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NCB INDIA. TRAINING PROJECT

FINAL REPORT

Project DP/IND/84/020
"Strengthening of NCB Capabilities in
Productivity Enchancement of Cement Industry"

Project Component (Subcontract IV):
Process Optimization in Cement Plants for Productivity Improvement

TABLE OF CONTENTS

LIST OF APPENDIXES

1. TITLE

The final report is the outcome of

Project DP/IND/84/020
"Strengthening og NCB Capabilities in
Productivity Enchangement of Cement Industry"

Process Optimization in Cement Plants for Productivity Improvement

The project consisted of a special arranged course

>   **from Febr.4 to April 20, 1991 at**
>   **F.L. Smidth & Co. A/S (FLS)**
>   **77, Vigerslev Allé**
>   **DK - 2500 Valby**
>   **Copenhagen, Denmark**

which included the following visits

from Febr. 20-22, 1991 to Ålborg Portland Cement Plant, Denmark
from March 3-15, 1991 to Ribblesdale Cement Plant, U K and
from April 8-12, 1991 to Ålborg Portland Cement Plant and various
                        other cogeneration plants in Denmark

The three engineers selected by NCB/UNIDO to participate were:

>   **Mr. A.K. Mishra, mechanical engineer**
>   **Mr. S.V.R.K. Murthy Rao, chemical engineer**
>   **Mr. A. Manna, mechanical engineer**

This report contains the views of FLS, which do not necessarily
correspond to the views of NCB or UNIDO.

The writer of the report is

>   **Ms. Hanne Bang Nielsen, B. Sc., Civil and Structural Engineer**
>   **Seminar Director.**
>   **Plant Services Division.**
>   **F.L. Smidth & Co. A/S**

who has been responsible for the implementation of the project.

2. SYNOPSIS

The objectives of the project was to upgrade the skills with the Indian cement industry as to match the needs of modern, enviromentally sound and safe production units.

The project was financed by UNIDO as one of the components of the education package for process optimization of the Indian cement industry.

The operation objectives was specifically to educate within the following two components

- operation of large precalciner kilns and grate coolers
- cogeneration of waste heat

The project's duration was 3 x 11 manweeks.

The report consists of a description of the course at FLS-Head Office, Copenhagen, Denmark, at Ålborg Portland Cement Plant, Ålborg, Denmark and at Ribblesdale Cement Plant, United Kingdom.

It describes the prep .rations and implementation of the project including an extensive site report covering the elaboration of the findings at the Ribblesdale Cement Plant, United Kingdom.

3. INTRODUCTION

3.1 The need for the project

The future demand of cement in India calls for an considerable increase of the capacity of the cement plants and a stronger technological support of the Indian cement industry. It will be necessary to apply more modern techniques to the present plants and new modern plants have to be constructed taking into consideration energy savings, enviromental protection, preventive maintenance etc., etc..

Modern cement plants ara technically sophisticated using e.g. computer controlled operating systems. Industry growths have created a demand for more skilled engineers, which cannot be satisfied only from training resources available in India.

With the increasing demand for cement and NCB being a governmental consulting organisation for the whole cement industry it has been decided to educate some of the NCB-engineers to be able to cope with the future requirements.

4. PROJECT DESCRIPTION

4.1 Reception of the engineers

The three gentlemen, Mr. A.K.Mishra, Mr. S.V.R.K. Murthy Rao and Mr. A.Manna arrived Denmark on Febr. 4. 1991. and were met in the airport by the Seminar Director, Ms. Hanne Bang Nielsen. Following the official welcome and presentation of FLS to the three guests by a representative of the FLS-Management, a meeting was held with the chief lecture⸱ and the coordinator Hanne Bang Nielsen. At the meeting the outlined programme was presented to the guests and the substance was discussed in details with the aim at adjusting the programme to the individual requirements and to their education, knowledge and experience.

No major adjustments were done as the Indian engineers found the subjects most suitable.

4.2. Introduction of F.L. Smidth

FLS is the world's major cement machinery supplier as well as the leader within research and development of new technologies not only for new cement plants but also within the area of rehabilitation taking into consideration the requirements for energy saving and enviromental protection etc..

FLS therefore has the capability to implement the project and was selected to do so

4.3 Implementation of the project

4.3.1 Organisation

A contact person in FLS, Seminar Director Ms. Hanne Bang Nielsen, has been selected to ensure, that the project is carried out in accordance with the Terms of Reference and to take care of the daily needs of the three engineers.

The training was carried out under the responsibility of the chief lecturer, Mr. Peter Green-Andersen, who is one of FLS' most experienced operation and commissioning engineers. Whenever needed his drew on the entire FLS-expertise in Denmark.

FLS issued to the guests a letter "To Whom It May Concern", which certified, that the engineers were the guests cf FLS and gave the names and private adresses of the project's key persons. The letter would be useful in case any unforseen event occurred

outside FLS and made sure, that responsible persons from FLS could be reached 24 hours every day.

Personal insurances were taken out on each guest and information given to make the guests feel comfortable in a new country.

Because of the chilly Danish winter and the fact that the guests arrived with tropical clothes only, they were immediately furnished with suitable winterclothes.

4.3.2 Documentation

The documentation was selected in accordance with the Terms of Reference. Eash set consisted of 3 volumen, approx. 500 pages. The List of Contents is given in Appendix No. 1. As the full documentation is very extensive, only examples of some of the lecturers are shown, Appendix No. 2.

4.3.3 Implementation at FLS-Head Office

The programme is enclosed, Appendix No. 3. No major adjustments were done during the course and the programme was implemented as shown. Examples of itineraries and programme for special events are given in Appendix No. 4.

The chief lecturer was normally lecturing, but called on specialists whenever suitable.

The lectures were given in a classroom using audiovisuel equipment. When needed visits were made to relevant departments in FLS and discussions held with the specialists on the subject in question.

The guests received the required office utensils (calculator, paper, pencils, etc.) and were for their plant visits furnished with a set of working clothes and safety shoes.

One Sharp Personal Computer PC 6200 was placed at disposal for each engineer during thier entire stay, and they were instructed in the use.

4.3.4 Visit to Ålborg Portland Cement Plant

After a general introduction and a visit to the quarry a tour of the plant was done. Special emphasize was given to the world's largest semi-dry kiln recently installed. After having discussed the flow-sheet, the new kiln line was scrutinized in flow-order. Visits were paid to the crusher, the preheater tower from the top to the bottom, the calciner, the kiln feed, the burner-platform, the grate-cooler and the outlet. Much time was spent in the control-room, where the employees explained their duties. The work was followed for quite some time.

4.3.5 Visit to Ribblesdale Cement Plant

For the subject "Operation of large precalciner kilns" a visit to Ribblesdale Cement Plant was arranged. Prior to the visit the flow-sheet and the machinery of the lant were discussed and the plans for the visit were gone through in details. Instructions were also given before the departure regarding the measurements and observations to be taken.

During the fortnight from March 3 to 15, 1991 the training was carried out at Ribblesdale Cement Plant near Manchester, United Kingdom, at an ILC (In-Line-Calciner) Precalciner kiln with the capacity of 2600 tpd. Operation and working performances were scrutinized on the spot by taking measurements and other parameters necessary for a professional evaluation. This was done under the guidance of the FLS chief lecturer in close cooperation with the operation staff at Ribblesdale.

Subsequently the findings were discussed and a site report elaborated by the engineers, Appendix. No. 5.

4.3.6 2nd visit to Ålborg

This second visit April 8-12, 1991, was done under the guidance of the company Ålborg Ciserve International Ltd., which is the most advanced specialists within the field of co-generation of waste heat in general. At present FLS in cooperation with Ålborg Ciserve Intl. is constructing a cogeneration installation at Ålborg Portland Cement Factory.

The design of this only installation in Denmark was presented and discussed followed by a visit to the site. Although the construction in under progress, the visit was most valuable.

Subsequently the group was visiting five cogeneration plant in various places in Denmark. These plant were designed by Ålborg Ciserve Intl. and related to generation of power and district heating.

4.3.7 Special requests

In addition to the programme the engineers had expressed their interest insome special courses, a desire, which naturally had been met. These courses were

- High Level Kiln Control. Fuzzy Logic executed at the company FLS-Automation.
- Burnability of Clinker
- Laboratory Control   and
- Kiln Alignment

The lectures were given by the specialists in the respective fields and were most appreciated.

5. CONCLUSIONS

On the last day a conclusive meeting was held with a representative from the FLS Management in order to summarize the three months' work.

Even with one of the engineers being more motivated and more skilled than the two others in operating in a non-Indian enviroment, it was, at this final interview, expressed by all, that the purpose of the project has been fulfilled. They found that the course had been a challenge, and the knowledge received most valuable, all of which will be shared with the colleagues in India.

Copenhagen, July 19, 1991

Hanne Bang Nielsen
Seminar Director

July 19. 1991
HBN

NCB INDIA. TRAINING PROJECT

FINAL REPORT

Appendix No. 1

**Project DP/IND/84/020
"Strengthening of NCB Capabilities in
Productivity Enchancement of Cement Industry"**

Project Component (Subcontract IV):
Process Optimization in Cement Plants for Productivity Improvement

BICP

nr 35 51 24

VOLUME 3

PROCESS DESCRIPTION AND PROCESS CONTROL
FLS'S COOLER PROGRAMME
COOLING OF CLINKER, CLINKER COOLERS

EVALUATION OF PREVIOUS COOLER
EXAMINATIONS
CASE STUDY

WASTE HEAT

ENERGY SAVINGS IN THE CEMENT INDUSTRY

KILN CONVERSION FROM WET PROCESS TO MORE
EFFICIENT PROCESSES

BICP

nr. 35 51 24

July 19. 1991
HBN

NCB INDIA. TRAINING PROJECT

FINAL REPORT

Appendix No. 2

Project DP/IND/84/020
"Strengthening of NCB Capabilities in
Productivity Enchancement of Cement Industry"

Project Component (Subcontract IV):
Process Optimization in Cement Plants for Productivity Improvement

Lecture 13.3

PROCESS SIMULATION AND

OPERATOR TRAINING

FS F.LSMIDTH

FLS-SDR/OPSTATION

1. CONTROL SYSTEM SUMMARY

This paper describes the FLS-SDR/Opstation System
which is the operators Man/Machine interface for o-
perating an industrial plant. It has been
specifically and designed for cement plant
operation, but has also been installed in various
other industries.

FLS-SDR/Opstation System is an integrated module of
an SDR-System which is interfaced to a PLC system.
The PLC system takes care of the device control,
(motor start/stop/sequencing/interlocking), and the
loop control.

The purpose of this document is to describe the
SDR/Opstation itself and not the underlying
facilities in the SDR-system, the PLC-system, or the
associated hardware.

The FLS-Opstation as part of a plant control system.

Physical placement	System
Control room	FLS-Opstation, Work-station for operator
EL-Instrument room	FLS-SDR system with central computer(s), disc(s), and tapestation(s).
Field	FLS-725 system with remotely placed PLCs

SDR - PLANT CONTROL SYSTEM

4 OPERATOR WORKSTATIONS

4 COLOUR
HARD
COPY
PRINTER

DRAWING
KEYBOARD

CONTROL ROOM

Opstations

COLOUR
CONTROLLER   CC   CC

SYSTEM TERMINAL

HP-1000   HP-1000

SYSTEM TERMINAL

TAPE   DISC

DISC   TAPE

EL-INSTRUMENT ROOM

Computers, Discs,

Tapestations,

Terminals.

HIWAY CONFIGURATION TO PLCS DEPENDS ON TYPE.

PLC PROGRAMMING
TERMINAL

| PLC 1 | PLC 2 | PLC 3 | PLC 4 | PLC 5 | PLC 6 | PLC 7 | PLC 8 |

FIELD

Remotely Placed

PLCs

The SDR-Opstation system can be upgraded to include
a number of other FLS-computer based packages like:
FLS-QCX (Quality by Computer and X-ray), Fuzzy Logic
Control, FLS-Cemscanner, FLS-Power Guide, PC-link,
and various other system.

The SDR-Opstation system can be delivered as a
"tailor-made" system ready to use after
FLS-Commissioning or as an empty system with
training courses and FLS supervision assistance.

The system is designed for control of a single main
machine or an entire cement plant with one or two
production lines.

Each FLS-SDR/Opstation provides control of all
departments and may provide redundancy on all
levels.

2. OPERATOR STATION

The operator's stations provides the operator with a
wealth of new opportunities to obtain relevant
information from the system on the display and to
carry out control actions. The operator's station
consists of a colour CRT display unit, an operator
keyboard, and a trackerball.

Simple drawing of FLS-Opstation.
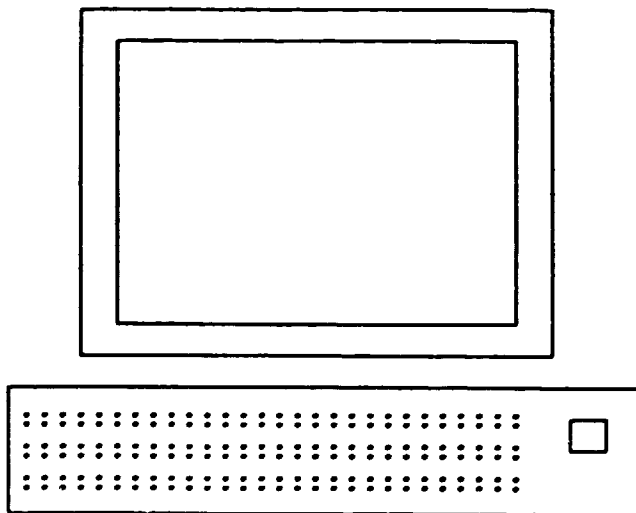
DISPLAY FACILITIES

The Opstations are symbol oriented displays, where special efforts have been made in providing high resolution to make reading easier and to reduce the risks of misinterpretations.

The information displayed on an Opstation is easy to read as large and small symbols can be intermixed and graphics and texts can be tightly packed without reducing the readability.

Important facts and figures are emphasized by increasing their size while necessary but less important information is displayed in smaller symbol sizes.

For example, the Opstation colour display offers:

- Five different character sizes can be used in the same display to increase overview.

- User-definable symbols of any size and shape.

- 16 foreground colours with or without flash.

- Thick and thin lines can be drawn easily.

- Presentation of trend curves with a resolution better than 0.3%.

- Presentation of process variables by bargraphs.

- Zoom function gives quadrupled enlargement of any part of the display.

- Symbol smoothing gives horizontal and vertical lines the same light intensity.

- On-line picture editor for easy extension and change of display diagrams. The editor includes facilities to mix parts from different pictures.

- The system has room for approx. 60 pages of memory based graphics and 900 pages of disc based graphics. The number of dynamic fields per page is virtually unlimited.

- The screen resolution is 720 x 336

OPERATOR KEYBOARD

The following describes the standard features of
each of the keys on the SDR operator keyboard.
The workstations consists of a colour display unit,
a keyboard with 144 keys and a tracker ball to allow
the operator select by pointing on the screen. The
keyboard is divided into two sections, the
supervision section - the left-hand part - and the
utility section - the right-hand part. (See encloced
lay-out of keyboard keys)

Supervision Section

This section occupies 90 keys of the keyboard, with
15 columns and 6 rows.

Definition of the term "Department"

The supervision section is organized in functional
groups called departments. A "department" is defined
as one or more production units often being
controlled by one master PLC. In the SDR system, all
points have a department number, indicating which
department they belong to. The department is of
importance with regard to its alarm handling and
reporting. Each department occupies one of the 15
columns in the keyboard.

For each department the following three types of
keys are available.

Department Alarms

The 15 department alarm keys are placed in the first
(upper) row of the keyboard and they are all
equipped with LEDs (light emitting diodes).
Activation of the pushbutton will generate an alarm
survey with point code, point text, point value,
alarm limit violation, and time registrations for
alarm occurence and alarm disappearance. The
resolutions of the time stamps are 10 milliseconds.

The operator can scan between "all department
alarms", "standing department alarms only", and
"department events" (changes made to system in the
department) by means of a toggle switch.

The operator can scroll back and forth in time
either page by page, or directly by entering a
certain time.

Department Curves.

In the second row the department curves are found.
The trend curves for the 4 most significant analog
values within the department are displayed. The
curves can be scrolled back in time allowing the
user to investigate old situations in detail.
The data comes from the SDR log system where all
analog measurements are logged in 5 log intervals,
which normally are 20 minutes, 2 hours, 8 hours, 24
hours, and 1 week.

Department Mimic Diagrams, Mimic keys 1 - 60

These keys display the general mimic diagrams, as
generated by the systems engineer during mimic
picture editing. The mimic diagrams are live
diagrams, that hold the dynamic information of
process values and - status. Detailed operator
information is obtained from these mimics by
applying Utility keys.

For each department there will normally be three
types of pictures. (See also examples enclosed).

1.   Overview pictures for normal operation.
     These are used 90 % of the time when the
     department is operating.

2.   PLC interlocking and Start-up diagrams

3.   Loop configuration diagrams.

Utility Section

The Utility Section contains all keys used for changing specification, selection hierarchy, and general utilities in connection with display of supervision pictures.

F1 - F9:
Soft keys corresponding to select fields 1-9 at the bottom of the mimic pictures. The key function depends on the picture shown. In order to make a simple system, only one level in the 'selection tree' is used.

-, ., 0, ..., 9:
Numeric keys for general use.

USER 1 - 6
General purpose keys.

ALL ALARMS, ALL EVENTS
Alarm survey containing all alarms or events from all departments in one list.

ALL STATES
General purposes mimic diagram to give an overall view of the system status.

FUZZY
Presentation of special Fuzzy Logic Control Language (FCL) pictures. The content is generated from the on-line process control language FCL.

ZOOM
A segment of the display is expanded 4 times.

HARD COPY
The screen picture is copied to the hard copy unit.

STEP BACK
Used for stepping back to previous picture.

CLEAR ENTRY
The selected input field is cleared.

CLEAR SCREEN
The predefined 'Clear Screen' mimic is displayed. Normally an empty mimic or a general overview.

RESET
Any input request is reset and the selection hierarchy is changed to prior selection.

ENTER
An input is terminated and the content of the input
field is transmitted to the computer.

DEF. POINT
Selection of detailed information of a point by
keying in point identification code.

GET CODES
Changes all the point values displayed on the mimic
diagrams into point identification code and vice
versa.

GET PICT
Get picture is used for selection of a new mimic
diagram, either by number or by pointing out a
picture symbol on the display. This function is used
to access up to 900 pictures found on the hard
disc.

GET CURVE
Get curve for the analog point in question.

GET EVENT
Get alarms/event for point in question.

GET POINT
Selection of detailed information of a point by
pointing out the measurement in question on the
display. Certain point parameters will appear in the
bottom three lines of the display and may be
changed here by the operator.

GET CNTRL
Selection of detailed information of control loops
by pointing out a controller symbol on the mimic
display. Certain controller parameters will appear
in the bottom three lines of the display and may
be changed by the operator.

ALARM STOP/ALARM CANCEL
Reference is made to "Alarm Handling"

PRGRM.SLCT, Stop, Start, MSTR STOP
Reference is made to "SDR Control Functions".

3. SDR CONTROL FUNCTIONS

The FLS-SDR System is assumed to be connected to an PLC distributed control system. The functions implemented in the FLS-SDR System are the operator control of sequencing and interlocking programs in PLC's, hereafter called device control and the operator control of analog control loops, hereafter called loop control.

DEVICE CONTROL

Routing of flow/transport and mode of operation of a production unit is specified by selecting a subset of the programmed sequences and programs.

All communication between PLC's and the FLS-SDR System takes place through the exchange of machine status words (MSW) with an 8 bit information, describing e.g. motor status, valve status, or PLC-sequence-program status.

The PLC program information is registrated within the SDR system as a point with its status displayed by a text and associated colour.

The program points are shown on the mimic diagram as selection fields, and the selection is made by pointing and using the pushbutton 'select',"SLCT".

G

The FLS-SDR functional keyboard includes 4 fixed
pushbuttons:

1. Select Program
2. Start Program
3. Stop Program
4. Master Stop

The function of the 4 pushbuttons are as follows:

Select Program
The 'SLCT' pushbutton is a toggle switch.
This means that if a running program is being
selected, then it will be: "selected to stop". On
the other hand, if it is stopped and being selected,
it will be: "selected to start".

Start Program
When the desired programs has been selected 'START'
is activated in order to start the sequence. All
programs within the department being "program
accepted" (selected and ready to start) will be
started. No other programs will be influenced.

Stop Program
During operation of the production unit it is
possible to change the selection of PLC-programs.
This is done by activating 'STOP' which will stop
all programs within the department which have been
"selected to stop". The remaining programs are not
influenced.

Master Stop
This is used for a total stop of the machine or
department displayed at the mimic, meaning that all
devices will be stopped or brought to their defined
safety condition. A subsequent activation of 'START'
will start all programs selected and bring the
machine or department back into normal operation
again.

LOOP CONTROL

In the FLS-SDR System a loop controller is defined by 4 points.

1. PV   - process value
2. SP   - set point value
3. OUT - output value
4. MODE - controller mode: MAN/AUTO/PASSIVE/EXT

The use of 4 FLS-SDR points is made in order to perform limit checking, response function and alarm/event registration for all 4 variables.

Detailed use of GET CONTROLLER, GET CNCL.

Selection of detailed information of control loops is done by softkeys or by pointing out a symbol on the mimic display representing a control loop. After activation of the key the following selection picture will occur in the bottom three lines of the screen.

Mode: MAN	SP	OUT					
AUTO	MAN	96.7	56.0	UP 5	UP 1	DOWN 1	DOWN 5	R1R02Y1
1	2	3	4	5	6	7	8	9

The changes are now made to the controller by use of the function keys.

F1:   AUTO   Select Automatic control mode.
F2:   MAN   Select manual mode.
F3:   SP   New setpoint may be keyed in.
F4:   OUT   If the controller is in manual a new output value can be keyed in.

F5:   + 5 %   The function of these four keys is to
F6:   + 1 %   to increase/decrease the SP/OUT
F7:   - 1 %   value depending on the state of the
F8:   - 5 %   controller (AUT/MAN).

F9: DETAIL   The control-loop is named 'R1R02Y1' after the tag-number of the set-point. Activation gives further controller informations and quick trend curves showing the response function with indication of PV, SP, and OUT. (Process value, Set-Point, Output)

4. SDR ALARM HANDLING

The following gives a survey of the FLS-SDR alarm handling:

1. Alarm Checking
2. Colour/Status Change
3. Alarm Annunciation
4. System Alarms

1. Alarm Checking

The alarm checking is part of the standard point treatment, which is a table-driven sequence of establishing value, status, statistics, etc. for all measurements, digital inputs, and calculated values.

Analog Measurements and Calculated Values:

All values are checked against high and low alarm limits with hysteresis. The system has special alarm functions such as multiple high/low alarms (up to 9), deviation alarms etc.

Digital Input/Output:

Digital input/output are treated in groups of up to 8 signals forming a device status word (MSW). A MSW will normally hold all information related to one machine unit, f.inst. a pump. The database contains a number of point treatment algorithms, and each algorithm consists of tables defining how the bitpattern should be interpretet concerning:

- Logical value (bit pattern), and corresponding
- Value (text reference)
- Status (text reference)
- Color (out of 16, plus flashing light)
- Symbol change (used for dampers and gates)
- Alarm registration (yes/no)
- Accumulation of operating hours (yes/no)

The digital algorithms can be defined individually, which makes it possible to build up new algorithms, complying precisely with specific wishes with regard to function and alarm philosophy. Algorithm changes can be made on-line.

2. Colour/Status Change

The colours and status reference texts specified are
the one normally used by F.L. Smidth & Co.

Analog Measurements and Calculated Values:

```
Green:          Normal
Red:            Alarm state, high, low
Red flashing:   New alarm, not acknowledged
Pink-Brown:     Alarm checking stopped
                due point interlocking
Magenta:        Open loop, instrument fault
```

Digital inputs: Programs

```
Green:          Running
Green Flash:    Running, but selected to stop
Brown:          Stop without alarm
Yellow:         Selected to start, and PLC
                has given program accepted
Yellow Flash:   Selected to start, but not
                ready due to interlocking
Cyan:           Start in progress
Red:            Alarm of any type
Red flashing:   New alarm, not acknowledged
White flash:    Local
Pink-Brown:     Alarm checking stopped
                due point interlocking
Magenta:        Error, instrument fault
```

Digital inputs: Motor

```
Green:          Running
Green Flash:    Running, but selected to stop
Brown:          Stop without alarm
Yellow:         Selected
Red:            Alarm of any type
Red flashing:   New alarm, not acknowledged
White:          Local
White flash:    Local in alarm
Pink-Brown:     Alarm checking stopped
                due point interlocking
Magenta:        Error, instrument fault
```

3. Alarm Annunciation, Stop and Cancelation

When ever a new alarm is registrated it will:

- Start an audible alarm in the keyboard and in the PLC.
- Show the new alarm in all header lines.
- Start red flash in the LED (light emitting diode) in the keyboard for the actual department of the point.
- Change the point colour to red flash.
- Write the alarm into the alarm list in red colour.

To stop the alarm the operator must use the ALARM STOP key. It has the following function:

- Send message to perform Alarm stop function to all PLCs. (Stop audible alarm).
- Remove alarm message from header alarm line. on all screens.
- New alarms within the selected department, are turned to steady red, and the LED of the department alarm key is changed to steady light.

To cancel the alarm, the operator must use the ALARM CANCEL key (ALARM CNCL). The function of the key has been made dependend of the actual picture on the screen, in order to force the operator to look at the department in which he wants to cancel alarms. The issue of Alarm Cancel functions as follows:

- Send message to the PLC associated with the department presently displayed to perform alarm cancel function. Example: If a motor has stoppped on overload, the operator has to give an ALARM CNCL, before he will be able to re-start it.
- The light in the department alarm key LED is turned off. When the light is off it indicates that no new alarms have occured since the last ALARM CNCL.
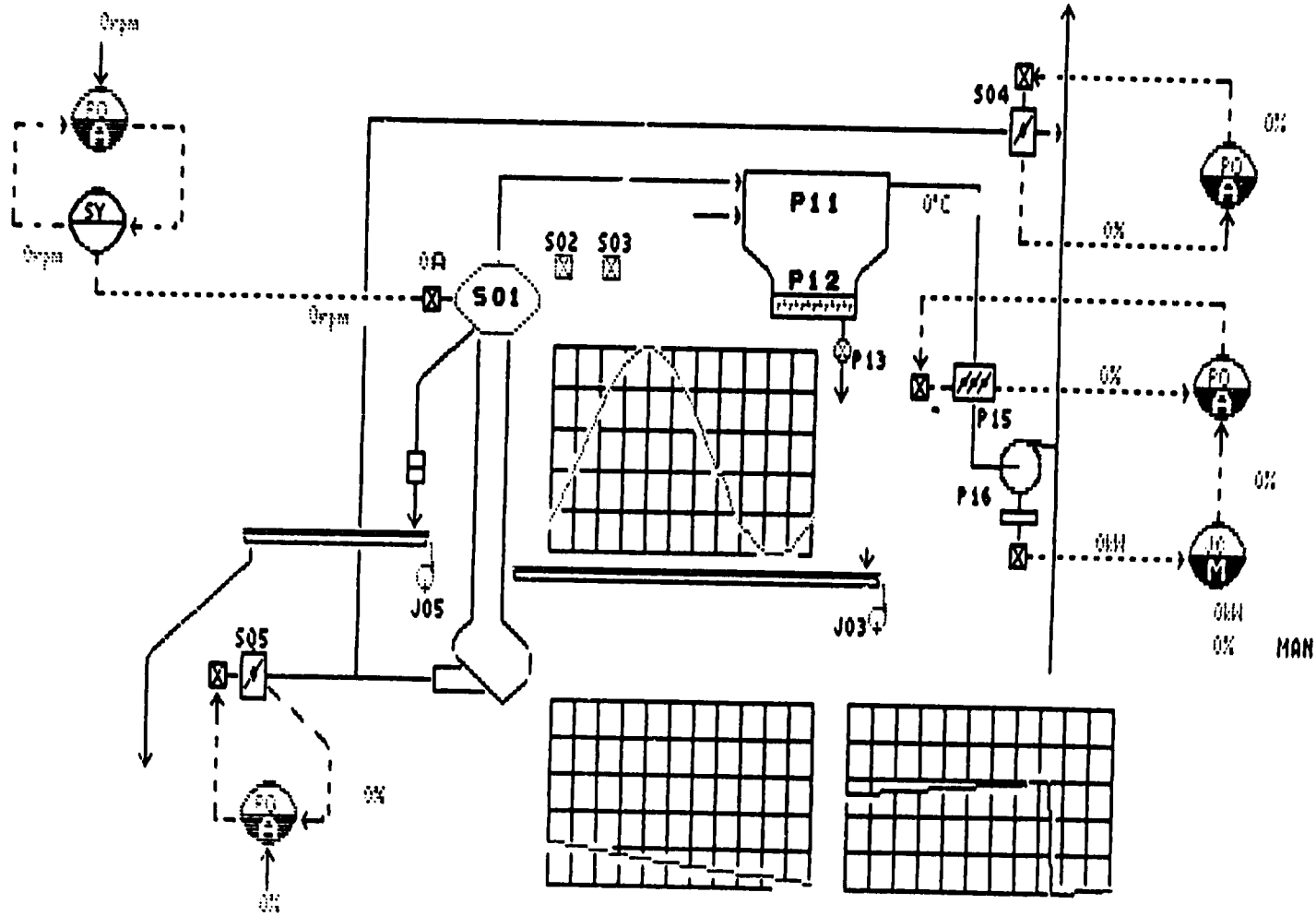
SDR/Opstation
Operator Keyboard layout

A1 ALARMS	R1 ALARMS	R2 ALARMS	R3 ALARMS	H1 ALARMS	W1 ALARMS	C1 ALARMS	W2 ALARMS	C2 ALARMS	K1 ALARMS	K2 ALARMS	21 ALARMS	22 ALARMS	24 ALARMS	SYS ALARMS	F1	F2	F3	F4	F5	F6	F7	F8	F9
1 CURVE	2 CURVE	3 CURVE	4 CURVE	5 CURVE	6 CURVE	7 CURVE	8 CURVE	9 CURVE	10 CURVE	11 CURVE	12 CURVE	13 CURVE	14 CURVE	15 CURVE	7	8	9	1 USER	2 USER	3 USER	4 USER	5 USER	6 USER
1	` 5	! 9	~ 13	# 17	$ 21	% 25	& 29	/ 33	(37	) 41	= 45	? 49	. 53	* 57	4	5	6	ALL ALARMS	ALL EVENTS	ALL STATES	1 FUZZY	2 FUZZY	3 FUZZY
2	6	Q 10	W 14	E 18	R 22	T 26	Y 30	U 34	I 38	O 42	P 46	] 50	54	> 58	1	2	3	ZOOM	HARD COPY	STEP BACK	DEF POINT	CLEAR ENTRY	CLEAR SCREEN
3	7	A 11	S 15	D 19	F 23	G 27	H 31	J 35	K 39	L 43	\ 47	[51	LF 55	< 59	0	.	-	GET CODE	GET PICT	MSTR STOP	STOP	START	RESET
4	8	SS 12	Z 16	X 20	C 24	V 28	B 32	N 36	M 40	. 44	, 48	- 52	; 56	: 60	SHIFT	GET CURVE	GET EVENT	GET POINT	GET CNTRL	ALARM STOP	ALARM CNCL	SLCT	ENTER

The alarm line keys are marked with the FLS-codes for department names.

REGULATORER FOR SEPAX

RAAMQLLE R1

FL SMIDTH
INTERNATIONAL CEMENT PRODUCTION SEMINAR

M GENST. TRANS
R VAND
R LAVTRYK
R HQJTRYK

SKALLER 1
HAST 0%
SP 0%
PCT 0%

SKALLER 2
HAST 0%
SP 0%
PCT 0%

LIPARIT
HAST 0%
SP 0%
PCT 0%

SORT SAND
HAST 0%
SP 0%
PCT 0%
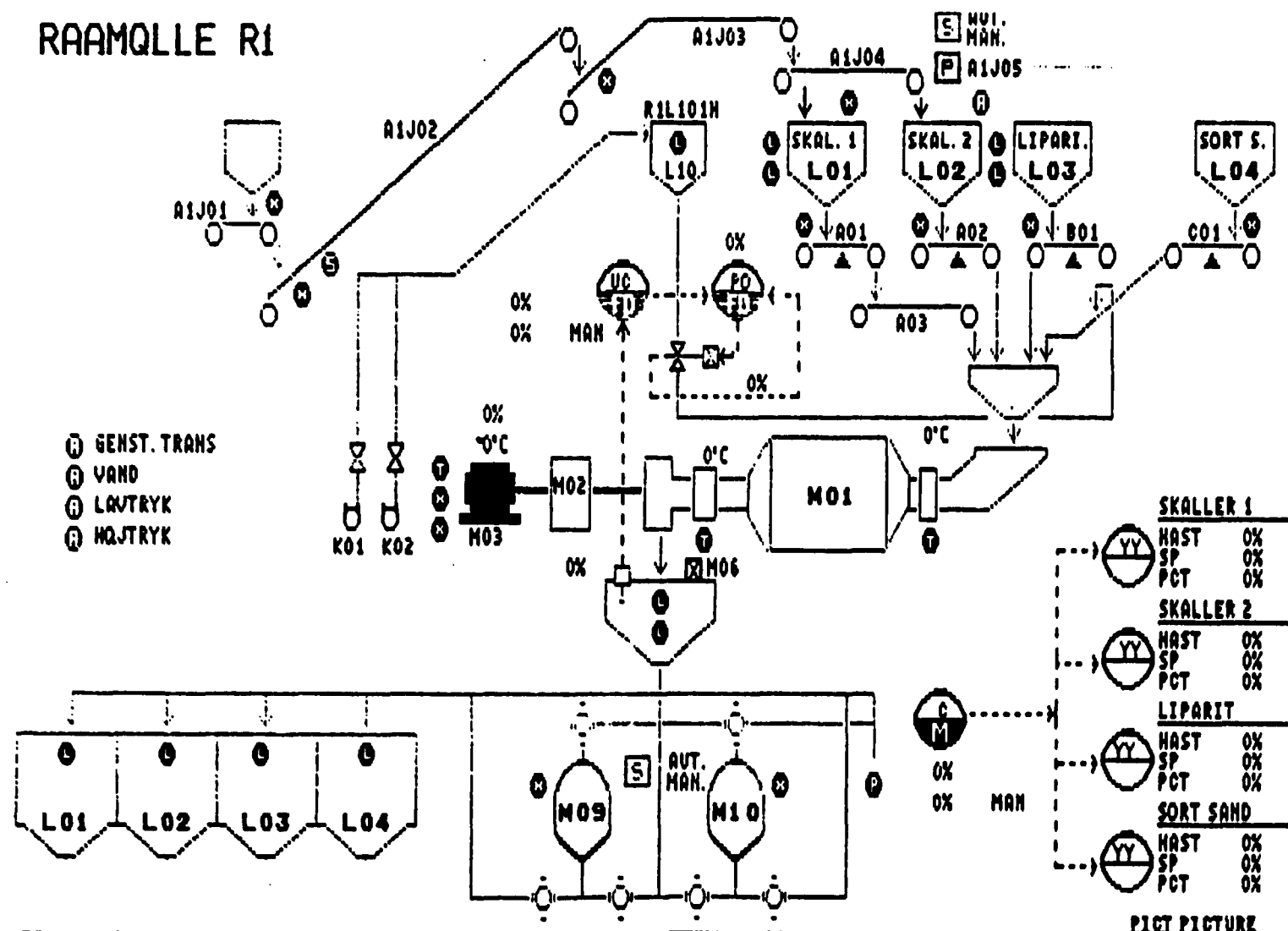
PICT PICTURE 2

Mode : MAN   SP AUT   SP MAN
  AUTO   MAN   0.0   0.0   UP 5   UP 1   DOWN 1   DOWN 5   R1R02Y1

CEMENTMØLLE 2

START-FEJL

MØLLERI	PROG ACC L S
▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪	PRG.2
Z2P23	RUN
Z2P25	RUN
Z2P36	RUN
Z2J05	RUN
Z2P21	RUN
Z2S02	RUN
Z2P33	RUN
Z2P12	RUN
Z2P32	RUN
Z2P16	RUN
Z2P31	SPD MON
Z2S01	RUN
Z2J03	SELECT
Z2J01	SELECT
Z2M21	SELECT
Z2M20	SELECT
Z2M03	SELECT
Z2A01	SELECT
Z2K01	SELECT

GIPSFØDER `PROG ACC` `L` `S`
PRG.3
Z2C01   SELECT

LIPARITFØDER `STOP` `L` `S`
▪   PRG.4
Z2B01   STOP

SILIKAFØDER `STOP` `L` `S`
▪   PRG.5
Z2D01   STOP

MALEVAESKE `STOP` `L` `S`
▪   PRG.6
Z2F01   STOP

JERNSULFAT `PROG ACC` `L` `S`
▪   PRG.7
Z2E04   SELECT
Z2E03   SELECT
Z2E02   SELECT
Z2E01   SELECT

BUNDVARME

Z2P31   RUN   `S`

KOMPRESSOR `STOP` `L` `S`
PRG.1
Z2P29   STOP

PICTURE 25

WATER FLOW MIN

START
SEQUENCE

SPEED WEIGHT

POS-1

POS-2

POS-2

WATER FLOW MIN

LOCAL

PICTURE 17

FLS-SDR/REPORTER

The FLS SDR system is a very flexible computer
control system that enables several posibilities for
generating printed information. All forms of printed
information, curves or tables, is in the SDR-system
is refered to as a report.

The SDR system may further be interfaced to a PC or
an other computer to allow for user edited reports.

Reports may be requested at any time on demand
through a normal operator dialogue both on the
operator's console and the system terminal, or they
may be generated automatically as part of predefined
report packages.

The purpose of the reports is to provide printed
records on operating data including process variable
quantities, operating hours, alarm/ -event reports,
etc. The quantitative basis for the reporting
functions is supplied by the point treatment.

1. ALARM REPORTS

The resolution of the alarm registration is the PLC
treatment period approx 10 msec.

Normally the interface PLCs are programmed to let
only the first alarm through in order to reduce the
total number of registered alarms.

However, in case the interface is of non-FLS
standard then the SDR-system itself includes some
facilities for alarm suppression.

The alarm line includes point code, alarm type,
point text, present point value, alarm limit value,
and alarm hours, including alarm-on date and time
and alarm-off date and time.

Alarm reports can be printed for one measurement,
for one plant department, or for the whole plant.

Alarm reports
Holds a list of plant alarms with time registration
of both occurrence and disapperance. (See enclosed
example)

Alarm surveys
Holds a list of standing alarms with time
registration of occurrence.

Event reports
Holds a list of the changes to the system
definitions and a time registration of operator
inserted values.

2. PLANT REPORTS.

The plant reports are comprised of point value
reporting including hourly operating values as well
as production and consumption figures.

Though the general lay-out of the plant report is
fixed, the user may define the actual components of
each report page. As the collection of operating
information takes place independently of the
reporting functions, the plant reports can be
modified at any time without interfering with the
proper operation of the SDR System.

The user can define 24 reports each containing 16
different points.

Plant Reports are made for:
Hour, 8 Hour, Day, Week, Month, Year periods.

For analog points, the reports contain information
of spot values, statistical calculated values, and
accumulated values; and, for digital points the
reports contain information on operating hours. (See
enclosed example).

```
Minimum value,
Maximum value
Average value
15 minute accumulation
1 hour accumulation
8 hour accumulation
24 hour accumulation
1 week accumulation
1 month accumulation
1 year accumulation
machine operating hours
alarm state hours
```

fig. 1, List of generated figures for reporting.

3. GRAPHICAL PACKAGES, TREND CURVES

For all analog values any trend curve can be printed. Since the system holds a scroll function to review historical data, any situation may be analysed in detail long after it happened. The automatic report printing system also applies to the graphical packages allowing the user to start printing at specific hours. (See enclosed example)

Window Length	Frequency Log-System	Total time for holding values
20 min	10 sec	2 hours
2 hours	30 sec	7 days
24 hours	10 min	30 days
1 week	1 hour	1 year
1 month	3 hours	2 years

fig. 2, Example of a trend curve system set-up.

4. POINT LISTS

All points can be listed with point information given in a compressed form. The list will contain informations like: Tag number, text, address, conversion algorithm, etc.

Further will it hold information on: First mimic diagram picture number on which the point is found (SDR-Opstation only), number of registered plant alarms, and number of registrered instrument alarms. Instrument alarms are registered for analog points in case of open loop and for digital points in case of illegal bit-pattern. The point lists can be sorted by point number or address. (See enclosed example).

NCB	2 DEC 1988	FLS-CPS100	13.24.05	3000 TPD SLC KILN

ALARM REPORT   DEPARTMENT   1   **DEMAND REPORT**

						REMARKS
U1A51T1	PREH. CYCL 1 GAS TEMP	A-HIGH 333.4degC	360.0	2 DEC 13.16.15	2 DEC 13.20.19	....
U1A52T1	PREH. CYCL 2 GAS TEMP	A-HIGH 530.4degC	600.0	2 DEC 13.16.29	2 DEC 13.20.19	....
U1A53T1	PREH. CYCL 3 GAS TEMP	A-HIGH 684.6degC	750.0	2 DEC 13.16.29	2 DEC 13.20.19	....
U1A52T2	PREH. CYCL 2 MAT. TEMP	A-HIGH 521.4degC	600.0	2 DEC 13.16.29	2 DEC 13.20.19	....
U1A53T2	PREH. CYCL 3 MAT. TEMP	A-HIGH 672.6degC	750.0	2 DEC 13.16.48	2 DEC 13.17.03	....
U1A51A1	PREHEATER EXIT O2	A-LOW 4.32%	0.50	2 DEC 13.16.48	2 DEC 13 20.19	....
U1-MAX1CO	DO CNTL FOR MAX 1 CO	A-HIGH 0.0%	1.5	2 DEC 13.17.01	2 DEC 13.19.42	....
U1-MAX2CO	DO CNTL FOR MAX 2 CO	A-HIGH 0.0%	1.5	2 DEC 13.17.01	2 DEC 13.19.42	....
U1A51A2	PREHEATER EXIT CO	A-HI1 0.0%	3.5	2 DEC 13.17.03	2 DEC 13.17.17	....
U1A51A2	PREHEATER EXIT CO	A-HI2 0.0%	4.5	2 DEC 13.17.17	2 DEC 13.18.15	....
U1A51A1AL1	MAX 1 CO IN EXHAUST GAS	ALARM ALARM		2 DEC 13.17.17	2 DEC 13.17.18	....
U1A51A1AL2	MAX 2 CO IN EXHAUST GAS	ALARM ALARM		2 DEC 13.17.17	2 DEC 13.17.18	....
U1A51A1AL1	MAX 1 CO IN EXHAUST GAS	ALARM ALARM		2 DEC 13.17.23		....
U1A51A1AL2	MAX 2 CO IN EXHAUST GAS	ALARM ALARM		2 DEC 13.17.23		....
U1A51A2	PREHEATER EXIT CO	A-HIGH 0.0%	2.5	2 DEC 13.18.15	2 DEC 13.18.59	....
U1A53T2	PREH. CYCL 3 MAT. TEMP	A-HIGH 672.6degC	750.0	2 DEC 13.18.30	2 DEC 13.20.19	....
U1-OUTPUT	PRODUCTION AT KILN OUTL.	A-HIGH 3091.t/24h	3500	2 DEC 13.19.44	2 DEC 13.21.03	....
U1B55P3	TERTIARY AIR PRESSURE	A-HIGH 61.4mmUG	100.0	2 DEC 13.20.00	2 DEC 13.20.48	....
U1U01A3	NO AT KILN INLET	A-HIGH 450.9ppm	500.0	2 DEC 13.20.48	2 DEC 13.23.28	....

ALARM REPORT   DEPARTMENT   1   **DEMAND REPORT**

NCB	2 DEC 1988	FLS-CPS100	13.24.05	3000 TPD SLC KILN

CAPE GIRARDEAU   27 APR 1986   SDR-78   8.07.17   SDR/CEM/FUZ

TREND REPORT   2   FLS USE
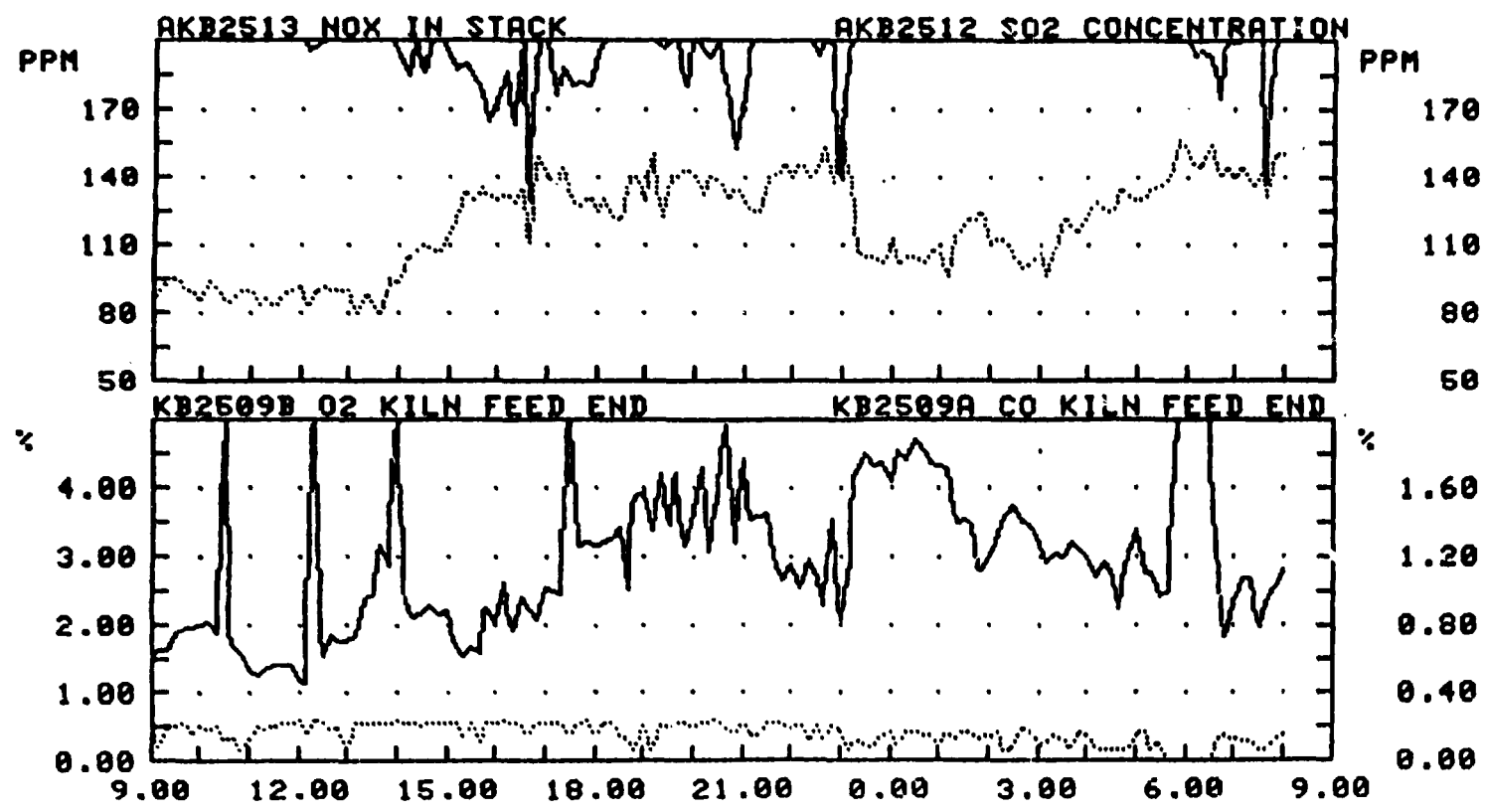
Q - POINT LIST   10:06 AM MON . 13 JULY. 1987

	Tag	Description															
								.020	99999.0	0.000	99999.0	-99999.	0	0	0	
2	R2A02Q1	LIMESTONE	10 AI3000	2	3	.001	-1.000 Mt	2	30000.0	0.000	ON	ON				.
								2.000	99999.0	0.000	64.535	-1.000	1	0	0	
3	R2B01Q1	PURPLE SHALE	10 AI8001	2	3	.001	-1.000 Mt	2	100.000	0.000	ON	ON	
								1.000	99999.0	0.000	64.535	-1.000	1	0	0	
4	R2C01Q1	LATERITE	10 AI0002	2	3	.001	-1.000 Mt	2	100.000	0.000	ON	ON	
								.020	99999.0	0.000	64.535	-1.000	1	0	
5			-1	15	0	1.000	0.000	0	100.000	0.000	ON	ON	
								.020	99999.0	0.000	99999.0	-99999.	0	0	
6	R2B01S1	PURPLE SHALE FEEDER	10 AI1400	2	1	100.000	0.000 %	0	100.000	0.000	R2M03	ON	
								2.000	99999.0	0.000	102.375	0.000	1	0	0	
7	R2C01S1	LATERITE FEEDER	10 AI1401	2	1	100.000	0.000 %	0	100.000	0.000	R2M03	ON	
								2.000	99999.0	0.000	102.375	0.000	1	0	0	
8	A2L04S1	RECLAIMER CHAIN	10 AI1402	1	1	100.000	0.000 %	0	100.000	0.000	A2L04	ON	
								2.000	99999.0	0.000	102.375	0.000	1	0	
9	R2M01T1	MILL INLET	10 AI1403	2	1	1000.00	0.000 degC	0	1000.00	0.000	R2M03	ON	
								20.000	9998.00	350.000	800.000	0.000	1	0	
10	R2T11Z1	HEAT GENERATOR	10 AI1408	2	1	100.000	0.000 %	0	100.000	0.000	R2T11	ON	
								2.000	99999.0	0.000	102.375	0.000	1	0	
11	R2P06Z1	LOUVRE DAMPER	10 AI1409	2	1	100.000	0.000 %	0	100.000	0.000	R2P05	ON	
								2.000	99999.0	0.000	102.375	0.000	1	0	
12	R2U11I1	CONVEYOR	10 AI1500	2	1	120.000	0.000 %	0	125.000	0.000	J2P09	ON	
								2.400	99999.0	0.000	122.050	0.000	1	0	
13	N2N05I1	BLOWER	10 AI1501	2	1	120.000	0.000 %	0	125.000	0.000	R2U11	ON	
								2.400	99999.0	0.000	122.050	0.000	1	0	0	
14	N2N06I1	BLOWER	10 AI1502	2	1	120.000	0.000 %	0	125.000	0.000	R2U11	ON	
								2.400	99999.0	0.000	122.050	0.000	1	0	0	
15	N2N07T1	BLOWER	10 AI1503	2	1	120.000	0.000 %	0	125.000	0.000	R2U11	ON	
								11.520	99999.0	0.000	122.050	0.000	1	0	0	
								2.400	9999.00	0.000	122.050	0.000	1		.
18	N2N01L2	CF SILO	10 AI1506	3	1	25555.6	3577.00 t	0	25000.0	0.000	ON	ON	
								479.160	99999.0	13000.0	22002.6	7998.12	1	0	0	
19	R2M03J1	MILL MOTOR	10 AI1507	2	1	6650.00	0.000 kW	0	6000.00	0.000	R2M03	ON	
								0.000	99999.0	0.000	7020.88	0.000	1	2	
20	R2P05J1	FAN MOTOR	10 AI1508	2	1	1028.00	0.000 kW	0	1000.00	0.000	R2P05	ON	
								2.056	99999.0	0.000	1052.42	0.000	1	2	

B - POINT LIST   11:02 AM MON., 13 JULY, 1997

NO.	CODE	TEXT	TYPE	ADDRESS NTWRY PLC	INPUT WORD	BYTE	OUTPUT WORD	BIT	DEP	ALG	PLC NETWORKS NUMBERS	POINT TREAT.	EVENT TREAT PIC
1	HORN	HORN FOR ALARM ANNOUNCEH	3	1 1	18	1	2	1	15	57	0 0 ON	ON	0
2	R2 EMERGENCY	EMERGENCY STOP	3	1 1	302	0	-1	-1	2	14	0 0 ON	ON	0
3	R2 START	START WARNING RAW MILL	3	1 1	304	1	-1	-1	2	19	0 0 ON	ON	0
4	R2 LOCAL	LOCAL TEST PERMISSION	3	1 1	304	0	1	9	2	13	0 0 ON	ON	0
5	R2 PRG-01	R2M03	3	1 1	6	1	1	8	2	20	0 0 ON	ON	0
6	R2 PRG-02	FAN R2P05	3	1 1	6	0	1	7	2	20	0 0 ON	ON	0
7	R2 PRG-03	BLOWER R2H05	3	1 1	7	1	1	6	2	20	0 0 ON	ON	0
8	R2 PRG-04	FILTER R2P01	3	1 1	7	0	1	5	2	20	0 0 ON	ON	0
9	R2 PRG-05	SHALE R2B01	3	1 1	8	1	1	4	2	20	0 0 ON	ON	0
10	R2 PRG-06	SEPERATOR R2S01	3	1 1	8	0	1	3	2	20	0 0 ON	ON	0
11	R2 PRG-07	BLOWER R2H06	3	1 1	9	1	1	2	2	20	0 0 ON	ON	0
12	R2 PRG-08	FILTER R2P11	3	1 1	9	0	1	1	2	20	0 0 ON	ON	0
13	R2 PRG-09	I.ORE R2C01	3	1 1	10	1	2	16	2	20	0 0 ON	ON	0
14	R2 PRG-10	MILL AUX.	3	1 1	10	0	2	15	2	20	0 0 ON	ON	0
15	R2 PRG-11	BLOWER R2H07	3	1 1	11	1	2	14	2	20	0 0 ON	ON	0
16	R2 PRG-12	FILTER R2P41	3	1 1	11	0	2	13	2	20	0 0 ON	ON	0
17	R2 PRG-13	HEAT GENERATOR	3	1 1	12	1	2	12	2	20	0 0 ON	ON	0
18	R2 PRG-14	SEPERATOR R2S04	3	1 1	12	0	2	11	2	20	0 0 ON	ON	0
19	R2 PRG-15	BLOWER R2H08	3	1 1	13	1	2	10	2	20	0 0 ON	ON	0
20	R2 PRG-16	FILTER R2P08	3	1 1	13	0	2	9	2	20	0 0 ON	ON	0
21	R2 PRG-17	L.S.SCRAPER	3	1 1	14	1	2	8	2	20	0 0 ON	ON	0
22	R2 PRG-18	RAW MILL BELTS	3	1 1	14	0	2	7	2	20	0 0 ON	ON	0
23	R2 PRG-19	BLOWER R2H09	3	1 1	15	1	2	6	2	20	0 0 ON	ON	0
24	R2 PRG-20	CHECK WEIGH	3	1 1	15	0	2	5	2	20	0 0 ON	ON	0
25	R2 PRG-21		3	1 1	16	0	2	4	2	20	0 0 ON	ON	0
26	R2 PRG-22		3	1 1	17	1	2	3	2	20	0 0 ON	ON	0
27	R2 PRG-23		3	1 1	17	0	2	2	2	20	0 0 ON	ON	0
28	R2 PRG-24		3	-1 -1	-1	1	-1	-1	2	20	0 0 ON	ON	0
29	R2P02	FILTER FAN	3	1 1	31	1	0	0	1	1	0 0 ON	ON	0
30	R2 CCR	CCR CONTROL SELECTED	3	1 1	302	1	-1	-1	2	14	0 0 ON	ON	0
31	R2P09	FILTER FAN	3	1 1	32	1	0	0	1	1	0 0 ON	ON	0
32	R2P10	FILTER SLUICE	3	1 1	32	0	0	0	1	1	0 0 ON	ON	0
33	R2P44	FILTER FAN	3	1 1	33	1	0	0	1	1	0 0 ON	ON	0
34	R2P46	FILTER SLUICE	3	1 1	33	0	0	0	1	1	0 0 ON	ON	0
35	R2P21	FILTER FAN	3	1 1	34	1	0	0	1	1	0 0 ON	ON	0
36	R2P31	FILTER FAN	3	1 1	34	0	0	0	1	1	0 0 ON	ON	0
37	R2P51	FILTER FAN	3	1 1	35	1	0	0	1	1	0 0 ON	ON	0
38	R2P61	FILTER FAN	3	1 1	35	0	0	0	1	1	0 0 ON	ON	0
39	R2P71	FILTER FAN	3	1 1	36	1	0	0	1	1	0 0 ON	ON	0
40	R2P92	FILTER FAN	3	1 1	36	0	0	0	2	1	0 0 ON	ON	0
41	R2A08	THRUSTER FLAP	3	1 1	37	1	0	0	2	1	0 0 ON	ON	0
42	R2H12	AIR SLIDE	3	1 1	37	0	0	0	2	1	0 0 ON	ON	0
43	R2H14	AIR SLIDE	3	1 1	38	1	0	0	2	1	0 0 ON	ON	0
44	R2J03	AIR SLIDE	3	1 1	38	0	0	0	2	1	0 0 ON	ON	0
45	R2J05	AIR SLIDE	3	1 1	39	1	0	0	2	1	0 0 ON	ON	0
46	R2U01	AIR SLIDE	3	1 1	39	0	0	0	2	1	0 0 ON	ON	0
47	R2U03	AIR SLIDE	3	1 1	40	1	0	0	2	1	0 0 ON	ON	0
48	R2P02	AIR SLUICE	3	1 1	40	0	0	0	2	1	0 0 ON	ON	0
49	R2P04	AIR SLUICE	3	1 1	41	1	0	0	2	1	0 0 ON	ON	0
50	R2U08	BLOWER	3	1 1	41	0	0	0	2	1	0 0 ON	ON	0

GENERAL DESCRIPTION
FLS-SDR/PowerGuide

LIST OF CONTENTS

FLS-SDR PLANT CONTROL SYSTEM

General description, FLS-SDR/PowerGuide System.

1. INTRODUCTION.

Cement Plant operation is an energy-extensive process. The electrical power consumed on a modern cement plant accounts for more than 45% of the total energy used to produce cement.

Managing electrical energy is an important key to overall profitability. In order to minimize the electricity cost the power consumption has to be monitored more closely. The optimal way to do this is to apply an effective power management program based on production planning/scheduling and supervision and control of all energy-related variables at the plant.

With this in mind F.L.Smidth & Co.A/S has developed a computerized electrical power management system, **the SDR/PowerGuide System**, which is an optional module to the computer based process control system, the FLS-SDR System (Supervision, Dialogue, Reporting and Control System) designed for applications in the cement and related industries.

The FLS-SDR/PowerGuide System is supplied as a complete ready-to use package and does not require computer programming by the user.
The PowerGuide System is menudriven based on function keys and selection tables displayed on the screen. The operator can call for real-time and historical trends for the most important parameters, control and cost reports as well as graphical figures for the actual power and energy distribution together with guidelines for optimal production planning based on minimum power consumption per production department. Automatic load shedding for each plant section based on pre-defined load scheduling and power planning figures is the operational part of the PowerGuide System.

The FLS-SDR/PowerGuide System is one of the advanced computerized control technologies offered by FLS to improve productivity and profitability in the cement industry.

FLS-SDR PLANT CONTROL SYSTEM

General description, FLS-SDR/PowerGuide System.

2. ECONOMIC EVALUATION.

The basic functions of management - planning, organizing, decision making and controlling - apply to the use of electrical power management too. Controlling the power costs is thus an important factor in the economy of a cement plant.

The rate of power cost depends on a complicated set of rules taking power consumption during certain time periods into account, peak loads, type of loads, local tariff structure, etc.

Besides minor fixed charges the electric utility bill is composed of following two elements:

1) **The energy usage charge** which represents the kilowatt-hours (kWh) actually consumed for operation of the equipment.

   The energy usage cost can be reduced by taking advantage of the low rate hours by effective load control, i.e. switching on and off non-critical equipment parts at certain pre-scheduled times of the day or night and/or in a specific sequence.

2) **The demand charge** which reflects the maximun kilowatt (kW) usage which the power company must make available for peak plant operation. In other words, the 15,-30,-or 60 minutes interval during which the most power is used sets the rate for the demand charge for an entire billing period. This charge represents normally 30 to 70% of the electric bill. In some cases 15 or 30 minutes period of peak usage will determine the minimum demand charge for as long as several months.

The demand charge offers the greatest potential savings. By distributing demand throughout the day/night unnecessary and costly power peaks can be avoided.

Measurements from several cement plants have indicated that the demand charge was found to be fluctuating between 20% and 45% from month to month. Smoothing these peaks through active power management means an opportunity for significant savings.

FLS-SDR PLANT CONTROL SYSTEM

General description, FLS-SDR/PowerGuide System.

....continued

The Power Management System developed by FLS can provide a very ef-
fective means of reducing power costs. Due to continuously on-line
process monitoring and load control a reduction of the overall demand
and power consumption can be expected, thus reducing the power costs
significantly. Further, for the plant personnel a better energy cost
awareness and readiness to handle more complex production scheduling
should be a benefit too.

3. SYSTEM FUNCTIONS.

For maximum functionality the FLS-SDR/PowerGuide System may be fully
integrated with the FLS-SDR System. This means that all user facili-
ties of the basic SDR configuration are available for the user's of
the PowerGuide System.

The FLS-SDR/PowerGuide System is composed of following functional mo-
dules:

1) **Power Planning**: For each defined plant section to determine the
   optimal demand setpoint and power consumption figures based on a
   optimized production planning calculated by the system.

2) **Power Control**: Execution of a continuous on-line load supervision
   and control to ascertain whether consumption and demand remains
   within the defined targets. The Power Control is based on the Po-
   wer Planning figures.

3) **Power Reporting**: Visualizing of the energy operating performance
   based on energy data stored for each defined plant section.

FLS-SDR PLANT CONTROL SYSTEM

General description, FLS-SDR/PowerGuide System.

...continued

The system functions are based on following data for each plant section which has to be loaded into the FLS-SDR/PowerGuide System either as operator's input or as a continuously on-line measurements via the real-time data acquisition module in the SDR-system.

- Forecast consumption/sales figures related to the future market situation, i.e. an overall production planning schedule based on periodic variations of cement consumption, consumer forecast and economic trends. .
- Storage capacities of silos.
- Actual storage levels of silos.
- Inventory desired.
- Nominal production rates.
- Installed rated power.
- Maintenance condition of production equipment, e.g. production halts due to preventative maintenance work.
- Conditions for stopping and starting equipment parts.
- Power consumption figures.
- Demand rate
- Tariff structure

Based on these inputs the SDR/PowerGuide system will be able to execute the following tasks:

3.1 Power Planning:

Based on desired production quantities within a considered time period a production plan for each plant section is calculated taking into account the overall plant operation which will yield to the lowest power costs. This is based on maintaining a very stable demand. A production planning optimization algorithm is executed based on registration of the actual and potential power consumption, the tariff limits and registration of the storage capacity and storage levels of the silos.

The production plan is composed of an operating schedules for short and/or long term planning based on the optimal energy demand profile.

FLS-SDR PLANT CONTROL SYSTEM

General description, FLS-SDR/PowerGuide System.

...continued

The operating schedules is calculated on basis of the best possible demand setpoint and planning for low tariff hour utilization in a specific time period.

The Power Planning figures will both be indicated on the operators console and stored for later retrieval.

3.2 Power Control:

The Power Control Module is the operational part of the SDR/PowerGuide system. Based on the Power Planning figures the Power Control is performed as a continuous on-line load supervision and control to ascertain whether the consumption and demand remains within the specified targets.

In all plants, various pieces of equipment such as fans, heaters and conveyors could be shut down for a few minutes in a the pre-defined time period (normally 15 minutes) to reduce demand. Frequently, equipment runs idle or with minimum loads. Non-critical equipment can be switched on and off automatically by the PowerGuide System or manually by the operator guided by the PowerGuide System. More critical equipment has to be running continuously due to saftety reasons either of personnel or machinery. It means that the different type of "loads" have to be defined prior to execution of the Power Control function.

The Power Control is composed of a load control which can be executed either "manually" by the operator or "automatically" by the system.

In manual mode or "Operators Guide" the load control information is issued by the PowerGuide System via the operators console and print outs from the system printer. Based on the calculated load shedding tables and the actual production planning figures the operator will be able to perform manual off switching of pre-defined loads in a specified sequence or prevents certain pre-defined loads from being switched on the mains during peak-load periods.

FLS-SDR PLANT CONTROL SYSTEM

General description, FLS-SDR/PowerGuide System.

...continued

By using simple commands via the operators console the PowerGuide system issues the necessary control information for the overall process control system.

In "automatic" mode the the non-critical loads are switched on-off automatically by the PowerGuide System, while the operator assumes responsibility for the critical loads in accordance to the load classification schedule and the Power Planning figures issued by the PowerGuide System. In "automatic" mode the load control information will be displayed on the operators console for operators guidance and the necessary control information will issued for the overall process control system.

The demand and the utility's time pulse inputs from the process control system are used to ensure synchronization with the utility. The PowerGuide System calculates per plant section the total power and issues an active power curve based on a pre-defined time period. The actual power value is constantly compared with a setpoint value and a special task for power shedding is performed taking the Power Planning figures into account. The power shedding calculations are used both in manual and automatic mode.

For the load classification, three type of loads is generally defined in the PowerGuide System:

Load I:

Loads with the highest priority as kilns and coal mills which are planned to operate more and less continuously for as long as possible. These loads are not applied to the Power Control Module.

Load II:

Loads which are normally smaller and more flexible and can be scheduled for infrequent stops to allow alternate operation during the day. Typical loads in this category are crusher(s), conveyor systems and raw and cement mills. These loads are applied to the Power Control Module either for "manual control" or "automatic control".

FLS-SDR PLANT CONTROL SYSTEM

General description, FLS-SDR/PowerGuide System.

...continued

Load III:

Loads with the lowest priority, highest flexibility and least short term effect on the production. Typical loads of this category are auxiliary systems and conveyor systems. These loads are applied to the Power Control Module for "automatic control" only.

3.3   Power Reporting:

The Power Reporting Module is closely related to the Power Planning anf Power Control Modules for issuing various planning and tariff figures, demand and consumption figures, load factor curves, alarms/warnings and statistics etc. visualized on the colour graphics display terminal and the system printer.

Based on the energy data stored in the PowerGuide system the following features are available for the plant personnel either automatically or on request by the operator:

1) Planning and tariff information indicated as figures in graphs and tables per time period.

2) Dynamic demand profiles per time period of each defined plant section indicating the necessary information to control peak demand.

3) Accumulated consumption figures for performance evaluation of areas or single machines in the plant section.

4) Trend curves indicating actual demand, power consumption and power factor per time period per plant section.

5) Dynamic load shedding lists per plant section per time period indicated on the display screen in various colours depending on the actual demand situation.

FLS-SDR PLANT CONTROL SYSTEM

General description, FLS-SDR/PowerGuide System.

...continued

6) Warning indication when pre-selected loads per plant section exceeds the demand limit specified either automatically by the PowerGuide System or by the operator.

7) Alarm indication if the actual demand per plant section exceeds the demand setpoint.

8) Statistical graphs/curves indicating daily, monthly and yearly figures related to the load/power consumption/production and consumption per plant section.

In addition to above mentioned features, special reports and calculation algorithms can be defined and specified on-line by the user.

4. CONCLUSIONS.

As energy becomes a more important factor in the production cost calculation, one of the main issues for many cement plants is reducing the energy bill, especially that for electricity in order to stay competitive. To compete globally the cement companies must lower the production costs.

Using the FLS-SDR/PowerGuide System means improving competitiveness through power costs reduction. Depending on the local tariff structure for electricity saving estimates indicates that for a full operational PowerGuide System one can expect reduction of the electrical energy costs of 15-25% without lowering the production performance. In addition to the direct economical benefits, the PowerGuide System has enhanced energy savings awareness among employess and improved understanding of where and how well electrical energy is being used as basis for further analysis and savings.

As the SDR/PowerGuide System is an add-on module to the basic FLS-SDR configuration all SDR facilities applied are available for the user of the PowerGuide system. It means that the PowerGuide System can be tailored to meet specific user requirements combined with the standard features implemented in the PowerGuide package.

APPENDIX

TO

LECTURE 13.8

SIMULATION, OPTIMIZATION AND PROCESS CONTROL SYSTEM

FOR CEMENT PLANTS

SIMULATION, OPTIMIZATION AND PROCESS CONTROL SYSTEM FOR CEMENT PLANTS

by

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Abstract

The paper describes a Cement Process simulator (CPS) being developed for the Centre for Continuing Education of the National Council for Cement and Building Materials (NCB) as per NCB's specifications and system design, to be used mainly for operator training at their training centre in Hyderabad.

The simulator includes a full-scale operator control desk where the operator can experience real control room environment with both a conventional analog instrumentation panel and a computerized operator work station with colour display and function keyboard.

The simulator is easily adaptable to different milling and pyroprocessing systems. At present the following cement processes are foreseen: Vertical roller mill for raw mix grinding, 4-stage preheater kiln with planetary cooler, precalciner kiln with grate cooler, and ball mill for clinker grinding.

Besides training of operating personnel from cement plants the system can be used to perform specific process studies to evaluate and optimize process performance, and it can even if required be taken to a cement plant and used for on-line process control.

1. Introduction

The proper control of cement plant operation is a key element in the production of high quality cement. This implies comprehensive and well maintained instrumentation and control systems in the plant, but also a high level of training and skill of the operating personnel responsible for the daily operation of the plant.

This fact has become even more pronounced during the last decades with the very big and investment-intensive plants controlled from a single central control room by only one of a few operators responsible for the hour-to-hour production.

The traditional way of training operators has been to have them serve a period of apprenticeship to a senior operator. Whilst in new cement plants it is quite difficult to provide the proper training of operators before the commissioning of the plant, even in case of existing plants such training is normally discouraging as any mistake on part of the trainees can cost the plant in terms of down-time of equipment and loss of production.

For these reasons the cement industry has shown increasing interest in using simulators as means for operator training, a method already well-known for training airplane pilots, tankship officers, operators of nuclear power stations, oil rigs, etc.

This paper outlines a Cement Process Simulator (CPS) being developed for the use of the Centre for Continuing Education at NCB (NCB-CCE) in India as per NCB specifications and system design to be used mainly for the training of operating personnel, and supervisory staff from the cement industry.

The hardware of the system has been based on standard hardware for the FLS-SDR System from F.L.Smidth, Denmark. Such systems are being used for process monitoring and control in a large number of cement plants all over the world and quite a few in India itself. The FLS-SDR standard software covers all the required functions for adjustment, control monitoring mimic generation, status displays, alarm and report generation for large number of process variables. In addition to this software FLS has developed the special simulation software capable of reproducing realistic cement process responses to control adjustments.

The objectives of the CPS is to provide a control room scenario where cement plant operators and supervisors can experience various operating conditions - both normal and abnormal - thereby increasing their knowledge and understanding of cement plant operation. In summary the system facilitates:

- training of new plant personnel and updating of existing personnel.
- improving proficiency of the plant personnel in their respective areas of operation.
- providing the plant personnel a better understanding of the entire cement manufacturing process and inter-relationship between process variables.
- enabling operators to take quick corrective actions after disturbances.
- minimizing decision making errors at the plant control panel.
- Optimizing the performance of each unit operation and each subsystem in the cement plant.

● The simulation package will comprise simulation of 4-stage single-string preheater kiln with planetary cooler, single and double-string preheater/precalciner kiln with grate cooler, vertical raw grinding roller mill, and open/closed-circuit ball mill for finish grinding. The sizes of plants that can be selected for simulation are 300, 600, 900, 1200, 1500, 2000, 2500, 3000 and 4000 TPD.

2. The CPS in NCB's Scope of Activities

In line with the objectives of a national body like NCB primarily devoted to Research, Technology Development and Transfer, Education and Industrial services for the whole cement and allied industries in the country, the complete system has been visualized, configured and designed by NCB in such a way as to make it the most versatile and effective training tool for the cement industry, specially of the type as in a developing country like India.

● The cement industry in India presently comprise 33 wet process plants, 6 semi-dry/semi-wet process plants and 45 dry process cement plants, out of which only about a dozen plants are equipped with substantial micro-processor based process control and monitoring system.

It was thus realised by NCB that with these diversified processes and technologies adopted at present by the Indian cement industry and the corresponding different exposures obtained by the operating personnel in different cement plants, a standard micro-computer with only a CRT terminal and a printer will not be comprehensive enough to be an effective tool for training of operators. Thus having a standard simulator trainer based on an IBM-PC or similar micro-computer terminals would have created a condition wherein most of the trainees coming from cement plants with conventional control panels would have worked on completely unfamiliar type of system with CRT console, and at the end of such training would have gone back to their own plant not

● to use such a system again for long time to come.

Keeping this in mind, NCB was therefore of the view that only a full-scale system with conventional analog control desk which is interfaced to the computer system, thus creating an option for the trainees to either work on a conventional panel or on a CRT console, would be the most appropriate training aid for its Centre for Continuing Education (NCB-CCE) with its thrust locating at Hyderabad.

The installation of the simulator system shall give tremendous boost to the activities of the NCB-CCE, which has already made significant contribution to the training needs of the Indian cement industry - having today organised over 250 long term, short term and sponsored training programmes for over 5,000 personnel from the cement industry.

●

3. The CPS Hardware

The equipment for the CPS consists of the control desk, the Instructors Console and a process computer system, fig. 1.

3.1. The Control Desk

As mentioned earlier realism is considered of key importance for a good operator training. Consequently the control desk is similar to conventional control panels or desks found in cement plant control rooms.

The control desk includes, fig. 2:

      16 PID controller set point stations
       1 15 channel indicating instruments
       8 3-pen recorders
       1 35 point alarm annunciator panel
       2 push-buttons keyboards for start/stop of various drives
       1 Operator Workstation with a colour CRT, function keyboard and hard-copy printer.

The control desk can operate in two modes:

   i) Analog Control Panel mode, with process information presented to the operator on the controllers, pen-recorders, indicating instruments, etc. The colour CRT in this case is used to present the mimic diagram with status information of process section being simulated.

   ii) Workstation mode, where the entire process control is exercised through the computerised workstation and the function keyboard. The analog control panel instrumentation is not used.

3.2. The Instructors Console

The Instructors Console is a conventional computer terminal used by the instructor to supervise the training session.

The training programmes shall be conducted through a 3-Tier package covering:

   i) Training of operators: which shall give maximum stress on the development of the necessary skill for day-to-day operation.

   ii) Training of supervisors: which in addition to above, shall also impart a deeper knowledge on the cement manufacturing process and shall include techniques for the optimisation and process control of various unit operations.

iii) Training of Managers: which shall lay more
emphasis on process control and optimisation of
the plant operation, decision-making at higher
levels depending on the performance data and
parameter values obtained from the system etc.

By simple commands the instructor sets up the simulation
model for a training session, and during the training ses-
sion he can monitor on the terminal display the behaviour of
the trainee and the status of the process simulation.

Throughout the simulation the instructor can introduce
disturbances to the simulated process, e.g. stop of a fee-
der, blocking of a cyclone, changing kiln feed chemistry
etc. to observe and train the trainees ability to react
correctly to both normal and abnormal process conditions.

The various failures/disturbances which can be created by
the instructor at the press of a key-button shall cover all
major equipment drive failures, instrument defects, hot-
spot, ring formation, plugging of cyclone, heavy leakages in
preheater tower and kiln air-seals etc.

Also, the instructor can control the timing of simulation
like speeding it up to get through process paths of minor
interest, or setting time back to discuss and rehearse a
difficult operating situation.

3.3. Process Computer System

The process computer system simulating the process sections
and operating the control desk is a Hewlett-Packard 1000-
series technical computer, type A600+, with 2 MByte of memo-
ry and equipped with a 24 MByte Winchester disc with built-
in tape streamer back-up, see also fig. 3.

The workstation hardware, make ASEA Tesselator, comprises a
colour CRT, function keyboard, picture editing keyboard and
3-colour hard-copy printer. The Tesselator has been develo-
ped especially for use as man-machine interface in computer
control systems and includes a number of rather unique
character definitions enabling creating of very legible
process diagrams.

A process interface unit with 48 analog inputs, 48 analog
outputs, 32 digital inputs and 32 digital outputs plus a
built-in PLC (Programmable Logic Control) function for motor
control simulation provides the interface between the compu-
ter and the control desk.

This interface also permits the equipment at a later stage
to be moved and connected to a real cement plant process, if
it should be so wished.

3.4. Training Room-layout

At the time of writing the room to house the simulator has not been finally designed. Fig. 1 shows a tentative sketch of the proposed training room, at the Centre for Continuing Education of NCB, measuring approximately 100 m, and including also black board, projector screens, explanatory planches and writing desks for use during simulation sessions.

4. The CPS Simulator Software

The software for the CPS consists of three distinct parts, fig. 4:

- SDR/Opstation software package to drive the Operator Workstation.

- CPS simulation software to perform the process calculations.

- HP software for user development of own programmes.

The software modules are operating under the RTE-A real-time operating system, standard for the HP1000 A-series computers. For the SDR/Opstation and CPS simulation software a special FLS designed task handler called SPLICE and data base management system called FUS are employed. Most of the software is written in FORTRAN.

4.1. SDR/Opstation Software

The SDR/Opstation software is in all identical to software used in actual FLS-SDR plant control systems to drive operator workstations in a central control room. The software includes functions for:

- dynamic process diagrams
- process value surveys
- start/stop of machines
- trend curves
- process operating logs and reports
- alarm surveys
- start/stop and event reports

The use of the SDR/Opstation software package in the CPS implies that the trainee works on the simulator using the same display diagrams and control keys as will be used in a real control room. In the latter case the control desk would comprise of 3-6 Workstations, in the present CPS only one Workstation has been envisaged.

4.2. Process Simulator Software

Based on the controls set by the operator the process simulation software calculates the operating values which in real life would be provided by sensors and transducers.

To set up the process simulation function the instructor specifies the simulation in terms of, fig. 5:

- **Process Type:** Type of pyro-processing or milling system. This will automatically select the necessary stationary process model, dynamic description parameters, disturbance possibilities, measurement descriptions, workstation pictures, report definitions etc.

- **Process Model Parameters:** Used to scale the process model for the Process Type selected for simulation. The CPS provides files for several process model parameter sets, making it possible to store in the system pre-defined data sets from different plants for easy set up of a simulation for a specific plant.

- **Simulation Control:** These parameters control the execution of the simulation and enable the instructor to select disturbances and the speed of simulation, i.e. real time, or slower or faster to suit the training situation. A multitude of disturbances may be applied simultaneously.

Whereas Process Type and Process Model Parameters are selected and set initially at the start of a training session, the Simulation Control parameters are used during the session to control and change the simulation according to the instructors - and trainees - wishes.

At the end of a training session the instructors console produces a print-out of the trainees performance, for example abnormal conditions reached during training, reasons for stop of simulation, time taken by the trainee to control and normalize the process conditions, etc.

4.3. Simulation Principle

The mathematical model for the simulation of a given Process Type consists of three parts, fig. 6:

1. Stationary model
2. Dynamic model
3. Camouflage model

The Stationary model involves a set of rather complex cal-
culations using the laws of physics and empirical knowledge
to calculate the stationary operating values x for a given
set of process input values u (x and u are vectors). The
process inputs, or control variable, u are specified by the
operator on the Workstation keyboard, or the control keys of
the Analog Control Panel. Typical inputs for a kiln are kiln
speed, fuel to kiln, kiln feed, fan speed etc. The calcula-
ted operating values x would then be stationary values of
temperatures, pressures, gas flows, heat consumption, clin-
ker quality, etc.

To simulate the delayed reaction of the process to a given
set of input values the stationary output values from the
stationary model x are superimposed on a Dynamic model cal-
culating the influence of time using normal feed-back calcu-
lations, e.g. :

$$z(t+1) = z(t) + A(z(t) - x)$$

where z are the dynamic output values, t is time, and A the
feed-back matrix containing the dynamic description parame-
ters. Above equation generates normal first-order lag
response behaviour, but variations and extension of the
equation can be used to simulate also more complex time
response involving higher order behaviour and time delays.

The Camouflage model adds make-up in the form of noise,
oscilations, offsets etc. to the output variables to make
them look realistic. The Camouflage model will produce the
values y that are actually presented to the operator as
observed output values on the Workstation display or the
Analog Curve Panel instrumentation. x and z are like this
intermediate values used by the simulation calculation and
generally not known to the trainee. The trainee will observe
only the output values y, and based on his observations he -
or in automatic mode, the Fuzzy control strategy - will ad-
just the control inputs u to make the process operation
satisfactorily.

During the simulation session the instructor can control the
speed of the process by adjusting the Dynamic model, and he
can introduce disturbances by changing parameters in both
the stationary model and the Camouflage model.

The instructors console provides a simple command for the
instructor to instantly regain the steady-state operation
from any failure/abnormal condition.

4.4. Programming and Development Software

The SDR/Opstation and CPS Simulation Software mentioned above incorporate dedicated programming functions for the user to define the systems treatment and presentation of process operating information in relation to the supervision and control tasks. Measurement handling and report definitions are specified by fill-in-the-blanks tables, process pictures are edited directly on the workstation using a special drawing keyboard, and a special programming language called Fuzzy Control Language, in short FCL, can be used to write algorithms and also define control strategies, e.g. for simulation of fully automatic computer control of the kiln.

To supplement these programming tools the system includes standard Hewlett-Packard program generation tools like file manager, editors, FORTRAN, assemblers, data base management software, etc. for user development of own programmes. In periods where the system is not used for operator training or process evaluation it can then be utilized as a general-purpose technical computer system.

5. Conclusion

Although the use of simulators for operator training is not new to the cement industry, the present simulator is considered unique for the following reasons:

- it is made up of computer equipment and instrumentation also used in actual plant control systems. This means the operators work on the simulator using the same instruments, displays and control keys as they do meet in a real cement plant.

- it incorporates operator training on both conventional control instrumentation (Analog Control Panel mode), or on a pure computerized colour terminal with function keyboard (Workstation mode), which is most ideally suited for the cement industry in India with diversified processes and technology lines.

- besides being able to be operated in a manual mode by the trainee, the simulator includes an automatic mode in which the system can demonstrate automatic kiln and mill control by computer using control strategies formulated in Fuzzy Logic.

- the simulator can be effectively used for off-line process optimization by being scaled for simulation of a particular department of a specific plant.

- if desired the simulator can be moved to an actual plant site and be used for control on an actual plant.

The simulator is specified and developed jointly by NCB.
India and F.L.Smidth, Denmark and adapted to the operating
conditions and requirements of a cement industry with
diversified processes and technology lines, as in India,
making it a flexible and effective training as well as
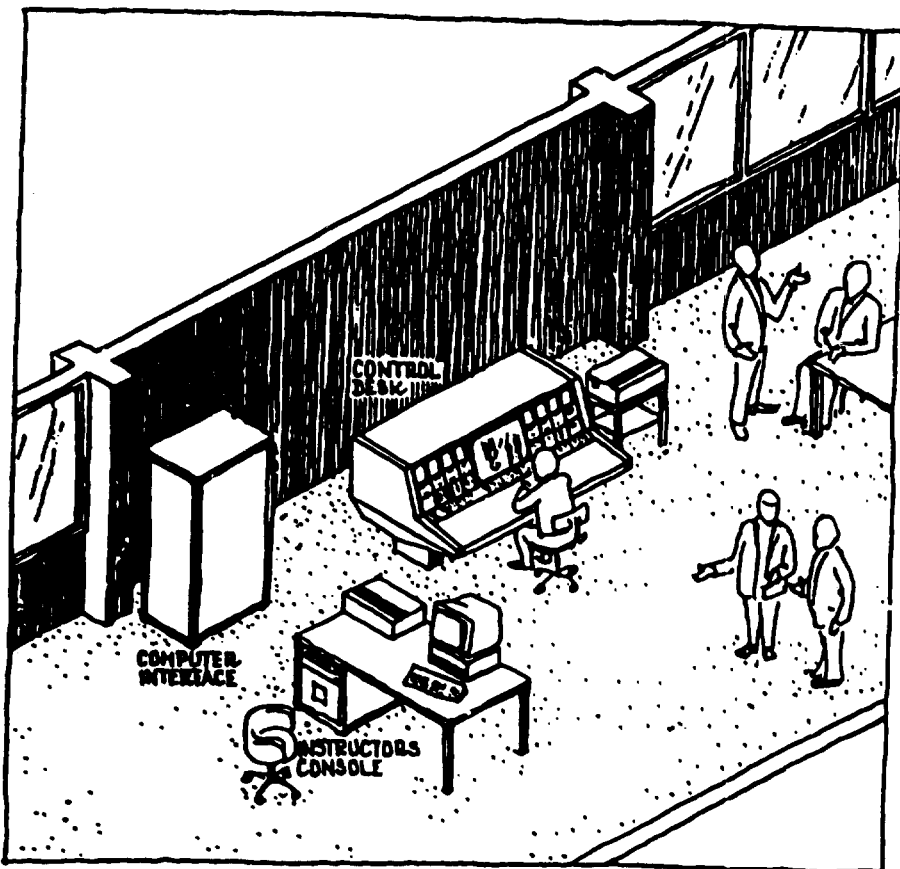process optimization tool for the cement industry.

11

① ALARM ANNUNCIATOR PANEL
② 3-CHANNEL PEN RECORDER
③ WORKSTATION COLOUR CRT
④ 115-CHANNEL INDICATING INSTRUMENT
⑤ CHANGEABLE LABELLING PLATES
⑥ MOTOR CONTROL KEYS
⑦ WORKSTATION FUNCTION KEYBOARD
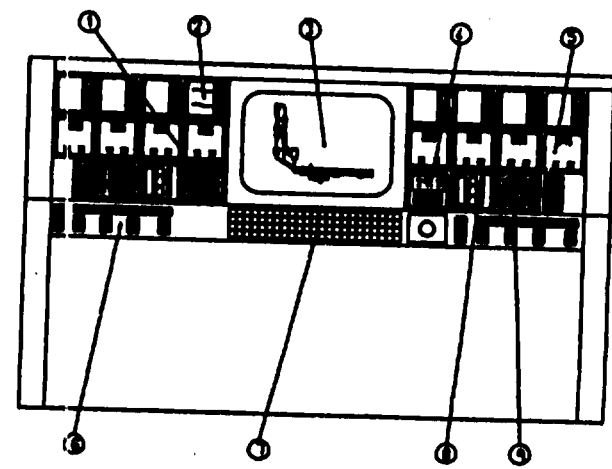⑧ PID CONTROLLER SET POINT STATION
⑨ PID CONTROLLER DISPLAY UNIT

Fig. 1 The CPS Cement Process Simulator
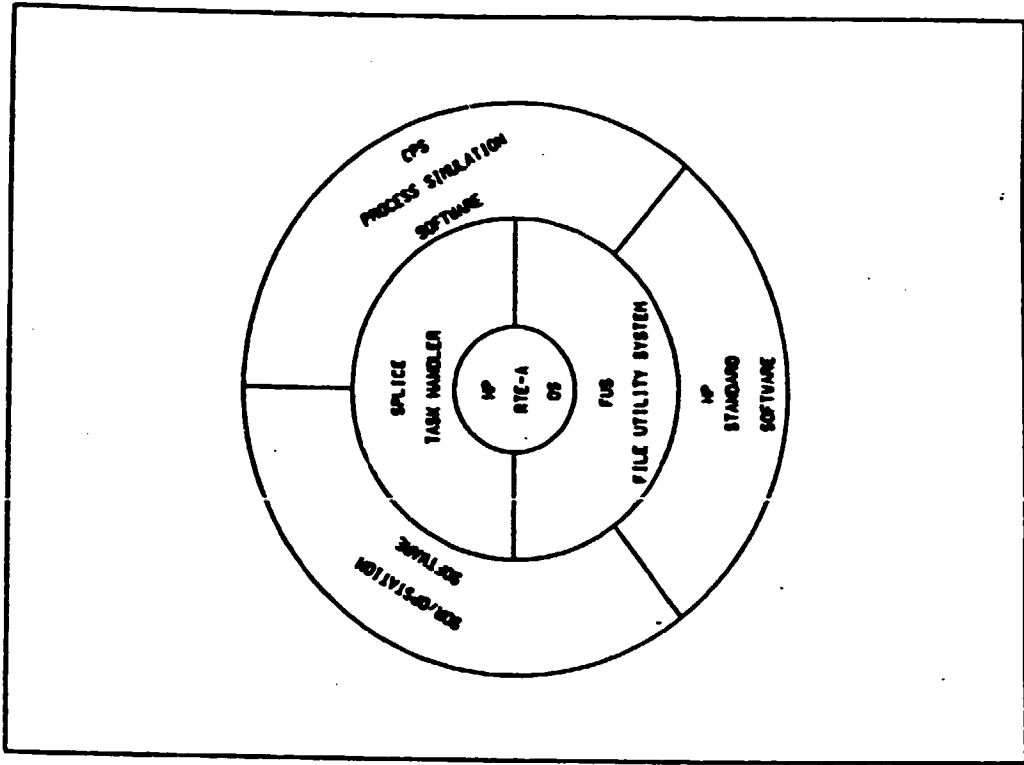
Fig. 2 The CPS Control Deak
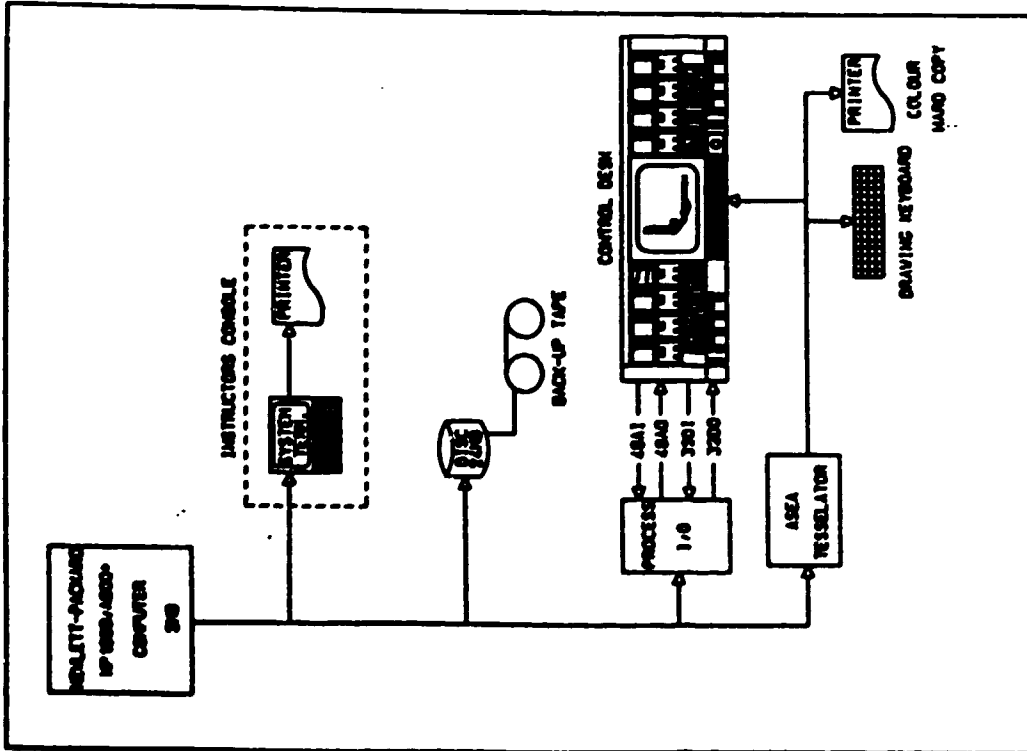
Fig. 4 System software overview

Fig. 3 The CPS hardware configuration
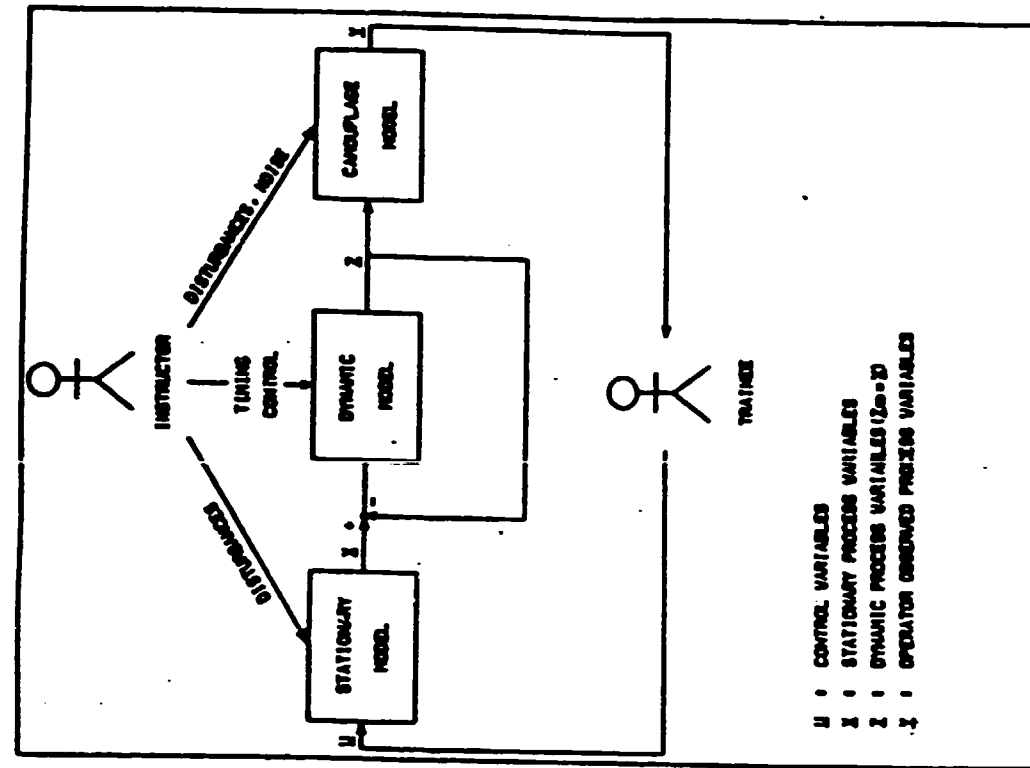
Fig. 6 The simulation principle
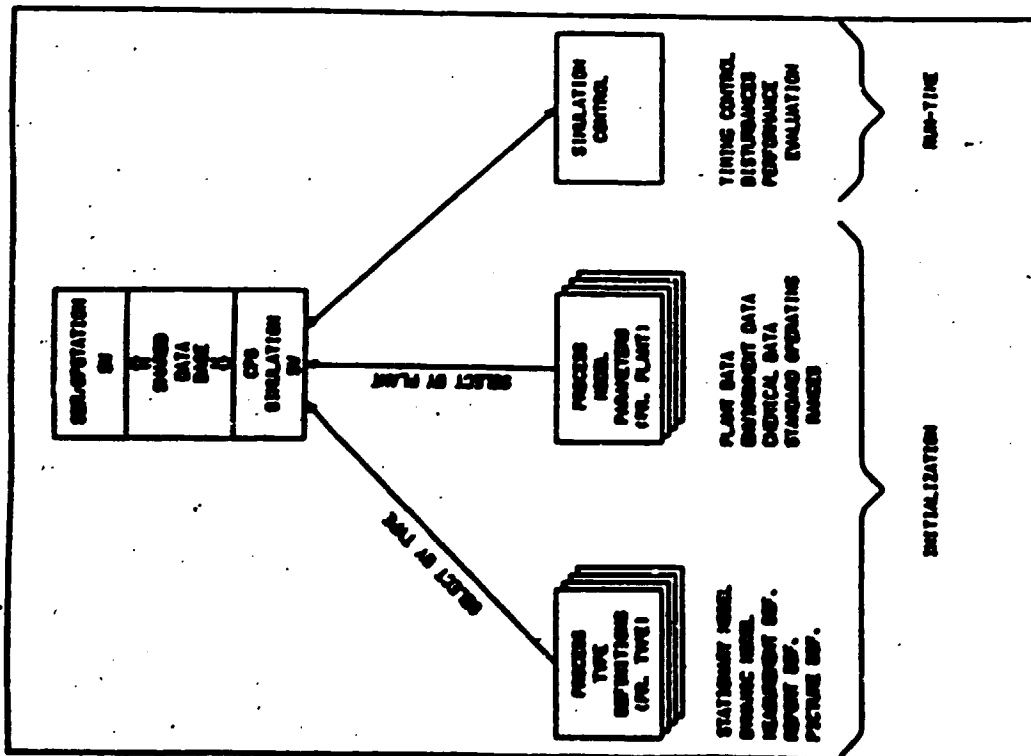
Fig. 5 The CPS software organisation

LECTURE 13.11

CEMulator – A REAL-TIME SIMULATOR FOR TRAINING OF CEMENT OPERATORS

CEMulator

A cement process simulator
for operator training
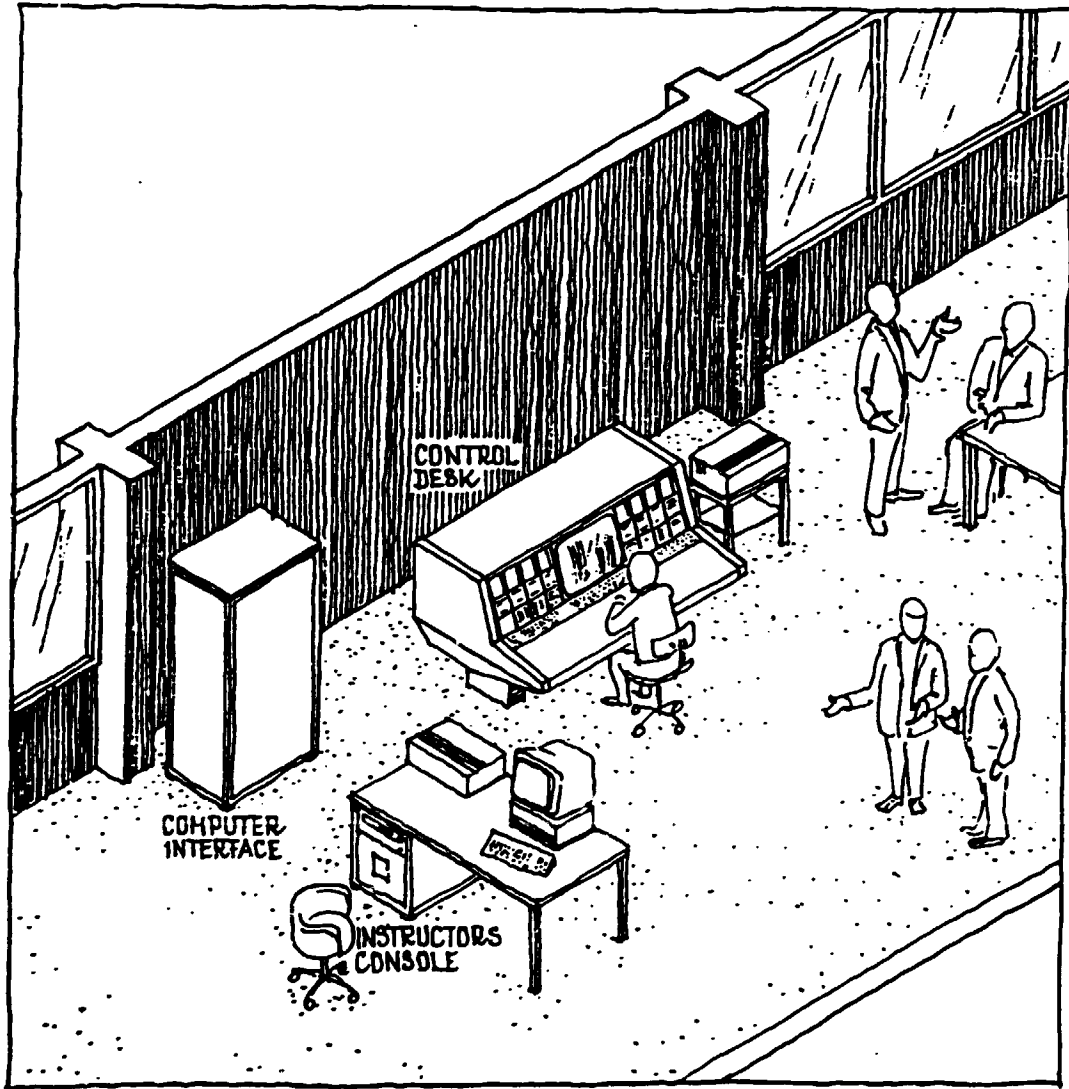
F. L. SMIDTH
Automation Division

CEMulator - a real-time simulator for training of cement operators

Abstract.

Today a cement plant represents an enormous investment which makes it more important than ever that the operators understand the process and are capable of running it securely and economically as regards the operation and the environment. Loss in production due to poor quality or stops due to damage is very costly and education of cement kiln operators and other production personnel on a simulator is therefore appropriate.

F.L. Smidth & Co., A/S, Automation Division has during the last 3 years developed a computer-based simulator for simulation of kiln processes as well as vertical- and tube mills.

The simulator made by FLS distinguish itself by using the same operator communication equipment as used in central control room of the cement plant.

The process model is a comprehensive and complex mathematic description of the physical, chemical and thermo dynamic relations concerning the cement production. This part of the development alone has taken up 3 man years.

The result is an absolutely realistic model not only concerning the levels of the different processes in stable operation but also during the changes after adjustment and disturbances.

In particular, disturbances are naturally interesting on a simulator because either you cannot or will (must) not provoke these on the plant itself and you can therefore only sporadically train the operators to judge and manage these

situations correctly.

The article will give a description of the physical/chemical bagground of the CEMulator.

The mathematic model, the solution method and the necessary approximations will be described.

Interface between operator and simulator programme will be described.

Examples are included to illustrate how the CEMulator reacts when it from a stable state is exposed to one single fluc-tuation in the process parameters or exposed to one single disturbance.

90 001

1.   Introduction

The direct cause of the projects start was an order from U-NIDO for a training simulator for an education center in Hyderabad in India. The user, National Council for Cement and Building Materials (NCB), arranges courses for engineers and production personnel (operators) from the Indian cement industry and required in this connection a simulator to demonstrate the used theory and improve the understanding of running of cement plants.

Some PC-based simulating programmes were available but according to NCB these were not realistic enough botn regarding the simulation model and regarding the operator communication.

The simulator developed by FLS and NCB distinguish itself by using the same operator communication as used in central control room of the cement plant. The production bases of the CEMulator are, therefore, identical with for instance those colour screen stations which have been installed at Rørdal's new kiln 87. Further, the CEMulator to NCB contains a complete control desk with curve writters, alarm lamps and buttons which also make it possible to watch and operate the process via more conventional instrumentation as it is seen at most cement plants today.

The first parts of the CEMulator to NCB were installed in 1988 and have been diligently used at NCB's courses ever since. 3ased on experiences and not least NCB's critics and proposes, adjustments and improvements of the simulating programmes have been carried out; some operator stations have been added in order to give more people opportunity to follow the simulations at the same time. The latest simulation models of tumbling ball mills will be installed medio 1990.

2.   Modulus construction

As known the clinker prcduction process consists of 3 steps: A preheating, a chemical reactor - being the kiln and an off cooling. Therefore, it is naturally to split the simulator model into moduluses - this is done partly to make the model more clear and partly to make it possible to make changes in one modulus without having to change the entire model for that reason.

The simulator kiln process model is put together by 4 moduluses: a preheater modulus, a kiln modulus, a clinker cooler modulus and a modulus which describes the pressure and fan system. All moduluses are obvious closely connected but with relatively simple connections.

The preheater modulus is made in a number of different models which correspond to a great part of the different types of preheater towers that exist and which F.L. Smidth produces. For instance, the simplest model a suspension preheater tower (shown on fig. 1) or the most complex model an in line calciner with excess air and tertiary air inlet (shown on fig. 6).

The clinker cooler is made in 2 different models. A planet cooler and a grate cooler. From the grate cooler the heated air can be fired partly into the kiln and partly into a calcinator.

3. A brief describtion of chosen equations

As a brief describtion of how the condition of the different variables varies as a function of time, place and other variables, it is here desided to describe how "over all" mass balance for the solid phase is calculated in the kiln.

The kiln is dynamically calculated. It is divided into 20 steps which each consists of a solid phase and a gas phase. In any cross section of the kiln ideal mixture of each phase is presumed. Each phase consists of 3 sets of variables, one which describes mass balances, one which describes chemical combinations and one which describes the thermo dynamic relations. Concerning the chemistry - the raw meal which consists of lime stone, clay and for instance fly ash contains a number of different reactants; Seen from empirical knowledge of the process the model is limited to 7 components and 4 reaction equations which are the most important as regards mass balance and the heat development in the solid phase of the kiln. Being as follows:

Components		Concentrations		Mol weight
#1	$CaCO_3$	C_1	$kg\ CaCO_3/kg\ CaO_t$	$m_1 = 100$
#2	CaO	C_2	$kg\ CaO/kg\ CaO_t$	$m_2 = 56$
#3	SiO_2	C_3	$kg\ SiO_2/kg\ CaO_t$	$m_3 = 60$
#4	C_2S	C_4	$kg\ C_2S/kg\ CaO_t$	$m_4 = 172$
#5	C_3S	C_5	$kg\ C_3S/kg\ CaO_t$	$m_5 = 228$
#6	Al_2O_3	C_6	$kg\ Al_2O_3/kg\ CaO_t$	$m_6 = 102$
#7	C_3A	C_7	$kg\ C_3A/kg\ CaO_t$	$m_7 = 270$

CaO_t — Total amount of CaO at the given point in kiln

Reactions

			Enthalpies
#1	$CaCO_3 \rightarrow CaO + CO_2$		$\Delta H_1 = -764 \ kcal/kg \ CaO$
#2	$2CaO + SiO_2 \rightarrow C_2S$		$\Delta H_2 = 295 \ kcal/kg \ CaO$
#3	$CaO + C_2S \rightarrow C_3S$		$\Delta H_3 = 0 \ kcal/kg \ CaO$
#4	$3CaO + Al_2O_3 \rightarrow C_3A$		$\Delta H_4 = -185 \ kcal/kg \ CaO$

Reaction rate

The reaction rate is a very complex affair with diffusion of the chemical reactants into the lumps of quarts and lime stone which the raw meal consists of - actually, a process of which there is little knowledge of how runs. Therefore, it is desided to anticipate that the reaction rate is a simple Arrhensius reaction.

Reaction rate:

Reaction rates

$r_1 = C_1 \, exp(A_1 - E_1/RT_s)$	$kg \ CaO/kg \ CaO_t$	produced by 1
$r_2 = C_2^2 C_3 \, exp(A_2 - E_2/RT_s)$	$kg \ CaO/kg \ CaO_t$	used by 2
$r_3 = C_4 C_2 \, exp(A_3 - E_3/RT_s)$	$kg \ CaO/kg \ CaO_t$	used by 3
$r_4 = C_2^3 C_6 \, exp(A_4 - E_4/RT_s)$	$kg \ CaO/kg \ CaO_t$	used by 4

r_i — reaction rate [h^{-1}]

C_i — Component concentration [kg/kg CaO$_t$]

$exp(A_i)$ — Frequency constant

E_i — Activation energy [kcal/mol]

R — Universal gas constant [kcal/mol K]

T_s — average surface temperature of particles [K]

Axial velocity:

If we look at the axial velocity of the solid phase in the kiln it is a function of the rotation rate of the kiln and of the slide angle which the material reach before it goes down. This slide angle changes through the kiln, in the beginning, where no melt has been created yet; but where a calcination of the calcium carbonate will occur, the slide angle will depend on the velocity with which the CO_2 development is carried out. The CO_2 development can in the beginning of the kiln be of such power that it is a question of fluid bed and, therefore, a very little slide angle. La-

5

ter in the kiln the temperature has increased so much that contents of aluminium and ferric oxides in the raw meal will begin to melt whereby it will be a more sticky mass and thereby an increased slide angle. At even higher temperatures also the contents of silicates in the raw meal will begin to melt.

In (1) an expression for the axial velocity of the solid phase of the rotary kiln is written, based on these mechanisms, when the density and the chord length are approximated to be constant.
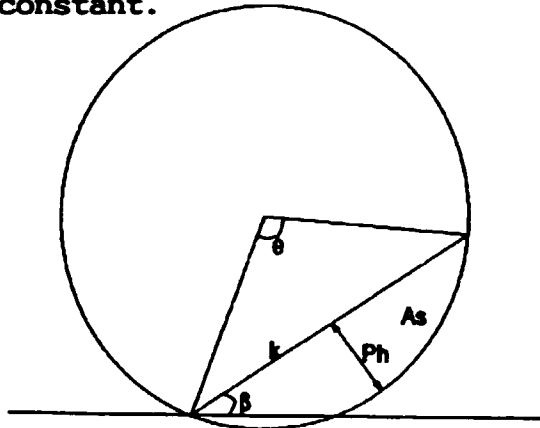
Figure 3 Kiln cross section.

$$v_s \approx C \times \frac{1}{t_r} \times \frac{\tan \alpha}{\sin \beta}$$

$$\beta\left(T_s, \dot{C}_c\right) = \beta_0 + \beta_t + \beta_c$$

C — Constant

k — Chord length [m]

α — Axial sloping angle of kiln [rad]

t_r — Rotation time [hr]

P_h — Charge height [m]

Z — kiln axial coordinate [m]

θ — Central filling angle [rad]

D — Internal diameter [m]

A_s — Charge gross section area [m^2]

v_s — Axial velocity [m/hr]

β_0 — Repose angle when no liquid and no fluidization is present

β_t — Increment in β due to liquid formation

β_c — Decrement in β due to fluidization

6

"Over all" mass balance

With a known reaction rate of the chemical components and a known axial velocity of the solid phase it is possible to place a number of partial differential equations with regards to time and place for the mass balance for the single chemical components as well as for "over all" mass balance.

$$\frac{\partial(\rho_s \times A_s)}{\partial t} + \frac{\partial(v_s \times \rho_s \times A_s)}{\partial Z} = D_s$$

ρ_s — constant

$$\frac{\partial A_s}{\partial t} + \frac{\partial(v_s \times A_s)}{\partial Z} = \frac{D_s}{\rho_s}$$

$$D_{CO_2} = \frac{m_{CO_2}}{m_2} \times \frac{r_1}{\sum\limits_1^7 C_i} \times \rho_s \times A_s = -D_s \text{ produced kg } CO_2/\text{m/hr}$$

ρ_s — solid bulk density [kg/m^3]

A_s — charge cross section area [m^2]

v_s — axial velocity [m/hr]

D_s — solid mass transfered [kg solid/m/hr]

r_1 — produced kg CaO/CaO$_t$/hr

m_{CO_2} — molar weight of CO_2

m_1 — molar weight of $CaCO_3$

m_2 — molar weight of CaO

$\sum\limits_1^7 C_i$ — kg solid/kg CaO$_t$

$\rho_s \times A_s$ — "hold up" kg solid/m

4. Numerical solution

The partial differential equations in the kiln modulus are all numerically solved by first order Taylor differens app-roximations where the accuracy in the decision of the slope is improved by a prediction-correction method. The backend of the kiln is used as a development point as it is pressu-med that the quantity, temperature and composition of the added raw meal from the preheater tower are known.

The model is calculated with dimensionless parameters for the mass flow, axial and radial dimensions, time and con-centrations.

$$\dot{M}^* = \frac{\dot{M}}{\dot{M}_n}$$

$$Z^* = \frac{Z}{L}$$

$$t^* = t \frac{v_n}{L}$$

X^* — dimension less parameter

X_n — nominal value of parameter

Z — axial coordinate

t — time

v_n — nominal feed material velocity

L — length of kiln

$\dot{M}$ — mass flow

Hereby, a grid with the dimensionless time as abcisse and the dimensionless axial coordinat as ordinat can be put down and a solution to the partial differential equation for "over all" mass balance can be found.

Numerical solution:

$$\frac{\partial A}{\partial t} + \frac{\partial (vA)}{\partial Z} = f_3$$
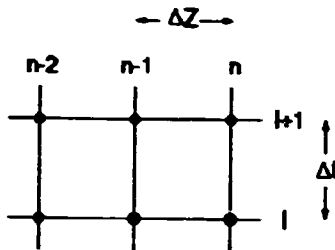
Figure 4 Grid.

$$\Delta t = \Delta Z$$

$$\frac{\partial A}{\partial t} = \frac{A_n^{i+1} - A_n^i}{\Delta t}$$

$$\frac{\partial (v\,A)}{dZ} = \frac{1}{2}\left(\frac{v_n^i\,A_n^i - v_{n-1}^i A_{n-1}^i}{\Delta Z} + \frac{v_{n-1}^i\,A_{n-1}^i - v_{n-2}^i A_{n-2}^i}{\Delta Z} \right)$$

$$= \frac{v_n^i\,A_n^i - v_{n-2}^i A_{n-2}^i}{2\,\Delta Z}$$

$$\frac{A_n^{i+1} - A_n^i}{\Delta t} + \frac{v_n^i\,A_n^i - v_{n-2}^i\,A_{n-2}^i}{2\,\Delta t} = f_3$$

$$A_n^{i+1} = f_3\,\Delta t + A_n^i - \frac{1}{2}\,v_n^i\,A_n^i + \frac{i}{2}\,v_{n-2}^i\,A_{n-2}^i$$

9

5. Key numbers

The key numbers of the model -
The kiln-modulus itself which is the most complex modulus of
the model consists of 38 linked differential equation.

1 for axial velocity
1 for "total hold up" in the solid phase
1 for gas mass flow
4 for reaction rate of chemical reaction equations
7 for chemical concentrations in the firu phase
1 for carbon burning in the gas phase
1 for flame length
6 for chemical concentration in the gas phase
1 for the total heat balance of the firm phase
4 for the heat transfer of the firm phase
1 for the total heat balance of the gas phase
5 for the heat transfer of the gas phase
1 for the heat balance of the kiln walls
2 for heat conduction by the surfaces of the kiln walls
1 for the surface loss of the exterior kiln wall
1 for the kiln torque

These 38 differential equations are by implementation redu-
ced to 15 hyperbolic and 1 parabolic partial differential e-
quations. Approx. 160 different condition variables, vectors
of condition variables and constants are used for the kiln
modulus.

The cooler modulus (the grate cooler) consists of 2 linked
differential equations:

1 for the air temperature
1 for the clinker temperature

Approx. 70 different condition variables, vectors of condi-
tions variables and constants are used for the cooler modu-
lus.

The preheater modulus is calculated as a static model. It
consists of 16 linear equations - for a preheater tower with
4 cyclones.

6 for chemical reations of minor components
1 for the calciner process
1 for the recarbonatisation
1 for the mass balance per cyclone
1 for the heat balance per cyclone

Approx. 65 different condition variables, vectors of condi-
tion variables and constants are used for the preheater mo-
dulus.

6. Limitations of the Model

As the model is made for real-time process simulation of the production process of cement it has been necessary to limit the calculation time most possible; it is, therefore, chosen to avoid iterations between the values of the condition variables where ever this can be done securely, for instance is the common interface over the preheater modulus and the kiln modulus not iterated. The kiln modulus is calculated with the previous interface of the time step towards the preheater as regards the quantity, temperature and composition of the raw meal. In contrast the preheater modulus, which is calculated after the kiln modulus, has just the calculated interface to the kiln. This can be defended with the fact that the materials residence time in the preheater modulus is much less than the residence time in the kiln. It is with the same argumentation that the preheater modulus is calculated stationary.

This compared to the simplifications which are necessary to model such a complex process as the production process of cement does; that a precise predictive destination of the process parameter should not be expected when speaking of a specific process. But at the same time it should be mentioned that it is succeeded to create a model which, when speaking of a general process of cement production, gives exceedingly realistic results. Both regarding steady state results and regarding response to the changes of the process parameters.

7. Implementation

For simulation of kiln processes a HP 1000 A900 series computer used. The simulator is a part of a greater software package developed by FLS Automation Division for process control. Which means that the execution of the simulator programmes is carried out by the already exsisting real-time task handler called Splice, which is also a part of the SDR-system, while the SDR-system is used for control of the values of the "process" simulator. The simulator environment is shown on fig. 5

The SDR-system.

The SDR-sytem has three main functions.

Supervision of process signals, analogue as well as digital.

Dialogue between the operator and the process.

Reporting of process signals, alarm grapfics, etc.

For these purposes points in which the process signals are used can be treated. The SDR-system operates with three types of points. A-points for the analogue signals, B-points for digital process signals and C-points in which some typical calculations for both A and B point signals can be carried out.

To the SDR-system one or more terminals are conducted but often these are only used for more superficial changes in the system.

OPstation.

In a typical control system an OPerator STATION is used to communicate between operator and process.

At this station, in assistance to control of the process, the operator has mimic diagrammes which show machinery belonging to a department for instance the kiln department at his disposal. To the mimic diagramme some dynamic spots which show chosen A, B and C spots are connected, either as numeous values, as colours or both.

From these mimic pictures, the operator can control set points and start or stop the machinery, remove alarms etc. A number of mimic pictures is shown on fig. 6, 7 and 8.

The instructor console.

The simulation programmes mainly consist of three moduluses.

One modulus which take care of the communication between the instructor and the simulation via the database.

One modulus which take care of the communication between the SDR-system and the simulation.

The simulation itself.

The SDR-Simulator system is shown on fig. 9

From the first modulus TICOM following functions are carried out:

a) Start and stop of the simulation

b) Production situations should be kept for later use (7 situations all together can be kept)

c) Generation of errors at set points, analogue points and in the process itself.

The other modulus TRUN transfer the values from the set points of the SDR-system to the variables of the simulation programmes; and further it transfers the calculated analogue values to the A-points of the SDR-system. Further, errors of set points and analogue points are implemented here.

The third part is already discussed.

8. Disturbances

The following disturbances or interruptions are implemented at the kiln simulator:

Set-points:
Disturbances can be introduced to the single set-points in order to make a difference between the set-points which are used for the calculation of the process values of the model and the set-points put in by the operator. Offset errors or set-points may go quickly or slowly towards zero.

Analogue points:
Disturbances can be introduced to single A-points in order to make a difference between the values the operator can read from the mimic-diagrammes and calculated values. Offset errors or A-points may go quickly or slowly towards zero.

Air seal leakage changes:
False air can be added to the system at all air seals - at the buttom of each cyclone, by front and backside of the kiln etc.

Cylone blockage:
The third stage downcomer in the cylone tower can be jammed - this will reduce the flow of material and make an accumulation in the cyclone.

Kiln hot spot:
Falling down of insolation in the kiln can be simulated.

Kiln crust loss:
Crust loss in the heated end of the kiln can be simulated.

Kiln ring formation:
Ring formation in the cold end of the kiln can be simulated.

Engine error:
Engine error like motor stop by means of error introduced in

the PLC programmes can be simulated.

Further, the chemical and physical qualities of the raw meal and the fuel can be changed.

The errors can be introduced one by one or as many as requested can be introduced at one time.

9. Process values from simulation sessions

Figure 10-14 illustrates a number of curves showing the value of some of the calculated A-points. These curves are taken from the OPstation. All sessions are simulated on the kiln simulation model shown on fig. 6 to 8 - an In Line Calciner kiln with grate cooler.

The curves shown on the figures 10 to 13 are all from the same simulation, the kiln is in this simulation running in a stable condition, there has been no changes in set-points values and no disturbances has been introduced. The variation of the A-points values are all due to a random fluctuation of the kiln fuel feed rate at 5% around the set-point value of the fuel feed rate.

Figure 14 shows the variation of some of the A-points after a crust loss in the hot end of the kiln, where nothing has been done to suppress the effect of the crust loss.

10. Conclusion

As it appears from above the CEMulator is a comprehensive and rather complex mathematic model based on physical and chemical condition equations though a few empirical models are included where the necessary simplifications have made it impossible to make a direct calculation.

The result is a simulator which can be adjusted to existing building and production levels of cement kilns and which react to process changes and interuptions analogical to how the real cement production process reacts. And a simulator where the operator communication is the same as used at existing plants.

Apart from the above described models of the cement kiln process a simulator model of a vertical mill (raw mill) has been made, and a simulator model of a pipe mill (cement mill) is being made. It is not planned that the simulator model of the raw mill, rotary kiln and the cement mill respectively are to be connected to a joint unit but on the contrary that they are to be simulated as individual units.

The CEMulator is a tool which is specially qualified for e-
ducation of new and training of experienced cement opera-
tors. As they via the CEMulator can be exposed to - and
learn to handle situations which under normal circumstances
could have very serious consequences.

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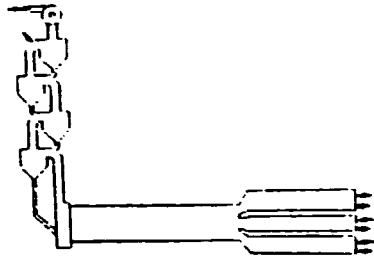
Fig. 1   Suspecion preheater kiln with planet cooler
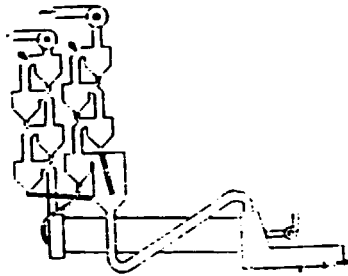
Fig. 2   Separate Line Calciner kiln with grate cooler
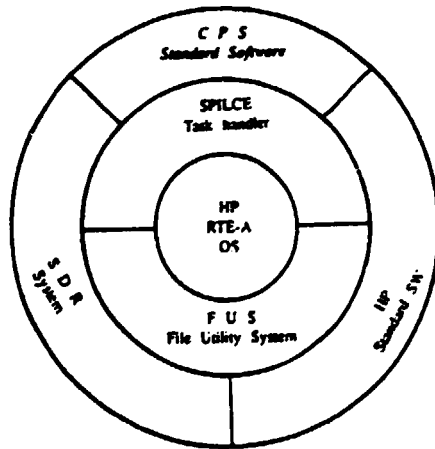
Fig. 5   Simulator software environment

16
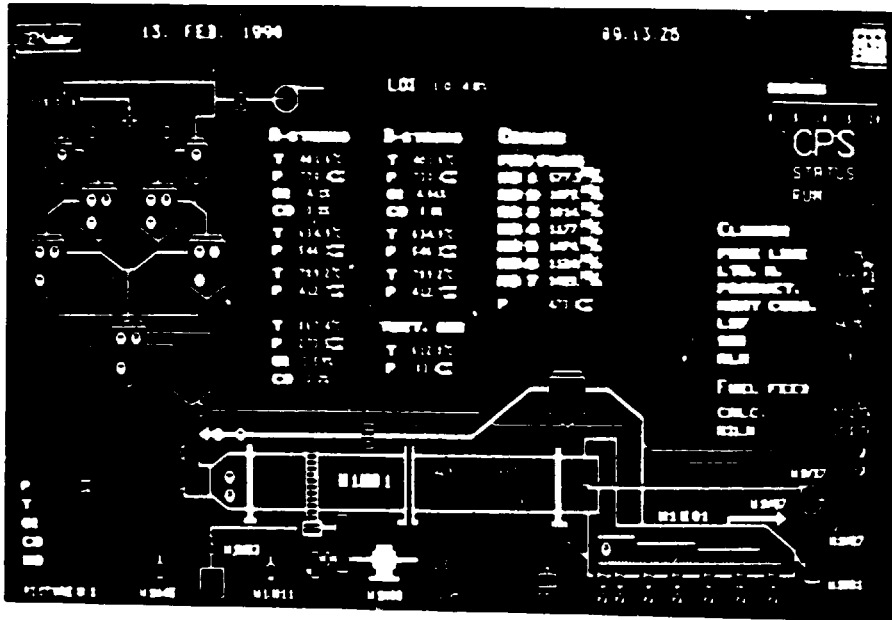
Fig. 6   Process mimic OPstation picture
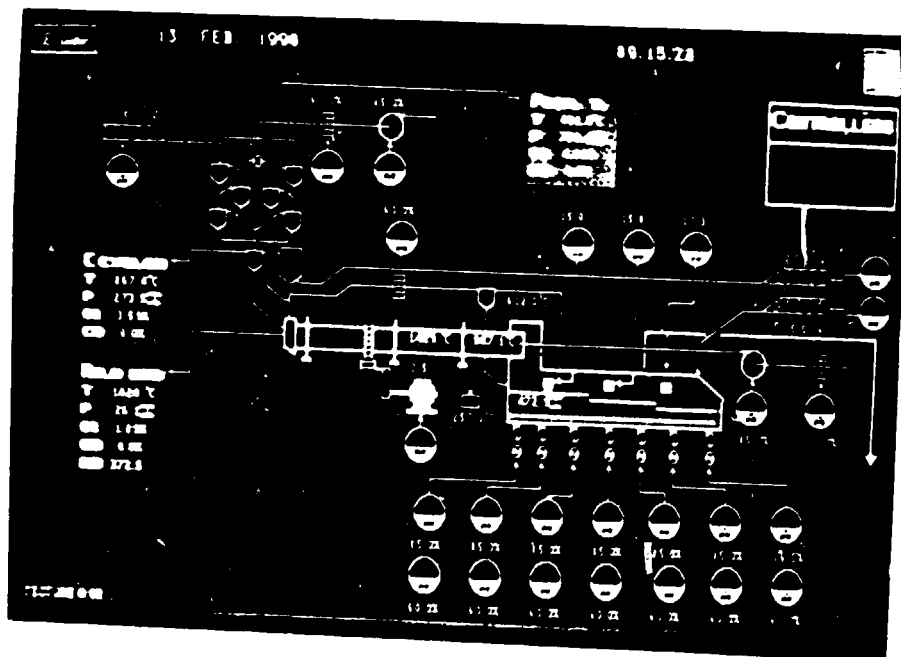
Fig. 7   Controller OPstation picture
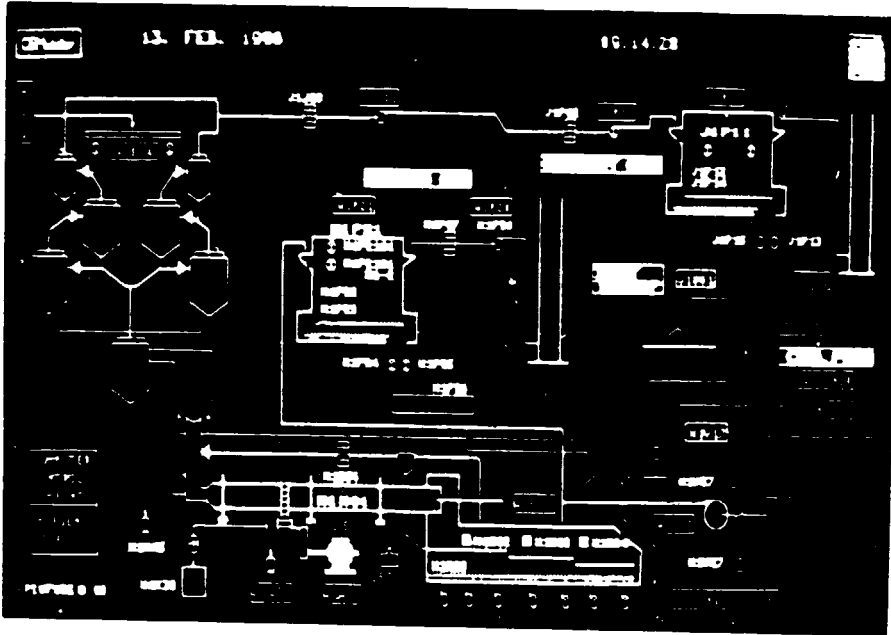
Fig. 8   Motor start-stop OPstation picture
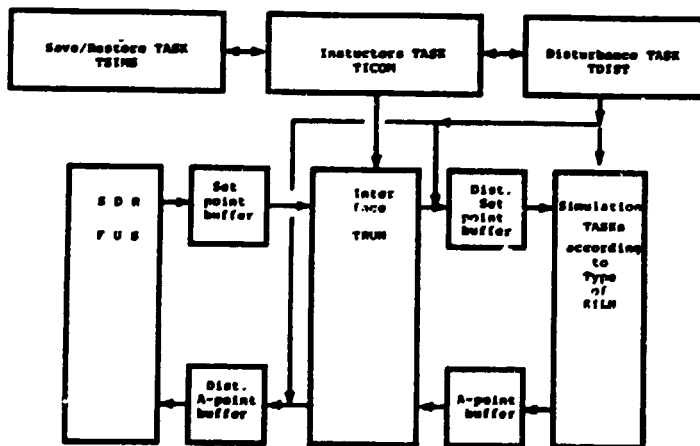
Fig. 9   SDR-Simulator system

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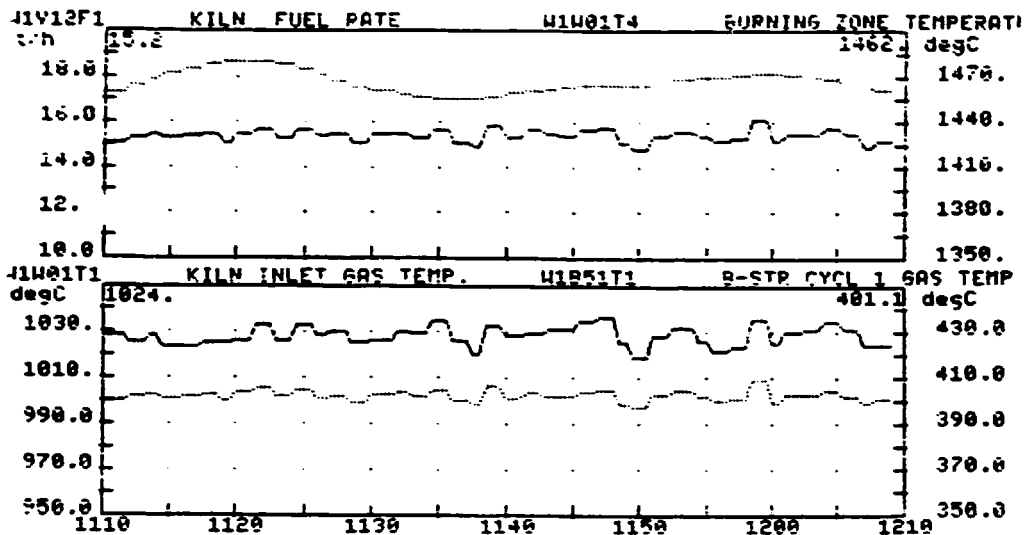
Fig. 10 Change of burning zone temperature, kiln inlet gas temperature and temperature of gas out of preheater tower at a kiln in stable state, where only disturbance is a random fluctuation of kiln fuel feed rate at 5% around set-point value.
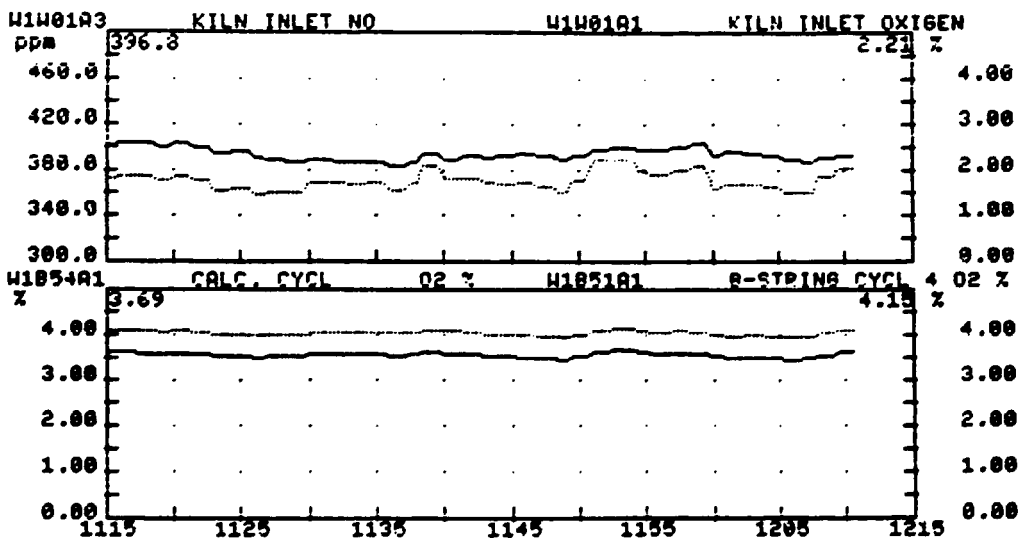
Fig. 11 Change of kiln inlet nitrogen-oxid, kiln inlet oxigen, oxigen in calciner cyclon and oxigen out of preheater tower at a kiln in stable state, where only disturbance is a random fluctuation of kiln fuel feed rate at 5% around set-point value.

19
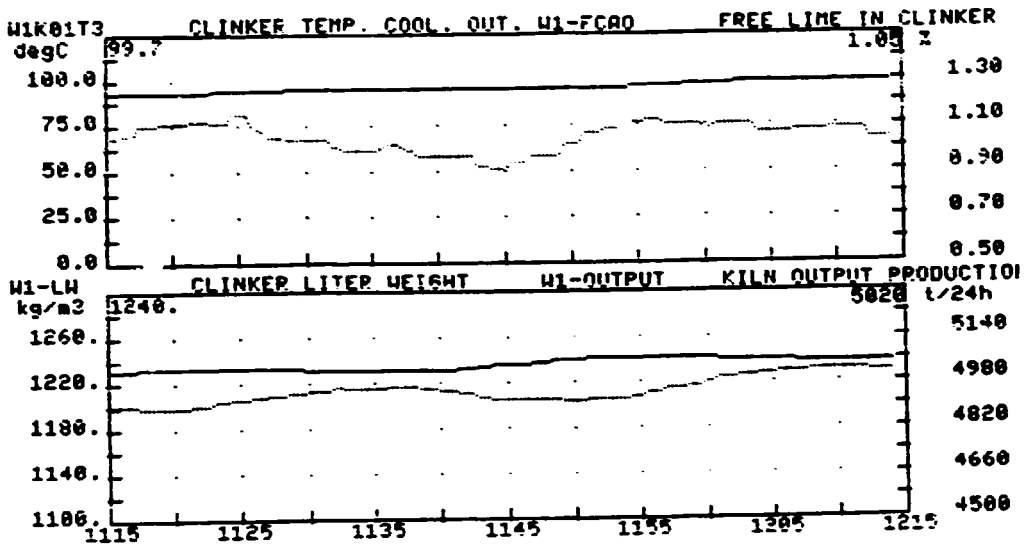
Fig. 12   Change of clinker temperature, free lime in clinker, clinker litre weight and clinker production, all measured at cooler output, at a kiln in stable state, where only disturbance is a random fluctuation of kiln fuel feed rate at 5% around set-point value.
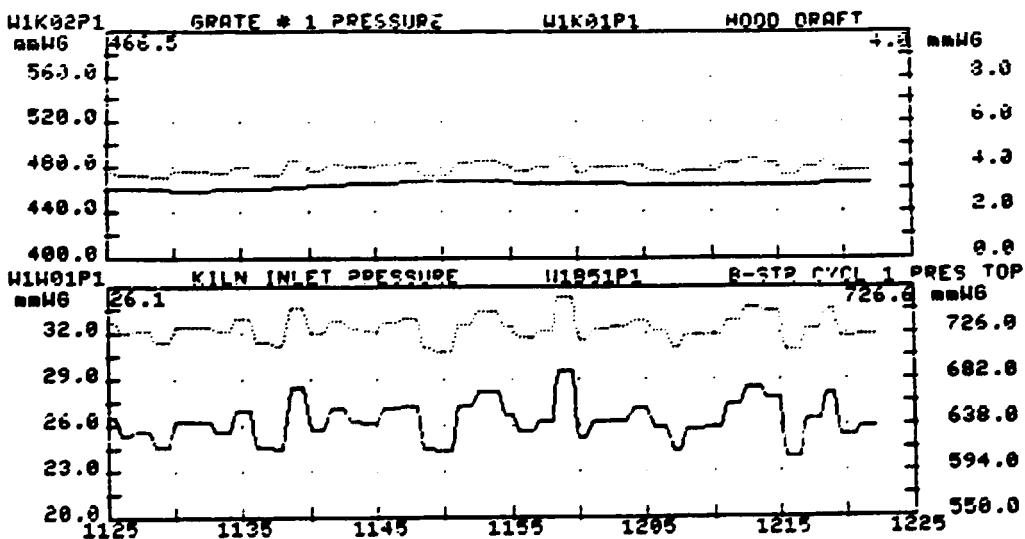
Fig. 13   Change of over pressure under 1th grate in grate cooler, under pressure in kiln hood, under pressure in backend of kiln and under pressure after preheater tower before ID fan, at a kiln in stable state, where only disturbance is a random fluctuation of kiln fuel feed rate at 5% around set-point value.

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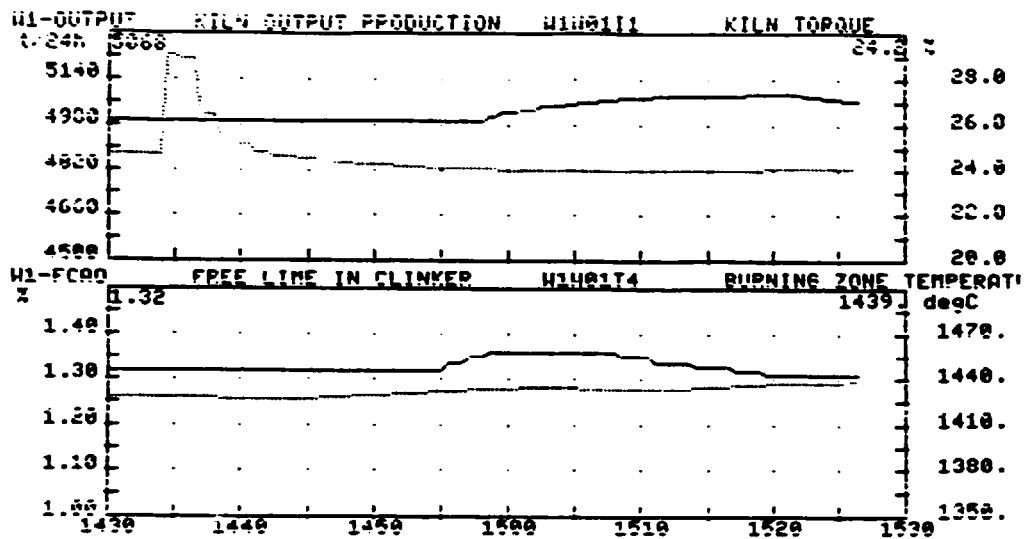
Fig. 14   Change of clinker production measured at cooler
output, kiln torque, free lime in clinker measured
at cooler output and burning zone temperature, at a
kiln in stable state, where the only disturbance is
a crust loss introduced at 2:34 pm in the hot end
of the kiln, and where nothing has been done to
suppress the effect of the crust loss.

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Reference list.

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[7]   Fei, Peng: "Mathematisches Modell zur Beschreibung des Termichen Verhaltens des Zyklonvorwärmers", VDZ-Kongress, 450-454, 1985

[8]   Ames, W.F.:   "Numerical Methods for Partial Differential Equations", Academic Press, 1977

[9]   Christensen, N.H.: "Burnability of cement raw mixes at 1400 deg. C, II The effect of the fineness" F.L. Smidth & Co., 1978

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NCB INDIA. TRAINING PROJECT

FINAL REPORT

Appendix No. 3

Project DP/IND/84/020
"Strengthening of NCB Capabilities in
Productivity Enchancement of Cement Industry"

Project Component (Subcontract IV):
Process Optimization in Cement Plants for Productivity Improvement

NCB INDIA, TRAINING PROJECT

Febr. 4 - April 20, 1991
Programme

WEEK	LECTURE	VOLUME	SUBJECT
1 Feb.4-8, 1991	VII.1-4.1-1.1	1	FLS's Kiln Programme including preheaters and precalciners Kiln systems
	I.1-3.0-8.1	1	Combustion and combustibles burner installations
	13.6	1	International Cement Production Seminar Gas analysis equipment
2 .cb.11-15, 1991	VII.2-4.1-5.0	1	NO_x as control parameter Relationship between cement kiln operation and content of NO_x in kiln exit gases
	IV.2.0.0.-1.0	1	Calculation of mass, gas, heat and energy balances Gas balances, general theory
	IV.2-0.0-7.0	1	Calculation of mass, gas, heat and energy balances False air determination and calculation
	IV.2-0.0-2.0	1	Calculation of mass, gas, heat and energy balances General measurements and calculations for determination of gas and air flows
		1	F.L.S. Comminution Manual
3 Feb.18-22, 1991	13.11	1	International Cement Production Seminar. CEMulator - A real time simulator for training of cement operators
3	13.8	1	International Cement Production Seminar. Process simulation and operator training

NCB INDIA, TRAINING PROJECT

WEEK	LECTURE	VOLUME	SUBJECT
2 Feb.11-15 1991	IV.4-4.0-4.1	2	Calculation of mass, gas, heat and energy balances
			Influence of operating parameters on heat consumption for preheater kilns
3 Feb.18-22, 1991	IV.4-4.0-1.1	2	Calculation of mass, gas, heat and energy balances. Heat balances
	IV.4-4.0-1.0	2	Calculation of mass, gas, heat and energy balances
			Heat balances in kiln systems
			Examples
	IV.4-4.0-1.0	2	Calculation of mass, gas, heat and energy balances
			Heat balances in kiln systems
			Case study
		2	Introduction to Sharp Personal Computer PC - 6200
			Operation Manual
		2	Case study using F.L.S.-computer programmes
		2	Evaluation of previous kiln examinations using F.L.S.-computer programmes
			Case study
4 Feb.25 - Mar.1,1991		2	Preparation for plant visit to United Kingdom
5-6 Mar.4-15, 1991			Carry out a thorough examination covering the clinker burning process from kiln feed to clinker transport
7-8-9 Mar.18 - Apr.5,1991		2	Represent a complete evaluation of the kiln and cooler performance
10 Apr.8-12, 1991		2	Example of a complete evaluation of the kiln and cooler performance

NCB INDIA, TRAINING PROJECT

WEEK	LECTURE	VOLUME	SUBJECT
4 Feb.25.- Mar.1,1991	VII.1-4.0-2.0	3	Process description and process control F.L.S.'s cooler programme Cooling of clinker Clinker coolers
		3	Evaluation of previous cooler examinations Case study
11 Apr.15-19, 1991	5.14	3	International Cement Production Seminar Waste heat
	15.1	3	International Cement Production Seminar Energy savings in the cement industry
	5.4	3	International Cement Production Seminar Kiln conversion from wet process to more efficient processes

NCB INDIA. TRAINING PROJECT

FINAL REPORT

Appendix No. 4

Project DP/INϽ/84/020
"Strengthening of NCB Capabilities in
Productivity Enchancement of Cement Industry"

Project Component (Subcontract IV):
Process Optimization in Cement Plants for Productivity Improvement

FLS F.L.SMIDTH

Plant Services Division

NCB INDIA. TRAINING PROJECT

Programme for February 4.and 5. 1991
REVISED

HOURS	ACTIVITY		Action
	Monday, February 4, 1991		
14.00	Pick up at Kastrup Airport arr.by SK 632		HBN
	Transport to Hotel Vestersøhus,Vester Søgade 58		
20.00	Pick-up at Hotel, dinner at the		HBN
	restaurant Indian Palace		
	Tuesday, February 5, 1991		
9.00	Pick-up at Hotel Vestersøhus		HBN
9.15	Arrival at F.L. Smidth Head Office		
		Room No.	
9.30	FLS Photographer	B 010	JMi,HBN
10.15	Official wellcome	E 23	MSP
	Presentation of FLS Slide Show		
	and FLS film "Working Worldwide"		
11.15	Introduction to the lecturer	E 23	P G-A
12.00	Lunch	FLS-Cafe	MSP,HBN
13.00	Presentation of lecture room	E 115	P G-A,HBN
	and discussion of programme		
16.00	Accompanied to Hotel Vestersøhus		HBN
	and how to find the Hotel by		
	public transportation		

Hanne Bang Nielsen
Seminar Director

NCB INDIA. TRAINING

Programme for visit to Aalborg
April 8 – 12, 1991

HOURS   ACTIVITY

Monday, April 8, 1991

9.00   Dep. Copenhagen Central Station
            platform No.5 by Inter City train No. IC 129
            waggon No.10, seats Nos.45, 46 and 47.

15.40   arr. Aalborg Central Station and received by
            representative from Aalborg Ciserv International

            Aalborg Ciserv International A/S
            Gasværksvej 24
            9100 Aalborg
            telephone No. 98 - 163333
            fax No. 98 - 163022

            staying at

            Slotshotellet
            Rendsburggade 5
            9000 Aalborg
            telephone No. 98 - 101400
            fax No. 98 - 116570

Tuesday, April 9, 1991

9.00   Pick-up at the Hotel.

9.00- 9.30 Meetings and lectures at Aalborg Ciserv Intl.
            Visit to cogeneration installation being constructed
            at Aalborg Portland Cement Factory

Wednesday, April 10, 1991

9.00	Pick-up at the Hotel.
9.00-10.00	Introduction to visit at Reno Nord, Aalborg
10.00-12.00	Visit to Reno Nord
12.00-13.00	Lunch
13.00-16.00	Visit continued
16.00	Return to Hotel

Thursday, April 11, 1991

8.00	Pick up at the Hotel
8.00-10.00	Driving to Horsens
10.00-12.00	Visit to Horsens Power Generating Station
12.00-13.00	Lunch
13.00-14.30	Driving to Nybro
14.30-16.00	Visit to Natural Gas-treatment Plant at Nybro
16.00-	Driving to Slagelse

Staying at Hotel in Slagelse

Friday, April 12, 1991

9.00-12.00	Visits to Power-generationplant Slagelse and to Waste-incineration Plant at Slagelse
12.00-13.00	Lunch
13.00-	Driving to Copenhagen, Hotel Vestersøhus

Hanne Bang Nielsen

NCB INDIA. TRAINING

Programme for April 19, 1991
ITINERARY for returntravel.

HOURS	ACTIVITY	ACTION
	Friday, April 19, 1991	
9.00	Pick up at Hotel Vestersøhus for sightseeing and shopping	SW
12.00	Lunch at FLS cantine B	SW, P G-A
13.00	Meeting for summaries and conclusions at MSP's office	P G-A, MSP
15.00	Packing and final collection of papers.	
18.30	Pick up at Hotel, dinner at the restaurant INDIA PALACE H.C. Andersens Boulevard 13	MSP, P G-A
	Saturday, April 20, 1991	
8.30	Pick up at the hotel for Kastrup Airport	SW
10.25	dep. Copenhagen by LH 1349	
11.50	arr. Frankfurt	
13.25	dep. Frankfurt by LH 760	
	Sunday, April 21, 1991	
0.40	arr. New Delhi	
	Monday, April 22, 1991 (mr. Murthy Rao only)	
16.00	dep. New Delhi by IC 839	
18.00	arr. Hyderabad	

Hanne Bang Nielsen

F.L.SMIDTH

NCB INDIA. TRAINING PROJECT

FINAL REPORT

Appendix No. 5

**Project DP/IND/84/020
"Strengthening of NCB Capabilities in
Productivity Enchancement of Cement Industry"**

**Project Component (Subcontract IV):
Process Optimization in Cement Plants for Productivity Improvement**

Plant:	Country:	Order No.:	
			NCB/PBM
Castle Cement, Ribblesdale	England	90-100.437	9176PSO

Plant visit from March 4 to March 15, 1991

Introduction:

Castle Cement, Ribblesdale plant, was visited from March 4 to March 15, 1991, with an aim to evaluate the performance of kiln no. 7 through thermal energy balance as part of training on optimisation of kiln and cooler at F.L.Smidth & Co.

The kiln no. 7 at Ribblesdale plant is of the ILC type, 4,15 x 58 m, with Folax cooler 824S. The rated capacity of the kiln is 2200 tpd. The preheater is a 4-stage preheater with twin cyclones in 1st stage and with an in-line calciner. Kiln had provision for by-pass up to 30% which has been permanently closed now. Most of the preheater gases are taken through the MPS roller mill.

Various measurements of process variables were carried out during the visit. A detailed heat balance followed by some comments and recommendations have been made.

As a whole, the plant is running very well. The degree of maintenance is appreciable.

Clinker weighing test:

A clinker weighing test was conducted on March 11, 1991, from 8.00 hrs to 20.00 hrs, for a duration of 12 hours.

Basis = 12 hours of operation.   t/12 hrs

Kiln feed, counter in panel   = 2181.0

   Kiln feed with 1% dust loss
   (assumed) = 2181 x 0.99   = 2159.0

H_2O in feed = 0.5%

LOI = 34.8%

Kiln feed to clinker = 2159 x 0.995 x 0.652 = 1400.0

   Coal ash   =   4.8
                                             ─────────
                                             = 1404.8

Plant:	Country:	Order No.:
Castle Cement, Ribblesdale	England	90-100.437

Clinker weighed = 1331.5

Loss during weight test

= 1331.5 x 0.01 (assumed) = 13.3

= 1344.8

Missing clinker = 1404.8 - 1344.8 = 60.0 t/12 h

This difference in calculated and weighed clinker is 4.3%, which corresponds to

$$\frac{60}{0.652 \times 0.995} = 92.5 \text{ t/12 hrs of raw meal.}$$

t/12 hrs

Actual kiln feed used = 2159 - 92.5 = 2066.5

Kiln feed to clinker

= 2066.5 x 0.995 x 0.652 = 1340.6

Coal ash = 4.8

= 1345.4

1% loss in weight test = -13.3

= 1332.1

$$\frac{\text{Clinker}}{\text{Raw meal}} = \frac{1345.4}{2066.5} = 0.651$$

But the clinker to raw meal factor used by plant is 0.630.

The difference in calculated and weighed clinker is 60 t/12 hrs which corresponds to 92.5 t/12 hrs of raw meal. This shows that there is an error of 4.3% in feed counter. Therefore there is a need for calibration of kiln feed load cells.

Plant:	Country:	Order No.:	
Castle Cement, Ribblesdale	England	90-100.437	NCB/PBM 9176PSO

Dust weighing test

About 9 different measurements on dust collection were carried out on March 5, 1991, and on March 6, 1991, when the raw mill was stopped and when it was running, respectively.

Kiln feed = 170 tph   Kiln feed = 170 tph
Raw mill = on   Raw mill = off

S.no	Dust(tph)	S.no	Dust(tph)
1	13.8	1	13.46
2	12.4	2	18.00
3	11.8	3	16.40
4	11.7	4	17.32
5	11.6		
$\bar{x}$	12.3	$\bar{x}$	16.30

The above measurements show that there is a dust loss of 9.6% without raw mill and 7.2% with raw mill running. Though according to plant personnel, total dust is fed back to kiln, we found due to the dust transport lay-out that same amount of dust is going back to the CF silo. It is estimated to be 1%.

Heat consumption based on coal weight test

S.no	Kiln	Calciner
1	3.870	5.960
2	3.720	6.010
3	3.650	5.660
4	3.300	5.840
$\bar{x}$	3.634	5.868

Coal to kiln   = 3.634 tph

Coal to calciner = 5.868 tph

Total   = 9.502 tph

Heat value of coal = 7962 kcal/kg coal.

$$\text{Heat consumption} = \frac{9.502 \times 1.15 \times 24 \times 0.96 \times 7962}{2689}$$

$$= 745.5 \text{ kcal/kg clinker}$$

Plant:	Country:	Order No.:
Castle Cement, Ribblesdale	England	90-100.437

The heat consumption calculated above is 745 kcal/kg clinker. This is the heat from coal only. In the calculation of actual coal consumption, a factor of 1.15 is used in order to adjust the stock of raw coal. This factor is used by plant people also in their calculations.

Measurements in preheater

Process conditions were measured on March 11, 1991. Enclosure 1 shows the measurement details. Kiln condition during the measurement was as follows:

Kiln feed	= 182 tph
Clinker (from weight test)	= 2689 tpd
Coal consumption:	
Kiln	= 4.18 tph
Calciner	= 6.75 tph.

Temperature differences (ot's) between different stages in preheater are as follows:

Cyclone 1-2	= 207.5°C
Cyclone 2-3	= 171.0°C
Cyclone 3-4	= 79.0°C

There is a difference of 52°C between the two top cyclones. As it is not possible to distribute the feed exactly between the 2 cyclones, some difference in temperature always is seen. The present difference of 52° will have only little influence on the temperature of material leaving top cyclones.

The temperature after preheater is 410°C which is high. This can be attributed to the presence of combustibles in raw meal.

The ot between cyclones 3 and 4 is 79°C only. This is because of low residence time in calciner due to high production and because of improper mixing of coal and air in the calciner.

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The pressure drops over cyclone stages are as follows:

Cyclone 1 + outlet	= 228 mm WG
Cyclone 2 + riser	= 152 mm WG
Cyclone 3 + riser	= 170 mm WG
Cyclone 4 + calciner	= 205 mm WG

The pressure drop in the preheater system is on the higher side due to the high production. The kiln was running at 22% higher than its rated capacity.

The oxygen level in the preheater is kept to the minimum. This also shows that the false air is minimum. The presence of CO at various locations is due to the combustibles in the raw meal.

The degree of calcination is 84% as calculated from LOI of kiln feed and LOI of material leaving the 4th cyclone. The temperature of 878°C in the 4th cyclone is high for this degree of calcination.

Material pipe from cyclone 3 is split into two, one going to the calciner and the other going to the riser duct as shown in enclosure 2. It was observed that occasionally the material flow to the kiln riser pipe from cyclone 3 was very small, which is confirmed by the high temperature of 995°C shown in the enclosure. It is advantageous to have more material flow to riser pipe from cyclone 3 to prevent blockage of riser pipe due to high temperature.

It was also observed that more material from cyclone 4 than normally was recirculated to the calciner by the kiln gases. This is due to side intake of material to the kiln.

In the calciner, process conditions were measured at 2 different locations along the circumference. There is a difference of 4.8% in the O_2 level between the two locations. This is due to one measuring point being located near the coal entrance to calciner. This also shows that the mixing of air and coal is not perfect in the calciner.

Primary air measurement

Pitot measurements on primary air to kiln burner were carried out on March 7, 1991.

Diameter of pipe	= 0.243 m
Area = A	= 0.0462 m²

Plant:	Country:	Order No.:
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P_d = 104.3 mm WG

P_s = 655 mm WW

Temperature = 20.8°C

Density of air = 1.275 kg/m³

Velocity = V = $4.43 \dfrac{104.3}{1.275}$ = 40.06 m/s

Quantity = q = AV = 0.0462 x 40.06 x 1.275

= 2.369 kg/sec.

= 0.076 kg/kg clinker

Diameter of nozzle = 0.195 m

$V_{nozzle} = 40.06 \times \dfrac{0.243^2}{0.195^2}$ = 62.2 m/s

Primary air = 18.9% of L_{min}

Airlift for kiln feed

Compressors = 2 x 70.0 m³/min. at 14°C

Sp. weight = 1.23 kg/m³

Air to airlift = 140 x 1.23 = 172.2 kg/min.

$= \dfrac{172.2}{60}$ = 2.87 kg/s

At a production of 2689 tpd airlift air

$= \dfrac{2.87 \times 24 \times 3600}{2689 \times 1000}$ = 0.092 kg/kg clinker

Plant:	Country:	Order No.:	
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Radiation from kiln and preheater

Radiation from preheater is shown in enclosure 3.

	tcal/h	kcal/kg
Cyclone 1	740	6.6
Cyclone 2	289	2.6
Cyclone 3	481	4.3
Cyclone 4	399	3.6
Calciner	482	4.3
Riser	155	1.4
Tertiary air duct	779	7.0
Total	3325	29.7

Radiation from kiln

Enclosure 4 gives the calculations for radiation from kiln.

Radiation from kiln = 39 kcal/kg clinker.

Radiation loss from preheater and kiln are within normal range.

Measurements in cooler

Measurement of excess air in cooler stack was carried out. Only one measurement was taken because of problems with heavy tube used for Pitot measurement and due to the location of measuring point.

Hot air from cooler and excess air from cooler were measured on March 11, 1991, over 30 min. Enclosure 5 shows the trends of these temperatures with time.

Production   = 2689 tpd

Frequency of measurement   = 1 min.

Duration   = 30 min.

Tertiary air temperature   = 792°C

Excess air temperature after cooler = 242°C

Temperature of excess air in chimney = 217.6°C

Plant:	Country:	Order No.:
Castle Cement, Ribblesdale	England	90-100.437

Specific weight	$= 0.7175$
P_d	$= 7$ mm WG
P_s	$= -5$ mm WG
D	$= 2.63$ m; A $= 5.43$ m²
Quantity	$= 53.9$ kg/s

According to 2493 tpd of clinker production on the day of measurement

Quantity	$= 1.868$ kg/kg clinker

But for use in the heat balance, the excess air quantity has been derived at using the heat balance on cooler in the following way.

Calculation of excess air from cooler:

Energy supply to cooler:	Kcal/kg clinker
Air: X x 16 x 0.237	$= 3.8$ X
Clinker: 1 x 1400 x 0.262	$= 366.2$
Clinker dust: 0.15 x 1400 x 0.262	$= 55$
Total heat in	$= 421.2 + 3.8$ X

Energy out of cooler:

Air to calciner considering false air: 0.878 x 792 x 0.255	$= 177.3$
Clinker: 1 x 120 x 0.192	$= 23.1$
Air to kiln: 0.345 x 0.26 x 1000	$= 89.7$
Excess air: (X - 1.223)0.243 x 242	$= 58.8$ X-71.4197
Dust: 0.15 x 1000 x 0.24	$= 36$
Radiation	$= 7$
Total out	$= 58.8$ X + 261.18

Plant:	Country:	Order No.:
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$$X = \frac{421.2 - 261.18}{55} = 2.909 \text{ kg/kg clinker}$$

Assuming 10% ineffective air

$$X = 2.909 \times 1.1 = 3.2 \text{ kg/kg clinker}$$

Excess air = 3.2 - 1.2235 = 1.977 kg/kg clinker.

Air balance on cooler

Secondary air to kiln:

Heat consumption	= 285 kcal/kg
Excess air	= 10%

Air to kiln:

$0.3265 \times 0.873 \times 1.226 \times 1.348$	= 0.471 kg/kg clinker
Primary air	= -0.076 kg/kg clinker
False air in hood (estimated)	= -0.050 kg/kg clinker
secondary air from cooler	= 0.345 kg/kg clinker

Air to calciner:

$0.6735 \times 0.873 \times 1.333 \times 1.343$	= 1.05 kg/kg clinker
Airlift air	= -0.092 kg/kg clinker
False air in preheater	= -0.080 kg/kg clinker
tertiary air from cooler	= 0.878 kg/kg clinker

Escess air from cooler	= 1.977 kg/kg clinker

Plant:	Country:	Order No.:
Castle Cement, Ribblesdale	England	90-100.437

Standard cooler loss

Excess air:

Kcal/kg

$1.977 \times (242 - 12) \times 0.243$ $= \overline{110.50}$

Clinker: $1 \times (120 - 12) \times 0.19$ $= 20.50$

Radiation $= 7.00$

$= 138.00$

Dust circulation:

$0.15 \times 1400 \times 0.262$

$- 0.15 \times 1000 \times 0.24$ $= 19.00$

$= 157.00$

Quantity of air out of preheater

	Nm^3/kg cl	kg/kg cl
1. Kiln		
$0.3265 \times 0.873 \times 1.226$	0.350	
0.35×1.348		0.471
2. Calciner		
$0.6735 \times 0.873 \times 1.333$	0.784	
0.784×1.343		1.050
3. From CO_2	0.278	0.550
4. Water in raw mix		
$\dfrac{0.5}{100} \times \dfrac{100}{100-34.8}$		0.0077
	1.4215	2.0787

Plant:	Country:	Order No.:
Castle Cement, Ribblesdale	England	90-100.437

$$_0 = \text{specific weight} = \frac{2.0787}{1.4215} = 1.462 \text{ kg/Nm}^3$$

$$= 1.462 \times \frac{273}{273 + 410} = 0.5845 \text{ kg/m}^3$$

$$\text{Total quantity of air} = \frac{2.0787 \times 2689 \times 1000}{24}$$

$$= 232.901 \text{ kg/hr}$$

MATERIAL BALANCE

Heat consumption = X kcal/kg clinker	IN	OUT
Clinker		1.00
Coal ash A	$- 0.0048 \times 10^{-3} \, X$	
Raw mix to clinker B	$1.5337 - 0.0074 \times 10^{-3} \, X$	
CO_2 from raw mix D		$0.5237 - 0.00253 \times 10^{-3} \, X$
Free water from Rm	$7.707 \times 10^{-3} - 37.186 \times 10^{-9} \, X$	$7.707 \times 10^{-3} - 37.186 \times 10^{-9} \, X$
Comb. H_2O from Rm		$10.276 \times 10^{-3} - 49.58 \times 10^{-9} \, X$
Diff.		$-0.0003 - 0.00004958 \times 10^{-3} \, X$
	$1.5414 - 0.00264 \times 10^{-3} \, X$	$1.5414 - 0.00264 \times 10^{-3} \, X$

Plant:	Country:	Order No.:	NCB/PBM
Castle Cement, Ribblesdale	England	90-100.437	9176PSO

INPUT HEAT BALANCE

	°C	kg/kg	kcal/kg°C	kcal/kg
Fuel				X
Free heat	16	$\dfrac{x}{7643.5}$	0.237	0.0005x
Primary air	20.8	0.076	0.237	0.4
Rest	16	$-0.076+1.693 \times 10^{-3} x$	0.237	$-0.292+6.42 \times 10^{-3} x$
Grate cooler	16	1.977	0.237	7.50
Raw feed	89 410	1.536– 0.016	0.215 0.241	27.8

$$35.41+1.0069x$$

OUTPUT HEAT BALANCE

	°C	kg/kg	kcal/kg°C	kcal/kg
Combustion products	410		0.229	0.229x
CO_2 from raw meal	410	$0.524-0.00253 \times 10^{-3} x$	0.237	50.9–0.003x
Vapour from free water	410	$0.0077-0.00004 \times 10^{-3} x$	0.464	$1.465-0.0076 \times 10^{-3} x$
Vapour from comb. water	410	$0.0103-0.00005 \times 10^{-3} x$	0.464	1.96–0.00001 X
Dust	410	0.115	0.24	11.3
Radiation	Kiln Preheater			39 28

Plant:	Country:	Order No.:	
Castle Cement, Ribblesdale	England	90-100.437	NCB/PBM 9176PSO

Cooler loss:

	°C	kg/kg	kcal/kg°C	kcal/kg
	--	-----	---------	-------
Heat in clinker	120	1.0	0.193	23.2
Radiation				7.0
Excesss air	242	1.977	0.243	116.26
Heat of formation				387.0

				666.08+0.266x

$35.41 + 1.0069x = 666.08 + 0.226 \ x$

i.e. $0.7809x \quad = 630.67$

$\quad x \quad\quad = 807.62 \ kcal/kg$

Heat consumption based on coal weigh test is 745.5
kcal/kg cl. A factor of 1.15 is used in this calculation to
match the stock of raw coal. An overall heat balance taking
coal quantity as an unknown factor gives a value of 807.6
kcal/kg cl. By deducting the heat from combustibles in raw
meal, this quantity will be 685.6 kcal/kg cl, which is far
less than the heat consumption calculated from coal weigh
test. This gives an indication that the factor 1.15 is on
higher side.

Results of Simulation program.

The kiln simulation program with the measured data gives a
heat consumption of 679 kcal/kg cl excluding the heat from
combustibles and free heat. Results of the simulation pro-
gram are shown in enclosure 6.

Measurements in raw mill.

Measurements on raw mill circuit were carried out on 14.3.91
to find out the false air content at various locations. De-
tails of the measurements are given in enclosure 7.

It is clear that as compared to previous measurements car-
ried out in October 1989, the pressure drop at the mill in-
let duct has considerably reduced from (-120-170) = 150 mm
WG to (-40-105) = 75 mm WG.

The false air in the mill circuit is shown in enclosure 8.
As is evident, the false air between points 0 and 1 has in-
creased slightly as compared to the previous measurements of
1989. But across the rest of the mill circuit it is quite
low. Between points 6 and 7 it is zero. This indicates a
high degree of maintenance in the mill circuit.

Analysis of kiln feed and raw meal.

Enclosures 9 and 9A give average values and standard devia-
tions of LSF, SIM and ALM of kiln feed and raw meal respec-
tively. The standard deviations of kiln feed are perfect and
those of raw meal are of course higher, which indicates that
CF-silo is working well.

As it can be observed from enclosures 9 and 9A, the LSF of
kiln feed was lower on 5.3.91 when raw mill was off. The
reason for this is the amount and chemical composition
(lower LSF) of dust circulated when raw mill was off. The
slightly decrease in LSF from 97 to 95 had a positive effect
on kiln and cooler performance due to better nodulisation
and lower dust recirculation between kiln and cooler.

So we suggest that the set point on LSF be reduced to 95
and see the long time effect of the change on the process.

Plant:	Country:	Order No.:	
Castle Cement, Ribblesdale	England	90-100.437	NCB/PBM 9176PSO

On the basis of investigations in the plant during the visit, and based on the calculations it seems to be possible to improve the process conditions with certain minor modifications. In the following part of the report, the suggestions for different sections of the plant are included.

1. Checking and calibrating the kiln feed load cell.
2. Checking and calibrating the coal feeding system.

Preheater.

To avoid recirculation of material from kiln riser duct to material tube from 3rd cyclone, a flapper valve in the material tube is recommended.

A dividing gate under A53 to split the material between riser pipe and calciner will give a possibility of controlling the coating in riser pipe, reducing pressure drop etc.

As the by-pass provision is not being used, it may be eliminated and the material pipe from the cyclone 4 should be straightened to minimize recirculation of material between kiln riser and calciner.

If, in future, by-pass is needed it should be above and opposite side to the existing provision.

Coal to the calciner is fed at a single location through a single pipe. From the measurements made on calciner, it is clear that the mixing of air and coal is not perfect. To improve the mixing, the coal pipe to the calciner should be split into two, one going to the present location and the other to the opposite side of the present location along the circumference of the calciner. For example, this could be done by adding a FK pump to the existing hopper and measuring screw system.

Cooler.

Tertiary air temperature after cooler was varying often as shown in enclosure. To keep the deviations to a minimum, which also ensures improvement in calciner performance, a feed forward control in cooler is envisaged. To control the grate speed, in addition to the under grate pressure signal, a feed forward signal of tertiary air temperature after cooler has to be used. This improves cooler performance also.

NCB INDIA. TRAINING PROJECT

FINAL REPORT

Appendix No. 6

Project DP/IND/84/020
"Strengthening of NCB Capabilities in
Productivity Enchancement of Cement Industry"

Project Component (Subcontract IV):
Process Optimization in Cement Plants for Productivity Improvement

SUMMARY OF EQUIPMENT SHIPPED

Apollo Computer Hardware consisting of:

1 ps DN-4000 Apollo workstation, 4 MB memory, 155 MB harddisc,
     60 MB cartridge tape drive, 19" 8-bit plane color monitor

1 ps Upgrading harddisc to 348 MB

1 ps Additional 4 MB memory board

1 ps Versatec C2700 A3-plotter

1 ps UNIBOX interface

1 ps Facit matrix printer

1 ps Calcomp C9100 A0 digitizer incl. cursor

1 ps RS 232 interface for Apollo

1 ps Table for digitizer

1 ps Power supply

and

Additional Equipment

1 Portable velocity/flow measuring instrument for dust-laden
  gasses, type 4000 (Ultrasonic)

1 Dual trace oscilloscope, type Textronix

1 Portable microprocessor based gas analysis system for
  CO, CO_2, SO_2, NO_x, type Testoterm

1 Sequential blasting machine and seismograph system

which completes the order