SHORT REPORT ON OPERATING A MODERN CEMENT WORKS

Dr. Dennis Le Sar
Operations Manager
Cape Portland Cement Company Limited

ABSTRACT

During 1971-1974 a complete new plant was built at our old De Hoek Works. Features of the new plant include:
A sophisticated system of pre-blending raw materials from the quarry which permits the feeding of a thoroughly blended material to the next stage of production. Samples of the material are taken by an automatic sampler and are analysed by an X-ray fluorescence spectrometer, with the results being fed directly into a process control computer. The chemical analysis is also used for the next stage of the process for automatically controlling the rates of feed to the raw mill. The X-ray fluorescence spectrometer accurately determines the calcium, silica, iron, sulphur, magnesium, alumina and potassium content of the materials concerned within two minutes.
The kiln incorporates a 4-stage preheater cyclone system and the whole operation is controlled by extensive automation and instrumentation operating from a centralised control room. On the whole, the plant has performed well, except for a series of chokes in the preheating system. The frequency of these has been considerably diminished by various physical modifications and some alterations to operating procedures.

The Company and the Works

The Cape Portland Cement Company was incorporated in 1921 with an original share capital of R700 000. It took over the assets of the Hermon & Picquetberg Lime Company and established its first factory at De Hoek about six kilometers from Piketberg.

The initial manufacturing capacity was 54 000 tonnes of cement per year and this was increased through the following thirty years to reach 270 000 tonnes per year. The next extensions were at Riebeek West where a kiln was started in 1959 and a further extension in 1968 brought the production capacity of the Company to roughly 820 000 tonnes of cement per annum.

When the demand for cement further increased, it was decided to replace the old plant at De Hoek with a new, modern plant. Construction of this plant started in late 1971 with the kiln being commissioned in June, 1974. The final cost of the new plant was roughly fifteen and a half million Rand and it is capable of producing approximately 500 000 tonnes of cement per year.

The Raw Materials

Limestone

A hard, blue-grey, secondary limestone, extracted by open-cast mining methods from a quarry adjacent to the Works. The material is drilled and blasted and then transported to the primary jaw crusher situated within the quarry. The crushed material (-150 mm) is raised by a conveyor belt to the secondary crusher station sited at the surface, next to the quarry. This station houses twin units, each consisting of a triple-deck vibrating screen and a Hazemag impact breaker. The oversize material is crushed (95%-25 mm) whilst the smaller sized fractions coming from the quarry can either be diverted to the waste dump or combined with the crusher product, which is conveyed to a stockpile. There are two stockpiles of low/medium grade "run-of-quarry" limestone and one high-grade pile.

TABLE 1

Typical Analyses of Limestone Samples ex Crushers

Constituents/ Ratios	Low/Medium grade		High grade	
	%	%	%	%
SiO_2	13,5	11,5	9,1	6,5
Al_2O_3	3,0	2,5	2,1	2,2
Fe_2O_3	1,0	0,5	0,6	0,9
Ca O	46,7	48,9	50,1	51,0
SO_3	0,3	0,2	0,4	0,4
K_2O	0,7	0,5	0,5	0,4
MgO	1,5	1,3	1,2	0,9
Na_2O	0,4	0,2	0,3	0,3
Cl	0,007	0,004	n.a.	n.a.
L.S.F.	111,5	135,3	176,2	236,7
Silica Ratio	3,4	3,5	3,5	2,1
A/F	3,0	3,1	3,6	2,4

TABLE 2

Variation of K_2O and SO_3 content in Limestone Samples

Sample No.	L S F %	K_2O %	SO_3 %
1	100,6	0,78	0,71
2	121,2	0,64	0,57
3	133,1	0,62	0,81
4	136,2	0,65	0,71
5	146,2	0,58	0,73
6	150,2	0,81	0,63
7	161,7	0,69	0,81
8	167,5	0,46	0,63
9	166,9	0,44	0,86
10	178,9	0,41	0,83
11	208,8	0,25	0,51
12	220,2	0,25	0,51
13	262,8	0,16	0,45
14	283,0	0,26	0,52
15	286,4	0,08	0,53

Shale

Most of the overburden on top of the limestone, and the material surrounding it, consists of a soft yellow shale. Prior to installing the new plant at the Works the raw mix used to consist solely of limestone and shale. Much of the limestone deposit consists of a mixture of a slightly harder grey shale (with a composition similar to that of the yellow shale) and the much harder limestone. When there is an excessive amount of shale mixed with the limestone it is screened out, as described above, to upgrade the quality.

Yellow shale is extracted and fed through the system as and when required, and stored in a separate stockpile.

TABLE 3

Typical Analyses of Shale Samples ex Crushers

Constituents	%	%	%	%
SiO_2	65,5	71,5	60,2	57,0
Al_2O_3	12,8	13,4	16,4	17,1
Fe_2O_3	8,7	9,2	7,5	8,0
CaO	-	-	2,8	4,2
SO_3	-	-	0,1	0,4
K_2O	2,8	2,8	3,3	2,8
MgO	1,1	1,0	1,6	1,4
Na_2O	n.a.	n.a.	0,4	0,7
Cl	n.a.	n.a.	0,1	0,1

Sand and Iron Ore

About 2% of river sand and 1,2% of iron ore (haematite) are added to the raw mix (on average) in order to keep the silica and A/F ratios as constant as possible.

TABLE 4

Typical Analyses of Sand and Iron Ore Samples

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	K_2O	MgO	Na_2O	Cl
	%	%	%	%	%	%	%	%	%
Sand	97,7	1,2	0,8	0,03	-	0,3	0,1	0,1	0,04
Iron Ore	17,3	3,9	66,2	1,2	0,2	0,5	0,7	0,3	tr.

THE RAW MIX CONTROL

Equipment

X-ray Spectrometer:

Make:	Siemens
Type:	Multichannel MRS-2T
X-ray tube:	Ag Cr 61 with chrome anode
Elements:	Fe Mg S Ca K Al Si
Crystal:	LiF100 AdP PET Quartz PET PET PET
Counting time:	2 min.
Tube:	KV/MA 50/44
Press:	Hertzog Automatic Press

Communication between X-ray spectrometer and computer is established by means of the following signals: 32 digital inputs, 4 digital interrupts and 14 digital outputs from S/7.

Computer:

Make:	IBM S/7 Model A16
Storage:	16 K words, each consisting of 16 bits
Typewriters:	1 - 5028 operator station 2 - 1053 printers
Disks:	1 Fixed 4 Removeable

Power failure interrupt

Automatic restart

Interval times

Analog inputs 96

Digital inputs 128 (32 Process interrupt)

Digital outputs 48

Samplers:

1. SALA sampler

   Situated between the secondary crushers and the preblending stacker, this device automatically samples (at pre-set intervals) all material being conveyed to the various stockpiles; it reduces the sampled material to a coarse powder and splits and mixes it. When the sample is collected a button is pressed to indicate to the computer that this has been done, and the computer then "reads" the belt weigher in order to determine the quantity (in tonnes) of material which the sample represents.

2. FLS Raw mix sampler

   Situated after the raw mill.

Plant:

1. Weserhütte Preblending Stacker and Reclaimers:
The stacker lays down the piles of crushed limestone in a series of 400 longitudinal layers, arranged in the "windrow" fashion (NOT chevron pattern). There are two "run-of-quarry" limestone stockpiles, one high-grade limestone pile, and one shale stockpile. The reclaimers are fitted with swivelling bucket-wheels which cut across the entire 400 layers (built-up over several days) each 5 minutes. The theoretical blending effect is 20 : 1 (i.e. square root of 400), and, as far as can be ascertained, this is borne out in practice.

2. Two storage silos:
One for river sand and one for iron ore.

3. Schenck weighing equipment:
Belt weighers to record rate and weight of material stockpiled, and control speed of stacker, and reclaiming rates.

Four weigh-feeders, controlled by the computer, to proportion and control the feed to the raw mill.

4. F.L. Smidth Raw Mill:
Tirax-unidan mill, rated at 110 tonnes per hour for a product with 10% residue on the 170 mesh screen.

5. Two Claudius Peters Homogenising Silos:
Each of 6000 tonnes capacity, and fitted with a "misch kammer". Guaranteed to have a blending effect of 5 : 1.

Control:

1. Raw Materials Preblending:
The raw materials are fed to the prehomogonising store via a belt weigher and an automatic sampler. The material is deposited on one of four piles. An account is kept by the computer of the contents, in tonnes, of wet materials in each pile. During the filling up of a pile, the average chemical analysis is calculated
The basis for these calculations is:
Samples taken out by the automatic sampler, as well as analog and digital signals from the prehomogonising store and the feeders of the raw mill.

2. Raw milling:

The quality of the kiln feed is controlled by blending four, three or two raw materials. The chemical requirements as regards the kiln feed are determined by setpoints for:

(1) LSF

(2) SR

(3) A/F

The quality of the kiln feed is controlled on the basis of average raw mix samples taken after the Raw Mill.

The chemical requirements as regarding the raw mix are determined as follows: After passing the Claudius Peters homogenising silos, the raw mix should fulfill the required setpoints as far as possible. The automatic sampler of the raw mill is emptied about once every hour. The analysis of this average sample, and the corresponding consumption in tonnes of each of the four raw materials, is used for up-dating the limestone analysis. The knowledge of the raw materials analysis and the deviations accumulated are used in the calculation of the proportioning of the raw materials to be fed to the raw mill in the next hour.

3. X-ray Analysis and Control:

A raw mix sample is taken every hour mixed and analysed.

The analytical procedure used is:

Grind 40 gram Raw Mix + 0,5 gram Boric Acid for 4 minutes in a Bleuler Ring Mill. 29 Grams of ground material + 1 gram wax is then mixed for 2 minutes. A special communications code is then dialed indicating to the computer the type of analysis, production line, type sample and sample no. The sample is then fed to the press, the spectrometer started, and 4½ minutes later the results are typed out on the one 1053 printer. New % setpoints are also automatically calculated for the 4 feeders and printed on the other 1053 printer. The feeders are set to the new percentages by the computer, and a new updated limestone analysis is calculated.

The X-ray is serviced daily by laboratory assistants and standard samples (tablets) are analysed. If these analyses are out of limits (0.5 LSF, 0,1 SR and 0,1 A/F) the X-ray is recalibrated. Once a shift a quality control sample is analysed - including sample preparation. These analyses are used to check the accuracy of the spectrometer and the sample preparation. A number of safety precautions are incorporated in the computer programs to prevent the analysis of the wrong material as raw mix. Measurement of relative half-width is done every month as further check on the spectrometer.

The X-ray is at present used to analyse raw mix, kiln feed, limestone, filter dust, clinker and cement (for gypsum control).

TABLE 5

Typical analyses of limestone and shale ex stockpiles, raw meal ex mill, and raw mix as fed to kiln (i.e. after silos).

Constituents	Limestone %	Shale %	Raw meal %	Kiln feed %
SiO_2	9,9	64,5	13,8	13,7
Al_2O_3	2,4	12,9	2,9	2,9
Fe_2O_3	0,9	8,3	2,3	2,2
CaO	46,5	0,01	42,9	43,1
SO_3	0,4	-	0,7	0,8
K_2O	0,6	2,9	0,8	0,8
MgO	1,3	1,1	0,9	1,0
Na_2O	n.a.	n.a.	n.a.	0,1
Water-soluble Cl	n.a.	n.a.	n.a.	0,01

TABLE 6

Weekly Clinker Analyses for Five weeks

Week ended :	20.6.76	27.6.76	4.7.76	11.7.76	18.7.76
SiO_2	21,2	21,2	21,2	21,1	21,2
Al_2O_3	5,6	5,6	5,5	5,7	5,7
Fe_2O_3	3,7	3,6	3,6	3,6	3,7
CaO	65,3	65,4	65,4	65,4	65,3
SO_3	0,9	0,8	0,9	0,8	0,8
K_2O	1,0	1,0	1,0	1,0	1,0
MgO	1,7	1,8	1,8	1,8	1,7
Na_2O	0,2	0,2	0,2	0,2	0,3
Loss on Ign.	0,3	0,3	0,3	0,3	0,3
L.S.F.	95,5	95,7	95,9	96,0	95,3
S.R.	2,28	2,30	2,33	2,27	2,26
A/F	1,51	1,56	1,53	1,58	1,54

THE KILN

An F.L. Smidth (Denmark) kiln, with a 4-stage preheater consisting of twin first-stage cyclones and single second-,third- and fourth-stage cyclones. The kiln is 66 m long and has an internal diameter (before lining) of 4,35 m. It is fitted with an F.L.S. conditioning tower and electrofilter. Raw meal feed-rate is controlled by means of a Schenck solids-flowmeter and the kiln is coal fired, and consumes approximately 3,43 MJ/kg clinker (820 k.cals/kg.). Operation commenced on 20 June 1974.

Guaranteed output rate of clinker is 1150 metric tonnes per day, but the kiln operates comfortably anywhere in the range 1050 to 1350 tonnes per day. It has been operated as low as 950 and as high as 1390 (possibly even higher) tonnes per day, but at these extremes constant supervision is necessary.

It was predicted by F.L.S., from the alkali/sulphate ratios of our materials, that we could expect a "soft" build-up in the riser pipe between the kiln and the 4th-stage cyclone, and that this material would harden if it was not removed on a regular basis. This has been the case, and the material is removed twice a shift by poking through holes provided. If this is not done the pressure drop in this area builds up visibly on the chart. In two years of operation it has not been necessary to stop the kiln for a major build-up in this area.

Build-ups of material (also relatively soft) have occurred at various points in the cyclone pre-heater system, and after 22 weeks operation (twice) these have apparently started breaking up under their own weight, and the lumps falling down have caused chokes in ducts where there are restrictions, in some cases resulting in cyclones filling up with hot material. This has necessitated stopping the kiln for a day until the cyclone was cleared.
Various modifications have been made to overcome this problem, as described below:

Physical Modifications:

March 1975 (during first major kiln shut-down)

1. Thermocouple removed from feed pipe below No. 4 cyclone into kiln and resited in the cyclone itself. (This caused several chokes by trapping lumps which would otherwise have passed through into the kiln).

2. The flexible joint in the above pipe was moved to a different position, and poke holes were provided.
3. Additional poke holes were provided throughout the system.
4. An inspection door was provided in the top of the 4th cyclone so that a ledge, where material settles, can be cleaned when necessary.

November 1975

5. All flexible joints were lagged (to prevent "condensation" of hot material).

Feb./March 1976 (during second major shut-down)

6. Alteration to inlet of No. 4 cyclone - to change its shape to the approximate "natural" shape caused by build-ups in this area - as recommended by F.L.S.

May 1976

7. Air jets provided at the "splash-plate" at the entrance of the feed pipe from No.3 cyclone. (This splash plate had become distorted and was removed on 22 Jan. 1976 as it was obviously causing chokes. During March '76 it was replaced with a thicker, stronger plate, but there was still a tendency to choke on start-up. Operating the airjets for about an hour after each start-up has prevented further chokes in this area).

Operational Changes:

1. Reduce feed-rate to kiln before any planned stops of the kiln. Because of the long "feed-line", if this is not done, on restarting the kiln it is initially "flooded", and then "starved" - during which period material (consisting mostly of dust return) gets over-heated and tends to form lumps.
2. STOP the kiln immediately at the first indications (given by instruments) of a possible choke. The first few times inspections were made (without stopping) and/or instruments were checked, by which time a minor choke had become a major choke.
3. Regular, careful maintenance of the conditioning tower. Faults in this system result in it choking, which reduces the total amount of material going to the kiln and this results in overheating in the preheater.
4. The dust return system is emptied during stops. Otherwise "uncontrolled" amounts of material are fed to the kiln during the restart.

5. The ledge on No. 4 cyclone is cleaned during any scheduled stops (for other purposes) of about 4 hours or more. This was first done on 28 November '75, and there was a large build-up. On 26 Jan. '76 the build-up was much smaller, and on 15 June 1976 (after physical modification No. 6) there was no build-up.

The Works Manager believes that the most significant physical modifications made were numbers 1 and 7, and that the most time-saving operational change is No. 2 - there have been no major chokes since this was introduced.

TABLE 7

Analyses of Various Materials

Constituents	Kiln feed	Clinker	Filter Dust (1)	Filter Dust (2)	Riser * Pipe	Cyclone ** Fins
	%	%	%	%	%	%
SiO_2	14,0	21,3	14,7	15,1	13,7	13,4
Al_2O_3	2,8	5,7	4,2	4,5	3,8	4,0
Fe_2O_3	1,8	3,7	2,8	2,9	1,7	2,2
CaO	43,0	65,2	40,1	39,4	39,4	45,8
SO_3	0,7	0,9	1,5	1,7	12,2	2,8
K_2O	0,8	1,0	1,4	1,4	2,9	16,6
MgO	0,9	1,8	1,0	1,0	0,9	2,8
Na_2O	0,3	0,2	n.a.	n.a.	n.a.	5,4
Cl	0,02	0,002	0,18	0,19	n.a.	1,0
Loss on ign.	34,5	0,3	n.a.	n.a.	n.a.	5,9

* A porous, fairly hard, greyish material removed from the riser pipe on 11.2.75. Note the high SO_3 content.

**On 28th November 1975 the top side door on No. 4 riser pipe was opened for inspection. A build-up consisting of soft material and hard coating in the form of fins was found in the top of the cyclone. These fins were removed and a portion analysed, Note the high alkali content.

TABLE 8

Summary of Cyclone Chokes

Choke Number	Date	Time	Length of Stop hours	Cyclone Number	Clinker Production Rate tonnes/day	Weeks after firing up kiln	Kiln stop prior to choke			Time between kiln start and cyclone choke hours
							Date	Time	Reason for priorstop	
1	25-7-74	17.00	28,5	3	-	5	25-7-74	16 30	Feed trip	0,5
2	18-9-74	10.55	29,5	4	-	13	18-9-74	09 45	Feed trip	1,0
3	20-11-74	17.25	112,0	2 & 3	1296	22	20-11-74	13 43	Exhaust fan trip	3,5
4	30-11-74	16.18	18,5	4	1100	23	28-11-74	11 50	Feed trip	+12
5	2-1-75	01.25	24,0	4	1310	28	1-1-75	17 25	Clinker dragchain choke	4,5
6	4-1-75	23,30	1,5	4	1240	28	4-1-75	23 00	Exhaust fan trip	0,1
7	11-1-75	07.00	9,5	4	1200	29	11-1-75	01 03	Feed trip	5,0
8	29-1-75	01.30	10,0	4	1100	32	28-1-75	20 25	Power dip	4,0
9	3-2-75	20.30	27,0	4	1060	33	1-2-75	22 50	Power dip	+12
10	5-2-75	02.35	1,75	4	960	33	3-2-75	20 30	Cyclone choke	3,0
11	10-2-75	08.30	13,0	4	1080	34	5-2-75	02.35	Previous choke	+12
12	4-3-75	08.55	11,0	4	1010	37	26-2-75	02 15	Coal screw failure	+12
13	17-9-75	23.30	7,75	3	970	22	15-9-75	14 45	Feed trip	+12
14	18-9-75	16.00	3,5	4	970	22	17-9-75	23 30	Previous choke	9,0
14(a)	18-9-75	19.55	1,25	4	970	22	18-9-75	16 00	Previous choke	0,5
15	3-11-75	01.35	2,5	4	1130	29	31-9-75	17 25	Power dip	+12

TABLE 8 continued

Summary of Cyclone Chokes

Choke Number	Date	Time	Length of Stop hours	Cyclone Number	Clinker Production Rate tonnes/day	Weeks after firing up kiln	Kiln stop prior to choke			Time between kiln start and cyclone choke hours
							Date	Time	Reason for priorstop	
16	3-11-75	06.20	6,25	4	-	29	3-11-75	01.35	Previous choke	2,2
16a	3-11-75	12.55	11,5	3	-	29	3-11-75	06.20	Previous choke	0,25
16b	4-11-75	00.34	0,75	3	-	29	3-11-75	12.55	Previous choke	0,1
17	10-11-75	01.55	2,0	3	900	30	9-11-75	14.05	Power trip	12,0
17a	10-11-75	01.25	1,75	2	900	30	10-11-75	01.55	Previous choke	0,5
18	13-12-75	05.45	2,5	1	967	34	13-12-75	04.00	Dust transport overloaded	0,75
18a	13-12-75	00.25	0,5	1	-	34	13-12-75	05.45	Cyclone choke	1,0
19	21-12-75	09.42	5,0	3	980	36	18-12-75	17.10	Kiln feed control fault	+12
19a	21-12-75	15.30	14,25	3	-	36	21-12-75	09.42	Cyclone choke	0,75
20	26-12-75	08.25	16,25	3	980	36	26-12-75	07.52	Power trips	0,2
21	27-12-75	07.20	0,3	3	810	36	27-12-75	06.15	Clinker transport trip	0,2
22	1-1-76	12.00	0,25	3	980	37	1-1-76	11.20	Firing fan trip	0,3
22a	1-1-76	12.53	1,0	3	980	37	1-1-76	12.13	Cyclone choke	0,2
23	10-4-76	11.28	6,25	3	600	0	10-4-76	-	Kiln start up	10,5
24	16-4-76	06.45	2,5	2	1080	0	15-4-76	21.45	Power trip	2,3
25	28-4-76	11.50	2,8	3	1279	2	28-4-76	10.26	Cooler repair	0,25
-	16-8-76	-	-	-	1050	18	-	-	-	-

CHLORIDE CYCLE

Although the chloride content of our raw materials is relatively low, a high concentration does build up in some areas of the kiln. This is illustrated (in round figures) in Figure 1. Chlorides, however, are not considered to be a major problem.

TABLE 9

Chloride concentrations

Material	Date	Chloride content
Raw meal ex mill	Dec. 1975	74 ppm
" " " "	Jan. 1976	69 "
" " " "	Feb. 1976	67 "
Kiln feed ex silo	Jan. 1976	71 "
Raw water	-	79 "
Clinker	Jan. 1976	28 "
"	" "	22 "
"	Feb. "	18 "
"	" "	29 "

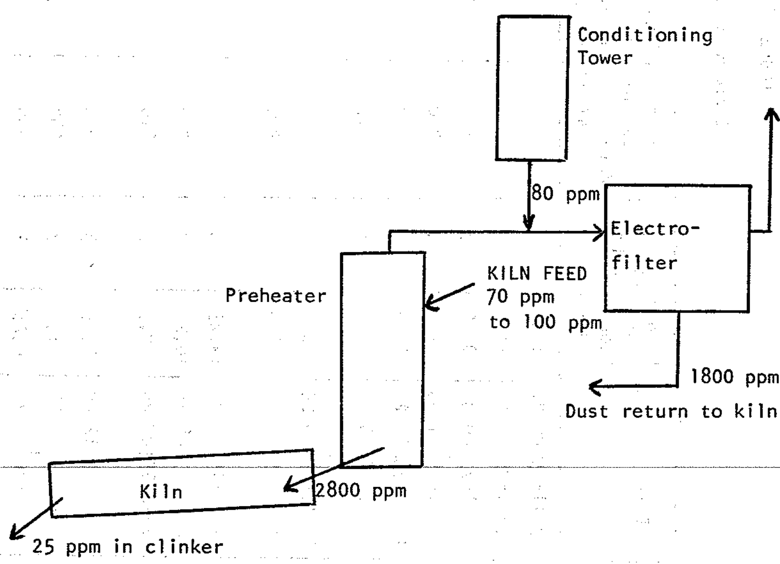

FIG. 1
Approximate chloride concentrations

CONCLUSION

Table 8 has been of assistance in developing measures to prevent chokes, or at least to reduce their severity.

On two occasions the main trouble commenced 22 weeks after firing-up the kiln - i.e. 22 weeks after starting with cyclones free from build-ups. Thereafter most cyclone chokes were associated with kiln stops (where more than 12 hours had elapsed since the previous stop it was not considered relevant). This led (a) to physical modification No. 1 - which seemed to push most of the chokes from No. 4 cyclone up to No. 3 cyclone, and this in turn led to modification No. 7. This splash plate (to "splash" the feed into the riser pipe leading to No. 4) is situated at the bottom of a long vertical duct from cyclone No. 3. As long as the material keeps flowing there is no trouble, but during a stop it seems to harden up and/or become sticky, so that it no longer flows freely, and therefore chokes up No. 3 cyclone. Operating the air jets for about an hour after each stop seems to prevent this.

It is now 18 weeks since firing up the kiln (with clean cyclones) for the third time - and we are all awaiting the 22nd week with hopeful interest!

Acknowledgements

My thanks to the Management and Staff of the Cape Portland Cement Company - particularly the Manager Chemical Services and the Works Chemist De Hoek - from whose various reports I have "borrowed" considerably.