CONTROL AND INSTRUMENTATION FOR MODERN COKE OVENS

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INTRODUCTION

The measurement of the temperature distribution within a coke oven battery has long been a problem for BSC and other coke producers and many possible solutions have been proposed, most of which have never progressed beyond the prototype stage. It is essential to know the temperature distribution throughout the battery in order to produce high quality coke consistently, to prevent damage to the fabric of the battery and to ensure the most efficient use of the fuel used for underfiring.

Two method of measuring battery temperatures have been developed at British Steel Corporation's Corporate Process Research Laboratories. One is an enhancement to the traditional method of flue block temperature measurement and the second is a technique which automatically measures the temperature of the coke as it is ejected from the oven.

Both of these techniques are being rapidly adopted on BSC's coking plants which are also introducing new methods of underfiring gas control which yield substantial energy savings when linked with the temperature measurement schemes mentioned above.

In addition the development and use of other simple instrumentation techniques have helped optimise coke production.

FLUE BLOCK TEMPERATURE MEASUREMENT

In order to produce coke of the correct and consistent quality it is necessary to optimise the distribution of the underfiring gas throughout the battery. This means that it is necessary to determine how the gas is being burnt in each individual flue and this has been traditionally done by measurement of the temperature of each burner block. A hand-held disappearing filament pyrometer was sighted on the burner block, adjusted to make the filament disappear, the reading noted and entered on a notepad.

Cross-Wall Temperatures and Battery Averages

The two most common forms of logging are cross-wall temperatures and battery average temperatures. In the former case all flues in a given wall are monitored and in the latter selected flues, usually two per wall, are logged for every wall in the battery.

In the case of cross-wall temperatures a cooling curve correction must be applied. This correction is necessary because gas is only burnt in any given flue for 30 minutes in each hour, the flue being used as a waste gas duct for the alternate 30 minutes, ie. at any one time 50% of the flues will be "on-gas" and 50% "off-gas". The changeover is known as reversal. The optimum time for taking a temperature reading is 10 minutes after reversal but it is obvious that all temperatures cannot be taken simultaneously and therefore a cooling curve is used to compensate for the time after reversal at which the pyrometer reading was taken. Thus it is also necessary for the operator to accurately note the time at which each individual temperature reading was taken.

As if this were not complicated enough, temperature readings can only be taken when walls are off-gas, as the flue cap has to be removed in order to sight the pyrometer on the burner block. This would be no real problem were a whole wall to be "on-gas" or "off-gas", but the way in which the oven walls are heated varies from one coke oven manufacturer to another and the usual patterns are either for alternate flues to be on- or off-gas or for inner or outer sets of flues to be on- or off-gas, the pattern of flues on- and off-gas usually alternating with alternate walls.

Thus what at first sight should be a simple measurement to take is complicated by:

a) a time consuming measurement technique
b) the need to compensate for the time at which the measurement was taken
c) the need to know which measurement to take next.

Similar problems exist with the measurement of battery averages.

Use of a Hand-Held Computer

On a typical coking plant if a flue block temperature reading could be taken every minute then it would take about 40 hours to make a complete set of profiles. It was therefore of paramount importance to speed up the measurement process. Nothing can be done about the need to remove and replace the flue cap but measurement could be speeded up if an automatic temperature sensing device were used. The Land/Minolta Cyclops 52 continuous radiation pyrometer was chosen because its antecedents were already in common use within BSC and it has an RS 232 port and is therefore capable of transmitting any measurement made directly to computer or microprocessor. The operator merely needs to sight the pyrometer on the burner block and pull the trigger for a measurement to be made. The temperature, as measured, is displayed at the bottom of the operator's field of view as he sights the device. Emissivity may be set to 1.0 as black body conditions essentially prevail for this measurement.

As the output can go direct to some form of data logging device then this eliminates the need for a notepad. However, the logging device needs to record the time of measurement and therefore must have time-of-day clock facility. If the logging system could also store fixed data, ie. the cooling curve, and could perform simple arithmetic, then this would eliminate the need for separate cooling curve correction. If it were fully programmable then customised software could be written for the measurement of Cross-Wall and Battery Average temperatures. For these reasons the Husky Hand Held Computer was chosen.

The system therefore covers all the requisites for an improved method of measurement mentioned in the previous section and is portable and suitable for use on battery top, as shown in Figure 1.

One obvious advantage once a programmable device has been chosen is that software can be produced which is configured to suit a particular coke oven battery. Thus the complexities of producing Cross-Wall and Battery Average data, as mentioned above, can be taken care of.

Figure 2 illustrates a typical screen display during a cross-wall logging sequence. The top display shows the options available to the operator - Relog (R), Jump (J), Nolog (N) and Endlog (E) - which may be used instead of taking a temperature reading. Also shown is the next flue to be logged. In the second display a temperature of 1245°C has been logged for flue 2, wall 2, battery 1 and the next temperature measurement is awaited. In the central display "Nolog" has been selected causing a menu of reasons for not taking a reading to be displayed. "Flame" in the flue is selected and displayed against flue 4, wall 2, battery 1 in the fourth display. Thus logging continues until a cross-wall, series of cross-walls or battery average run has been completed when "Endlog" is selected as in the bottom display.

The customised displays are used to steer the operator around the oven so that he does not lose track of which flues temperature have been measured, particularly where complex underfiring patterns are involved.

Output Devices

The Husky Computer has an associated printer. The hand held device is merely plugged into the printer and, again via screen requests, the operator instructs the machine to transfer the data. Software has been written to give output in tabular or graphical form as shown in Figure 3, and routines have also been written to transfer flue block temperature data to desktop and mainframe computers.

The system has now been widely adopted across BSC's cokemaking plants.

AUTOMATIC CROSS-WALL TEMPERATURE MONITOR

Although the above development has speeded up the data acquisition by a factor of 2 to 3 and ensured that all necessary data are collected and are corrected as required, it is still desirable to know the temperature of the coke being produced to ensure that carbonisation is correct.

It was decided, therefore, to attempt to measure the temperature of coke as it is ejected from the oven, the idea being that if it were possible to look into the fissures formed during carbonisation then a good correlation should exist between the position of the coke on the oven and wall (flue) temperatures and any necessary corrective action could be taken.

Initial trials in 1978 have led to the development and installation of the system on three of BSC's coking plants to date.

It soon became apparent that there would be three essential requisites for an automatic system:

a) that the temperature should be measured accurately and be a true reflection of the temperature of the coke.
b) that the temperature distribution should be related to the positions of the flues within the heating walls.
c) that the system would need to be kept cool and free from ingress of coke dust.

These led to the development of the three elements which form the system:

a) the pyrometers and housings
b) the electronics unit
c) the instrument services module.

Pyrometers and Housings

The pyrometers are a standard unit from a commercial manufacturer, giving an output of 0-5 V over the temperature range 700 to 1200°C, modified so that they view a very small object when sited at the optimum distance from the coke. The optics give a field of view of 3 mm for an object distance of 450 mm. Thus the pyrometer is viewing into the fissures created during carbonisation. This has the advantage that not only is the true temperature of the coke body recorded but problems with emissivity are overcome due to the black body nature of the cavity. The pyrometers are mounted in the coke guide at a slight angle, so as to prevent dust and debris ingress, and are also air purged to keep the lenses clean. A standard water cooling jacket is provided and the whole mounted in easily accessible environmental housings.

Generally, three pyrometers are used to give the vertical as well as longitudinal temperature distribution but there is no reason why more than this number should not be used if required.

Electronics Unit

The original electronics unit was of the rack mounted type, incorporating cpu, memory , I/O and peak picker cards and a time-of-day clock.

The function of the peak picker is to take the raw pyrometer output and to process this to produce temperatures which are representative of the variations in temperature across the oven. Various signal processing techniques were evaluated but that eventually choosen operates as follows. The peak picker circuit samples the pyrometer data continuously, retaining the peak temperature experienced. The computer retrieves this peak value every 100 milliseconds and stores all such readings over the duration of the push, which is typically 30 seconds. Thus, approximately 300 readings are stored for each pyrometer. The data are then divided into flue zone and a peak average temperature is evaluated, ie. say there were 300 readings and 30 flues, each block of 10 temperature readings would be averaged and related to its corresponding flue.

This was found to be more representative of true oven temperatures than a standard peak picking routine. An example of raw data and cross-wall output from early trials is given in Figure 4.

The function of the rest of the electronics is to time and date stamp the data, read the number of the oven being pushed, interface to lamps and alarms both for internal diagnostics and for monitoring of the functioning of the services module and to output the data to a suitable display device.

Due to maintenance problems with the original electronics unit a version using a single board microcomputer has now been devised. This unit, shown in Figure 5, is fitted to all later systems. The sbc is a standard unit and supports a separate four channel peak picker board which sits "piggy-back" on the mother board.

Services Module

This is a simple device suppling air purging and water cooling to the pyrometers and alarms via the main electronics unit. It is mounted on the cokeside mobile machine, as is the electronics unit.

Overall System

An overall system schematic is given in Figure 6. As well as the three units described above it is necessary to have some method of identifying the oven for which the data are being gathered and some form of data output.

As shown in the diagram, one form of oven number input is via a thumbwheel interface. Interlocks can be provided to ensure that the operator changes the number before commencing a push. Another method of oven identification will be described later.

Output can be in the form of a local printer, by means of an alphanumeric display on th operator's control desk or may be transmitted by radio link to a 'ground-station' computer in the main plant offices. All of these systems have been used within BSC.

A typical set of cross-wall profiles is given in Figure 7.

UNDERFIRING GAS CONTROL

Having established that it is possible to monitor the temperature variation throughout a battery, it is then necessary to control the battery underfiring to give optimum carbonisation whilst minimising energy usage. Gas flow to individual burners and walls may be trimmed based on results obtained using the above techniques, but it is of paramount important to control the overall flow of energy to the battery.

Side Main Pressure Control

The normal method of underfiring gas control on a coke oven battery is by pressure regulation of the main supplying the gas, the pressure being controlled to a predetermined set point. This mode of control gives heat input compensation for ovens 'checked back' or taken off gas but does have some disadvantages, primarily that variations in calorific value of the gas are not taken into account in the heating strategy. This means that the thermal input to the battery is subject to fluctuations induced by CV variations, leading to wastage at high CV values. This method of control is therefore not an effective short or long term control strategy.

Heat Input Control

In an alternative control strategy, the heat input is determined from the product of the underfiring gas flow and Wobbe Index. This system will therefore compensate for changes in calorific value of the fuel but does not compensate for changes in gas flow when ovens are checked back or taken off gas. It is, therefore, primarily of use on modern or newly-commissioned batteries, where steady operation is the norm, but is of less value where the push rate is less steady and where oven repairs are a regular feature, which is often the case on older batteries.

Thermal Flow Control

It was, therefore, considered necessary to develop a method of control which incorporated the best features of the two systems above and this could be used under any oven operating conditions. This has been achieved by using the product of differential pressure across the whole battery and the Wobbe Index as a measure of the heat input to the battery.

Figure 8 is a schematic which shows all three modes of control and all three modes were made available on the recently commissioned Redcar Coke Ovens. Three features were highlighted as a resulted of trials carried out using the alternative method of control.

Firstly, substantial energy savings, of the order of 5%, could be made by employing either heat input control or thermal flow control as opposed to side main pressure control. Secondly, that thermal flow control was the superior system when ovens were being checked back or taken off-gas. Thirdly, that although heat input control was marginally superior to thermal flow control under steady operating conditions, the flow measurement had to be very accurate. In order to achieve the desired accuracy compensation had to be made for incoming gas temperature and partial water pressure variations.

Further Developments

At the Appleby Frodingham Coke Ovens, at Scunthorpe Works, thermal flow control has been taken a stage further. Rather than only using the indirect methods of temperature measurement outlined earlier, these have been augmented by special probes which have been inserted into the regenerators. Although there is still some lag between a change in underfiring gas flow and a temperature change in the regenerators, the response is rapid enough for use in a control loop. Also all ovens in the battery are measured simultaneously.

The temperature data collected are averaged by a small microcomputer to produce a temperature feedback signal. The error between the measured and setpoint (battery) temperature is then used as a thermal input setpoint which may in turn be compared with the actual thermal input to the battery.

The installation of this system has already yielded savings of about 3% in energy consumption. The work, however, is not yet complete and it is intended to introduce a third control loop, incorporating desired production rate as a setpoint input, as shown in Figure 9.

OTHER INSTRUMENTATION

Several other systems have been developed by the Process Research Laboratories or have been acquired from commercial supplies for use on coke ovens.

Coke Pushing Force Measurement

The force required to push coke from an oven has been found to be a good indicator of the oven condition and of how well it is being operated. Faults in oven heating and charging quickly show up as higher than normal pushing forces, and measurements of this parameter can be used to complement temperature measurement.

A system has been developed based on measurement of torque at the pusher machine ram drive.

The ram force required to push coke from an oven can vary over wide limits and is dependent on the condition of the coke mass and the oven chamber itself. The force is made up of several components inlcuding that required to slide the coke along the oven sole and the reaction between the slipper supporting the ram and the sole. A typical pushing force trace is therefore as shown in Figure 10, the ram force rising rapidly to a peak and then falling to a steadier lower level. The initial peak force is the figure used as a measure of oven "pushability". As will be shown later, the data logged at each push can be recorded together with oven number and time of pushing. This enables the establishment of a standard for the pushing force to be expected with good operation, identification of ovens susceptible to higher than normal pushing forces and highlighting of abnormal results which may be attributed to a number of factors.

The system described has been fitted to the majority of BSC's coke ovens and also supplied outside the Corporation.

Mobile Machine Alignment

A unit has been developed to aid the alignment of pusher and cokeside machines for door removal. Obviously, if the pusher machine is not correctly aligned then damage to the oven fabric will result and if the cokeside machine is not correctly aligned then the coke guide will not be in the right position to transfer the hot coke into the Coke Car.

The COLAS (Coke Oven Laser Alignment System) provides a beam of laser light which can be seen as a bright red dot on the battery by the machine operator. He can, therefore, centre the spot on small targets provided for each oven. The unit is manually activated and incorporates a timer which automatically cuts off the beam after a set period. Such systems have been installed on most of the Corporation's ovens and several outside BSC.

Automatic Oven Indentification

As mentioned in the section on the Automatic Cross-Wall Temperature Monitor, one method of identifying the oven being pushed is by the use of a thumbwheel encoder. An alternative is to use a commercially available tag transponder system. Small robust electronic tags incorporating low frequency radio transmitters/receivers and having a memory capable of holding a unique indentification code are mounted in suitable positions adjacent to each oven. Each mobile machine is fitted with an interrogation unit and reading head which generates a local electro-magnetic field and so activates the nearest tag, which responds by transmitting its stored code. The interrogation unit also checks that the tag is functioning correctly and that the signal received by the reading head is valid. Valid data is transmitted serially to external equipment.

Off-Car Communication

Again as mentioned in the Automatic Cross-Wall Temperature Monitor section, data can be transferred from the mobile machines by radio link. Such systems are available commercially and have been used to transmit not only cross-wall temperature data from the cokeside machine and ram beam torques from the pusher machine but also information relating to general oven practice as shown in Figure 11. Here data on door cleaning cycles, cross battery interlocks, oven status and oven number are taken from limit and pressure switches, manual and thumbwheel switches.

All outstations, on the mobile machines, store all data until polled by the groundstation. The data, which has previously been encoded into a status word with an error check character, is then transmitted. In this way the technical complexity of the outstation is minimised, the groundstation computer receives and checks data in an orderly fashion and charge/push data are received only after all required actions have been completed. Such systems have been fitted to Redcar and Dawes Lane Coke Oven Batteries.

ACKNOWLEDGEMENTS

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Figure 1 Measuring Flue Block Temperatures Using the Hand Held Computer

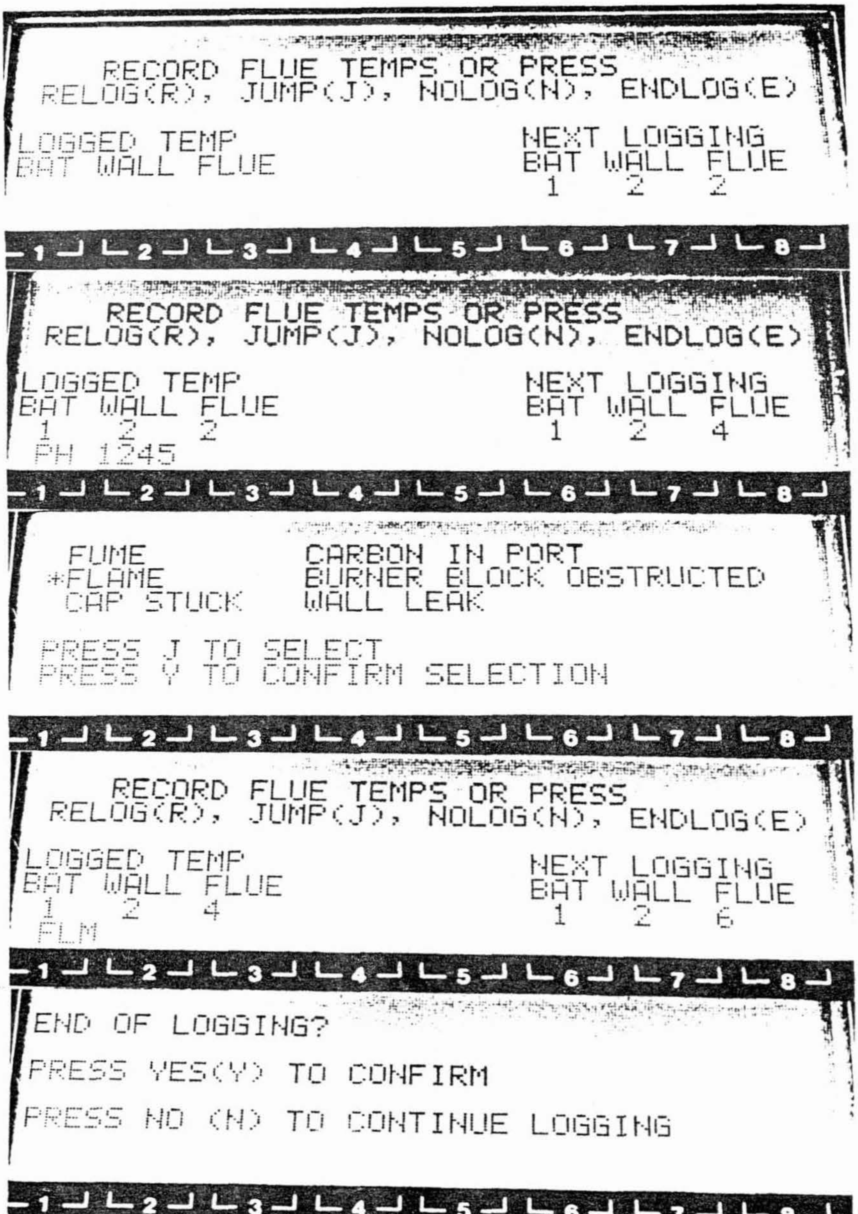

Figure 2 Example from Cross-Wall Logging Sequence

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TEESSIDE LABORATORIES
COKE OVEN TEMPERATURE
LOGGER
LOCATION:SOUTH BANK
CROSSWALL DATA
WALL: 1

FLUE     TEMP                FLUE     TEMP
 1       PH 1090              17      PH 1240
 2       BBK                  18      PH 1250
 3       PH 1130              19      PH 1275
 4       PH 1120              20      PH 1240
 5       PH 1120              21      FLM
 6       PH 1140              22      PH 1220
 7       PH 1180              23      PH 1225
 8       PH 1185              24      PH 1200
 9       PH 1170              25      PH 1170
10       PH 1200              26      PH 1140
11       PH 1210              27      PH 1160
12       PH 1200              28      PH 1130
13       PH 1250              29      PH 1130
14       PH 1230              30      PH 1135
15       PH 1240              31      PH 1100
16       PH 1230              32      PH 1050
                              33      CAP

              TEMPERATURE (C)

   1050 1100 1150 1200 1250 1300 1350
 --I----I----I----I----I----I----I----

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 3 ]]]]]]]]]]
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OUTER FLUES LOGGED AT 10:46
                   ON 19-01-1987
INNER FLUES LOGGED AT 10:16
                   ON 19-01-1987
```

Figure 3 Typical Cross-wall Output

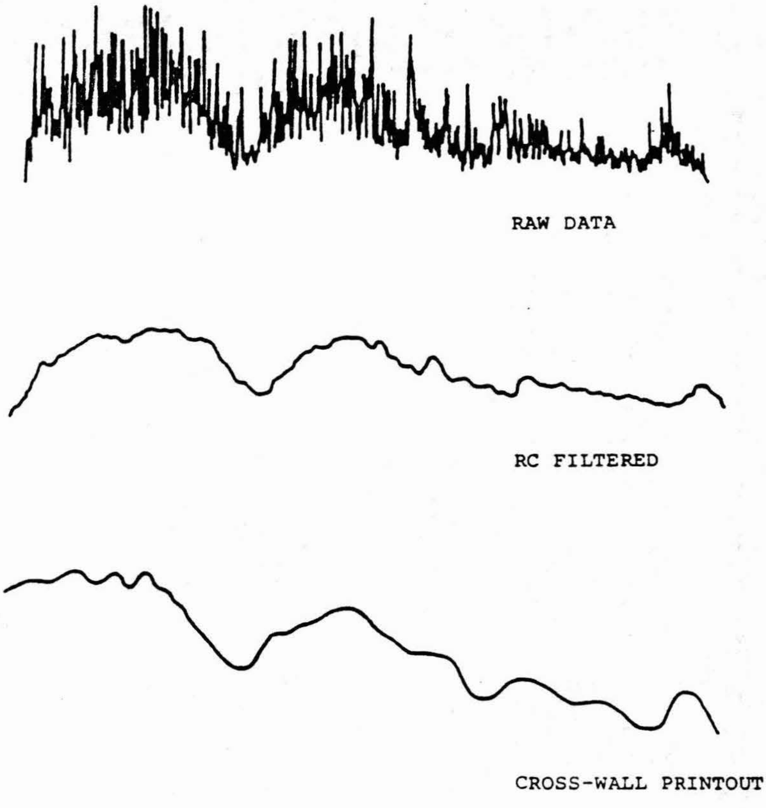

Figure 4 Relationship between raw data and the cross-wall output (early trials)

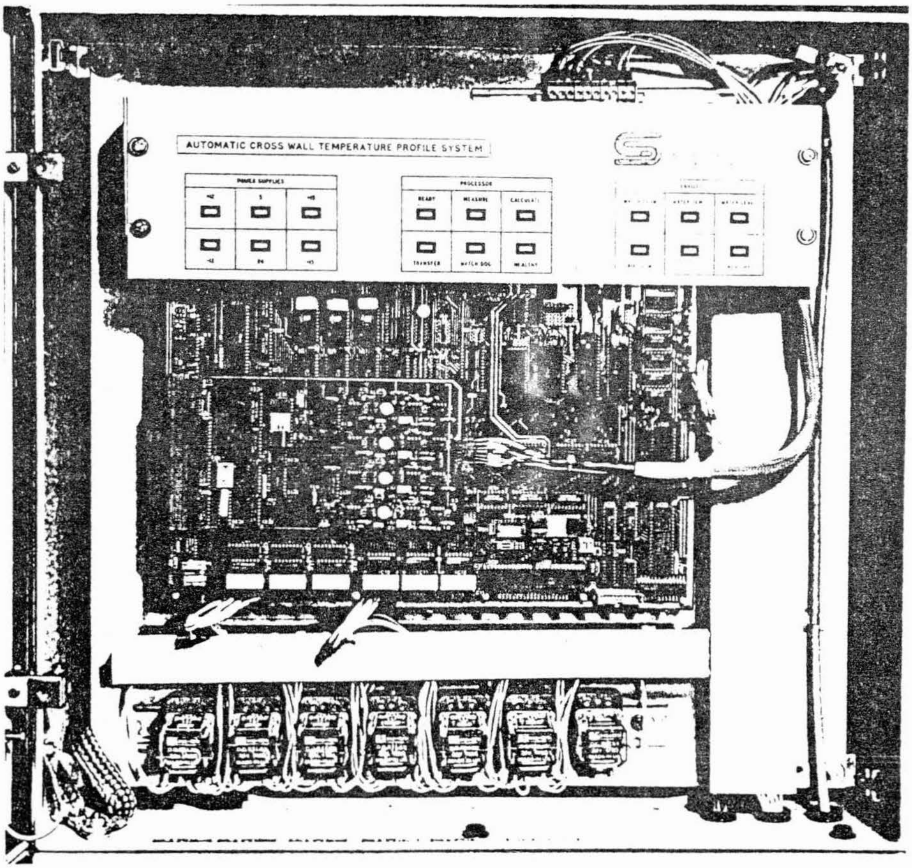

Figure 5 Electronics Unit

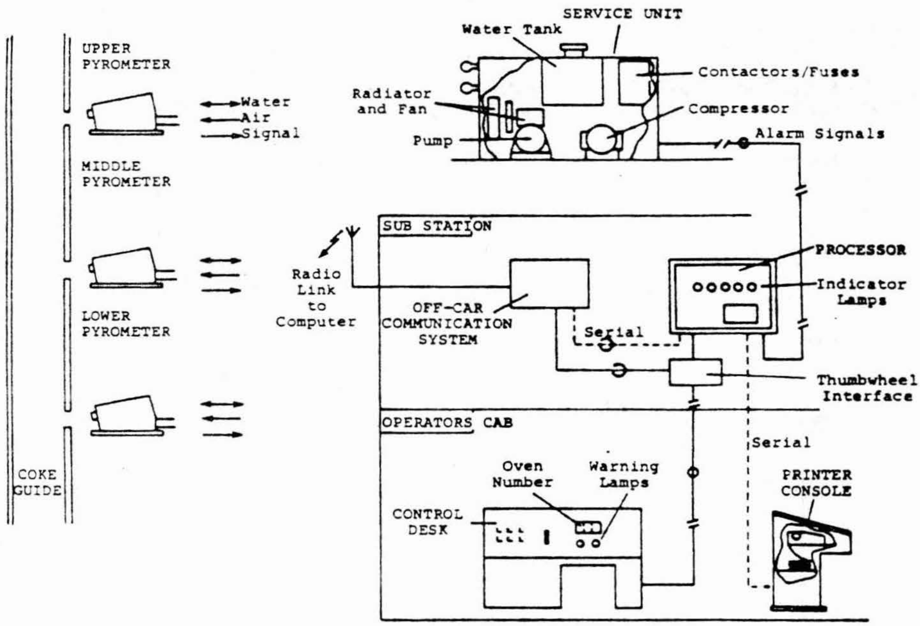

Figure 6 Overall system schematic

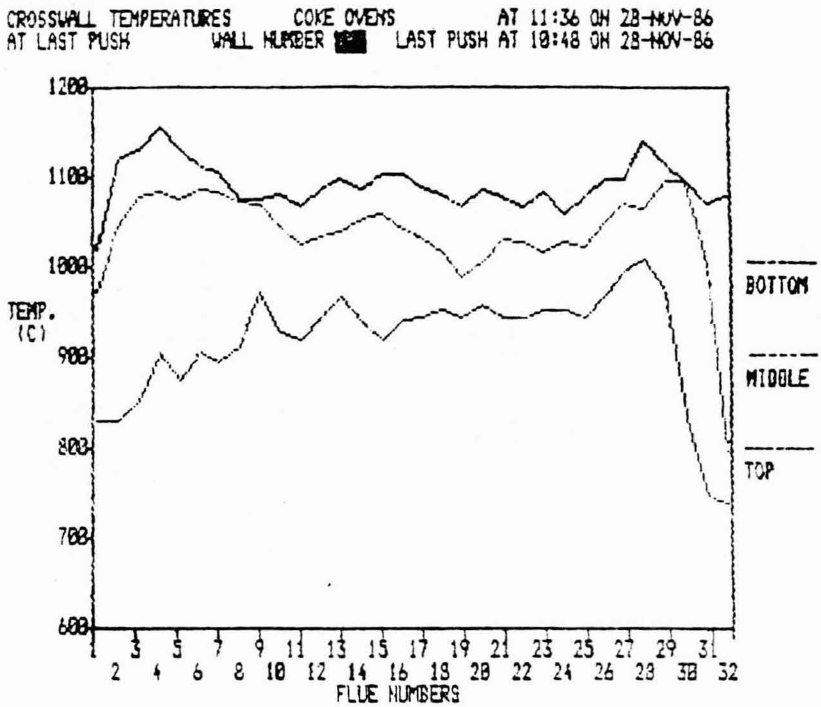

Figure 7 Typical set of cross-wall profiles

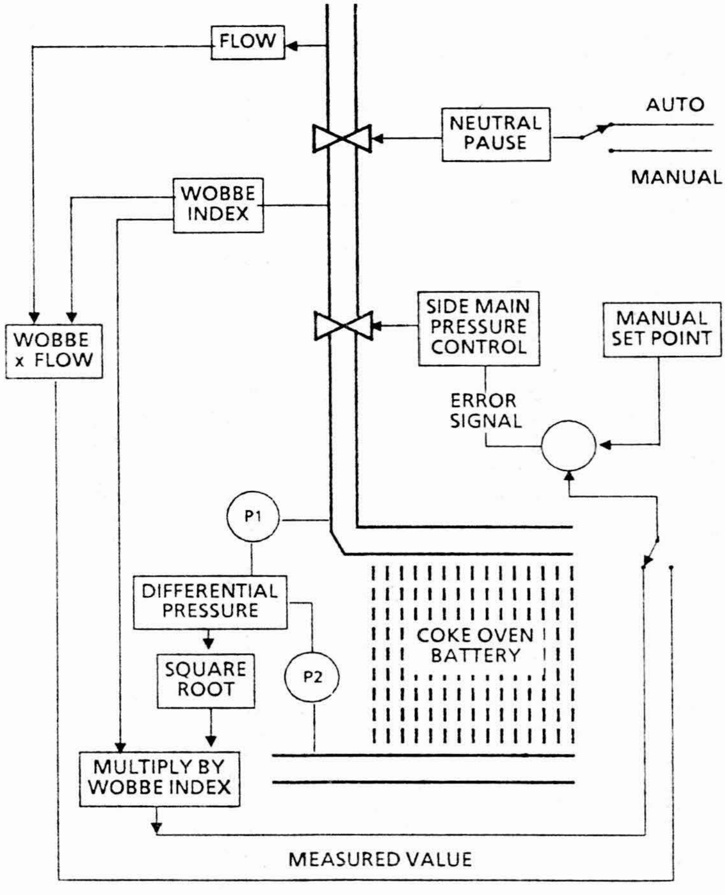

Figure 8 Alternative methods of underfiring gas control.

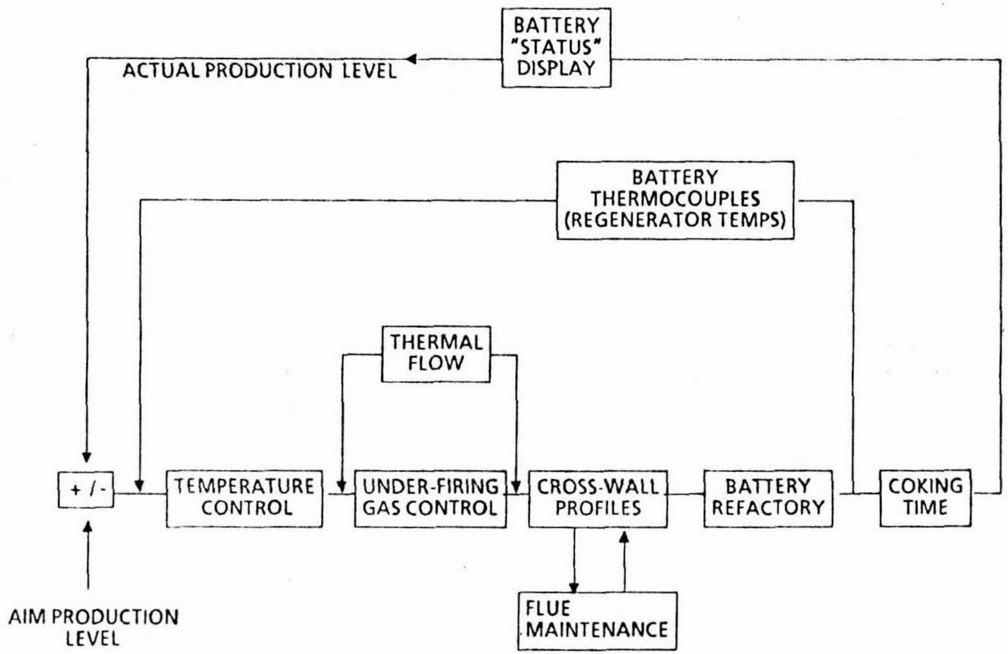

Figure 9 Nested loops for improved battery control

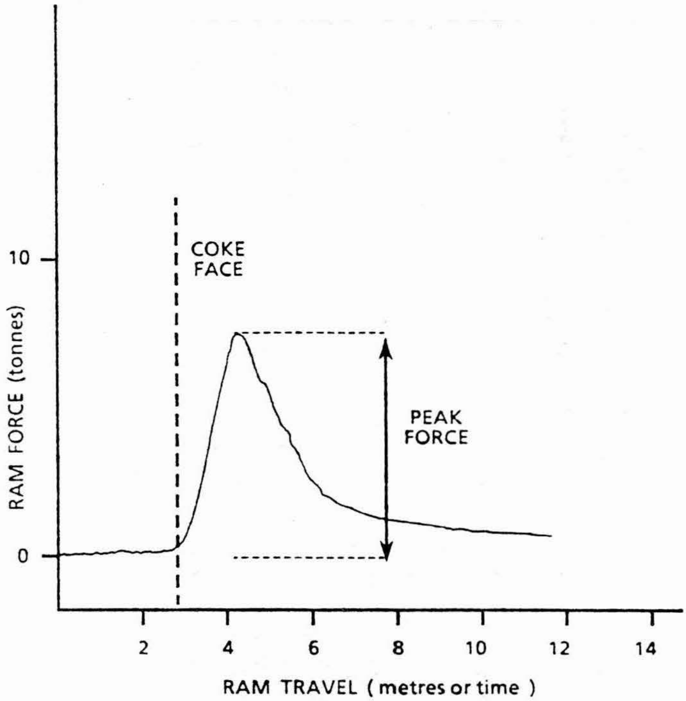

Figure 10 Typical ram force trace.

SHIFT REPORT COKE OVENS AT 10:29 ON 18-SEP-84 PAGE 13
PUSHING SUMMARY FOR BATTERY 1 FROM 21:00 ON 17-SEP-84

PUSH NO.	OVEN NO.	PUSH TIME	TORQUE MAX.	TORQUE MEAN	DOOR R	DOOR C	JAMB R	JAMB C	XBIO R	XBIO C	MODE	PROBLEM STATUS	COMMENT	
17	76	01:10	16.25	7.27	Y	Y	Y	Y	N	N	N 7			A
18	81	01:23	24.73	7.07	Y	Y	Y	Y	N	N	N 7			A
19	86	01:36	21.88	7.19	Y	Y	Y	Y	N	N	N 3			A
20	91	02:31	16.64	6.56	Y	Y	Y	Y	N	N	N 3			A
21	96	02:41	18.50	7.17	Y	Y	Y	Y	N	N	N 7			A
22	101	02:51	15.67	6.95	Y	Y	Y	Y	N	N	N 7			A
23	106	03:01	18.99	6.41	Y	Y	Y	Y	N	N	N 7			A
24	111	03:18	12.41	6.64	Y	Y	Y	Y	N	N	N 7			A
25	116	03:28	21.55	6.64	Y	Y	Y	Y	N	N	N 7			A
26	121	03:42	15.18	6.88	Y	Y	Y	Y	N	N	N 7			A
27	126	03:59	12.84	6.76	Y	Y	Y	Y	N	N	N 3			A
28	131	04:13	22.47	6.97	Y	Y	Y	Y	N	N	N 3			A
29	68	04:44	20.73	7.46	Y	Y	Y	Y	N	N	N 3			A
30	73	04:55	22.66	7.87	Y	Y	Y	Y	N	N	N 7			A
31	78	05:08	18.72	7.35	Y	Y	Y	Y	N	N	N 3			A
32	83	05:22	14.18	6.80	Y	Y	Y	N	N	N	N 3		*J.CLND MAN*	A

Figure 11 Oven Status by Radio Transmission