CHAPTER 1

OVERVIEW OF MANUFACTURE OF CEMENT

1.1 Beginning of Cement

"Cement" as Portland Cement was first made in a shaft kiln using dry process and later in rotary kilns.

That "Slaked" lime hardens with water was well known and was used as "Mortar" with sand in construction industry before the advent of cement.

Some "Natural rocks" contained all ingredients like CaO, SiO_2, Al_2O_3 and Fe_2O_3 in approximately right proportions so that they did not need any additions and when ground calcined and sintered in a kiln produced clinker which when ground with 5% gypsum produced what has come to be known as "Portland Cement".

Cement has hydraulic properties like slaked lime and hardens when mixed with water. Compressive strength increases in time and reaches its practical top limit after 28 days.

Mixing crushed stone, sand, cement and water makes "Concrete". When hardened it is like rock and hence is called "Synthetic rock". It has similar properties of high compressive but low tensile strengths.

When concrete is poured around steel it becomes Reinforced Cement Concrete - popularly known as RCC - and has high tensile strength also.

RCC has revolutionized construction industry and it is well nigh unimaginable to construct roads, dams, skyscrapers and silos and many other large and heavy buildings for residential or for industrial purpose without RCC.

Cement the main strength giving and binding ingredients is thus an all-important part of RCC and thus plays a vital role in the progress and development of a nation.

At present there is no substitute for cement. Hence, it will continue to play an all-important role in construction industry.

Yardsticks like inter alia per capita consumption of steel, power and cement are used to indicate state of development of countries. Advanced and developed countries have per capita consumption of cement of 400-500 kgs. As against it, in India per capita consumption of cement is only about 195/200 kgs.

1.2 Making Cement

Cement Industry started in a very small way, first as shaft kilns using dry process.

When it was found that the proper composition of raw mix required to making good quality clinker almost always needed, additions or correcting materials to compensate for constituents like Silica, Alumina and Iron Oxides, it became necessary to "Blend" the constituents after "Grinding".

Blending was then more convenient in wet stage in the form of slurry.

By this time Rotary Kiln had come to be used to make Cement. It would conveniently receive slurry as well. Thus process of cement making changed from Dry to Wet.

1.3 Dry to Wet to Dry Process of Manufacture

Wet Cement plants continued to grow in number and size and wet process was the predominant process of manufacture of cement till 1950 or so. It continued to be the dominant process in India for another two decades.

Wet process was simple and required less process control and instrumentation and manpower. But it consumed a large quantity of water and also heat energy in drying the slurry.

As fuel costs rose, alternative processes were investigated to reduce water content of slurry and thereby fuel consumption.

1.4 Semi-dry Process

Thus came into use 'semi-dry' process which needed only 8-10% water compared to 35-36% for wet slurry. Raw materials were ground and blended dry. Water was added to dry raw mix in a revolving pan to make nodules. The nodules were dried on a travelling grate preheater before feeding them to a rotary kiln or to a shaft kiln.

1.4.1 V. S. Kilns

Vertical Shaft Kilns also came to be developed for capacities up to 300 tpd (in Europe). They needed low volatile fuels like coke breeze.

1.5 Dry Process

When wet process plants had reached their peak capacity of 750-1000 tpd, developments in processes and machinery took place that once again changed the course of cement making.

1.6 Suspension Preheaters

In early 50s of the 20th Century, an epoch making concept was developed - that of Suspension Preheater.

The suspension preheater, with rotary kiln and grate cooler formed the heart of the cement plant and 'dry process' came to be adopted fast and number of wet process plants and semi dry process plants declined.

Even in India, which had predominance in wet process plants in numbers and capacity as late as sixties, the percentage has decreased to less than 3 % now.

1.7 Vertical Mills and Calciners

Other epoch making developments took place in 70s. They were using Vertical mills for grinding raw materials and coal and development of calciners which calcined raw meal before it entered the kiln. With a calciner, output of the same kiln could be increased by about two and a half times.

Vertical mills have also came to be used for grinding cement clinker and slag.

Roller Presses are also now part of grinding syatems

These two developments gave tremendous boost to the size of the plant and also to economies in power consumption.

1.8 Benchmarks in Manufacture of Cement

Progress in making cement described above has been shown in **Table 1.1.1** and pictorially in **Figs. 1.1.1(a), 1.1.1(b) and 1.1.2**

1.9 Fuel and Power Consumption

Fuel consumption was also steadily brought down from 1500 Kcal/kg clinker for wet process kilns to 800 Kcal/kg clinker for dry process kilns with 4 stage preheater and grate cooler. This has further come down to less than 700 Kcal/kg by using 6 stage preheaters.

Power Consumption has come down to 85-90 Kwh/Ton.

1.10 Green Cement

Cement industry is now conscious of the emission of green house gases emitted in the process of making cement. Green house gases cause global warming.

Cement Industry is therefore taking steps to reduce these emissions. Therefore it makes ' blended cements' like Pozzolana cement (PPC) and slag cement (BFSC) wherever possible. It also uses Alternate fuels to reduce emissions arising out of combustion.

Cement Industry in countries, like India which were short of power, had begun to install captive power plants to ensure continuity of power. This is taken one step further by using waste heat in exit gases from kiln and cooler to generate power.

These new developments have been dealt with in this new edition to the extent cement plant engineers are commonly required to deal with them.

1.11 Differences in Processes

Differences in various processes of making cement and equipment used therein have been brought out in **Tables 1.1.2 and 1.1.3 and in Fig. 1.1.2.**

1.12 Size of the Plant

From beginning with a 20-30 t.p.d. capacity, individual kilns have gone up in size upto 7500-10,000 tpd capacity. Plants of 3-4 mtpa capacity in one place have also become common.

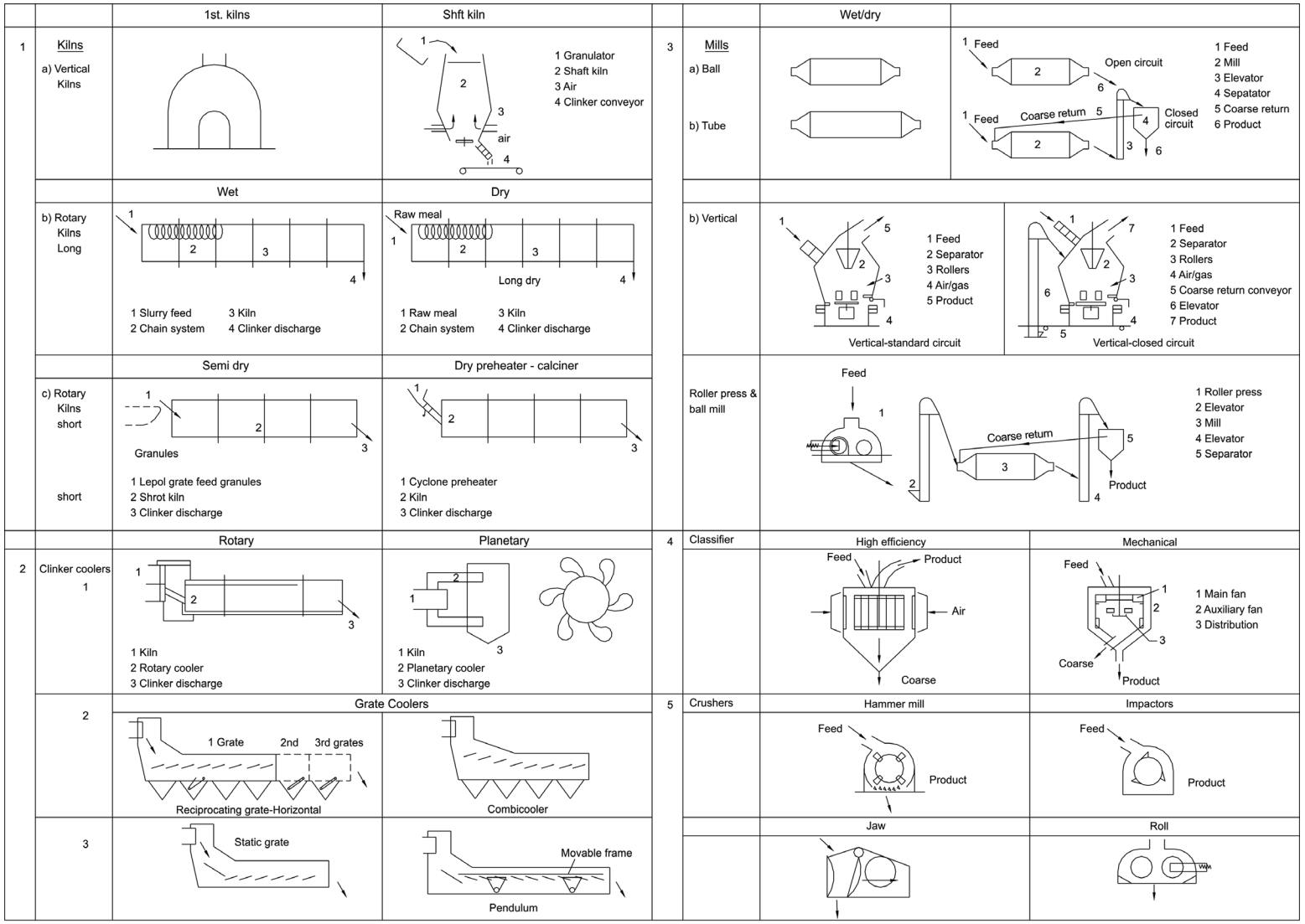

Fig. 1.1.1 (a) Benchmarks in manufacture of cement.

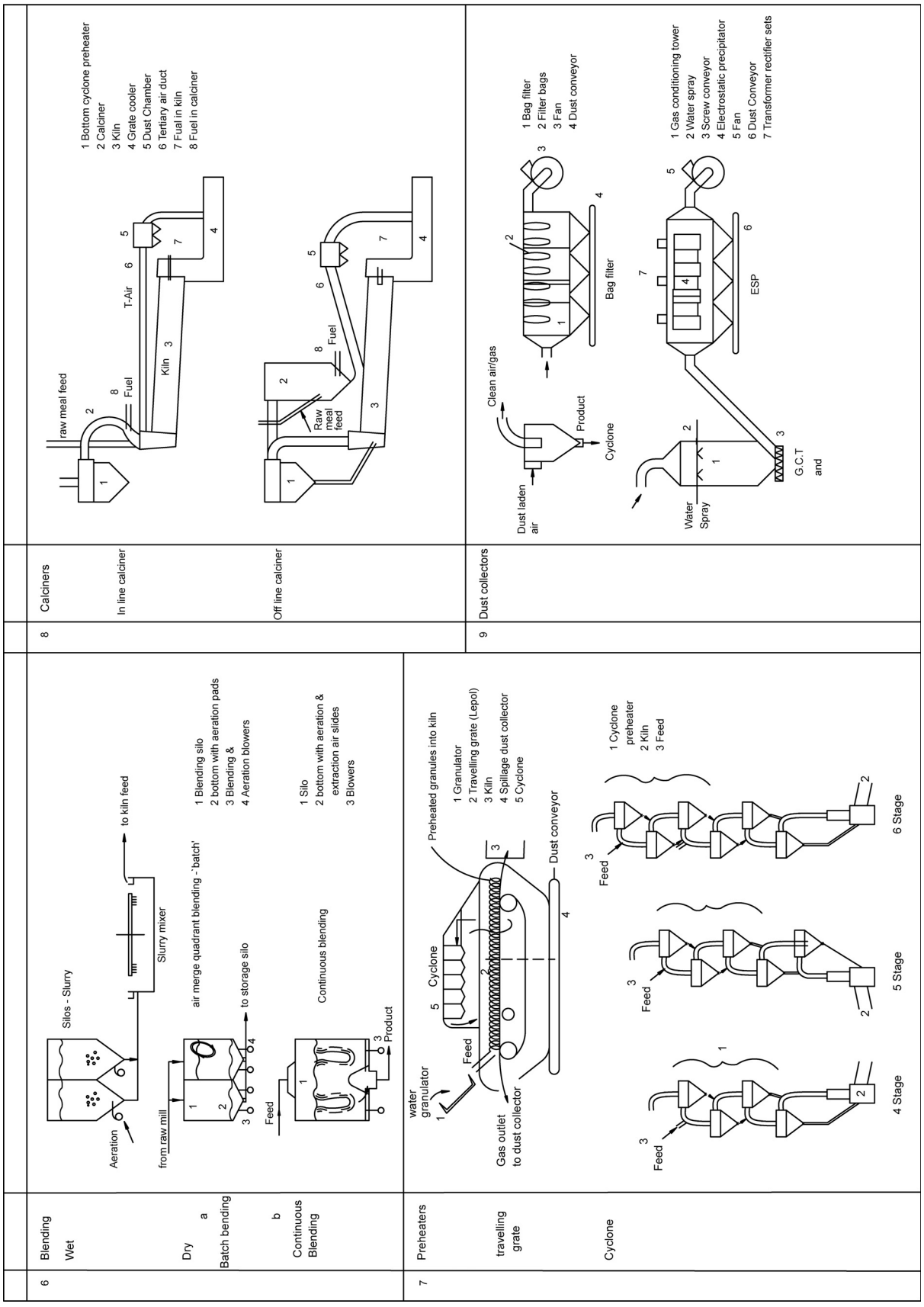

Fig. 1.1.1 (b) Benchmarks in manufacture of cement.

Table 1.1.1 Benchmarks in manufacture of cement.

Benchmarks	
Kilns	Shaft kiln-Rotary Kiln - Wet - Long dry - Short - Semi dry and Dry preheater kilns
Coolers	Rotary Cooler – planetary cooler; Traveling and Reciprocating grate coolers; Static grate, pendulum coolers and cross bar coolers
Preheaters	Calciners in wet kilns, traveling grate preheaters; Suspension preheaters 4 – 6 stages.
Mills	Ball and tube mills – mills with slide shoe bearings; Vertical ring and roller mills; Roller press and ball mill combinations; Horizontal Roller mill
Blending	Slurry blending – slurry mixer; Air merge blending – batch and continuous
Classifiers	Wet classifiers; Dry classifiers- grit separators, mechanical air separators; High efficiency separators
Crushers	Jaw, Hammer, Roll and Impact, mobile and semi mobile crushers
Packing machines	Stationary – rotary – rotary electronic
Calciners	In and off line; spouted bed, fluidized bed and many others
Despatches	Mechanized-automated loading of bagged cement; Bulk cement by road and rail and sea
Dust collectors	Cyclones; poly and multiclones; Bag filters- glass bag filters; Gravel Bed filters; Electrostatic Precipitators

The trend even in India is to go in for large plants to avail of economies of scale which can be achieved by using machineries (Vertical Mills, ESPS, etc.) which are suitable for and affordable by large plants.

The days of small plants and particularly those of VSKs are over and they would not be considered for any future cement projects.

1.13 Sizes of Cement Plants in India

Even in conventional plants using rotary kilns, there was a distinction.

1. Mini Plants of capacity - 300 tpd - to start with- but expanded to 1000-1200 tpd capacity by installing calciners
2. Large Plants of capacity - 600 tpd and above earlier, 3000 tpd and now to 10000 tpd above

Thus as far as process and types of machinery used are concerned, the distinctions between large and small plants have almost blurred. New projects are almost invariably for dry process plants of +1.0 MTPA capacity.

1.13.1 Large Cement Plants

There are already about 183 cement plants of +1 MTPA capacity. Average capacity per plant is 1.7 mtpa. Total installed capacity is 480 mtpa.

Table 1.1.2 Basic Differences between Various Processes of Manufacture of Cement.

Sr. No.	Section	Wet	Semi Wet	Semi Dry	Dry	Dry with calciner
(A)	**Raw material preparation**					
1.	Crushing	Common to all processes;machinery selected depends on size of plant and properties of stone				
2.	Grinding	Wet grinding in ball mills sometimes in closed circuit; product slurry with 35-40% water		Dry grinding; drying during grinding; mostly in closed circuit; using kiln gases for drying. ball mills, vertical mills and roller press in hybrid grinding product dry raw meal with less than 1% moisture		
3.	Homogenising	wet, air and mechanical agitation product blended slurry wth 35 % water		fluidisation techinques for blending dry pulverised raw meal batch or continuous blending;continuous blending will be preceded by prehomogenising in stock piles; product dry blended raw mix		
4.	Kiln feed	slurry with ~ 34 % moisture synchronised with kiln	either extruded pellets with 15% moisture or, dry raw meal dried in flash dryer	pellets with 8-10% % moisture	dry pulverised raw meal fed through volumetric or gravimetic feeders	

Table 1.1.2 *Contd....*

Sr. No.	Section	Wet	Semi Wet	Semi Dry	Dry	Dry with calciner
	(B) Pyroprocessing					
1.	drying	in kiln	drying of pellets	drying of nodules	preheating in kiln	preheating outside
2.	preheating	in kiln	in travelling grate preheater preheating in preheater		for long dry kiln	kiln in dry preheater kilns; mostly cyclone preheaters
3.	calcining	in kiln	dissociation of CO_2 beginning at ~ 600 ^oC and completing at ~ 950 ^oC			
			in kiln	largely in kiln	partly in preheater balance in kiln	almost totally out of kiln in calciner
4.	sintering		formation of clinker at 1250-1450 ^oC in kiln			
5.	clinker cooling		cooling of clinker to 65- 150 ^oC common to all processes			
			now mostly reciprocating grate coolers with variations like static grate, controlled flow and pendulum type are used			

Table 1.1.3 Different types of Equipment used in various Processes.
also see Fig. 1.1.2

Sr. No.	Process	Wet	Semi Wet	Semi Dry	Dry	Dry with Calciner
1.	crushing	common to all two stage crushing for ball mills; single stage crushing for Vertical mills and Roller Presses Jaw crusher – Hammer crusher combination for two stage crushing Impactors – single or two stage for single stage crushing semi mobile, mobile crushers for large plants				
2.	grinding	ball mill open or closed circuit autogenous mill		ball mills-air-swept or bucket elevator in closed circuit with conventional or high efficiency separators vertical roller mills - vrms with external circuit and high efficiency separators roller press and ball mill in various combinations		
3.	prehomogenising			stacker reclaimer systems used for prehomogenising of limestones and coal during building up of and extraction from stock piles		
4.	homogenising	pneumatic and mechanical agitation slurry mixers		blending systems basedon ‘fluidising’ techniques batch and continuous blending systems		
5.	kiln feed	metering of slurry synchronised with kiln	filter press and disagglomerator and flash dryer or filter press and extruder	noduliser with variable speed	weigh feeder or solids flow meters with prefeeders	

Table 1.1.3 *Contd....*

Sr. No.	Process	Wet	Semi Wet	Semi Dry	Dry	Dry with Calciner
6.	preheater	calcinator	travelling grate preheater or suspension preheater	travelling grate preheater or suspension preheater or shaft kiln	suspension preheater or shaft kiln	
7.	calcining					calciners in or off line
8.	clinkering	rotary long kiln	rotary short kiln	rotary short kiln shaft kiln	rotary short kiln rotary long kiln	rotary short kiln
9.	clinker cooling	common to all; rotary and planetary coolers for small plants – now almost discarded; reciprocating grate coolers of various designs like static grate, controlled flow grate pendulum cooler cross bar cooler etc.				
		Following processes are common to cement plants of all types differing in scale according to size of plant				
10.	coal grinding	ball or vertical mills with drying facilities				
11.	cement grinding	ball mills in closed circuit and high efficiency separators vertical mills with external circuit and high efficiency separators roller press and ball mill and high efficiency separators in a number of ways				
12.	cement packing loose cement	rotary or stationary packers to pack cement in jute/paper bags cement sent in bulk in bulk carriers by road byships etc.				
13.	cement despatches	by road or rail of bagged cement using semi or fully mechanised loading machines also by ship loads for export				

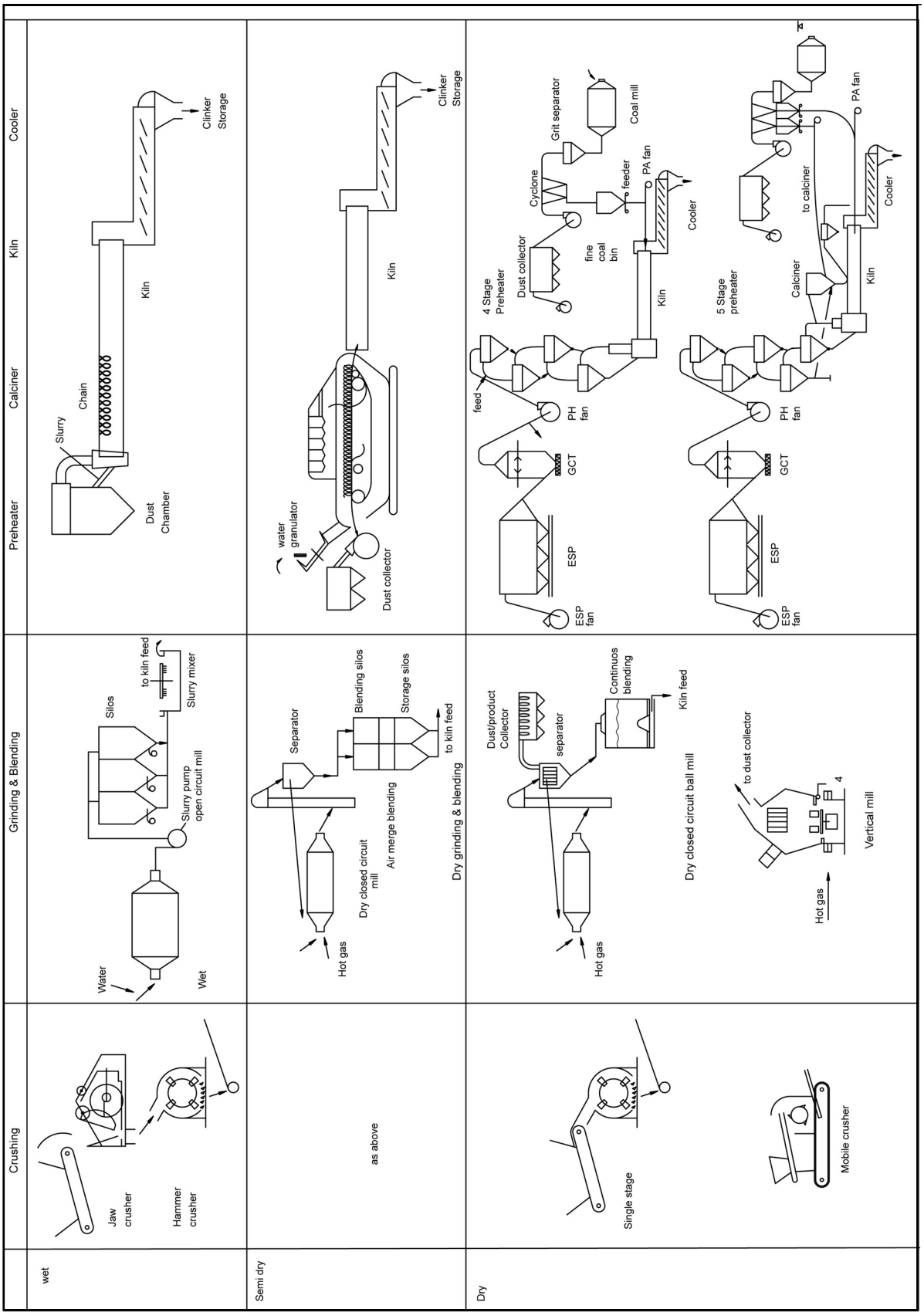

Fig. 1.1.2 Equipment used in manufacture of cement.