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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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PRODUCTIVITY IMPROVEMENT
THROUGH
OPTIMIZATION OF BALL MILL OPERATION

DP/IND/84/020/11-04

TECHNICAL REPORT*

MISSION : OCTOBER 20 TO NOVEMBER 30, 1986
AND
JANUARY 05 TO FEBRUARY 16, 1987

PREPARED FOR THE GOVERNMENT OF INDIA BY THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION ACTING AS EXECUTING AGENCY FOR THE UNITED NATIONS DEVELOPMENT PROGRAMME

BASED ON WORK OF MR JORGEN O CLEEMANN
EXPERT ON GRINDING TECHNOLOGY

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

* This report has not been cleared with the United Nations Industrial Development Organization which does not, therefore, necessarily share the views presented.

C O N T E N T S

A N N E X U R E S

EXPLANATORY NOTES

NCB	National Council for Cement and Building Materials. A Goverment Agency of the Indian Ministry of Industry.
Kwh/t	Kilowatt hours per ton
OPC	Ordinary Portland Cement
PPC	Pozzolana Portland Cement
C_2S	Dicalcium Silicate (Belite)
C_3S	Threecalcium Silicate (Alite)
C_3A	Threecalcium Aluminate
C_4AF	Tetracalciumalumina ferrite
%+0.09MM	% Residue on the 0.09 MM (90 Micron) Sieve

I ABSTRACT

PRODUCTIVITY IMPROVEMENT THROUGH OPTIMIZATION OF BALL MILL OPERATION

IND/84/020/11-04

The objective of the program was to obtain the productivity improvement through strengthening of the National Council of Cement and Building Materials (NCB).

The procedure has been to arrange a course in grinding technology for the NCB-group dealing with size reduction. After the course visits have been paid to ten cement plants in company with one or two NCB people in order to analyse the problems and to work out proposals to optimizations.

Most Indian Cement Plants have very hard limestone causing high energy consumption by grinding of the raw materials.

The Indian coals used for cement manufacture have high ash contents and are hard to grind. The energy consumption in coal grinding is therefore high.

Many cement plants have difficulties in procuring good quality limestone. This in connection with high absorbtion of coal ash in the clinker burning process involve that the cement clinker get a high content calcium disilicate. As the disilicate is very hard to grind most Indian cement plants also experience a

much higher than average energy consumption in connection with grinding of finished cement.

The consequence of the above is that most Indian cement plants have extraordinary high energy consumptions for grinding of raw materials as well as coal and finished cement.

Under the circumstances improvements to the grinding efficiency is much required. The first step should be to optimize the performance of existing grinding mills. In connection with new installation and modernization of existing plants, it is also very important to choose the most efficient equipment in the market.

II INTRODUCTION

The main purpose of the UNDP Project IND/84/020 is "To improve the total productivity factor in the industry and the technological levels of the various units of the cement industry in India through strengthening of the national centre" - The National Council for Cement and Building Materials (NCB).

One of the areas of this program is "Productivity Improvement through Optimization of Ball Mill Operation".

As UNDP-Expert for this post has been chosen Mr J O Cleemann, an expert in grinding technology.

The first mission has covered the periods October 20 to November 30, 1986 and January 5 to February 16, 1987.

The program for the first mission was: "Techniques of evaluating and monitoring the ball mill performance; Optimization of various process parameters such as mill loading, grinding media distribution, compartment size, circulating load etc.

The activities in connection with the mission have been organized by the NCB Program Leaders Mr V K Arora and Mr Kamal Kumar. One part of the activities took place at the NCB institute at Ballabgarh, the other was dedicated to plant visits and lectures organized by NCB - Hyderabad.

The work at the NCB Institute started with a number of lectures on grinding technology and practical work on optimization of mill installations. The lectures were followed by discussions and group works related to the lectures. After the plant visits the reports worked out were discussed.

Visits have been payed to a total of 10 cement plants out of which one consisted of raw grinding, coal grinding and clinker burning facilities only and one was a clinker grinding installation. On the visits, the UNDP Expert was accompanied by one or two NCB engineers from the size reduction group.

The work at the cement plants consisted in: collection of data and performance results, grinding tests and mill inspections, analyzing of samples and evaluation of results, discussions with Managers and staff people. At most of the plants lectures were given on grinding technology and new development in grinding and separation.

The people at the plants were most cooperative in supplying performance results, performing grinoing tests, stopping mills for inspections and analysing samples of grinding media and material samples.

III RECOMMENDATIONS

By optimization of chamber length and grinding media size as already proposed to a number of cement plants the energy consumption for grinding can be reduced by 10 - 20% at most Indian cement plants.

The utilization of good quality chrome alloy which now is being manufactured in India for lining plates and grinding media the costs of wear parts for grinding mills can be reduced by 25 - 50%.

The utilization of grinding heat for drying of slag involves the possibility of saving 10,000 tons coal per year at one plant for grinding of slag cement.

As more long term improvements high pressure rolls should be used as pregrinders for ball mills. This will especially be advantageous in grinding of hard limestone where energy savings of the order of 25 - 35% are realistic. High pressure rolls may also be justified in connection with grinding of finished cement although the energy saving here hardly will be more than 10 - 15%.

Many Indian cement plants have the possibility of replacing part of the ordinary high ash coal by lignite coal with low ash content (but high moisture content). This would improve the strength properties and the grindability of the cement clinker. To make possible utilization of large quantities of lignite coal with high moisture content installations for drying and grinding of lignite coal should be used.

Most Indian cement plants have open circuit grinding of finished cement. Installation of the new types of high efficient air separators and conversion to closed circuit grinding should involve 10 - 20% energy saving.

Because of high ash coal precalciner kilns are especially suitable for Indian cement plants. The coal ash absorbed in the calciner is intimately mixed into the raw meal. In this way the content of tricalcium silicate can be kept higher involving better strength properties and lower energy consumption by grinding of finished cement.

IV BALL MILL OPERATION AT INOIAN CEMENT PLANTS

A General :

Next to the clinker burning grinding is the most important process in cement manufacture. The total electrical energy consumption in cement manufacture will normally be of the order of 100 - 150 kwh/t out of which normally 60 - 70% is used in connection with grinding. Grinding mills also have a high consumption of grinding media and wear parts. In order to reduce the manufacturing costs for cement, it is very important to optimize existing mill installations as far as the grinding process is concerned and also to use high quality grinding media and wear parts with good resistance to wear. For new installations, it is very important to choose the most economical equipment.

The ball mills are highly dominating as machines for grinding in the cement industry. Although ball mills have been used for more than one hundred years the design is still being improved in order to reduce the grinding costs. This also goes for the auxiliary machinery like air separators and dust collectors.

For grinding of raw materials a number of vertical roller mills have already been installed in India. These mills are especially advantageous for grinding of raw materials with high moisture. As, however, most Indian cement raw materials have low moisture contents, the newly developed high pressure rolls used as pregrinders ahead of ball mills seem to be more suitable for Indian conditions.

Also for grinding of coal, vertical roller mills have been installed in India. The experience is, however, that the high content of coal ash with plenty of free coarse quartz causes excessive wear on rollers and grinding tables. Because of these problems and the fact that savings of the order of 5 - 10 kwh per ton of coal only amounts to 1 - 2 kwh per ton of cement roller mills may not be justified for grinding of Indian coal.

In grinding of finished cement, there is a new interesting development taking place for utilization of grinding by compression. Here high pressure rolls and vertical roller mills are being tried out. Up to now, however no conclusive results seem to be available.

8 Training of NCB personnel :

The purpose of the UNDP Project is not to assist the people in the cement industry to improve the productivity but to train the NCB personnel so that they can improve their assistance to the cement industry.

The first two weeks of the visits to India were used for planning of plant visits and for a training course on grinding technology in the cement industry. The course was attended not only by the people in the size reduction group but also often by people from other groups, so that the audience varied between 10 and 20 people.

<u>Subjects for the Lectures were</u> :

Ball Mills in general

- Ball charge
- Linings
- Partitions

Grinding of Raw Materials

- Wet grinding
- Drying in connection with grinding
- Different methods for dry grinding
- Vertical roller mills

Comminution Theories and sizing of mills

- The classical laws of comminution
- Size reduction as a 1st order process
- Sizing of mills

Coal Grinding

- Drying (free moisture & inherant moisture)
- Drying temperature versus dew point
- Ball mills
- Vertical mills
- Grinding in inert atmosphere
- Safety precautions

Cement Grinding in General

- Fineness
- Grindability
- Grinding aids
- Closed circuit grinding
- Internal water cooling

How to Evaluate the New High Efficient Air Separators

- Conventional Efficiencies
- Tromp curves
- Efficiency related to energy saving
- Comparison of the different efficiencies
- Internal air circuit separators

Cyclone type separators
New high efficient air separators
Examples of how to calculate the energy saving by closed circuit grinding

A practical Method for Evaluation of Strength Properties and Efficiency by Grinding of Portland Cement

Fineness determined by spec. surface and sieve residue
Specific surface versus sieve residue for constant slope of size distribution curves.
Specific surface versus sieve residue for constant strength
Examples of evaluating cement mill performance.

New Development in Cement Grinding

Vertical Roller Mills
High pressure Rolls

How to Improve on Existing Grinding Installations

Planning of grinding test
Sampling
Collection of performance data
Mill inspection and sampling
Analysis of samples
Evaluation of results
Recommendations to improvements

After each lecture the audiance was invited to ask questions. In connection with most of the lectures, the participants were activated in group works where they should solve problems related to the lectures. After the different groups had presented their solutions to the problems, we finished with general discussions on the subjects.

Most of the time has been spent on plant visits in company with one or two from NCB's size reduction group. At the plant the NCB people took active part in all the work involved like collection of performance results, carrying out grinding tests and mill inspections, analysing of samples and evaluation of results. In between the plant visit the reports were explained and discussed with the size reduction group.

C Performance Results from cement plants :

In connection with each plant visit a separate report has been worked out containing mill data, normal performance results, results from grinding tests and recommendations to improvements. These detailed informations can be found in the Annexures Nos 8 - 17. The idea of these reports is primarily to show examples of how to analyse mill performance and how to work out proposals to optimization. The reports can also be used directly by the cement plants in their optimization activities.

1. Grinding of Raw Materials :

A summary of results from grinding of raw materials at the cement plants, which have been visited appear from Annexure No. 1.

The specific energy consumption calculated for grinding to 10% sieve residue on the 90 micron sieve is for most plants of the order of 20 - 30 kwh/t which is 50 - 100% higher than average. India Cements, Sankari is extremely low with 7 kwh/t only and Panyam Cements is very high with 39 kwh/t. There is no significant difference between wet and dry grinding although dry grinding normally should have a 20 - 30% lower specific energy consumption for the mill proper.

For most of the raw mills the limestone feed has been coarse with 10 - 20% coarser than 25 MM. This causes often accumulation of coarse material in the first grinding chamber and in serious cases back spillage and reduced output.

At many plants the balls used in the first chamber have been too small for the coarse feed material and the grinding media in the last chamber too large for effective fine grinding.

As most raw materials only contain a few percent moisture drying in connection with grinding of raw meal is normally not limiting the output.

2. <u>Grinding of Coal</u> :

A summary of plant results appear from Annexure No. 2. Most of the coal mills have a specific energy consumption of 30 - 33 kwh/t calculated for grinding to 10% residue on the 90 micron sieve. Three plants show 40 - 50 kwh/t.

The Hardgrove index for Indian coal has been reported as 40 - 45°H. For grinding of coal with a Hardgrove index of 40 in fully air swept ball mills the normal specific energy consumption for the mill proper is 24 kwh/t to 10% residue on the 90 micron sieve.

Consequently the energy consumption is 25 - 50% higher than normal and for three of the mills upto 100% higher than normal.

At some plants, the moisture content is high especially when grinding a mixture of ordinary coal and lignite as at India Cement, Sankari (Annexure 1). In such cases the output will often be limited by the drying capacity for the coal mill.

Other observations were that the coal feed often is coarse (upto 3 - 4") and the grinding media in the last chamber much too large for effective grinding.

3. Grinding of Finished Cement :

Annexure No. 3 shows average results for grinding of OPC at the different plants. The calculated specific energy consumption for grinding to a specific surface of 3000 cm^2/g varies from 30 to 45 kwh/t and is mainly higher than the normal 33 kwh/t for open circuit grinding. Kwh/t for grinding to 10% + 0.09mm varies between 25 and 40. A normal figure is 25 kwh/t.

One reason for the high energy consumption in cement grinding is a high C_2S content in the clinker. The influence of C_2S on grindability appears from Annexure No. 4. The results indicate that a reduction of the C_2S content by 10% will reduce the kwh/t for grinding to the same specific surface by about 6. For grinding to the same sieve residue a 10% reduction of the C_2S content should reduce the energy consumption by 9 kwh/t. In the upper graph one point (No. 9) shows a very high kwh/t for grinding to 10% + 0.09 MM. The mill in question (Priyadarsini) had an extraordinary high (85 g) piece weight for grinding media in the last chamber.

Annexures Nos 5 and 6 show compressive strength and clinker composition. In Annexure No. 7 are strength properties shown in relation to the C_3S content. The strength properties are shown in percent of average strength properties for West German cements. In the comparison has been corrected for the granulometric influence according to the method published by Mr J Cleemann in Zement-kalk-Gips for January 1987.

Annexure No. 7 shows that the C_3S content has an important influence on the strength properties. One should expect more influence on 3 days strength than on 28 days strength. The results indicate, however, that, strength after 3, 7 and 28 days all increase by approximately 50%, if the C_3S content is increased from 25% to 50%. The points deviate considerably from the lines drawn indicating that other factors than the C_3S content influence the strength properties.

All the cement plants visited are grinding cement in open circuit. For coarse grinding (about 2800 SQ.CM/G) and for cements with low 3 days strength closed circuit grinding may not be justified.

D. Methods of Analysing Ball Mill Performance

1. Grinding Tests :

Before starting making improvements to a ball mill, it is important to analyse the performance. The best way is to carry out a grinding test over a 4 - 6 hours period. During the test especially output, power consumption and product fineness should be measured. At the same time many other parameters influencing the grinding like temperatures, ventilation, pressures and dew points should be measured. In closed circuit grinding samples of separator feed, Returns and final product should be analysed for fineness in order to calculate circulation on separator efficiency.

2. Mill Inspection and Sampling :

The grinding test should be terminated by a crash stop followed by mill inspection. In each chamber the level of grinding media and material should be measured. The condition of wear parts should be inspected and the openings in diaphragms and outlets should be measured.

Many people prefer to take material samples for every meter through the mill. The information from a large number of samples will normally not be of great value, instead, it is recommended to take a few large samples. Most important is a 3 - 5 kg sample taken in the outlet end of Chamber 1 just before the outlet grates. This sample will show how Chamber 1 is working. Other important material samples should be taken before diaphragms and outlet grates.

When taking out samples of grinding media, 200 pieces is an absolute minimum. In the second and third Chamber 500 pieces give a more representative sample. It is normally sufficient to take one sample from Chamber 1 and Chamber 2 and two or three samples from the last chamber.

Sieve analysis of feed material and material samples from the mill should be made at a number of sieves from 25 or 40 MM to 0.09 MM.

For the grinding media samples, it is sufficient to sort them up in 4 or 5 different size fractions as well as in broken grinding media and scrap. For each fraction should be determined weight and number.

3. <u>Evaluation of Test Results</u> :

The material samples, will give information on whether the grinding media have an appropriate size and whether the chamber length is suitable.

It is very often so that the feed material is too coarse for effective grinding in the first chamber. Remedies are then one or more of the following :

Finer precrushing
Larger balls
A longer Chamber 1

In the last chamber the grinding media will often be too large for effective fine grinding. The size of grinding media in the last chamber is however, related to slot width in diaphragms and outlet in the way that the size of grinding media used as replacement for wear preferably should be three times the slot width. If the proportion is less, then the consumption of grinding media will be unnecessarily large or by closed circuit grinding a large amount of small grinding media will circulate in the system.

E Methods to Improvement of Ball Mill Performance :

1. Proper precrushing :

Many cement plants have a single stage hammer crusher installation. Properly maintained these crushers can produce a product with 2 - 5% coarser than 25 MM which normally can be ground satisfactorily in a ball mill with 90 or 100 MM maximum ball size. Often, however, maintenance is unsatisfactorily so that the product becomes too coarse for effective grinding in a ball mill.

A grinding test will show whether the precrushing is sufficient. In the negative the precrushing should be improved. If that should not be possible the ball mill has to be optimized for the coarse feed by using larger balls and/or by making Chamber 1 longer. Wider slots in the first diaphragm can not be recommended as this will cause problems in the following chambers without relieving Chamber 1 essentially.

2. Optimization of Chamber Length and Grinding Media Size :

For optimum grinding efficiency the grinding media size should not be larger than required. Consequently Chamber 1 should not be longer than necessary for preparing the material for further grinding in the following chamber. The last chamber is twice as effective in fine grinding as the first chamber. Therefore, if the diaphragms can be moved 10% of the total mill length towards the inlet end the specific energy for grinding can be reduced by 10%. From a grinding point of view, it is more economical to have a short Chamber 1 with large size balls than a long Chamber 1 with rather small balls.

Determining for the length of the first chamber will often be accumulation of coarse material (coarser than 5 or 10 MM) to an extent where Chamber 1 gets over filled with material so that we get back spillage.

For grinding in the last chamber the grinding media will normally be much larger than required for optimum grinding efficiency. Limiting for how small grinding media can be used is the slot width in diaphragms and outlet grates because the size of grinding media being used as replacement for wear in the last chamber should atleast be 2.5 times and preferably 3 times the slot width.

3. New Development in Diaphragms :

For,open circuit grinding in a two chamber mill with optimum size grinding media in the last chamber the FLS - Combidan diaphragm with 2.5 MM wide slots is the ideal solution.

A number of diaphragms have been developed in order to keep a constant level of material in the first chamber :

Slegten - Magotteaux's constant flow diaphragm

F.L. Smidth's STANEX or constant level diaphragm

Polysius' constant level diaphragm

From a grinding point of view, it is important that the voids between the grinding media are almost filled with material. A certain level of material in the first chamber is, however, even more important for protection of lining plates and grinding media.

4. Classifying Linings :

Classifying linings of the carman type consisting of conical rings are widely being used in the cement industry. In one chamber mills for raw materials and coal they involve the big advantage of avoiding a diaphragm which wears and give resistance to flow of drying air.

In grinding of finished cement the development has been to change three chamber mills into two chamber mills with a classifying lining in the last chamber.

The newest development is, however, to use two chamber mills with a diaphragm which only gives passage to material finer than 1 - 2 MM. In this way there is no need for grinding media larger than 15 or 20 MM and no need for classification which also not is possible for such small grinding media.

5. Wear Resistant Materials for Lining Plates and Grinding Media :

In most of the world chrome alloys with 14 - 18% Cr and in some cases upto 30% Cr are dominating as wear resistant material for ball mills. Chrome alloy lining plates will normally last for 30000 - 50000 hours in the first chamber and 50000 - 80000 hours in the last chamber.

When using a good quality chrome alloy grinding media the consumption will typically be 20 - 40 g per ton OPC or 1/5 - 1/10 of the consumption of ordinary grinding media.

There has been some problems with chrome alloy grinding media produced in India being too brittle so that breakage has been much more than what can be tolerated. This was also a problem in Europe until a suitable hardening proceedure was introduced.

6. High Efficient Air Separators for Closed Circuit Grinding :

The new (third) generation of air separators with high efficiency has made it more attractive to use closed circuit grinding in the manufacture of finished cement. Especially the O-SEPA separator from Onoda Cement Comp. and the SEPAX - Separator from F.L. Smidth have proved to be highly efficient.

When changing over from open circuit to closed circuit grinding with an efficient air separator it is possible to save 20 - 30% of grinding energy by production of cement with the same 28 days strength but lower specific surface. If the 3 days strength has to be kept constant the saving will only be 10 - 20%.

As Indian OPC has to be ground to 2800 Cm^2/g and as 3 days strength normally is low closed circuit grinding may not involve the big advantages in grinding OPC.

For grinding of slag cement and pozzolana cement (PPC) closed circuit grinding should be preferred. In this way the grinding can be concentrated on the hard components like slag and clinker and the grinding heat can be utilized for drying of wet additives.

7. Utilization of Grinding Aids :

Especially in cases where coating and agglomeration is a problem grinding aids will often increase the output by 10 - 20%. There are many grinding aids in the market some of the most effective ones are :

Triethanolamine (TEA)
Ethylenglycol
Propylenglycol
HEA-2 and DDA-7 from GRACE

The quantities required are of the order of 200 - 500 gram per ton of cement. Only plant tests which are easy to carry out can show whether the addition of grinding aid will be justified. Black liquor from the paper mills and fatty acids also act as grinding aids. They have however to be used in larger quantities like 500 - 2000 gram per ton.

8. Cooling and Ventilation of Cement Mills :

The cheapest way of cooling cement mills is by spraying water inside the mill. The ventilation has to be sufficient for giving a dew point of about 60 - 70°C when using electrostatic precipitators and 50 - 60°C when using bag filters. In case of closed circuit grinding, it has in some cases been found advantageous to operate with heavy ventilation probably because fast removal of fines from the mill reduces the tendency of coating and agglomeration.

9. High pressure Rolls for Preparation of Mill Feed :

High pressure rolls for precrushing and pregrinding of raw materials and cement clinker are already being used. Suppliers are :

Humboldt Wedag
Krupp Polusius
F.L. Smidth & Comp.

The use of high pressure rolls involve an energy saving of the order of 10 - 15% in cement grinding and 20 - 30% in grinding of raw materials. The method should be very suitable for Indian raw materials which normally are rather dry and very hard to grind.

10. New Development :

Two very interesting developments are taking place. One is utilization of vertical roller mills for grinding of finished cement. Two industrial test installation have been in operation for three years in Japan. F L Smidth has build a plant for 25 TPH and Ube-Loesche a plant for 10 TPH. From both plants have been published articles showing about 40% saving in the total energy consumption for grinding of cement.

In Germany Gebr. Pfeiffer has one mill operating at the Teutonia Cement Plant in Germany. This mill is however not specially designed for cement grinding and the energy saving is only 10 - 20%.

Although vertical roller mills for grinding of finished cement look very promising the mills do not seem to have been developed to a stage where they are sufficient attractive to the cement manufactures.

An other interesting development is to use the high pressure rolls not only for precrushing and pregrinding but for the total cement grinding. This method was invented by professor Schoenert and is being practiced by Krupp Polysius. Heidelberg Cement has got the first industrial installation which is being tried out. It is being claimed that the energy saving compared with conventional grinding is of the order of 25%.

V CONCLUSIONS

The people with NCB, who have been actively involved in the training course and the plant visits should now be able to analyse ball mill performance and to work out proposals to improvements which gradually should lead to optimization of the performance. These NCB people have, however a limited experience and may therefore not always be able to find the very best solusions.

It is proposed that at least one person with NCB should have a profound education in grinding technology, so that he can be an effective leader of the size reduction group and an advisor in whom people from the cement industry can have confidence.

Education in grinding technology can be obtained at European technical universities. Unfortunately there are no upto date text books on grinding technology. Therefore all the newer knowledge will have to be found in technical magazines and to be learned by attending congresses and seminars.

ANNEXURE - I

SUMMARY OF RESULTS FROM GRINDING OF RAW MATERIALS

CEMENT PLANT	Moisture %	Spec.Energy Kwh/t*	% Residue On 0.09mm	Kwh/t TO 10% + 0.09 MM
UPSCC - Dalla	33	29	7	25
JAIPUR UDYOG				
INDIA CEMENT SANKARI	33	7	10	7
TAMILNADU CEMENT ALANGULAM	34	17	23	27
ORIENT CEMENTS	DRY	25	17	32
KESORAM CEMENTS	DRY	16	27	28
PANYAM CEMENTS	DRY	32	15	39
UPSCC - DALLA	DRY	24	18	32
PRIYADARSINI	DRY	14	17	18
J K NIMBAHERA	DRY	16	18	22

* For the mill proper

SUMMARY OF RESULTS FROM GRINDING OF COALS

CEMENT PLANT	Spec.Energy Kwh/t	% Residue on 0.09 MM	Kwh/t To 10%+0.09 MM
UPSCC - DALLA	25	15	30
JAIPUR UDYOG			
INDIA CEMENTS - SANKARI	35	8	32
TAMILNADU CEMENTS ALANGULAM	23	20	33
ORIENT CEMENTS	33	15	40
KESORAM CEMENTS			
PANYAM CEMENTS	30-35	20-25	45-50
PRIYADARSINI CEMENTS	29	23	45
J K NIMBAHERA	27	15	33

ANNEXURE - III

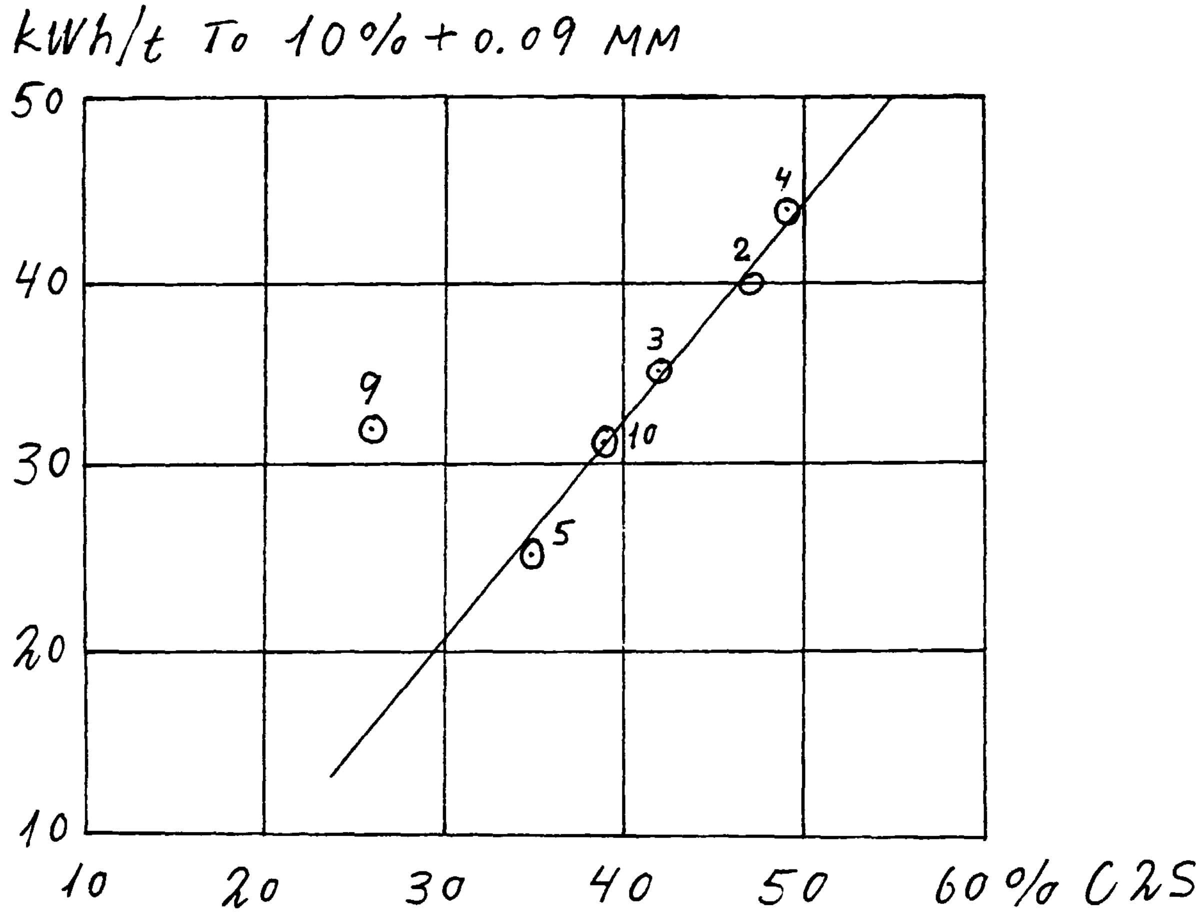
SUMMARY OF RESULTS FROM GRINDING OF ORDINARY PORTLAND CEMENT

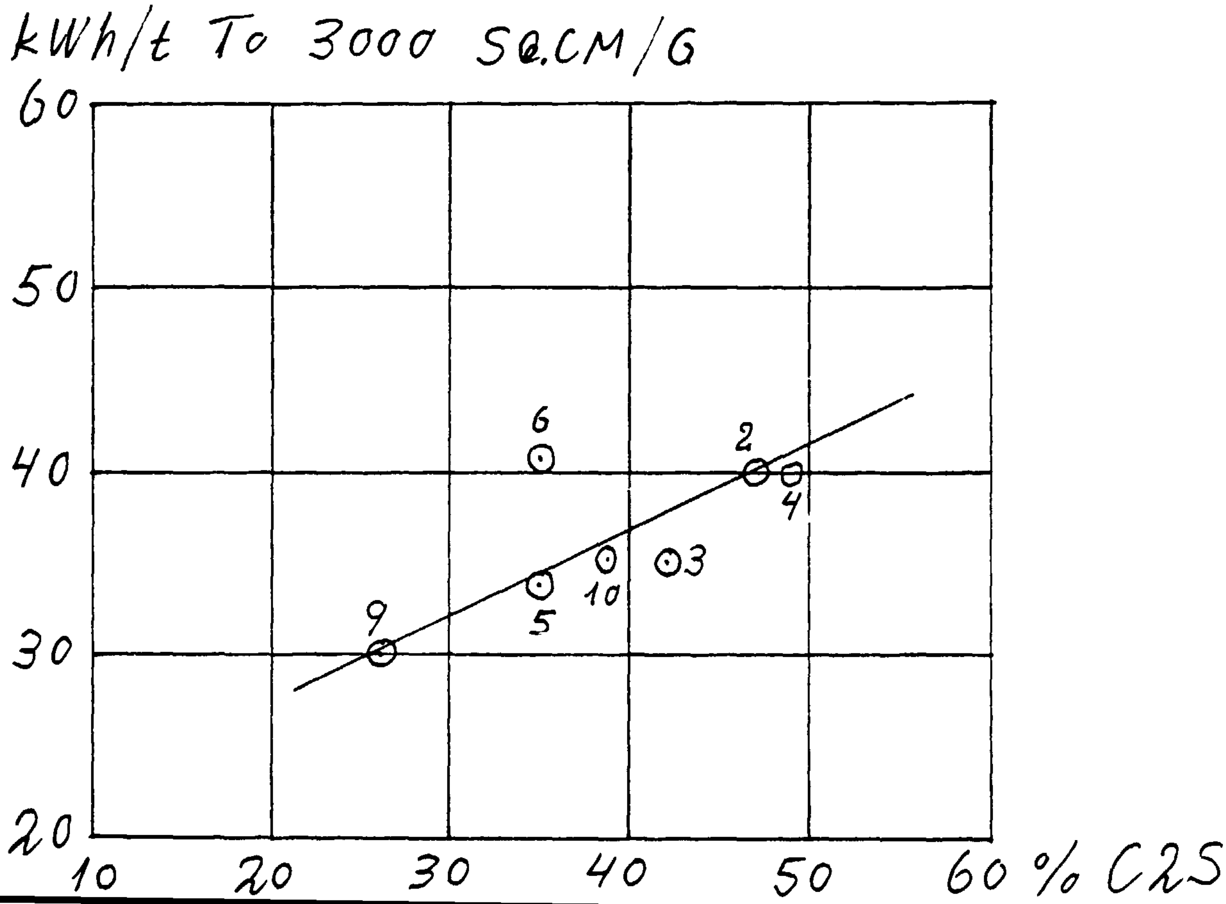
NO	CEMENT PLANT	SPEC.ENERGY kwh/t	SPEC.SURFACE Cm^2/g	% RESIDUE on 0.09 MM	kwh/t FOR 3000 cm^2/g	kwh/t FOR 10% + 0.09 MM
1.	UPSCC - DALLA					
2.	JAIPUR UDYOG	40	3000	10	40	40
3.	INDIA CEMENT - SANKARI	38	2685	8	45	35
4.	TAMILNADU CEMENT - ALANGULAM	39	2930	13	40	44
5.	ORIENT CEMENTS	30	2770	6	34	25
6.	KESORAM CEMENTS	34.5	2670	-	41	-
7.	PANYAM CEMENTS					
8.	UPSCC - DALLA		2980*			
9.	PRIYADARSINI	31	3070	11	30	32
10.	J K NIMBAHERA	32	2800	9	35	31

* LAB GRINDING

ANNEX No. 4.

THE INFLUENCE OF CALCIUMDISILICATE (C2S) ON GRINDABILITY





ANNEXURE - V

AVERAGE COMPRESSIVE STRENGTH OF ORDINARY PORTLAND CEMENT BASED ON DAILY RESULTS FOR ONE MONTH LATE 1986 AND EARLY 1987

No	Plant	MEAN STD.DEV.	BLAINE CM^2/G	COMPRESS. STRENGTH 3 days	7 days	28 days	STRENGTH PROPERTIES IN % OF W. GERMAN CEMENTS 3 days	7 days	28 days
1.	UP STATE CEMENT CORP. - DALLA	MEAN S.DEV.							
2.	JAIPUR UDYOG	MEAN S.DEV.	3000 125	219 30	274 40	284 30	47	65	82
3.	INDIA CEMENT - SANKARI	MEAN S.DEV.	2685 140	223 14	292 20	456 30	50	67	93
4.	TAMILNADU CEMENTS - ALANGULAM	MEAN S.DEV.	2930 126	206 4	267 8	371 14	44	63	77
5.	ORIENT CEMENTS	MEAN S.DEV.	2770 105	250 59	361 35	468 25	56	84	97
6.	KESORAM CEMENTS	MEAN S.DEV.	2670 130	296 7	390 7	529 7	70	97	117
7.	PANYAM CEMENTS	MEAN S.DEV.		245 33	330 37	412 85			
8.	UPSCC - DALLA (DRY)	MEAN S.DEV.	2980*	241* 32	309* 68	429* 46	50*	70*	85*
9.	PRIYADARSINI (PRICALC.)	MEAN S.DEV.	3070 102	305 37	412 46	564 62	63	96	119
10.	J K NIMBAHERA	MEAN S.DEV.	2740 93	266 15	371 22	512 32	60	92	108

* LAB GRINDING

ANNEXURE - VI

AVERAGE CLINKER COMPOSITION BASED ON DAILY CLINKER ANALYSIS FOR ONE MONTH

		UPSCC DALLA	JAIPUR UDYOG	INDIA CEMENTS	TAMIL-NADU	ORIENT	KESORAM	PANYAM	UPSCC DALLA	PRIYA-DARSINI	J.K. NIMBAHERA
SiO_2	MEAN	22.7	23.0	23.9	22.2	21.8	22.5	22.4	23.2	21.7	22.6
	S.DEV.	0.3	0.7	0.4	0.5	0.8	0.1	0.6	0.6	1.2	0.6
Al_2O_3	M	6.6	7.1	4.4	7.2	5.8	6.5	5.5	6.6	5.6	6.1
	D	0.2	0.7	0.4	0.2	0.05	0.1	0.6	0.3	0.9	0.4
Fe_2O_3	M	3.7	3.3	4.0	3.0	4.3	4.0	3.7	3.7	4.0	3.8
	D	0.3	0.2	0.4	0.2	0.18	0.1	0.3	0.2	0.6	0.2
CaO	M	60.4	62.4	65.0	62.5	63.4	64.5	65.0	61.4	65.1	64.7
	D	0.7	0.6	0.4	0.7	0.21	0.1	0.7	0.6	1.6	0.6
MgO	M	4.1	2.5	1.5	3.6	1.50	1.11		4.1		1.3
	D	0.1	0.2	0.2	0.2	0.08	0.05		0.1		0.1
LOI	M	0.89	0.8	0.3		0.28			0.7	0.45	0.5
	D	0.25	0.2	0.1		0.06			0.2	0.4	0.2
SO_3	M			0.43	0.25	1.17		0.6			0.3
	D			0.11	0.07	0.08		0.1			0.1
S - M	M	2.3	2.2	2.8	2.2	2.1	2.1	2.4	2.3	2.3	2.3
	D	0.1	0.14	0.14	0.07		0.06	0.1	0.1	0.2	0.1
A - M	M	1.7	2.2	1.1	2.4	1.4	1.6	1.5	1.9	1.5	1.6
	D	0.4	0.19	0.19	0.02		0.06		0.2	0.3	0.2
LSF	M	0.79	0.82	0.87	0.85	0.89	0.87	0.91	0.82	0.93	0.88
	D	0.02	0.03	0.02	0.02	0.05	0.03	0.03	0.02	0.06	0.02
Free CaO	M			2.4	2.8	1.5		1.2		2.1	1.8
	D			0.6	0.4			0.3		0.7	0.6
C_3S	M	9	26	35	20	37	39	47	19	48	35
	D	7	7	7	7	2	1	8	5	17	5

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		UPSCC DALLA	JAIPUR UDYOG	INDIA CEMENTS	TAMIL-NADU	ORIENT	KESORAM	PANYAM	UPSCC DALLA	PRIYA-DARSINI	J.K. NIMBAHERA
C_2S	MEAN	62	47	42	49	35	35	29	53	26	39
	S.DEV.	7	7	6	7	2	1	7	6	15	6
C_3A	M	12	14	5	14	8	11	8	11	8	10
	D	1	1	1	1	0.3	0,4	2	1	3	1
C_4AF	M	11	10	12	9	12	12	11	11	12	12
	D	1	1	1	1	0.3	0.3	1	1	2	1

ANNEX No. 7

STRENGTH PROPERTIES VERSU CONTENT OF TRICALCIUMSILICATE (C3S)