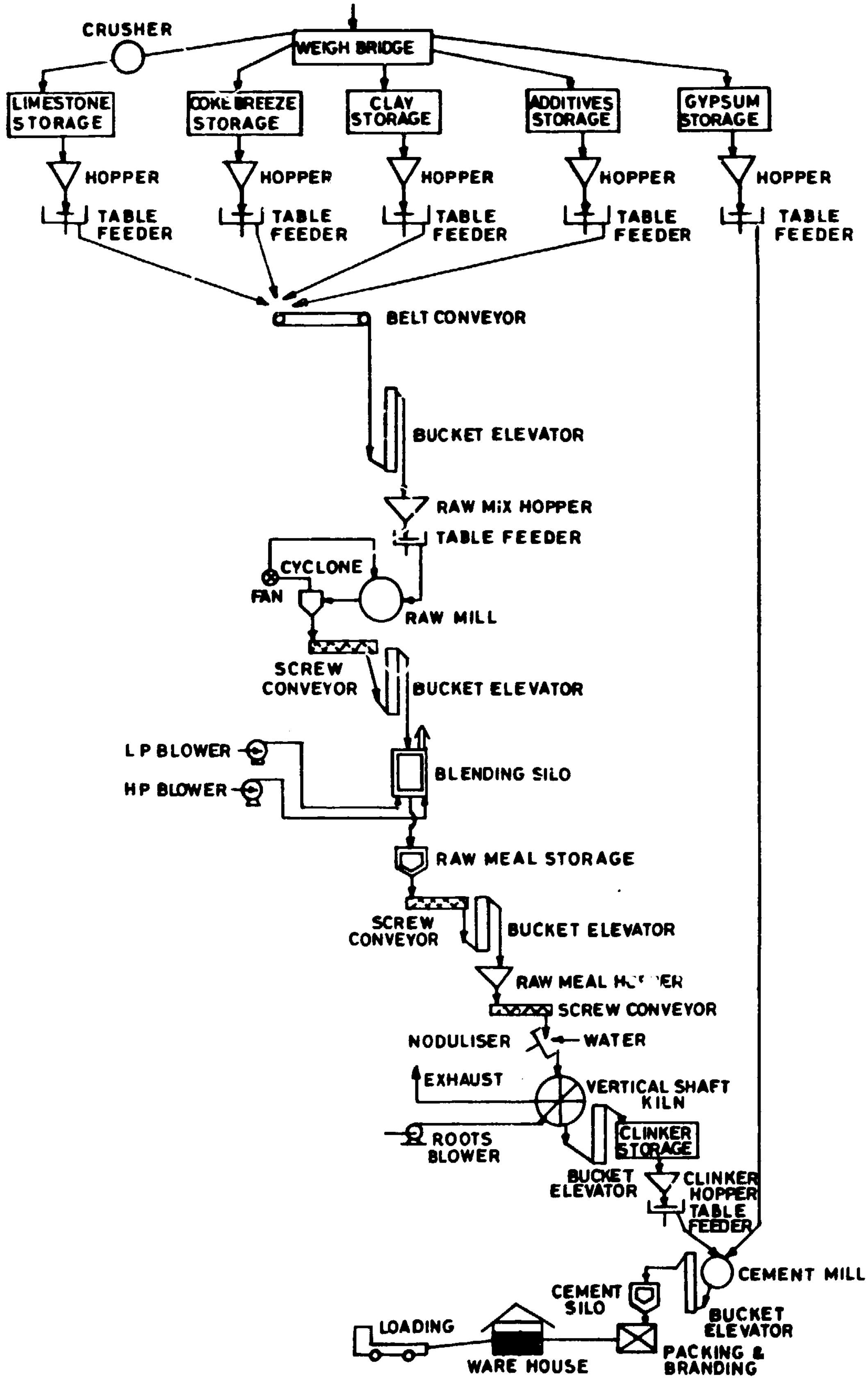


Fig 5 FLOW SHEET OF BLACK MEAL VERTICAL SHAFT KILN CEMENT PLANT

India, West Germany, Australia, Italy, Indonesia, Nepal, Bhutan etc. In fact, a wide variety of processes have been adopted for the manufacture of cement through Vertical Shaft Kiln and it would be desirable to mention some of these in the following sections.

3.5.1 Black Meal Process

This is the most popular type of process used for manufacture of cement through Modern Vertical Shaft Kiln in which the fuel (usually low volatile coal or coke breeze) is interground with the raw mix for efficient and uniform burning. Most of the cement plants using Vertical Shaft Kiln like CRI-Modern Vertical Shaft Kiln, Vertical Shaft Kiln supplied by M/s Loesche of West Germany etc are mainly based on the black meal process.

In this process, the vertical shaft kilns are fed with raw mix of appropriate composition in the form of nodules. The feed operation usually requires crushing of limestone to about -15 mm size in storage bins, proportioning of raw materials and grinding in a roller or ball mill, homogenizing and nodulizing in pan type noduliser. The successful operation of shaft kiln, to a great extent, depends upon the size of nodules, their uniformity, porosity and thermal stability. The noduliser consists of an inclined disc or pan rotating about its axis. Raw meal is charged into noduliser by means of screw conveyor and water is sprayed, while all the parameters are maintained at optimum conditions. A specially designed rotating scraper continuously cleans the bottom and the collar of the drum of the raw meal deposited. The nodules slide down the chute and are charged in the vertical shaft kiln evenly all around the periphery continuously with the help of a rotary feeder situated on the top of the kiln.

The vertical shaft kiln in which the nodules are converted into clinker consists of a cylindrical shell with conical portion at the top and lined with refractory bricks. The sintering is normally complete within the conical portion which is specially designed to accommodate for shrinkage of nodules. The various zones of reaction starting from the top of the kiln are: the drying zone, the calcining zone, the sintering zone and the cooling zone. The combustion air supplied by Roots blower ascending from below in the cooling zone absorbs heat from the descending clinker. The whole kiln charge composed of unburnt nodules and clinker rests on a flat grate rotating slowly at the bottom of the kiln and mounted over the kiln shaft. The grate is driven with the help of variable speed motor in order to control the discharge rate of clinker. The clinker is finally taken out of kiln bottom with the help of a triple air lock mechanically (or hydraulically) operated discharge gates or Gamma Ray controlled Material Block Tube System used in Modern Vertical Shaft Kilns.

3.5.2 Coal Slurry Process

A variation of the Black Meal process as proposed by Dr Steven Gottlieb is 'Coal Slurry Process' the main difference being in the method of feed preparation. The method requires the raw meal to be ground 'white', i.e. without fuel. The fuel (coal with volatile matter upto 16-18%) is ground separately in a wet ball mill to make slurry with about 50% moisture. The 'white meal' and the 'coal slurry' are separately stored in hoppers over the noduliser platform and are pumpe at controlled rates (through flow meters) into a double paddle mixer to mix the feed continuously and discharge into the standard noduliser where practically no or very little water is added to give final shape to the nodules. These nodules are charged and burnt in the vertical shaft kiln in the same manner as in the case of 'Black Meal' process.

The main advantage claimed by this process is that by wetting of the coal particles before nodulising, the retention time for the volatile component of the fuel is increased, thereby allowing this to travel to a zone where adequate oxygen is available to complete the combustion of the volatile matter within the bed - thereby permitting a higher volatile content in the coal when compared to that used in the 'Black Meal' process.

3.5.3 Differential Heat Burning Process

This process, which is a slight variation of the black meal process, has been reportedly tried out in a number of cement plants in China. In this process about 50% of the total fuel required is interground with the raw meal and the balance is added later prior to nodulisation. This has been based on the assumption that the heat requirement at the periphery of the bed in a VSK is usually more by about 150 kcal/kg of clinker than that in the middle and in this process some additional fuel is added at the periphery of the bed as compared to that in the middle to balance the heat distribution.

4.0 MINI CEMENT PLANTS IN INDIA

4.1 CRI-Modern Vertical Shaft Kiln Technology

Modern CRI-VSK technology was pioneered in India by Cement Research Institute of National Council for Cement and Building Materials as early as 1972 and was first tried out in 1974. The Modern CRI-VSK (Fig 6) cement plant as a compact unit incorporates the following features:

1. Efficient process control backed up by quality control measures and a fully equipped laboratory for physical and chemical analysis.

2. Microprocessor based instrumentation system has been provided to monitor all important process parameters on a continuous basis. All major system parameters are indicated and recorded.

3. In order to improve the burning process inside the VSK and to achieve higher output and better quality of product, automatic closed loop process control has been incorporated in the noduliser and VSK section.

4. Safety measures including carbon-monoxide alarm system and electrical interlocking of drives have been provided in order to protect the manpower and equipment which include a special alarm for combustion air failure to prevent any flame shoot out due to carbon-monoxide formation.

5. Continuously operated rotary feeder drive with adjustable tilt angle and adjustable height in order to achieve the desired bed profile in the VSK.

6. Automatic accurate raw material proportioning with electronic weighfeeder as optional feature.

7. Specially designed Double-Collar Noduliser with automatic closed loop control results in nodules of higher green strength due to extra-rollin action and desired size, porosity and moisture content.

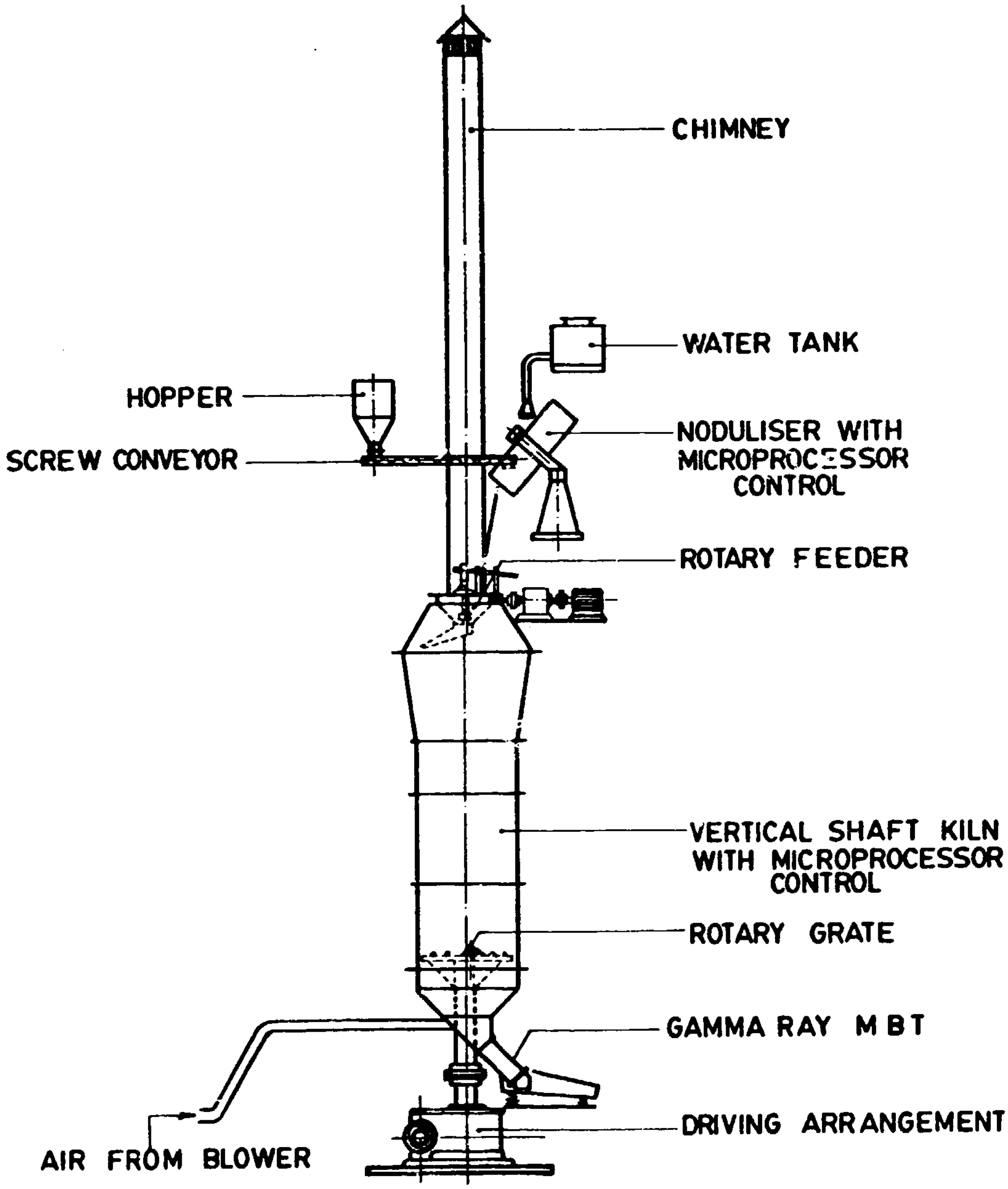


Fig.6

MODERN CRI VERTICAL SHAFT KILN

3. The material block tube for clinker extraction from the VSK along with 'Gamma ray level control device' has the advantages of less air leakage, less dust and noise, lower maintenance and more efficient burning process due to reduced fluctuations in the combustion air supply.

A typical flow sheet for mini cement plant based on CRI-Modern Vertical Shaft Kiln is shown in Figure 7.

Because of its inherent techno-economical advantages, mini cement plants based on the above technology have become extremely popular in India with about 26 plants already in operation (Fig 8) in the districts of Chitradurga (90 tpd & two 100 tpd plants), Bijapur (90 tpd & 20 tpd), Belgaum (30 tpd), Gulbarga (30 tpd & 20 tpd) and Tumkur (30 tpd) in Karnataka, Bhavnagar (100 tpd) and Junagarh (100 tpd) in Gujarat, Hazaribagh (100 tpd) in Bihar, Tezu (30 tpd) in Arunachal Pradesh, Tiruchirapalli (20 tpd & 30 tpd) and Salem (100 tpd) in Tamil Nadu, Gwalior (100 tpd), Damoh (100 tpd), Rewa (100 tpd) & Dhar (100 tpd) in Madhya Pradesh, Sikar (100 tpd) in Rajasthan, Sundergarh (100 tpd) in Orissa, Nalgonda (100 tpd) and Kurnool (100 tpd) in Andhra Pradesh, Dehradun (50 tpd) in Uttar Pradesh and Gomtu (100 tpd) in Bhutan and another 45 plants under different stages of erection and commissioning in addition to which the detailed techno-economic feasibility report for 100 more plants have already been completed by NCB. The economics of these plants have been separately covered in this publication which prominently brings out the advantages of such plants based on the CRI-Modern Vertical Shaft Kiln technology.

4.2 RRL Technology

Regional Research Laboratories (RRL), Jorhat constituent laboratories of Council of Scientific and Industrial Research (CSIR), has also done considerable work on the development of Vertical Shaft Kiln Technology under Indian conditions. About 5 plants based on RRL technology are operating in India and about 10 plants are under various stages of erection and commissioning. Out of these plants only one is of 100 tpd capacity and the remaining are of 40 tpd and smaller sizes.

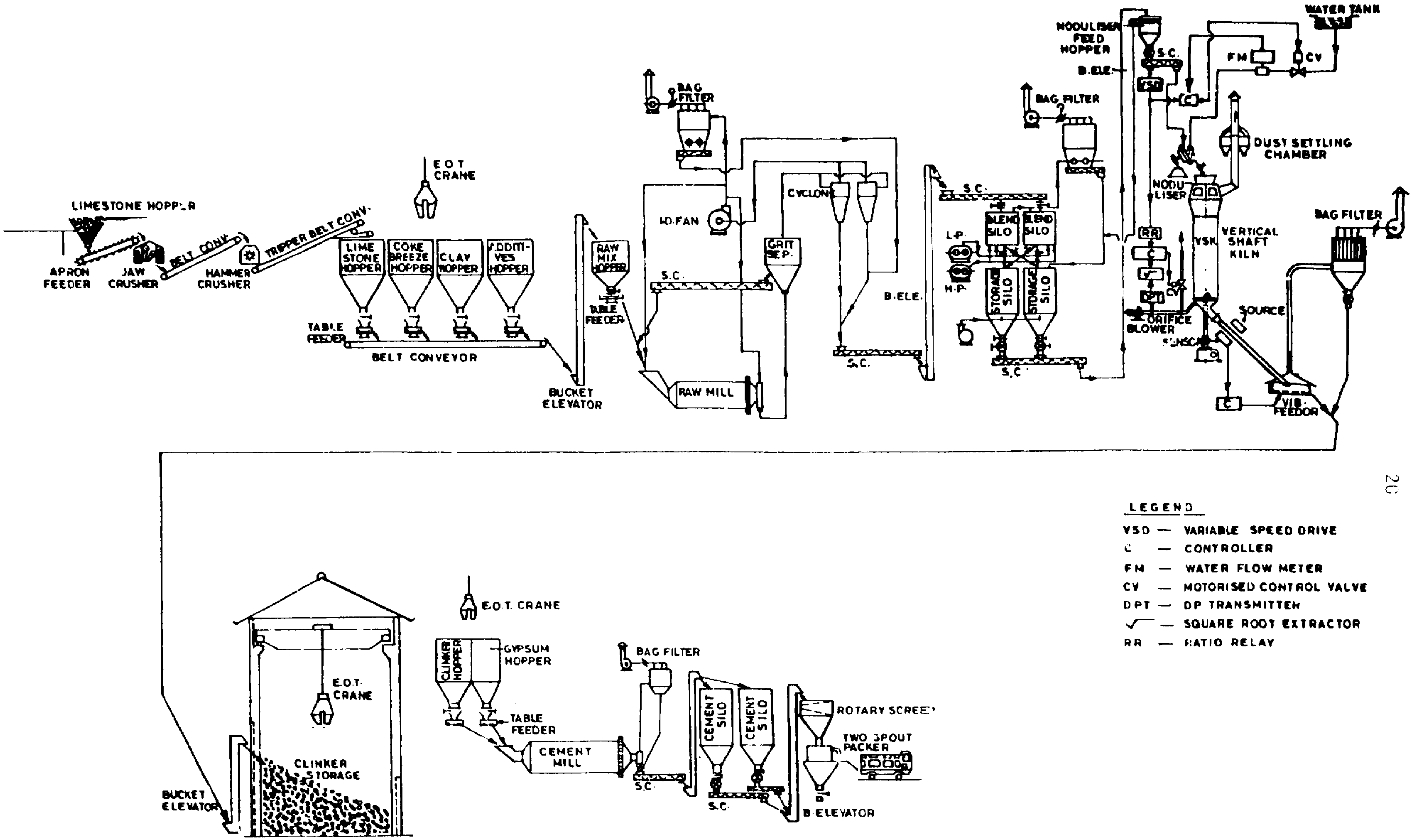


Fig.7 FLOW SHEET OF TYPICAL CRI-MVSK PLANT

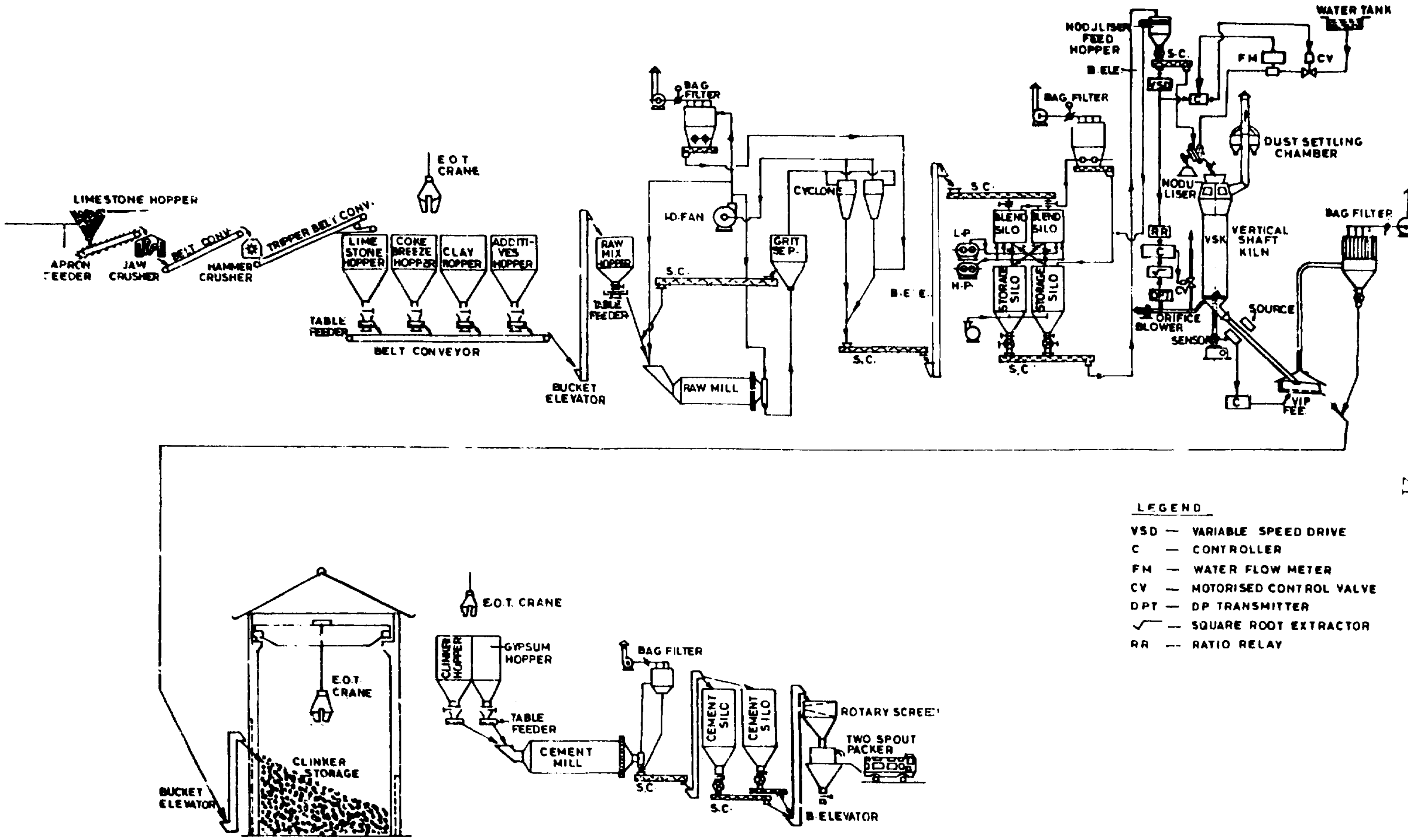


Fig.7 FLOW SHEET OF TYPICAL CRI-MVSK PLANT

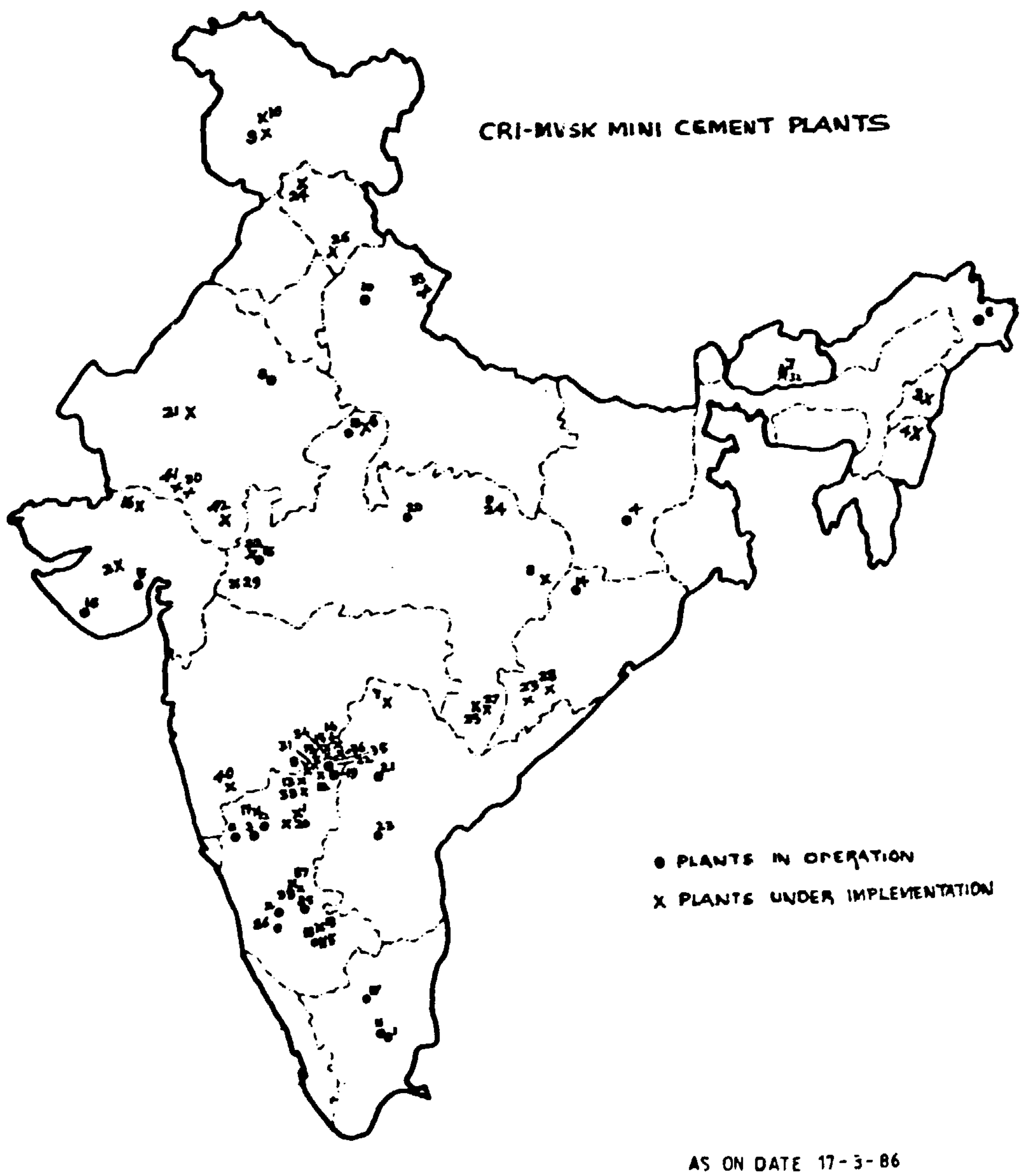

CRI-MVSK MINI CEMENT PLANTS
• PLANTS IN OPERATION
X PLANTS UNDER IMPLEMENTATION
AS ON DATE 17-3-86

Fig-8

This technology could not become very popular as RRL, unlike NCB, does not directly associate with the project right from the inception to the commissioning stage and the licenced fabricators/consultants could not effectively manage the turn-key supply, erection and commissioning of such plants.

4.3 M/s Dalmia Cement (Bharat) Ltd

A mini cement plant of 170 tpd based on the Gottlieb Coal Slurry Process is presently under operation in India at M/s Dalmia Cement (Bharat) Ltd at Dalmiapuram. Although the production of cement from the plant is reported to be satisfactory, the plant has not been able to achieve the advantage of using the high volatile Indian coal used by other rotary kiln cement plants and is reported to be using low volatile coal/coke breeze as being used by other VSK plants in India based on the black meal process. Thus the additional investment incurred by the plant due to separate coal slurry grinding and handling system has not given the expected returns.

4.4 Tiny Cement Plants

In India, any industry for which the cost of plant and machinery does not exceed US $ 292,000 comes under the definition of 'Small Scale Industry (SSI)' and is offered certain concessions. Keeping this primarily in view, certain individuals/small organisations have downscaled the VSK technology so as to offer such plants under the SSI. Such plants are in the size range of 5 to 20 tpd and are popularly known as Tiny Cement Plants. In this direction, an individual called Mr D P Saboo of Jodhpur in Rajasthan has put in considerable efforts, and has put up about 25 nos. of such tiny plants; most of these being based on high grade limestone deposits in the state of Rajasthan. The investment cost in such plants have been brought down by resorting to in-house fabrication of machinery as well as by elimination of certain equipment from the process line and resorting to manual operation.

However, unfortunately, the Tiny cement plant concept in India has taken a dangerous turn with a large number of other individuals/spurious organisations having entered the field of fabricating and supplying these plants, which are in fact poorly copied version of certain proven technologies without the provision of requisite technical back-up. This has already resulted in setting up of a few such tiny cement plants which have since become sick and have discontinued production.

4.5 J&K Cements, Wuyan

This 60 tpd plant is based on Lurgi Sinter Grate Process. This requires use of light diesel oil as a fuel in addition to the low volatile coal already contained in the nodules. The cement production at the plant has never exceeded 55% of the installed capacity. The cost of fuel is as high as US $ 14 per tonne of clinker. Apart from the high cost of production, the plant also finds it difficult to cope with frequent breakdowns and quite involved maintenance is required due to complicated machinery. The electrical energy consumption per tonne of cement produced is as high as 203 kWh. The heat consumption per kg of clinker production is also as high as 2404 kcals.

Although the quality of the cement produced by this process is reported to be meeting all the specifications well, the working of the plant and its profitability has all along been headache for the plant management. Due to the above constraints, the plant management have ultimately decided to discard the complete sinter grate system and have placed an order for CRI-Modern Vertical Shaft Kiln along with the necessary balancing equipment to replace the existing system, which is likely to be installed and commissioned by the middle of 1986. By the adoption of CRI-MVSK technology, it is estimated that the cost of production of cement in this plant could be reduced by about 40%. This clearly shows that the sinter grate technology has failed to be a techno-economically viable solution for the manufacture of cement in small scale.

4.6 Small Rotary Kilns

Use of small rotary kilns have been adopted by many countries for cement manufacture in small scale by downscaling the conventional rotary kilns. In India, there are about 15 nos. of rotary kiln based mini cement plants under operation and about another 10 nos. under implementation; most of these being designated as 200 tpd in order to derive incentives offered by the Government of India in terms of rebate in excise duty (which has since been discontinued) and a free market. However, most of these plants are using kilns of 3 m dia and 40 or 45 m length - which under Indian conditions are rated as 300 tpd. One of the major reasons for this has been the fact that the machinery fabricators/consultants did not find it technically appropriate to further reduce the kiln dimensions in view of anticipated problems relating to higher refractory failure.

Thus, although a few mini cement plants based on the rotary kiln technology have been set up in India as well as other countries of the world, mainly because of the reason that this technology is a direct down-scaling of the conventional rotary kilns which are technically well established, the cost of production and the investment cost per annual tonne of installed capacity in such plants are found to be exceptionally high due to the scale effects. Moreover, if one attempts to make these small rotary kiln plants economically viable, then certain processes and operations have to be eliminated and the degree of sophistication of instrumentation and process control systems would have to be lower which would amount to sacrificing some of the modern features which are essential for satisfactory performance and economic operation. Due to the inherent techno-economic disadvantages of mini cement plants based on rotary kiln as compared to those based on Modern Vertical Shaft Kiln - like higher investment cost, higher operating cost, higher energy consumption, higher pollution etc; the Government of India, as a matter of policy, is not encouraging any further setting up of mini cement plants based on rotary kiln technology.

5.0 MINI CEMENT PLANTS IN CHINA

5.1 Cement Industry in China - A Glance

The cement industry in China has been developing at a fast pace. The growth rate of cement industry works out to about 15% or 10 million tonnes per year. At present there are 57 large and medium size cement plants and more than 4800 mini cement plants. The mini cement plants are scattered all over China in 29 provinces, municipalities and autonomous regions. The cement plants on VSK or rotary kilns with dry, wet or semi-dry processes produce more than 60 types of cement. The present demand of cement in China is of the order of 110 million tonnes per year, which necessitates an import of about 2 million tonnes per year. The demand is estimated to touch 200 MTPA by the turn of the century.

5.2 Mini Cement Plants

At present there are over 4800 small cement plants as follows:

TABLE 1

Category	No	Cement Out Put (MTPA)	Percent Out Put
Above county level	1897	49.47	61
Below county level	2261	13.95	17
Owned by Ministries	698	17.64	22

Among the above plants there are 879 mechanised shaft kilns producing about 37 million tonnes and 169 small rotary kiln plants with an output of 8.4 million tonnes. The output of ordinary shaft kilns is about 18.39 million tonnes. Figures 9 & 10 show typical non-mechanised and mechanised kilns. In 1983, the output of the mini cement plants was 81.07 million tonnes. From the year 1976 upto the end of 1983 the proportion of cement produced by mini cement plants has increased from 63% to 73%.

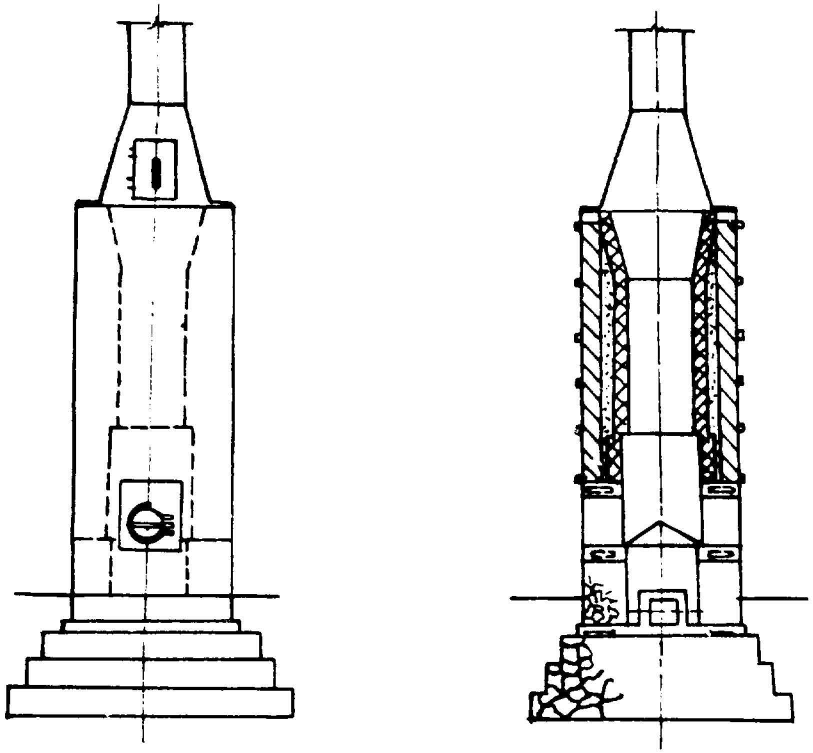


Fig. 9 A TYPICAL NON-MECHANISED SHAFT KILN

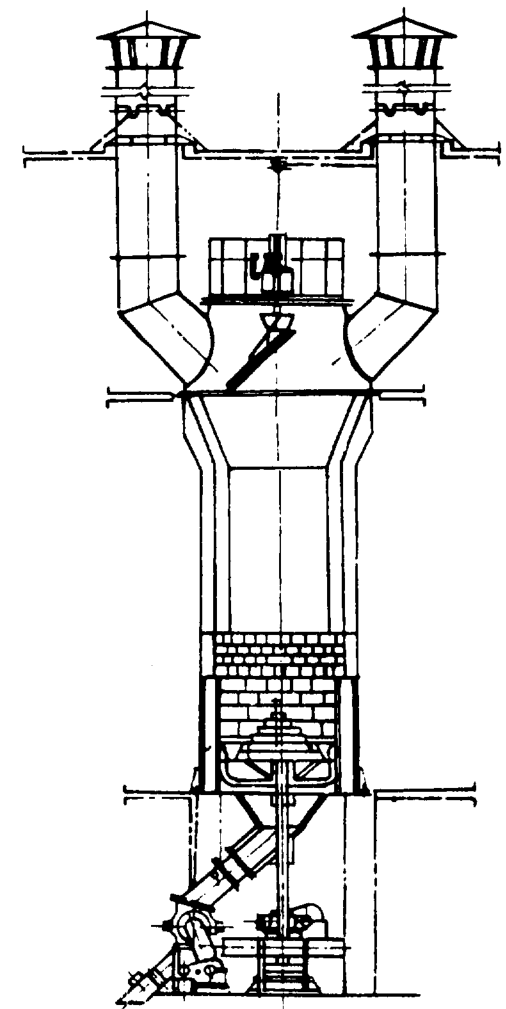


Fig.10 A TYPICAL MECHANISED SHAFT KILN WITH CONICAL GRATE

The development of the mini cement industry not only meets in quantity the requirements of state capital construction, but also satisfies the needs of house building and developing collective economy of the peasants in the country side

China is rich in cement resources, which are distributed in the vast territory of the country. It covers from the southern Hainan Island to the northern Heilong Jiang, from the eastern various sea side provinces including Taiwan to the western Xi Jiang and Xi Zang. Rich reserves of limestone, clay, shale can be found everywhere. Today cement plants of different capacities have been set up in 80% counties in each province.

In the course of the management and administration of the mini cement plants in China, the quality of the product has been improved and the heat consumption is lowered. For example, with the application of black or semi-black meal process, the differential thermal calcination method as well as compound mineralizer, today on the average quality of clinker has attained the grade No.542 and the heat consumption is 1035 kcal/kg.

TABLE 2

Important Indices for some Mini cement Plants

Plant's Name	Kiln Size dia x height (m)	Output tph	Heat consumption kcal/kg	Clinker grade	Free CaO%	Output per Unit cross section of the kiln t/m^2h
Boshan	2.5 x 10	8.42	1127	-	-	1.715
Hongu	3.0 x 10.2	11.68	1105	-	-	1.652
JiaXing	2.3 x 8.5	6.88	1045	566	3.24	1.81[illegible]
Zhan Jiang	2.5 x 9.5	9.39	949	535	2.16	1.913
Xixia	2.5 x 10	8.92	711	552	1.09	1.318
Jinan	2.9 x 9	12.13	1032	641	2.40	1.836
Qingtao	2.5 x 9	9.27	895	538	3.9	1.990
Tienjin	3.6 x 10	15.96	1241	497	2.18	1.568
Beijing	2.9 x 10	8.23	1180	493	3.60	1.246

Fig 11 shows the growth of mini cement plants as plotted from the data collected from various sources. The graphs show that the annual cement production from medium and large cement plants has gradually increased from 9.9 million tonnes to 27.2 million tonnes from the year 1965 to 1983 whereas the production from mini cement plants has recorded a steep increase in the last 8 to 10 years. Another striking phenomenon observed is that the continuous increase in production in the last five years does not match the growth in the number of mini cement plants. This, perhaps, is due to increased production of blended cements and increasing mechanisation/productivity improvement of existing mini cement plants.

5.3 Processes Used

China uses minor variations in the process with the vertical shaft kiln technology. There are some plants which use black meal process as in India, there are others which use semi-black meal process in which only a part of the total coal required is interground with the raw meal and the balance is added in coarse fraction later prior to nodulisation. Some plants use compound mineralizers also for lowering the firing temperature. Different types of discharge grates as shown in Fig 12 have been used in the vertical shaft kiln, like roller grate, flat grate, conical grate, reciprocating grate etc. Non-mechanised kilns use stationary grate. Since the Chinese plants, because of this design and operational features, emit sizeable amounts of dust, dust collection equipment like electrostatic precipitators, bag filters, etc are being installed. The smallest and the largest sizes of mechanized vertical shaft kilns in China have diameters of 1.7 metres and 3.6 metres, producing about 35 tonnes per day and 200 tonnes per day against design capacities of 45 tonnes per day and 380 tonnes per day respectively.

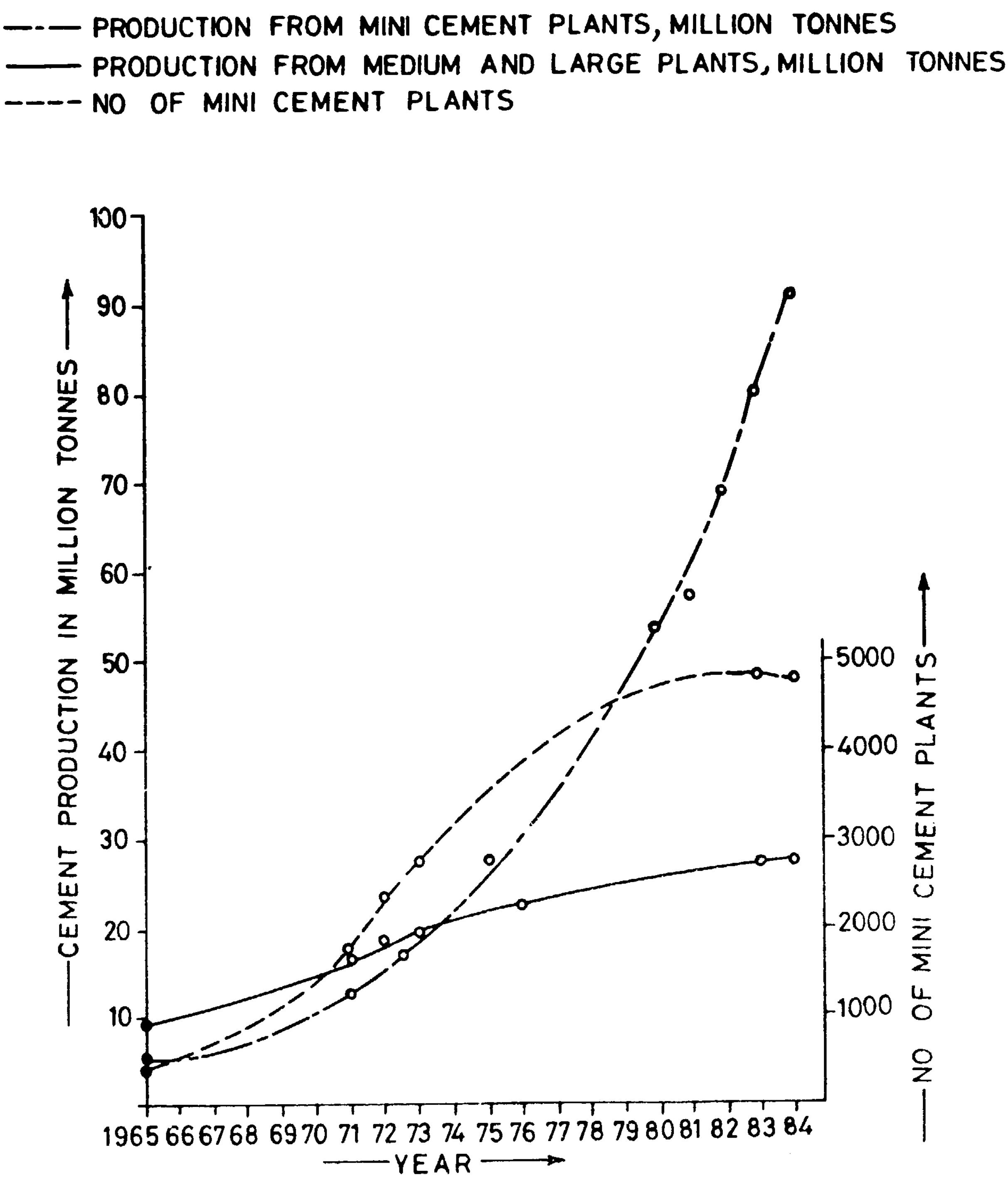
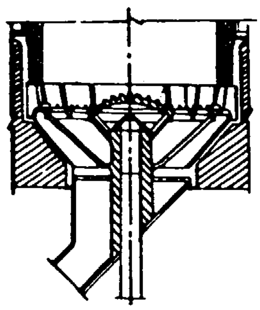
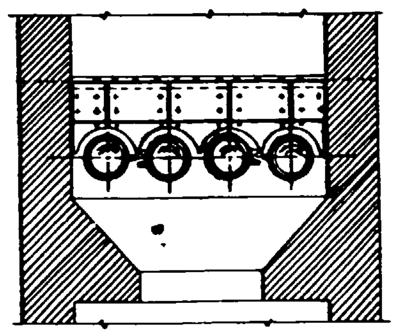


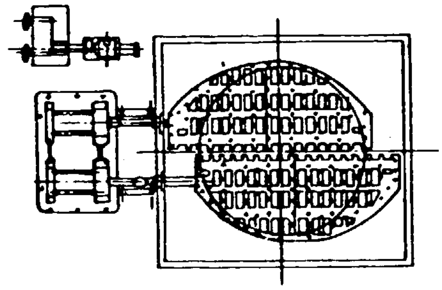
Fig.11. GROWTH OF MINI CEMENT PLANTS IN CHINA



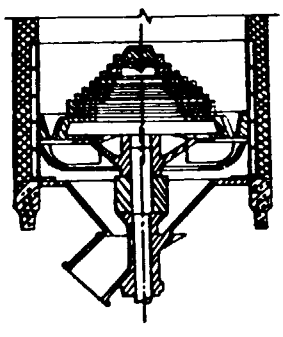
FLAT GRATE



ROLLER GRATE



RECIPROCATING GRATE



CONE GRATE

Fig. 12 DIFFERENT TYPES OF GRATES USED IN MECHANISED SHAFT KILNS IN CHINA

5.4 Problems Faced

A number of mini cement plants in China have been facing problems of non-uniform cement quality, poor management and operational skills, higher cost of production, high heat consumption, environmental pollution, etc. The Government of China has therefore decided to slowly disband the old non-mechanised plants numbering about 2000 and take up modernization of those plants which can produce cement of good quality through mechanization (at the rate of about 300 plants a year).

6.0 ECONOMICS

6.1 The economics of any mini cement plant depends upon a number of parameters like the technology adopted, process, location of the plant, selling price of cement, transportation aspects of the finish product etc. Based on NCB's experience in setting up a large number of mini cement plants and the feedback obtained from the plants already under operation, a summary of the normative project cost, cost of production and profitability of mini cement plants of different sizes have been compared and summarised in the enclosed tables 3 & 4. The above tables also include a sensitivity analysis wherefrom it may be observed that except for plants of very small sizes, the profitability of these mini cement plants are not adversely affected by variations in the input parameters. The figures in the tables are expressed in US dollar and value of US dollar being taken as Rs 12 (Indian currency).

Other relevant data, supplementary to tables 3 & 4 are given in the following tables:

Table 5 : Estimates of capital cost of 100 TPD (1x100 TPD CRI MVSK) and 200 TPD (2x100 TPD CRI MVSK) mini cement plants.

Table 6 : Estimates of annual cost of production of cement in 100 TPD (1x100 TPD CRI MVSK) and 200 TPD (2x100 TPD CRI MVSK) mini cement plants.

Table 7 : Breakeven analysis for a 100 TPD (1x100 TPD CRI MVSK) and 200 TPD (2x100 TPD CRI MVSK) mini cement plants.

Table 8 : Estimates of capital cost of 30 TPD (1x30 TPD CRI MVSK), 50 TPD (1x50 TPD CRI MVSK), 100 TPD (2x50 TPD CRI MVSK), 200 TPD (4x50 TPD CRI MVSK) and 200 TPD single line rotary kiln based mini cement plant.

Table 9 : Estimates of working capital requirement for a 30 TPD, 50 TPD, 100 TPD and 200 TPD mini cement plants.

Table 10: Estimates of annual cost of production of cement in 30 TPD (1x30 TPD CRI MVSK), 50 TPD (1x50 TPD CRI MVSK), 100 TPD (2x50 TPD CRI MVSK), 200 TPD (4x50 TPD CRI MVSK) and 200 TPD single line rotary kiln mini cement plant.

Table 11: Breakeven analysis for 30 TPD (1x30 TPD CRI MVSK), 50 TPD (1x50 TPD CRI MVSK), 100 TPD (2x50 TPD CRI MVSK), 200 TPD (4x50 TPD CRI MVSK) and 200 TPD single line rotary kiln based mini cement plant.

Table 12: Expected benefits/costs of the project based on the fourth year of operation in a typical case for 100 TPD (2x50 TPD CRI MVSK) mini cement plant.

As may be seen from the above tables the project cost of 200 TPD CRI MVSK cement plant (based on 2x100 TPD CRI MVSK) is about US $ 3828000 as against US $ 8250000 for a rotary kiln plant of same capacity, which shows that the investment cost per annual tonne of installed capacity in case of a CRI MVSK plant is almost 50% of that based on conventional rotary kiln technology. In addition to above, the cost of production of cement in rotary kiln mini cement plant is higher as compared to vertical shaft kiln of equivalent size due to higher consumption of fuel, power and higher component of interest and depreciation due to high capital cost.

6.2 As can be seen from the enclosed tables, under any technology within an upper and lower threshold, there are always scale effects which are bound to effect both investment and operating costs. Whilst there is a significant advantage in the investment and operating cost by changing the process and the process line from rotary to VSK; within the VSK mini cement plants also, the investment cost and specially the cost of production goes up when the size of the plant is made smaller and smaller. It is due to this reason NCB, in India, makes a very careful evaluation of the economic viability of these small size cement plants over their entire life cycle before any investment decision is undertaken. For example, in India, we have found that keeping the economic viability over the entire life cycle of the plant in view, normally mini cement plants with size of 50 TPD and above should only be encouraged untill and unless there are specific advantages which can be derived from a plant of still smaller capacity; in terms of limited raw material deposits, limited local demand and other socio-economic factors; which can only be evaluated on a case to case basis.

6.3 It is also worth mentioning that the same CRI-MVSK cement plant, because of its modern features including microprocessor based process control and monitoring system, can be used for manufacture of a large variety of special cements like high strength cement, cement for railway sleepers, expansive cement, oil well cement, etc apart from blended cement like portland slag cement and portland pozzolana cement without any change in the plant and machinery requirements. In fact all these special cements have already been produced in a few of the operating CRI-MVSK cement plants which has given a boost to the techno-economic viability of these mini cement plants in the country.

Table - 3

INVESTMENT, PRODUCTION COST AND PROFITABILITY OF 100 TPD (1x100 TPD KILN) & 200 TPD (2 x 100 TPD KILNS) CRI-MVSK MINI CEMENT PLANT

Sl No	Items	Cost 100 TPD	Cost 200 TPD
1	CAPITAL COST (US $ '000)		
	a/ *Fixed capital	2167.50	3660.33
	b/ **Margin money	87.50	166.67
	c/ Total capital	2255.00	3827.50
2	INVESTMENT PER TONNE OF INSTALLED ANNUAL CAPACITY (US $)		
	a/ Fixed capital	65.66	55.46
	b/ Margin money	2.66	2.53
	c/ Total capital	68.32	57.99
3	*COST OF PRODUCTION (of naked cement US $/tonne)	38.34	35.59
4	DEBT EQUITY RATIO	2 : 1	
5	PROFITABILITY UNDER DIFFERENT CONDITIONS (Percentages based on Equity Capital)		
	a/ Ex-works profit if cement is sold @ US $ 5 per bag of 50 kg		
	i/ US $/tonne	21.60	24.35
	ii/ Pre-tax %	85.40	115.70
	iii/ Post-tax %	42.70	57.90
	b/ Profit if salaries & wages are paid not as per cement wage board, all other conditions same as in (a) above.		
	i/ US $/tonne	22.68	25.58
	ii/ Pre-tax %	89.60	119.00
	iii/ Post-tax %	44.30	59.50
	c/ Profit if cement is sold within the radius of 100 km, all other conditions same as in (a) above.		
	i/ US $/tonne	17.44	20.69
	ii/ Pre-tax %	68.90	96.20
	iii/ Post-tax %	34.50	48.10

* Details incorporated in tables 5 & 6
** Details incorporated in table 9

Sl No	Items	Cost	
		100 TPD	200 TPD
a/	Effect on profitability		
	1/ if capital cost decreases by 10%		
	i/ US $/tonne	+ 1.08	+ 0.91
	ii/ Pre-tax %	+ 12.40	+ 15.50
	iii/ Post-tax %	+ 6.20	+ 7.40
	2/ if operation cost decreases by 10%		
	i/ US $/tonne	+ 2.81	+ 2.65
	ii/ Pre-tax %	+ 11.00	+ 12.40
	iii/ Post-tax %	+ 5.50	+ 6.20
	3/ if capital cost increases by 10%		
	i/ US $/tonne	- 1.08	- 0.91
	ii/ Pre-tax %	- 10.10	- 12.60
	iii/ Post-tax %	- 5.00	- 6.30
	4/ if operating cost increases by 10%		
	i/ US $/tonne	- 2.81	- 2.65
	ii/ Pre-tax %	- 11.00	- 12.40
	iii/ Post-tax %	- 5.50	- 6.20
	5/ if interest rate on long term loan is 12.5% instead of 14%		
	i/ US $/tonne	+ 0.60	+ 0.47
	ii/ Pre-tax %	+ 2.80	+ 3.00
	iii/ Post-tax %	+ 1.40	+ 1.50

Note: The cost figures given above are in US $ equivalent to Indian Rupees (1 US $ = Rs 12)

Table - 4

INVESTMENT, PRODUCTION COST AND PROFITABILITY OF 30 TPD (1x30 TPD KILN), 50 TPD (1x50 TPD KILN), 100 TPD (2x50 TPD KILNS) AND 200 TPD (4x50 TPD KILNS) CRI-MVSK MINI CEMENT PLANT

Sl No	Items	Cost of CRI-MVSK Mini Cement Plants				Cost of 200 tpd rotary kiln cement plant
		30 tpd	50 tpd	100 tpd	200 tpd	
1	Capital cost (US $ '000)					
	a. *Fixed capital	841.66	1468.33	2255.00	3829.16	8083.33
	b. **Margin money	31.66	46.66	87.50	166.66	166.66
	c. Total capital	873.32	1514.99	2342.50	3995.32	8249.99
2	Investment per tonne of Installed Annual Capacity (US $)					
	a. Fixed capital	85.02	89.00	68.33	58.02	122.47
	b. Margin money	3.20	2.82	2.65	2.52	2.[illegible]
	c. Total capital	88.22	91.32	70.98	60.54	124.[illegible]
3	*Cost of production (of naked cement) US $/tonne	53.42	46.75	39.50	36.17	46.50
4	Debt Equity ratio			2 : 1		
5	Profitability under different conditions (Percentages based on equity capital)					
	a. Ex-works profit if cement is sold @ US $ 5 per bag of 50 kg					
	i/ US $/tonne	7.02	13.69	20.94	24.27	13.94
	ii/ Pre-tax %	21.50	40.30	79.80	108.30	30.10
	iii/ Post-tax %	10.80	20.10	39.90	54.10	15.00
	b. Profit if salaries & wages are paid not as per cement wage board, all other conditions same as in (a) above					
	i/ US $/tonne	10.56	15.65	22.08	25.04	14.77
	ii/ Pre-tax %	32.30	46.00	84.10	111.70	31.90
	iii/ Post-tax %	16.20	23.00	42.10	55.90	15.90

* Details incorporated in tables 8 & 10
** Details incorporated in table 9

Sl No	Items	Cost of CRI-MVSK Mini Cement Plants 30 tpd	50 tpd	100 tpd	200 tpd	Cost of 200 tpd rotary kiln cement plant
c.	Profit if cement is sold within the radius of 100 kms, all other conditions same as in (a) above					
	i/ US $/tonne	2.35	9.52	16.77	20.10	9.77
	ii/ Pre-tax %	3.70	28.00	63.90	89.70	21.10
	iii/ Post-tax %	4.40	14.00	31.90	44.30	10.50
d.	Effect on profitability					
	1/ if capital cost decreases by 10%					
	i/ US $/tonne	+ 1.42	+ 1.44	+ 1.10	+ 0.94	+ 1.91
	ii/ Pre-tax %	+ 5.90	+ 7.90	+11.60	+14.70	+ 6.90
	iii/ Post-tax %	+ 2.90	+ 3.90	+ 5.30	+ 7.30	+ 3.50
	2/ if operation cost decreases by 10%					
	i/ US $/tonne	+ 3.93	+ 3.23	+ 2.35	+ 2.67	+ 2.74
	ii/ Pre-tax %	+12.10	+ 9.50	+10.30	+11.90	+ 6.00
	iii/ Post-tax %	+ 6.00	+ 4.30	+ 5.40	+ 5.90	+ 3.00
	3/ if capital cost increases by 10%					
	i/ US $/tonne	- 1.42	- 1.44	- 1.10	- 0.94	- 1.91
	ii/ Pre-tax %	- 4.70	- 6.40	- 9.70	-12.00	- 5.70
	iii/ Post-tax %	- 2.40	- 3.20	- 4.90	- 6.00	- 2.30
	4/ if operation cost increases by 10%					
	i/ US $/tonne	- 3.93	- 3.23	- 2.34	- 2.67	- 2.74
	ii/ Pre-tax %	-12.10	- 9.50	-10.80	-11.90	- 6.00
	iii/ Post-tax %	- 6.00	- 4.30	- 5.40	- 5.60	- 3.00
	5/ if interest rate on long term loan is 12.5% instead of 14%					
	i/ US $/tonne	+ 0.33	+ 0.30	+ 0.60	+ 0.53	+ 1,44
	ii/ Pre-tax %	+ 2.70	+ 2.60	+ 2.50	+ 2.70	+ 3.60
	iii/ Post-tax %	+ 1.30	+ 1.30	+ 1.20	+ 1.30	+ 1.30

Table - 5

ESTIMATES OF CAPITAL COST OF 100 TPD (1x100 TPD KIL.) AND 200 TPD (2x100 TPD KILNS) CRI-MVSK MINI CEMENT PLANT

Figures US $ '000

Sl No	Item	Amount	
		100 tpd	200 tpd
1	Land and site development	43.33	58.33
2	Buildings	425.00	853.33
3	Plant and machinery	1183.33	1958.33
4	Training expenses	4.17	4.17
5	Miscellaneous fixed assets	193.33	279.17
6	Preliminary and capital issue expenses	41.67	66.67
7	Pre-operative expenses	193.34	302.50
8	Provision for contingencies	83.33	138.33
9	Margin money	87.50	166.67
	Total capital cost	2255.00	3827.50

Table - 6

ESTIMATES OF ANNUAL COST OF PRODUCTION OF CEMENT IN A 100 TPD(1x100 TPD KILN) & 200 TPD (2x100 TPD KILNS) CRI-MVSK MINI CEMENT PLANTS

Basis: Fourth year of operation - 90% capacity utilization 330 working days/year

Sl No	Item	Consumption factor per tonne of cement	Rate/ Unit US $	Annual Requirement		Amount per tonne of cement (US $)	
				100 tpd or 29700 tpy	200 tpd or 59400 tpy	100 tpd	200 tpd
1	Raw Materials						
	a. Limestone	1.295 (t)	2.5	38462	76923	3.24	3.24
	b. Clay	0.235 (t)	1.0	6980	13959	0.23	0.23
	c. Coke breeze	0.203 (t)	45.33	6029	12058	9.30	9.30
	d. Gypsum	0.049 (t)	16.67	1455	2910	0.82	0.82
2	Power	125 kWh	0.05	3712500 kWh	7425000 kWh	6.25	6.25
3	Stores & consumable					1.25	1.25
4	Salaries & wages					4.33	2.92
5	Repairs & maintenance					1.10	0.94
6	Overhead expenses						
	a. Manufacturing					0.42	0.42
	b. Administrative					0.42	0.42
7	Depreciation of fixed assets					4.30	3.65
8	Amortizational projecting cost					0.80	0.63
9	Insurance charges					0.30	0.26
10	Financial Expenses						
	a. Interest on long term loan @ 14%					5.30	4.50
	b. Interest on short term loan @ 17.5%					0.77	0.75
	Total cost of production upto naked cement					38.83	35.58

Table - 7

BREAK-EVEN ANALYSIS*FOR A 100 TPD (1x100 TPD KILN) AND 200 TPD (2x100 TPD KILNS) CRI-MVSK MINI CEMENT PLANTS

Sl No	Item	Amount 100 tpd	Amount 200 tpd
1	Sales quantity (tonnes/year)	29700	59400
2	Net sales realization per tonne if cement is sold at the rate of US $ 5 per bag of 50 kg	60.44	60.44
3	Annual cost of production		
	a. Fixed Elements US $/tonne		
	i/ Salaries & wages	4.33	2.92
	ii/ Stores & consumables 25%	0.31	0.31
	iii/ Repairs & maintenance 75%	0.82	0.70
	iv/ Overhead expenses	0.34	0.34
	v/ Depreciation	4.30	3.65
	vi/ Insurance	0.30	0.63
	vii/ Amortizational project cost	0.32	0.28
	viii/ Interest on long term loan	5.30	4.50
	Total	17.02	13.83
	b. Variable Elements US $/tonne		
	i/ Raw materials	13.59	13.59
	ii/ Power	6.25	6.25
	iii/ Stores & consumables 75%	0.94	0.94
	iv/ Repairs & maintenance 25%	0.28	0.24
	v/ Interest on short term loan	0.77	0.75
	Total	21.83	21.77

$$\text{Break Even Point} = \frac{\text{Fixed Cost}}{\text{Net sale realization - Variable cost}} \times 100$$

$$\text{Break Even Point for 100 tpd(1x100 tpd kiln)} = \frac{17.02}{60.44 - 21.33} \times 100 = 44\%$$

$$\text{Break Even Point for 200 tpd(2x100 tpd kilns)} = \frac{13.83}{60.44 - 21.77} \times 100 = 36\%$$

* for Break-even chart refer to Fig. 13

Table - 8

ESTIMATES OF CAPITAL COST OF 30 TPD (1x30 TPD KILN), 50 TPD (1x50 TPD KILN), 100 TPD (2x50 TPD KILNS) AND 200 TPD (4x50 TPD KILNS) CRI-MVSK MINI CEMENT PLANTS AND 200 TPD ROTARY KILN CEMENT PLANT

Figures in US $ '000

Sl No	Item	Cost of CRI-MVSK Mini Cement Plants 30 tpd	50 tpd	100 tpd	200 tpd	Cost of 200 tpd rotary kiln cement plant
1	Land & site development	19.17	32.50	43.33	58.33)	
					)	941.67
2	Buildings	162.50	281.67	437.50	881.66)	
3	Plant & machinery	453.32	833.33	1250.00	2083.33)	
					)	4325.00
4	Training expenses	4.17	4.17	4.17	4.17)	
5	Miscellaneous fixed assets	50.00	110.00	193.33	279.17	916.67
6	Preliminary & capital issue expenses	2.50	2.50	41.67	66.67	175.00
7	Pre-operative expenses	95.00	148.33	198.33	310.00	991.66
8	Provision for contingencies	50.00	55.33	86.67	145.33	733.33
9	Margin money for working capital	31.66	46.66	87.50	166.66	166.66
10	Total capital cost	873.32	1514.99	2342.50	3995.82	8249.99

Table - 9

ESTIMATES OF WORKING CAPITAL REQUIREMENT FOR A 30 TPD,
50 TPD, 100 TPD AND 200 TPD CRI-MVSK MINI CCEMENT PLANT

UTILIZATION : 90%

US $ '000

Sl No	Items	Inventory period	Quantity 30 tpd	50 tpd	100 tpd	200 tpd	Rate/ Unit (Rs)	Amount US $ '000 30 tpd	50 tpd	100 tpd	200 tpd
1	Raw Materials										
	a) Limestone	1-1/4 m*	1202	2003	4006	8012	2.5	3.01	5.01	10.05	20.03
	b) Clay	1-1/2 m*	261	436	872	1745	1.0	0.30	0.44	0.90	1.75
	c) Coke breeze	4 m*	604	1005	2010	4020	45.33	27.70	46.10	92.10	184.25
	d) Gypsum	2-1/2 m*	91	151	303	606	16.47	1.52	2.52	5.00	10.10
	e) Packing materials (Bags)	1-1/2 m*	22275	37125	74250	148500	0.42	9.40	15.60	31.20	62.37
2	Power	1 m*						5.00	8.50	16.00	30.00
3	Stores & consumables	1 m*						1.00	1.55	3.10	6.20
4	Repairs & maintenance	1 m*						2.00	2.20	2.95	4.30
5	Salaries & wages	1 m*						10.52	9.70	11.30	15.25
6	Overhead expenses	1 m*						0.62	1.05	2.10	4.20
7	Insurance	3 m*						1.40	1.65	2.50	4.30
8	Goods in process	15 days						9.20	13.35	24.30	43.40
9	Finished goods upto naked cement	7 days						7.50	9.00	17.25	30.00
	Total working capital							79.17	116.67	218.75	416.65
	Margin money 40%							31.66	46.66	87.50	166.66
	Short term loan 60%							47.51	70.01	131.25	249.99

Table - 10

ESTIMATES OF ANNUAL COST OF PRODUCTION OF CEMENT IN A 30 TPD(1x30 TPD KILN) 50 TPD (1x50 TPD KILN) 100 TPD (2x50 TPD KILNS), 200 TPD (4x50 TPD KILNS) CRI-MVSK MINI CEMENT PLANT AND 200 TPD ROTARY KILN CEMENT PLANT

4th year of operation - 90% utilization — 330 working days/year

Sl No	Item	Consumption factor per tonne of cement	Rate/ Unit (US $)	Annual Requirement				CRI-MVSK Cement Plant Amount per tonne of cement (US $)				Rotary kiln cement plant 200 tpd
				30 tpd	50 tpd	100 tpd	200 tpd	30 tpd	50 tpd	100 tpd	200 tpd	
1	Raw Materials											
	a) Limestone	1.295 (t)	2.5	11538	19230	38462	76923	3.24	3.24	3.24	3.24	3.24
	b) Clay	0.235 (t)	1.0	2094	3490	6980	13959	0.23	0.23	0.23	0.23	0.23
	c) Coke breeze/coal	0.203 (t)	45.33	1809	3014	6029	12058	9.30	9.30	9.30	9.30	7.67 (0.23 @ US $ 33.33/t
	d) Gypsum	0.049 (t)	16.67	436	727	1455	2910	0.82	0.82	0.82	0.82	0.82
2	Power	125 kwh	0.05	1113750	1856250	3712500	7425000	6.25	6.25	6.25	6.25	6.50 (130 kwh @ 0.05/unit
3	Stores & consumables							1.25	1.25	1.25	1.25	1.67
4	Salaries & wages							14.18	7.34	4.59	3.09	3.34
5	Repairs & maintenance							2.28	1.77	1.18	0.97	1.92
6	Overhead expenses											
	a) Manufacturing							0.42	0.42	0.42	0.42)	
	b) Administrative							0.42	0.42	0.42	0.42)	1.25
7	Depreciation of fixed assets							5.42	5.30	4.35	3.79	7.67

Sl No	Item	Consumption factor per tonne of cement	Rate/ Unit (US $)	Annual Requirement 30 tpd	50 tpd	100 tpd	200 tpd	CRI-MVSK Cement Plant Amount per tonne of cement (US $) 30 tpd	50 tpd	100 tpd	200 tpd	Rotary kil cement plant 200 tpd
8	Amortization of projecting cost							1.19	1.03	0.84	0.64	1.17
9	Insurance charges							0.63	0.44	0.34	0.29	0.52
10	Financial expenses											
	a) Interest on term loan @ 14% p.a.							6.90	7.14	5.50	4.71	9.75
	b) Interest on short term loan @ 17.5% p.a.							0.95	0.80	0.77	0.75	0.75
11	Cost of production of naked cement							53.48	46.75	39.50	36.17	46.60

Table - 11

BREAK-EVEN ANALYSIS*

FOR A 30 TPD (1x30 TPD KILN), 50 TPD (1x50 TPD KILN), 100 TPD (2x50 TPD KILNS) & 200 TPD (4x50 TPD KILNS) CRI-MVSK MINI CEMENT PLANT & 200 TPD ROTARY KILN CEMENT PLANT

Sl No	Item	Amount 30 tpd	50 tpd	100 tpd	200 tpd	200 tpd rotary kiln plant
1	Sales quantity tonnes/year	8910	14850	29700	59400	59400
2	Net sales realisation per tonne if the cement is sold @ US $ 5/bag of 50 kg	60.44	60.44	60.44	60.44	60.44
3	Annual cost of production					
a)	Fixed Elements US $/tonne					
i/	Salaries & wages	14.18	7.34	4.59	3.09	3.34
ii/	Stores & consumables 25%	0.31	0.31	0.31	0.31	0.42
iii/	Repairs & maintenance 75%	1.71	1.33	0.38	0.73	1.44
iv/	Overhead expenses	0.84	0.84	0.84	0.84	1.25
v/	Depreciation	5.42	5.30	4.35	3.79	7.67
vi/	Insurance	0.63	0.44	0.34	0.29	0.52
vii/	Amortization of project cost	1.19	1.03	0.34	0.64	1.17
viii/	Interest on term loan	6.90	7.14	5.50	4.71	9.75
		31.18	24.73	17.65	14.40	25.56
b)	Variable elements US $/tonne					
i/	Raw material	13.59	13.59	13.59	13.59	11.96
ii/	Power	6.25	6.25	6.25	6.25	6.50
iii/	Stores & consumables 75%	0.94	0.94	0.94	0.94	1.25
iv/	Repairs & maintenance 25%	0.57	0.44	0.30	0.24	0.48
v/	Interest on short loan	0.95	0.80	0.77	0.75	0.75
		22.30	22.02	21.85	21.77	20.94

$$\text{Break-Even Point} = \frac{\text{Fixed Cost}}{\text{Net sales realization - Variable cost}} \times 100$$

*For Break-Even Chart refer to Figures 14 & 15

Break-Even point for a 30 tpd (1x30 tpd kiln) $= \frac{31.18}{60.44-22.30} \times 100$

$= 82\%$

Break-Even point for a 50 tpd (1x50 tpd kiln) $= \frac{24.73}{60.44-22.02} \times 100$

$= 64\%$

Break-Even point for a 100 tpd (2x50 tpd kilns) $= \frac{17.65}{60.44-21.35} \times 100$

$= 46\%$

Break-Even point for a 200 tpd (4x50 tpd kilns) $= \frac{14.40}{60.44-21.77} \times 100$

$= 37\%$

Break-Even point for a 200 tpd rotary kiln $= \frac{25.56}{60.44-20.94} \times 100$

$= 65\%$

Table - 12

EXPECTED BENEFITS COSTS OF THE PROJECT (BASED ON THE 4TH YEAR OF OPERATION) FOR 100 TPD (2x50 TPD KILNS) CRI-MVSK MINI CEMENT PLANT

A	OUTPUT AND PROFITS (US $ '000)		
1	Capacity output (3 shifts)		1995
2 a)	Value of output (net of excise duty)*		1795
b)	Other income		-
3	Value of output as percentage of 1		90
4	Change in the stock of goods		-
5	Sales (at factory price), (2a-4)		1795
6	Raw Materials		
a)	Domestic		128
b)	Imported		-
7	Fuel and power		462
8	Other inputs (specify)		
a)	Stores and consumables	38	
b)	Rent, Taxes & Insurance	10	
c)	Other Works Expenses	12	95
d)	Repairs & Maintenance	35	
9	Gross values added (5-(6+7+8))		1110
10a)	Depreciation		129
b)	Amortization of projecting cost		25
11	Net value added (9-10)		956
12a)	Wages & Salaries		136
b)	Administrative expenses		124
13	Interest		186
14	Royalty		-
15	Gross profit & interest (9-12)		850
16	Operating profit (15-(10+13+14))		510
17	Tax		255
18	Net profit (16-17)		255
B	PRODUCTIVE CAPITAL US $ '000		
1	Gross fixed assets		2255
2	Inventories		218
3	Capital employed (1+2)		2473
4	Number of workers		71
C	CAPITAL OUTPUT RATIO		
1	Capital/value of output (B_3/A_2)	1.38:1	
2	Capital/gross value added (B_3/A_9)	2.23:1	
3	Capital/net value added (B_3/A_{11})	2.58:1	
4	Capital/per worker (B_3/B_4) (US $ '000)	35	
5	Capital/wages & salaries ($B_3/A_{12}a$)	19.94:1	

D	PRODUCTIVITY INDICATORS (Ratio)	
1	Productivity per unit of capital (A_2/B_3)	0.7:1
2	Productivity per unit of labour (A_2/B_4)	25:1
3	Productivity per unit of wages & salaries ($A_2/A_{12}a$)	13.20:1
E	INPUT STRUCTURES (Proportion Percent)	
1	Raw materials value of output (A_6/A_2)	7.1
2	Fuel & power/value of output (A_7/A_2)	25.7
3	Other inputs/value of output (A_8/A_2)	5.3
4	Wages & salaries/value of output (A_{12a}/A_2)	7.6
5	Depreciation/value of output (A_{10}/A_2)	8.6
6	Interest/value of output (A_{13}/A_2)	10.4
7	Administrative expenses/value of output (A_{12b}/A_2)	6.9
8	Operating profit/value of output (A_{16}/A_2)	28.5
F	PROFITABILITY RATIO (Proportion Percent)	
1	Gross profit + Interest/Capital employed ($A_{15}+A_{13}/B_3$)	41.9
2	Operating profit + Interest/Capital employed ($A_{16}+A_{13}/B_3$)	28.1
3	Operating profit/sales (A_{16}/A_5)	28.5
4	Net profit/equity capital ($A_{18}/781$)	32.7
G	PAYMENT CAPACITY (US $ '000)	
1	Gross profit less royalty ($A_{15}-(A_{13}+A_{14})$	665
2	Tax provision (A_{17})	255
3	Repaying capacity (G_1-G_2)	410

* Net sales realisation per tonne has been taken as US $ 60.44 which is arrived as unde:

"

	US $/Tonne
Retail price	100.00
Less sales tax	9.17
Less excise duty	18.75
Less packing charges	8.33
Less payment to the research account	0.06
Less payment to the cement regulation account	0.75
Less dealer's margin of profit	2.50
	60.44

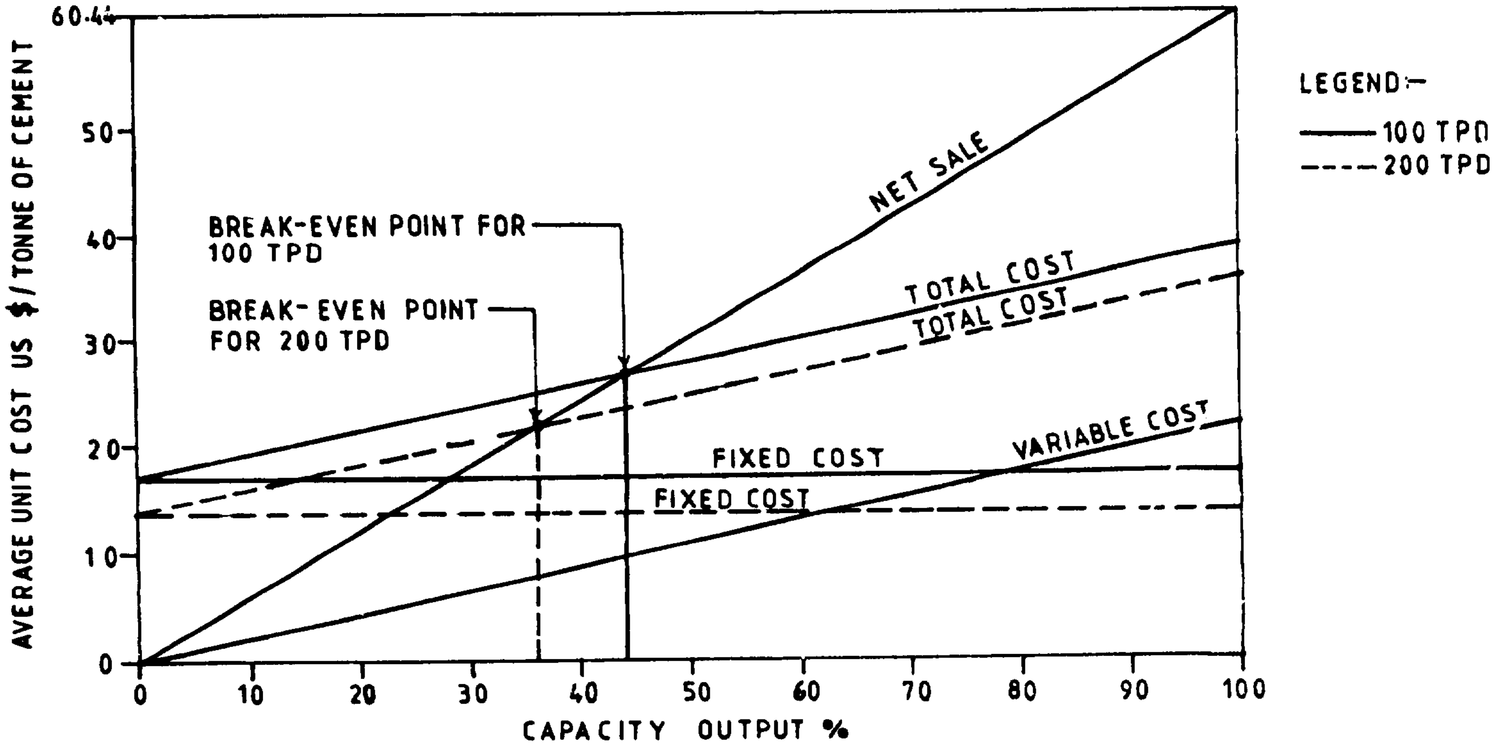


FIG.13 BREAK-EVEN CHART FOR 100 TPD (1X100 TPD CRI-MVSK), 200 TPD (2X100 TPD CRI-MVSK) CEMENT PLANTS

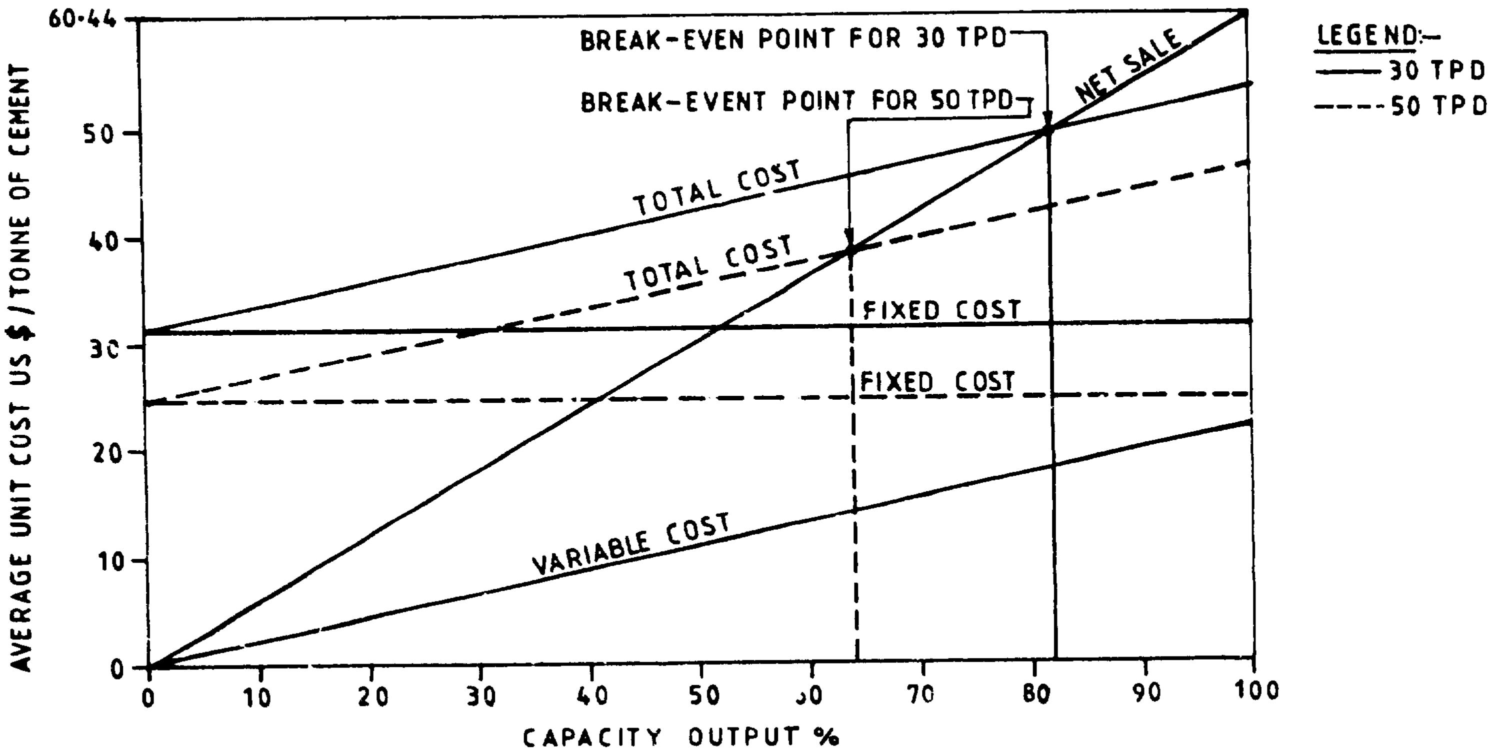


FIG.14 BREAK-EVEN CHART FOR 30 TPD (1X30 TPD CRI-MVSK), 50 TPD (1X50 TPD CRI-MVSK) CEMENT PLANTS

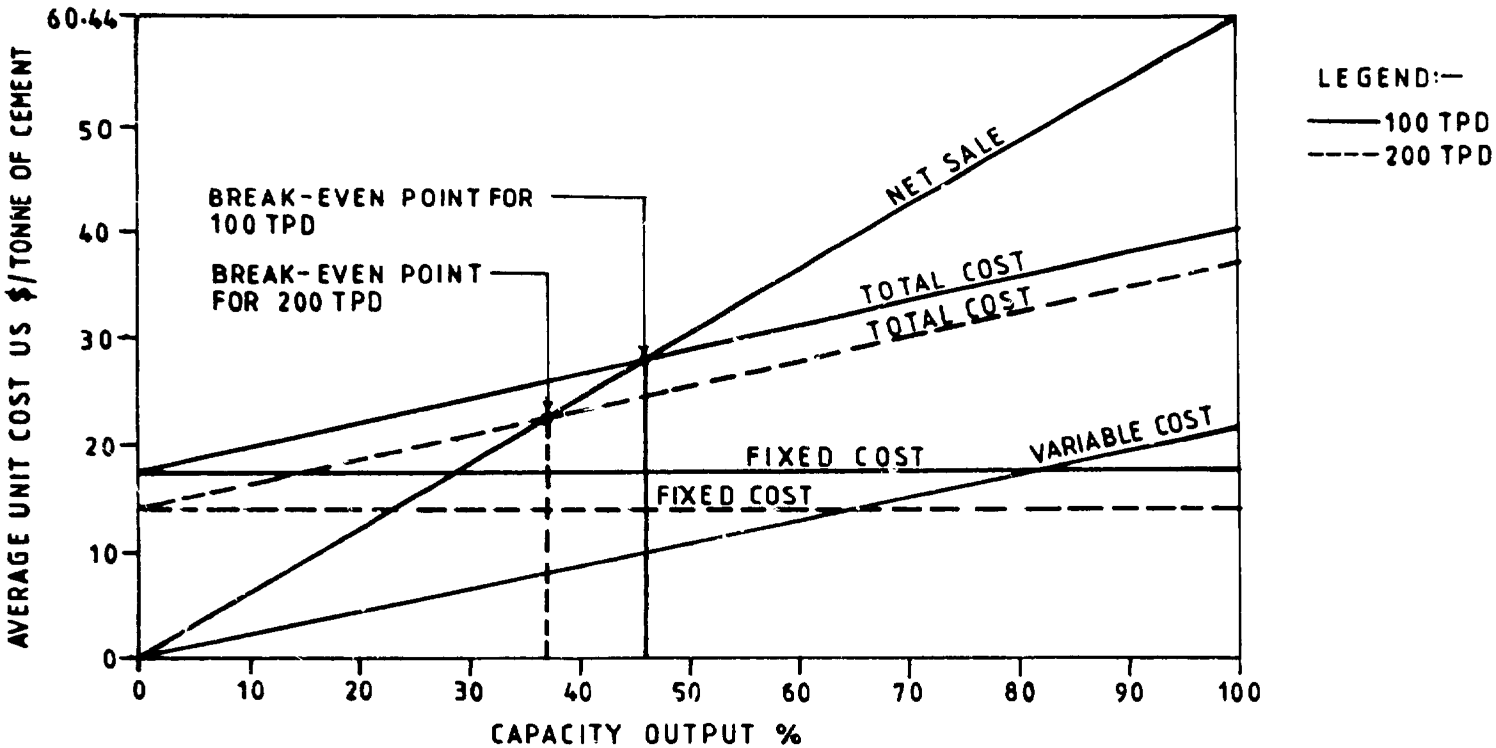


FIG.15 BREAK-EVEN CHART FOR 100 TPD (2X50 TPD CRI-MVSK), 200 TPD (4X50 TPD CRI-MVSK) CEMENT PLANTS

7.0 MINI CEMENT PLANTS IN COUNTRIES OTHER THAN INDIA AND CHINA

7.1 Although the latest information regarding the exact number of mini cement plants operating in different parts of the world are not available, Table 13 shows a global survey of vertical shaft kilns under operation in different countries.

TABLE 13

Global Survey of Vertical Shaft Kilns in Operation

Country	No. of locations	No. of Active Kilns
Kenya	1	6
India*	29	44
Iran	1	2
Australia	1	2
Belgeum	1	4
France	4	24
West Germany	4	31
Brazil	1	1
Austria	2	3
Greece	1	2
Italy	7	12
Nepal	1	1
Poland	1	6
Spain	7	26
Yugoslavia	3	18
China	29(provinces)	4856

Source: 1. World Cement directory, The European Cement Association, Cembureau, Paris 1980, 1983
2. Data available at NCB.
3. Report of the visit of Indian Delegation to China's Cement and Allied Industries in November 1984.

* excluding very tiny Vertical Shaft Kilns.

So far as mini cement plants based on CRI-MVSK technology are concerned, M/s Penden Cement Authority of Bhutan, have installed a 50 tpd CRI-MVSK plant at Gomtu and later expanded it to 100 tpd by installation of another 50 tpd CRI-MVSK line. One mini cement plant of 160 tpd capacity based on

Vertical Shaft Kiln of size 2.4 metre dia and 8 metre height supplied by M/s Loesche, West Germany is already under operation at the works of M/s Himal Cement Company, Nepal. Another mini cement plant of 30 tpd capacity based on CRI-MVSK is presently under implementation at Anboo-Khaireni in Nepal.

M/s Loesche of West Germany have supplied more than 14 mini cement plants based on black meal VSK process in more than nine countries. The first multiple VSK plant supplied by M/s Loesche had gone into operation in 1955 at the cement plant of M/s Portlandzemtnfabrik Blaubeuren Gebr. Spohn Ag at Blaubeuren, Germany. Later on M/s Loesche have supplied plants based on VSK to various countries like Japan, New zealand, Austria, Spain, Italy, Nepal, Brazil, Madagascar and Indonesia. In the latest design of 400 tpd (2x200 tpd) plant at Kupang in Indonesia, pre-blending techniques for controlling of the variation in quality of limestone and clay were employed. Different fuels of various mixtures have been used at Paggau ranging from anthracite dust to coke breeze and petrol coke, the application of which in all the cases have been reported to be a success.

In addition to above, M/s Maerz Ofenbau of Zurich also supplied mini cement plants based on VSK technology on turnkey basis. M/s Maerz are the exclusive licencee for the manufacture of Prerov machinery designed mini cement plants with as many as 16 cement shaft kilns operating in different parts of the world. The heat consumption in these plants is claimed to be about 900 kcal/kg clinker.

7.2 A comparison of the investment cost and cost of production of cement has been shown under Table 14 which includes certain typical examples of cement plants from various parts of the world including conventional 1 million tonne per annum large plant, 200 tpd rotary kilns, CRI-MVSK cement plants of different capacities, the VSK cement plant of M/s Himal Cement Co in Nepal supplied by M/s Loesche, West Germany and two typical examples of mini cement plants in China namely Jiaonan Cement Plant and Qungdo House Property Bureau Cement Plant; which are based on the data collected by an Indian Delegation which visited China in

November 1984 under the leadership of Dr H C Visvesvaraya, Chairman and Director General, NCB. It may be observed that since the mini cement plants in China are extensively used for the production of portland slag cement, the cost of production as well as the investment cost per annual tonne of cement is comparatively lower than the other figures which are for OPC. Moreover, the costs indicated in Table - 14 are for specific cases under different situations and hence cannot be directly compared.

Table - 14

COMPARISON OF INVESTMENT COST, COST OF PRODUCTION OF CONVENTIONAL LARGE PLANTS AND MINI CEMENT PLANTS IN DIFFERENT COUNTRIES

Sl No	Items	Average for conventional large plant (3000 tpd)	Average for 200 tpd Rotary kiln	Average for CRI-MVSK Cement Plants (India)				Nepal 160 tpd (Himal Cement Plant 1x160tpd Kiln)	China 250 tpd (Slag Cement) (Jaionan Cement Plant)	Oingdao ci 75 tpd sla cement (Housing & Property Bureau)
				30 tpd (1x30tpd kiln)	50 tpd (1x50tpd kiln)	100 tpd (2x50tpd) kilns)	200 tpd (2x100tpd) kilns)			
1	Capital Investment (US $ '000)	119833	8250	875	1500	2333	3833	3166*	4538	595**
2	Investment Cost per tonne of Installed Annual Capacity (US $)	121	125	88	91	71	58	60	55	24
3	Cost of Production of naked cement US $/tonne	38	47	53	47	40	36	72	26	25

* Cost relates to the year 1974 when plant was commissioned
Rs (IC - Indian Currency) = Rs 1.45 (NC - Nepalese Currency)

** Cost relates to the year 1964 when plant was commissioned
1 y = Rs 5.5 (IC)

1 US $ = Rs 12 (IC)

8.0 GEOLOGICAL INVESTIGATIONS

The process of cement manufacture and its quality is primarily controlled by appropriate selection and evaluation of raw materials. It is needless to emphasize that geological investigations, if done properly, will not only result in choice of the most suitable raw materials occurring in the area for the purpose but also in financial savings and other intangible savings in the avoidance of indecisiveness, procrastination and delay.

Proper attention, therefore, is to be paid in selecting those raw materials that satisfy the specifications for a particular cement manufacturing technology. NCB as the apex national body assisting the cement industry as a whole provides the necessary know-how, do-how and know-why assistance in this respect.

The bulk of geological work for limestone - the main raw material is desired normally at two stages:

i) during initial exploration and evaluation of a project, and

ii) during production and development, once a plant has been established.

NCB is fully equipped to carry out investigations during both the above stages depending upon the situation and requirement. During the initial stage, the job of geological exploration being time consuming in nature, is normally done in advance by the local agencies and based upon this the detailed investigations are carried out by NCB experts. However, if needed, necessary advice and directions are rendered for carrying out the exploration programme in accordance with the norms laid down by NCB. These norms take care of varying degree of structural and lithological complexities of a deposit including mineability and broadly three categories viz 'Simple', 'Complex' and 'Intricate' types have been identified, which warrant different degrees of exploration in accordance with their nature. During the evaluation stage, emphasis is mainly laid on the bore hole and other exploration data interpretation, their significance and systematic sampling to see the suitability of limestone or other allied deposits for cement manufacture in VSK. Systematic sampling embraces regular traverses to identify the various rock units including types of limestone and taking channel and chip samples at regular intervals across the strike of the formation. Bore hole and pit sampling is done to find out the depth wise quality variations in the deposit.

NCB also undertakes mine planning depending upon the type and nature of deposit and capacity of a plant in order to assist in the later stage during production of limestone deposit. Besides this, periodic sampling of the pit faces and mapping of the newly exposed features are also taken up during the production and development of benches in order to keep a strict control on the run-of-mine quality of limestone.

8.1 Quality Requirements of Raw Materials

The essential components that constitute the raw meal feed for cement making are calcium carbonate, alumino silicates, iron and aluminium oxides and some minor constituents. Out of these, the first three are important in the formation of cement clinker, while the fourth one affects the manufacturing process depending upon the type and quantity of minor constituents. The major components should be in such a proportion that they should satisfy compositional compatibility to processes, such as crushing, grinding, homogenisation, burning and clinker formation. Main guidelines determining the suitability of various raw materials for manufacture of portland cement through VSK technology are given in the following paragraphs.

3.1.1 Calcareous Component

The calcareous component of a cement raw meal is contributed by any rock containing $CaCO_3$. Though suitable calcareous materials, such as limestone, chalk, marl, sea shell, kankar or calcrete etc. can fulfill the requirement for cement manufacture, limestone serves the principal source of calcareous base due to its vast availability as compared to the other resources. It is always preferable to use sedimentary limestones and allied deposits in comparison to metamorphic and igneous varieties due to several technological reasons. However, the less favoured varieties do find their usage in cement manufacture after thoroughly studying their physico-mechanical, chemical and mineralogical properties and assessing their impact on the manufacturing process to the extent these are not detrimental to it.

The desirable chemical composition of cement grade limestone for CRI-MVSK technology falls in the following range:

CaO	More than 46%
SiO_2	Below 8%
Al_2O_3 & Fe_2O_3	As may be required to satisfy the moduli values of raw mix
MgO	3.5% maximum but preferably below 2.5%

Slight deviations in the above to the extent that the other additive material like clay can compensate for the difference so as to arrive at the desired raw meal composition as a whole are permissible without any adverse effect on the process.

Alkalies as a whole though desirable below 1%, do not have appreciable effect due to non-generation of alkali cycles in VSK unlike in a rotary kiln, if present in slightly higher quantities.

3.1.2 Argillaceous Component

Raw meal to the kiln is fed in the form of nodules. For nodulisability and to compensate for the deficiencies in Al_2O_3 and Fe_2O_3, sticky and plastic clays, which are usually hydrous alumino silicates, assume a greater deal of importance in the VSK process. Normally marshy land and black cotton soil meet the above requirement easily and at times, the overburden over a limestone deposit comprises a soil quite suitable for the above purpose.

8.1.3 Corrective Components

Any deficiency left over after the addition of limestone and clay components can be met with the addition of suitable rock types e.g. bauxite, iron ore, laterite etc and their quantity will depend upon the shortfall of the requisite components.

8.1.4 Coke Breeze/Jhama Coal (Low Volatile Coal)

Though they are primarily used as low-volatile fuels, they can in reality be treated as raw materials in view of these constituting a part of raw mix in CRI-MVSK technology. Actually, the chemical constituents of their ash contribute towards the total raw mix components. The preferable specifications of either coke breeze or jhama coal are as follows:

Ash	25-35%
Volatile Matter	preferably below 8%
Calorific value	5000 Kcal/kg or more

8.2 Categories of Reserves and their Requirements

Cement grade limestone reserves are categorised as "inferred", "indicated" and "measured" depending upon (i) degree of reliability of the estimate which in turn would depend on the degree of exploration carried out, and (ii) subject to mining constraints in the following order:

Inferred Reserve	when $V_g > 4\%$ and $V_r > 50\%$
Indicated Reserve	when $V_g > 3\%$ and $V_r > 30\%$
Measured Reserve	when $V_g > 1\%$ and $V_r > 10\%$

where V_g = anticipated deviation in CaO content from the actual value as mined, and

V_r = anticipated difference between the estimated and mined reserves.

In the case of mini cement plants, since mechanised mining is not a pre-requisite, financial decisions could be taken on the basis of indicated and inferred reserves only and these reserves would be calculated on the basis of the capacity of the plant and its total life of 45 years. Out of 45 years of total life of the plant, there should be sufficient reserves of indicated category for first 30 years and adequate inferred reserves for next 15 years. The requirement of indicated and inferred reserves based upon the above assumptions and taking into consideration 330 working days in a year and 1.5 as consumption factor for limestone for each tonne of cement produced, can be calculated with the help of the following simplified equations:

$$R_{ind} = 21.21 \times 10^3 C$$

$$R_{inf} = 14.85 \times 10^3 C$$

where R_{ind} : indicated reserves for 30 years

R_{inf} : inferred reserve for 15 years

C : capacity of the plant

Rounding off the figure obtained as above, the required reserves for mini cement plants of various capacities may be taken as given in Table 15.

TABLE -15

REQUIREMENT OF DIFFERENT CATEGORIES OF RESERVES FOR DIFFERENT CAPACITIES OF MINI CEMENT PLANTS

Category of Reserve	Quantity (Million Tonnes)				
	30 tpd	50 tpd	100 tpd	150 tpd	200 tpd
Indicated	0.64	1.06	2.12	3.18	4.24
Inferred	0.45	0.74	1.49	2.23	2.97

9.0 QUALITY CONTROL IN CRI-MVSK CEMENT PLANTS

9.1 Introduction

In manufacturing cement, there are several factors influencing the quality, quantity and therefore the production cost of cement depending upon the manufacturing process and the equipment used or on the actual situations of use, specific control points are located. If required, data at desired frequencies is collected at various control points, analysed and the corrective steps are taken to maintain consistency in the quality of the product.

9.2 Quality Control at Quarry

To determine the general variation between the prospecting data and the actual quality of limestone mined, feedback data should be systematically compiled for different benches and mining blocks. Such an analysis would accentuate any variation trends in quality. This would facilitate selective extraction from specific areas of the quarry and blending at the quarry to obtain consistent grade of limestone. This would ease the extent of controls on quality at the later stages of operation.

9.3 Size, Quantity and Reduction of Samples

The samples for chemical analysis may vary from 2x2x2 cm to 10x10x20 cm in size and 5 to 10 kg in quantity. Lump samples should preferably be of dimensions varying from 20x20x20 cm to 30x30x30 cm or 0.5 to 1 m long cores weighing 20 to 50 kg.

The bulk sample(s) for technological tests should be representative of the deposits. In case of deposits showing considerable variation in quality, the bulk sample(s) should not be only representative of the various parts of the deposits, but it should also represent the average material to be mined for the plant. Hence the bulk sample should be artificially prepared by mixing stone from different parts of the deposit in such a proportion that it shall simulate or bear closest resemblance to the actual run of mine stone.

The reduction of all samples other than the bulk samples shall be carried out by sequential crushing, grinding, mixing, screening and cone and quartering as depicted in Figures 16 & 17. Care should be taken so that the other half of the sample in each stage is retained in each case for reference in future and that the final quarter at each stage of reduction is entirely passed through the sieve.

For different technological tests and analysis, the minimum quantity of bulk samples required to be tested shall depend on the diameter of the largest particle and the degree of heterogenity. A tentative indication of the inter-relation among particle size, heterogenity and bulk quantity is given in Table 16 below:

TABLE -16

INTER-RELATION BETWEEN PARTICLE SIZE, HETEROGENITY AND SAMPLE QUANTITY

Diameter of largest Particle(mm)	Minimum sample quantity required (Kg)	
	Homogeneous to slightly hetero-geneous	Highly Hetero-geneous
0.7	0.025	0.05
1	0.05	0.1
2	0.20	0.40
3	0.45	0.90
5	1.25	2.50
6	2.45	4.90
7	5.0	10.00
15	11.25	22.50
20	20.0	40.0
50	125.0	255.0

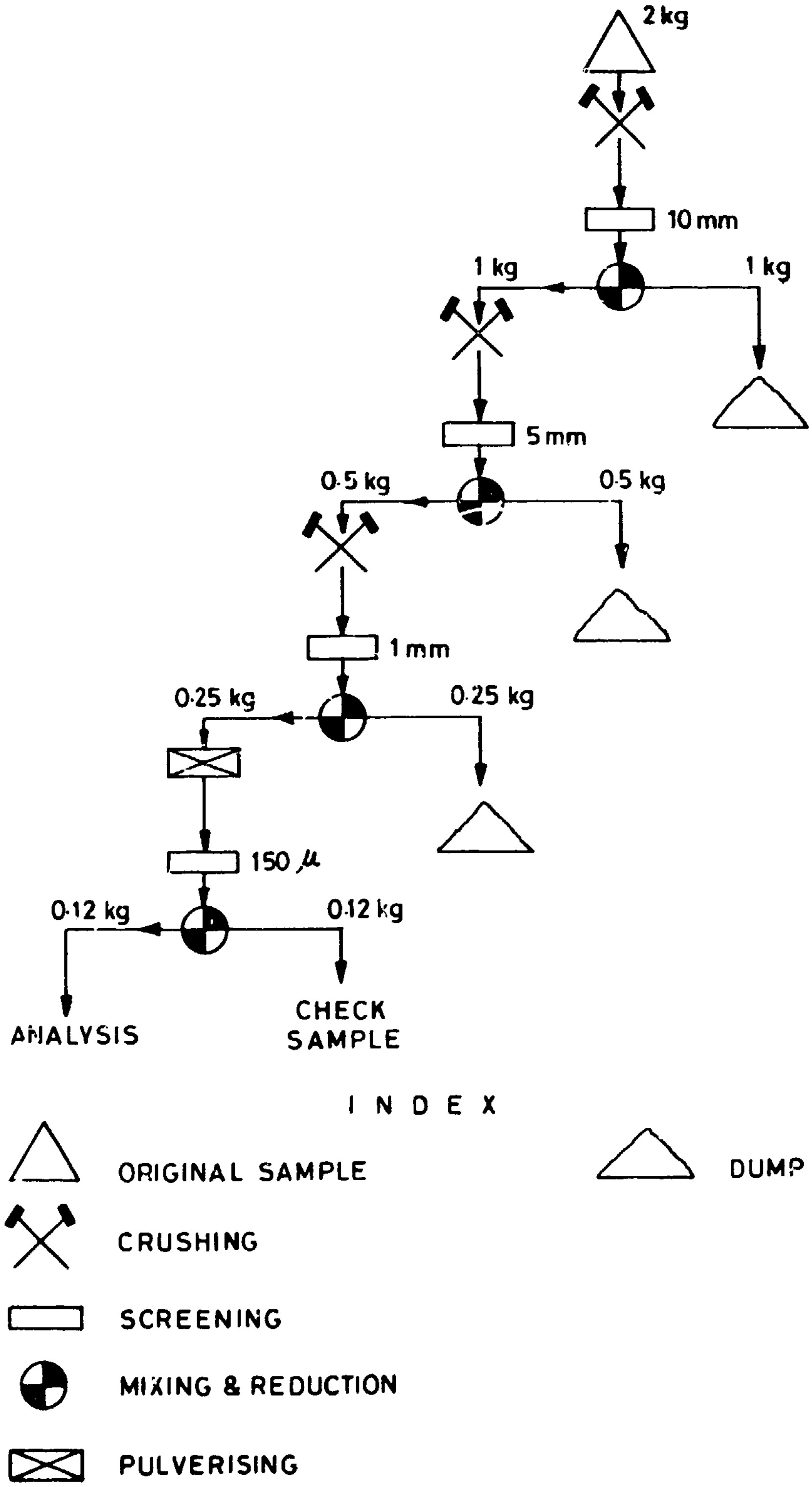


FIG. 16 FOR HOMOGENEOUS DEPOSITS

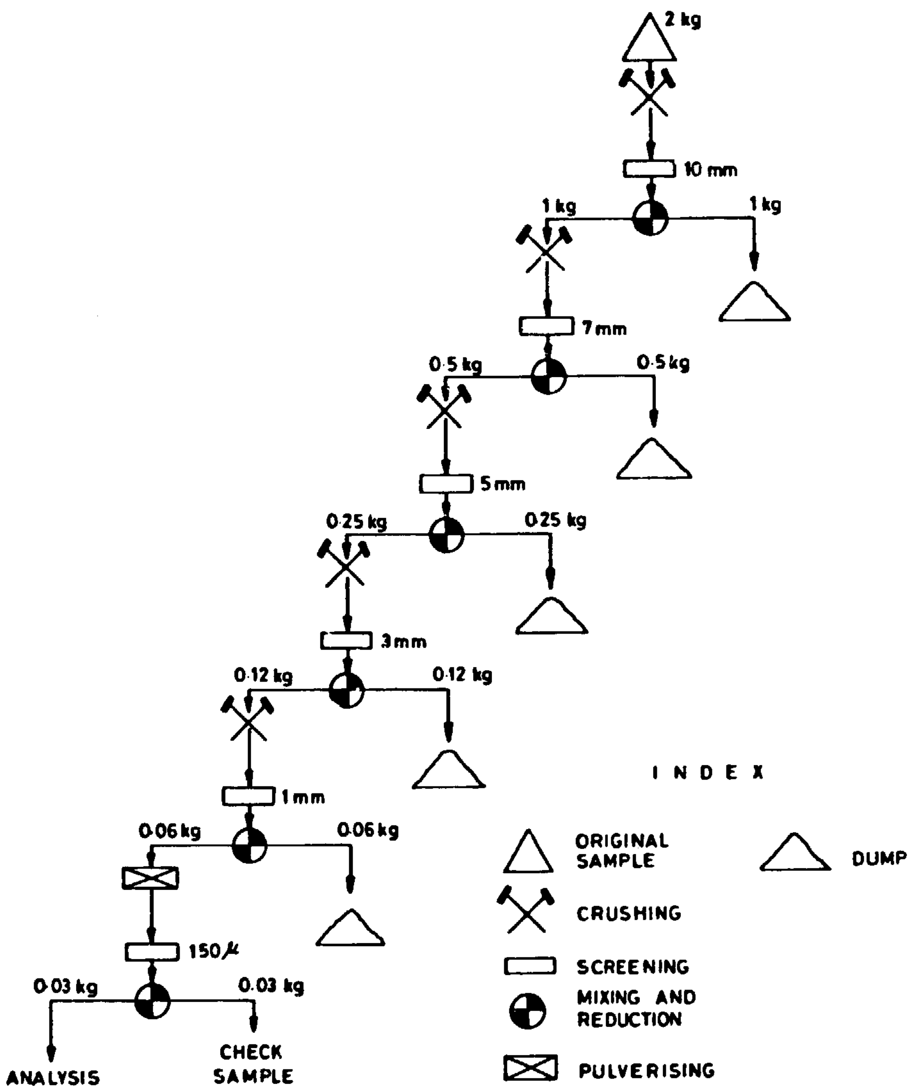


FIG. 17 FOR HETEROGENEOUS DEPOSITS

9.4 Sampling

Accuracy in sampling is a primary pre-requisite for fixing the grade of limestone. Each deposit warrants different combination of sampling methods depending upon size, shape and uniformity and exposure on surface in three dimensions, nature and extent of quality variation and precision of quality estimation aimed at. There are numerous types of sampling, each being characteristic for a particular face of the deposit. Those are:

TABLE -17

Type of sampling	Faces
Grab	Outcrops
Chip	Natural sections
Lump	Dumps
Channel	Pits
Groove	Trenches
Bulk	Large outcrops/ Quarries/Pits

9.5 Details of Analysis and Tests

Technological assessment of limestone shall consist of the following tests and analysis:

a/ Mineralogical and petrographic analysis
b/ Physico-mechanical tests
c/ Chemical analysis.

9.6 Fuel

Two kinds of analysis are in use for the classification of fuel:

a/ Proximate Analysis
This involves quantitative determination of moisture, volatile matter, fixed carbon and ash.

b/ Ultimate Analysis

This is for the exact calculation of combustion processes and involves quantitative determination of the constituents like moisture, carbon, hydrogen, sulphur, oxygen and nitrogen.

c/ Calorific Value

It is the most important property of fuels, i.e. the quantity of heat generated during combustion from unit weight of fuel.

9.7 Raw Mix Design

The chemical composition of portland cement clinker is described by several oxide components of which some are desirable and others are tolerated because they are unavoidable, though unwanted. Even in case of desirable oxides, the relative proportions have to be optimised in such a way that:

i/ a trouble-free and smooth operation of the plant is ensured.

ii/ production efficiency and fuel economy are maximised.

iii/ quality of the product satisfies all the requirements.

iv/ cost of production is minimised.

The raw mix design in a given situation, to put in a few words, consists of arriving at optimum proportions of the available raw materials in order to satisfy the above requirements.

9.7.1 Criteria for Raw Mix Design

Based on the practical experience gained over several decades and also on the research investigations, the relative proportions of major constituent oxides which will facilitate production and also ensure reasonable degree of performance have been defined in modulii values.

$$\text{Silica Modulus (MS)} = \frac{SiO_2}{Al_2O_3+Fe_2O_3} = 1.3 \text{ to } 2.2$$

Generally the silica ratio runs between 1.6 to 3.2. An increasing silica impairs the burnability by reducing liquid phase content, causes slow setting, hardening and also dusting in the kiln.

$$\text{Alumina Modulus (MA)} = \frac{Al_2O_3}{Fe_2O_3} = 1.2 \text{ to } 1.3$$

Alumina modulus determines the composition of liquid phase in clinker. Lower the ratio, harder is the burning. Higher ratio gives rise to lumping of clinker, high heat of hydration and fast setting. Preferred value for VSK is around 1.6.

$$\text{Lime Saturation Factor (LSF)} = \frac{CaO}{2.3\ SiO_2+1.2\ Al_2O_3+0.65\ Fe_2O_3} = 0.66 \text{ to } 1.02$$

The preferred values of LSF are in the range of 0.35 to 0.95. With LSF below the lower limit one can expect predominence of dicalcium silicate (belite) with lower temperature of burning while the LSF exceeding the upper limit are expected to require high burning zone temperature and may result in free lime content more than 0.5%. In other words within prescribed limits, the higher the LSF, the better the strength of cement but the more difficult is to burn the raw mix. Conversly the lower the LSF, the lower is the early strength of cement but easier it is to burn the raw mix.

9.7.2 Desirable Values for CRI-MVSK Plant

i/ Oxide values in raw meal

SiO_2	: 11.00 - 13.50%
Al_2O_3	: 2.50 - 4.50%
Fe_2O_3	: 1.25 - 3.5%
CaO	: 37 - 40.0%

ii/ Mineralogical composition of clinker

C_3S	:	30 - 60% gives early strength i.e. 3 days and also ultimate strength of 28 days.
C_2S	:	15 - 25% gives only ultimate strength
C_3A	:	10 - 15% gives early strength and reduces setting time.
C_4AF	:	10 - 15% contributes to colour.

iii/ Modulii values

LSF = 0.85 - 0.95
MS = 1.3 - 2.2
MA = 1.2 - 1.8

Liquid content at 1450^{o}C : 25 - 33%

10.0 OPERATION OF A CRI-MODERN VERTICAL SHAFT KILN

As already explained, in the black meal process, the cement raw materials are interground with the fuel and the resultant raw meal is blended and then converted into nodules of sufficient uniformity, strength and porosity in an inclined disc type noduliser by the addition of required quantity of water. The nodules are fed to vertical shaft kiln where the pyroprocessing takes place.

10.1 Before Lighting up

The kiln should be checked for

a/ Rotary grate : The grate segments and crown with cutter teeth should be intact and in position. A full revolution should be given to the grate to ensure it does not touch lining plates anywhere.

b/ Lining plates should not be loose.

c/ Refractory lining : The lining must be checked and repaired wherever necessary. If the thickness of lining in burning zone gets reduced below 80 mm, it must be replaced.

d/ All starters/main switches of the electrical installation should be checked whether they are all in working condition.

e/ Roots Blower : In accordance with the manufacturer's recommendations, oil must be checked. Filters must be cleaned. The weights in the safety valve are to be adjusted to suit to the anticipated kiln bed resistance.

f/ Chimney's damper, rotary feeder, kiln hood doors, discharge gates must be checked for their mechanical operation and lubrication.

g/ All the flanges of the kiln, bottom hood cup, chutes, discharge gates etc should be properly sealed so that the combustion air does not leak through the gaps between the joints.

10.2 Lighting up of the Kiln

The kiln should be filled with either the clinker already manufactured, or limestone chips or brick bats upto a level of 1-1.5 metres from the conical portion. Care should be taken that the material is dust free and while filling the refractory lining is not damaged. In order to remove the dust, the roots blower has to be run for about 15 minutes after every 1 metre depth of new material is loaded or better if the blower is run continuously while the kiln is loaded with the chips or clinker. After every 2 metres depth of new material has been loaded, the grate is set in motion, to ensure that the material is moving down the shaft evenly. Above this material, about 100 kg of dry firewood is now stacked uniformly over this bed in two or three layers. The chimney damper has to be opened partly and the air by-pass valves/ball valves are to be kept open in the kiln air duct. The firewood so spread would be lighted up using torches and after an incandescent bed is formed, steam coal is charged into the kiln. There will be an uniform incandescent bed of fire after few minutes. Now charging of the nodules can commence. One should refrain from adding a new charge of nodules until the edges of the fire can be just seen. When the bed level reaches to about 50 cm below the conical portion, the discharge gate is to be operated slowly.

10.3 Normal Kiln Operation

Stabilised kiln operation as obtained after the initial lighting up may now be continued under the following instructions:

1. Uniform discharge rate should be maintained as far as possible by adjusting the grate speed whenever necessary.
2. The nodule size, feed rate and bed level must be maintained.

3 The bed should always be covered with the nodules by continuously feeding them on a circle some distance away from the refractory lining so that the nodules themselves distribute both over the periphery and in the centre. A glowing ring on the periphery and continuous steam emerging from the centre of bed indicates good fire and good combustion conditions. The temperatures of various zones should be periodically recorded.

4 It is necessary to ascertain frequently that the entire bed is descending uniformly. This is ensured by cleaning the sides frequently with the help of a rod with flattened tip. While cleaning the sides, care must be taken not to damage the refractory of kilns.

5 Once the kiln is stabilised neither the process parameters nor the raw mix composition should be changed frequently.

10.4 Kiln Controls

10.4.1 Feed :

Strict controls should be observed on the preparation of feed right from the raw material stage. The table feeders/weigh feeders should be monitored periodically so that the component ratios conform to the values for raw mix design. Blending operation is carried out till a uniform blending with the desired T C content is obtained. The T C in raw mix should not vary beyond ± 0.20% of the desired value.

The nodules should be checked for appropriate size, porosity, moisture and strength on hourly basis. The feed rate and discharge rate should be synchronised to maintain constant bed level.

10.4.2 Air :

The combustion air can be regulated by adjusting the valve on by-pass pipe. The measurement is done with the help of two instruments provided on the burner's platform; one from the orifice plate to give combustion air flow and the other connected at the bottom for measuring the pressure at the inlet to the kiln which gives an idea of the bed resistance. If during a normal operation both the instrument readings are constant, the burner should understand that the kiln is filled with properly burnt clinker. In case the inlet pressure varies the burner gets indication that the bed resistance is varying and necessary corrective action should be applied.

10.4.3 Discharge Rate :

Under stabilised operating conditions, the discharge and feed rates should be synchronised to maintain constant bed level. If there are too big lumps or too loose a clinker near the grate, the discharge rate will fall or increase. Dependi g on the case, immediately the grate speed is to be changed; otherwise the bed level would rise or burning zone would collapse destroying the entire kiln operation in next few hours. Intermittent discharge is not desirable. The rotary grate speed should not be abruptly changed and it should be done gradually step by step.

10.4.4 Temperature :

A normal kiln operation is also judged from, in addition to the above, the temperatures of flue gases, clinker, burning zone, cooling zone and also of the kiln shell from outside. The temperature of the kiln is judged from the thermocouple based temperature indicators and also cross-checked by touching the kiln shell around periphery at various heights to feel the uniform temperature gradient. The desired temperature profile for a VSK is shown in Fig. 18.

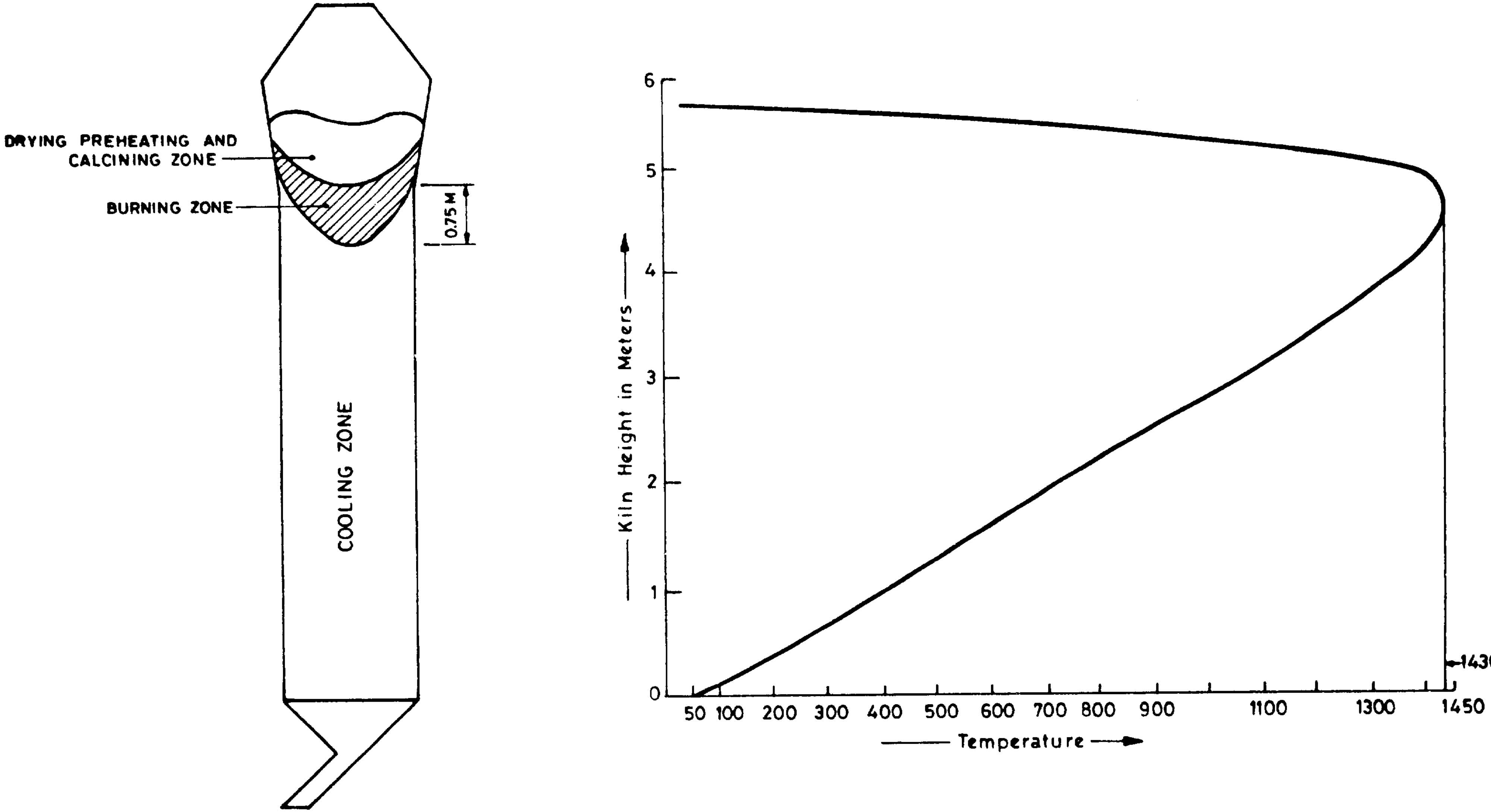


Fig. 18. TEMPERATURE PROFILE IN VSK

10.5 Kiln disorders :

10.5.1 Bridging :

When the clinker produced is so lumpy that it does not contain any loose material, there are chances that the lumps form a bridge and rest over the sides of the conical portion of kiln resulting in rise in fire bed. In such a case the feed should either be slowed down or stopped and air reduced. The bed should be given some disturbance in clearing the sides and poking from burner's platform. If necessary the roots blower should be stopped and then the feed. The bed should be able to descend with some effects. The cause should be investigated and the process parameters immediately rectified in order to avoid repetetion of this.

10.5.2 Side Discharge :

Some times if the clinker produced is suddenly too loose it would pass through the bigger lumps and get discharged quickly. Even red hot yellow nodules (clinker) may discharge representing that at a certain position there is no bed to support the burning zone. The burning zone seems to collapse and loose fire. In such a condition, the grate speed should be reduced or it should be stopped, to reduce discharge for some time and the burning zone built up slowly even though the level may rise. The discharge may be reduced till the trouble is overcome. The underburnt clinker may be separately stocked and appropriately blended with the good clinker at the time of grinding after ascertaining a suitable proportion. The kiln process parameters should be immediately attended to. This may be a result of maintaining the bed level too low inside the cone.

10.5.3 Lump Formation :

Sometimes a big lump may be noticed in the burning zone which is very strong and as big as kiln internal diameter. This may not descend. This generally occurs due to melting on account of a very high temperature there. The raw mix composition should be immediately examined and feed should be accordingly corrected. The fuel with low ash fusion or too much of fuel will cause this. The lump so formed should be broken with poking rods and grate speed should be adjusted to ensure its descent. At the same time too much poking should be avoided. The lumps that descend though big, give no trouble as they would get crushed and discharged as soon as they reach the rotary grate.

11.0 ENVIRONMENTAL CONTROL IN CEMENT PLANTS BASED ON CRI-MVSK TECHNOLOGY

11.1 Introduction

Environmental control aspects are being given increasing attention in recent years. Of the two aspects of pollution of immediate concern, viz. air and water pollution, the cement plants based on Modern CRI-VSK technology are virtually free of water pollution as no effluents are involved. Even as regards to air pollution, which basically can be caused by both particulates and undesirable gases, the CRI-MVSK plant operation ensures negligible emission of the latter such as carbon monoxide, oxides of nitrogen etc as the good operating conditions of the kiln generally prevents emission of such gases. The generation of particulates, however, is inherent in the manufacturing process and the associated unit operations and is controlled by the application of high efficiency dust collectors whenever required. The operation of vertical shaft kiln, which is the heart of the process, is such that negligible particulate emission takes place as the shaft kiln itself acts as an effective filter (as will be described later) thus eliminating the need for a separate dust collector. In this report the dust generation sources, their characteristics and the present practices to ensure lower dust emissions are discussed.

11.2 Dust Generation Sources and Characteristics

The various dust generation sources and their characteristics are considered below:

11.2.1 Mining

Mining is generally carried out manually in mini cement plants. The level of dust generations by drilling/blasting and loading of limestone is generally low. Dust suppression techniques such as water spray are generally found adequate.

11.2.2 Crushing

Generally a combination of primary and secondary crushers are used for size reduction. Dust generations are low and water spray systems are usually adequate. A cyclone or fabric filter can also be used under specific situations.

11.2.3 Raw Grinding

Depending upon the raw material characteristics and size of the plant, air swept ball mills or vertical roller mills are usually employed for the intergrinding of raw material and fuel. In both the cases, cyclones and fabric filters of higher efficiency are used to keep the emissions low.

11.2.4 Raw Material Blending and Homogenising

The ground raw materials are blended and homogenised pneumatically in blending silos. The generated dust is collected in high efficiency fabric filters to ensure low emissions.

11.2.5 Kiln Section

The following features, inherent in the design of the vertical shaft kiln, limits the dust emissions to practically negligible values even without the use of any separate dust control equipment:

a/ The raw meal fed to the kiln is in the form of moist nodules and accordingly no dust entrainment is possible at the feed point.

b/ The bed of nodules itself acts as an effective filter for any dust that is entrained in the lower portions of the kiln.

c/ Very low superficial velocities are maintained in the shaft kiln at which no entrainment is possible.

d/ The stack operates under natural draft, which not only ensures low velocities inside to reduce entrainment, but also helps in the settling of particles by gravity.

For the above reasons, no separate dust collector is required in the shaft kiln.

11.2.6 Cement Grinding

In mini cement plants based on CRI-MVSK technology, generally open circuit tube mills are employed for cement grinding. The mill works on overflow principle and the product is directly conveyed by mechanical conveyors to the storage silo. Cyclone or fabric filters are used to assist the dust collection which ensures very low dust emission.

11.3 Summary

The dust emissions are generally low in mini cement plants due to the adequate practices, use of high efficiency dust collectors, good house-keeping etc. By the very nature of the process, in the kiln the dust emissions are so low that no dust collector is required. The emissions are much lower than the proposed stack emission standard of 250 mg/Nm^3 under stable operating conditions of the kiln. Also the dust emission rate in grams per unit time is very low in a mini cement plant as compared to the large plants due to lesser gas quantities involved due to small size of the plant and very low gas velocities as the stack operates only on natural draft in the absence of any ID fan, and hence the emissions from mini cement plants are unlikely to cause nuisance to the surroundings.

12.0 TECHNOLOGY TRANSFER MECHANISMS

The success of any technology depends to a very large extent on the technology transfer and delivery mechanism adopted for its commercialisation. In fact, in all the technologies for cement manufacture in small scale as mentioned above, different technology transfer mechanisms have been followed by different organisations/individuals. For example, if we consider the case of VSK mini cement plants in India, it has been observed that in one case, where an individual attempted to down-scale one of the proven and available VSK technology and offer to various entrepreneurs as 'Tiny cement plants' within the limits of Small Scale Industries, he could partially succeed only because he offered to run the plants himself along with his Chemists/burners for a period of one year before handing them over to the entrepreneurs. Whereas in another case, where the technology was developed by a national organisation, it could not succeed mainly due to a weak technology transfer interface. In this particular case, the technology as developed was passed on to a few machinery manufacturer/consultants, but no back-up technical services support was provided to these machinery fabricators/ entrepreneurs either in terms of technical guidance, training of key manpower or assistance during erection and commissioning; due to which none of the plants based on this technology could become a successful enterprise.

In contrast to above, the CRI-MVSK technology, which was developed by NCB way back in 1974 through pilot plant studies by performing the necessary R&D work on a sick non-working 20 tpd VSK, was transferred to the industry through licencing of machinery manufacturers in different parts of the country, who supply the plant and machinery for such plants on turn-key basis. These machinery manufacturers offer the necessary performance guarantee for such plants while NCB offers its back-to-back guarantee to the machinery manufacturers. Under this technology transfer mechanism, NCB assists the entrepreneur through these machinery manufacturers right from concept to commissioning including imparting training to the personnel. There are 18 such machinery manufacturers licenced at present. For the preparation of techno-economic feasibility reports, NCB has tied up with a number of reputed technical consultancy organisations who undertake the preparation of such reports in consultation with NCB.

For the successful implementation of the mini cement plant projects based on CRI-MVSK technology, NCB keeps a close interaction with the entrepreneurs and the machinery manufacturers for monitoring of such projects. In fact, there are separate task force groups of experts within NCB for different specialised jobs such as geological and raw materials investigations, techno-economic project evaluation, quality control and inspection of plant and machinery, guidance for setting up analytical and quality control laboratories and erection and commissioning of such plants. There is a 'Development Committee for Mini Cement Plants' comprising of all the licenced machinery manufacturers, NCB experts and other eminent outside experts in the field where all developmental work connected with CRI-MVSK mini cement plants are planned, discussed and reviewed from time to time. As already mentioned, NCB attaches a lot of importance on strict quality control of plant and machinery being supplied and in order to implement the same, NCB, in consultation with the various machinery manufacturers have already worked out detailed specifications for various plant and machinery including the quality of raw materials to be used for fabrication, methods of fabrication etc which is obligatory on the part of every machinery manufacturer to strictly adhere to. Moreover, NCB has set out standard inspection norms for all important equipment and machinery of these plants and all the inspections are carried out in line with these. A portion of such inspection format which is carried out in mini cement plants is enclosed at Table 18 for reference. This is in addition to the in-house quality control standards and methods which every machinery manufacturer has to follow and the facilities which they should have with them in order to qualify for the licence from NCB.

NCB	NATIONAL COUNCIL FOR CEMENT AND BUILDING MATERIALS
	QUALITY ASSURANCE PLAN (CRI-MVSK PLANTS)

SL. NO	COMPONENT & OPERATION	CHARACTERISTICS	CLASSIFICATION	TYPE OF CHECK	QUANTUM OF CHECK	REFERENCE DOCUMENT	FORMAT OF RECORD	INSPECTION CLASSIFICATION			REMARKS
								ENTRE*	NCB	PLANT FABR*	
1	2	3	4	5	6	7	8		9		10
1	SHELL ASSEMBLY										
1.1	Steel Shell, Refractory	Material	Major	Visual, Dimensional	100%	Test Certificate	Test Certificate			M	
1.2	Fabrication, welding of Shell assembly	Welding control	Major	Weld Procedure	100%	Approved weld procedure Annexure-I	Route Card			M	
1.3	MVSK Chimney	Height	Major	Dimensional	100%	30 m above ground level	Inspection report	F		M	
2	[illegible]										
2.1	Fabrication	Openings	Major	Dimensional	100%	As per drg.	Inspection report			M	
2.2	Cutter tips	Hard facing deposition	Major	Dimensional	100%	As per drg.	Inspection report			M	
2.3	King Shaft	Machining	Major	Dimensional	100%	As per drg.	Inspection report			M	

QUALITY PLAN FOR MVSK	QUALITY PLAN NO. QP/MVSK/400/86/001	PREPARED BY [signature]	SHEET 1 OF 4
		APPROVED BY [signature]	DATE 3 March 1986

Table - 18

NATIONAL COUNCIL FOR CEMENT AND BUILDING MATERIALS

QUALITY ASSURANCE PLAN (CRI-MVSK PLANTS)

SL. NO.	COMPONENT & OPERATION	CHARACTERISTICS	CLASSI-FICATION	TYPE OF CHECK	QUANTUM OF CHECK	REFERENCE DOCUMENT	FORMAT OF RECORD	INSPECTION CLASSIFICATION			REMARKS
								ENTRE	NCB	PLANT FABR*	
1	2	3	4	5	6	7	8				10
2.4	Rigid Coupling	Machining	Major	Dimen-sional	100%	As per drg	Inspec-tion report			M	
2.5	Assembly of Dyno-drive, Reducers, Ki King Shaft, Rotary Grate and Machined Parts	Alignment, Dimensional conformity, completeness	Major	Visual, Dimen-sional	100%	As per drg	Inspec-tion report	E	P	M	
3	ROTARY FEEDER										
3.1	Assembly of Geared Motor, Bevel pair, Feeding Chute and Machined Parts	Alignment, Dimensional Conformity, Completeness	Major	Visual, Dimen-sional	100%	As per drawing	Inspec-tion report	E		M	
4	NODULISER										
4.1	Noduliser Drum	Dimensional Conformity Ovality, Co-axiality with Reducer Shaft	Major	Visual, Dimen-sional	100%	Ovality limit ± 5 mm	Inspec-tion report			M	

QUALITY PLAN FOR	QUALITY PLAN NO.	PREPARED BY	SHEET 2 OF 4
MVSK	QP/MVSK/100/86/001	APPROVED BY	DATE 3 March 1986

NATIONAL COUNCIL FOR CEMENT AND BUILDING MATERIALS

QUALITY ASSURANCE PLAN (CRI-MVSK PLANTS)

SL. NO.	COMPONENT & OPERATION	CHARACTERISTICS	CLASSIFICATION	TYPE OF CHECK	QUANTUM OF CHECK	REFERENCE DOCUMENT	FORMAT OF RECORD	INSPECTION CLASSIFICATION			REMARKS
								ENTRE	NCB	PLANT FABR.	
1	2	3	4	5	6	7	8		9		10
4.2	Assembly of Motor, Reducer, Noduliser drum	Alignment, Dimensional Conformity, Completeness	Major	Visual, Dimensional	100%	As per drawing	Inspection report	E		M	
4.3	Scraper Assembly, Assembly of motor, Reducers, Linkages and Scrapers	Alignment, Dimensional Conformity,	Major	Visual, Dimensional	100%	As per drawing	Inspection report	E		M	
5	DISCHARGE BY T.M(MHT)										
5.1	Assembly of Source Probe, Control Unit, Vibratory feeder	Alignment, Dimensional Conformity, Positioning of Source and probe	Major	Visual, Dimensional	100%	As per site conditions	Inspection report	E	P	M	
6.	TEST RUN	Test run	Major	No load/load	100%	Test procedure	Inspection report	E	P	M	

Note: M stands for Inspection by Fabricator.
E stands for Inspection by Entrepreneur.
P stands for Inspection by NCB.

QUALITY PLAN FOR	QUALITY PLAN NO.	PREPARED BY	SHEET 3 OF 4
MVSK	QP/MVSK/400/86/001	APPROVED BY	DATE 3 March 1986

ANNEXURE - I

WELDING PROCEDURE

1. For preparation of butt joints for single 'V' or assymetrical double 'V' or symetrical double 'V', the faces of the joints should be built together without any gap on the root.

2. The shells have to be either tack welded or fully welded by manual metalic arc welding with any low hydrogen electrode.

3. The joints should be free from grease, oil or any hydrocarbons, dirt, rust etc prior to welding.

4. From the outside of the prepared joint the root pass may be made with fully automatic submerged arc welding using 3.15 or 4 mm size of electrodes conforming to IS:2879-1964 with fused or agglomerated flux. Alternately manual metallic arc welding can also be allowed provided the same satisfies all the radiographic tests.

5. Subsequent passes can be made either with 4 or 5 mm rod with the same type of flux.

6. The electrodes for submerged arc welding and the flux should be from the same source.

7. The first two layers may be done in single pass. However, subsequent layers may be done with 2 or 3 passes in each layers depending upon the thickness of the plates to be welded.

8. After the welding of one side, the back side of the joint should be chipped off thoroughly to remove the root runs completely and then welding can be done as mentioned above.

13.0 CONCLUSION

13.1 As can be seen from the above, the present day solution for the manufacture of cement in small scale is only through adoption of Modern VSK technology, which like the large conventional rotary kiln plants requires constant technological up-gradation in terms of introduction of modern features in order to continuously bring down the investment and operating cost and to improve the quality of the product. Moreover, the size of a mini cement plant should be governed by an exercise which should be carried out for optimisation of the available resources and conditions like the available investment, raw materials, infrastructure and prevailing socio-economic conditions, in order to derive the maximum possible benefits from those illustrated under Section 2.0.