PARTICULARITIES OF PROCESS CONTROL AND REGULATION OF THE SOLMER COKE PLANT

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ABSTRACT

As soon as started up in 1974, SOLMER coke plant, located at Fos-sur-Mer, was already high graded equipped; it has still regularly kept on improving its facilities to increase its working results.

Nowaday, the 108 ovens (7.5m high) are producing 1.5 MT of metallurgical coke per year, for a 16 hour coking cycle corresponding to about 160 pushings a day, using one out of the two sets of machines.

This high working rate is directly in connection with increased coke requirement of the two blast furnaces, enlarged in 1982.

All along the first operation years, the efforts got on improvement upon working reliability of the facilities, specially oven machines. In 1980, a computer was set to automatically control heating of the batteries (patented proceeding CRAPO); then, it has been extended to following other functions :

- coke quenching automatic control,
- gas temperature into ascension pipes,
- strength of current while pushings,
- operator guide for coal reclaiming,
- printed reports concerning daily operation rate, management of materials (coals, coke, gas..)

Linked with such technological points, an important trend has been developped as regard as human relationship. First of all, the staff have systematically been involved in any strategy concerning the facilities (setting, modifying, etc.) Besides, within general policy of the whole plant, team works, training, self liability were increased in view to improve the staff's motivation.

In short, present performances of the coke plant, reached under high productivity since two years, are in accordance with coke needs (quantity-quality) of Solmer blast furnaces, well known as regard as their good operating results. Moreover, the coke plant people's active participation is a great deal in operating rate regularity, and it is quite important for keeping up the working tool.

I. INTRODUCTION

Within the context of the SOLMER integrated steel mill in FOS sur MER which began production in 1974, the function of the coke plant is to feed the two blast furnaces exclusively with coke. These blast furnaces have a daily maximum capacity of 6,000 tons of pig iron. The coke plant installations corresponded to the most recent technological advances of its time when it was built so as to ensure that it was highly productive and cost-effective.

Afterwards, a constant effort was made to improve the plant, especially for increased efficiency of the ovens and automation of various functions. This effort was completed by a new approach to the problem of human relations and involvement of the personnel.

These endeavours lead the coke plant to a level of results which are amongst the best in the world.

We will now develop the different points where progress has been made and present the recent achievements of the coke plant.

II. CHARACTERISTICS AND OPERATING CONDITIONS

The coke plant is made up of 108 ovens built by the DELATTRE-LEVIVIER company under an OTTO licence (Fig.1). They are divided into two batteries of 72 and 36 ovens ; their hot sizes are provided in table 1.

The batteries are the "compound" type with 34 flues twinned by walls and are heated either with blast furnace gas enriched with coke plant gases or with coke plant gas alone. Two sets of machines supply the batteries, one of which is on stand-by.

The blend is composed mainly of coal imported from the U.S.A., Australia and Canada.

Coke quenching is carried out in the classic way by watering. Screening of the coke gives two sizes (0 - 25 and 25 - 100 mm) with the possibility of crushing pieces larger than 100 mm.

The gas treatment plant has a capacity of 96,000 m3N/h. Its characteristics are as follows (Fig. 2) :

- variable speed gas exhausters are installed downstream from the gas treatment,
- condensation is the direct type,
- no by-products are recovered except for tar,
- ammonia is extracted from the gas by washing with water,
- the fixed ammonia salts in this water are treated with soda,
- after stripping, the effluents are biologically processed in an aeration tank and then flow into a lagoon before being emptied into the sea.

The general context for the plant as defined in 1972 assumed an annual production objective of 3 million tons of pig iron with a coke consumption rate of approximately 400 kg per ton of pig iron, completed by the injection of 80 kg fuel oil ; the coke plant was designed for this requirement in coke on the basis of an operating rate of 150 pushings per day with a coking time of 17.3 hours. As the blast furnaces were enlargened in 1982 and the injection rate reduced, there was increased need for coke which justified the efforts undertaken for increasing capacity to the present level of 1.5 Mt per year of metallurgical coke. The pushing rate thereby increased to 160 per day with a coking time of 16 hours.

III. EVOLUTION OF THE PLANT

I. DATA PROCESSING

The installation of the CRAPO system for the automatic heating of the ovens (see § III.5) was the beginning of an important data processing network for the coke plant. This first called for a 16/65 SOLAR computer supplied by SEMS-BULL, having a RAM of 1,024 kilobytes. This unit is surrounded by a group of peripherals (analog inputs and outputs, automatic control devices and system controls), several console-monitors (black and white and color) with hard copies and numerous printers in the two sections (production and technical offices).

This computer was then used to handle tasks other than the oven heating functions : materials management (coal, coke, gases), quality control follow-up in connection with the blast furnace computer and optimization of coal feeding from the storage areas (see § III.2).

The coke plant was equipped with complementary computers for the different sections (production, maintenance, laboratory, technical office) :

- Apple II and III, Victor S1 and Vectra HP microcomputers,
- computers installed on the oven machines and the reclaimer,
- an HP 3000 computer for the maintenance section.

A general diagram of this data processing assembly is provided in figure 3 ; note especially the numerous inter-connections with the other divisions of the steel mill.

All the installations of the coke plant are remote-controlled from two centralized control rooms. One manages the handling of coal, blend preparation, oven heating, the moving of the machines and the coke handling ; the other one includes all the controls for the gas treatment and water purification unit.

2. HANDLING AND TREATMENT OF THE COAL AND COKE

a. Storage and recovery

The coal arrives by ship only (ships of up to 175,000 tons) and are then stored in an area having a 500,000 ton capacity. The stackers are automatic and provide, if necessary, storage by small heaps for reducing grain size segregation. The central computer, connected to a microcomputer installed on the reclaimer, knows the exact co-ordinates of the latter. An algorithm checks that there are no errors in the coal quality and optimizes the planning for taking the coal from the storage area. An example of automatic screen display is given in figure 4.

b. Blend preparation and charging

The blend is fabricated in precise proportions thanks to the dosimeters located under the ten storage silos. The computer permanently checks the concordance between the theoretical and real ratios. Optimum grain sizing is obtained by milling with the possibility of by-passing for the fine coal.

Oven charging is carried out by volume. The weight of the coal is first measured in five hoppers placed on balances and automatically transmitted to the computer which triggers an alarm in case of a hitch ; calibration of these hoppers is carried out by the computer at least once per shift.

c. Coke quenching

The quantity of quenching water is regulated by the computer which takes the following parameters into account for each oven :

. the exact weight of the coke to be quenched,
. its average temperature,
. the temperature of the quenching water.

Infra-red detectors trigger water sprayers on the coke wharf conveyor belt whenever necessary. This provides a complement to all the other actions for perfecting the moisture level while protecting the installations.

3. OVEN MACHINES

Designed for high operating rates (up to 8 - 10 operations per hour), these machines, built by the Koppers company, are now very efficient. The following particularities provide some examples of their modern equipment :

. the translation and pushing by D.C. motors fed by thyristor bridges,
. The other devices activated by high pressure hydraulic jacks,
. three command possibilities : sequential (normal) operation, step by step (manual), and local operation (by jack).

. air-conditionned control cabins and electrical rooms
. video cameras and monitors as aids to the machine operators
. pusher and coke guide lasers which provide precise positioning
. an inductive connection system which ensures concordance between the pusher, coke guide and coke car.

Moreover, various new functions have been developped :

. a microcomputer installed on the pusher transmits the pushing motor's electrical current curve to the central computer. This computer then analyzes and processes the data in order to detect and indicate any abnormalities, especially in relation to the condition of each oven.
. the movements of the ascension pipe and collecting main valves are automatically and independently carried out by the pushing and the charging machines,
. the luting of the charging pads is automatically carried out by the charging machine,
. water is sprayed on the oven inlet plates the moment the door is extracted in order to limit the deposits, especially of tar.

We should also note that a project has recently been developed for the automation of all these machines. This project includes several phases :
. acquisition of the oven number during operation,
. automation of the translations,
. synchronization of each machine's sequences by the central computer,
. finally, and gradually, the complete automation of each machine.

The coke car will work automatically by the end of this year.

4. THE OVEN BATTERIES

After 13 years of operation and approximately 5,800 pushings per oven, all of the machines and the two batteries are in good working order despite the high operating rate over the last three years and several changes in the operating rate in the past. An analysis of this situation allows us to anticipate a work life of 30 years for the coke plant for a total of 13,000 operations per oven.

Taking into account the large size of these ovens, especially their exceptional height, it is evident that this objective can only be reached by being extremely careful about their operating conditions. Three essential points are to be considered :

- the regularity of operation which implies respect of the operating plan established with the computers, taking the following parameters into account :
  - the determined operating rate,
  - the tolerance of the coking time deviations
  - planned stops or shut-downs due to shift changes and programmed works

- the systematic maintenance of the cells according to the following aspects :
  - maintenance of the refractory materials
  - the removal of the graphite is carried out according to the empty oven technique, a method which SOLMER has mastered particularly well,
  - cleaning of the goosenecks, the ascension pipes and the charging holes.

- periodical follow-up of the evolution of the metal and refractory parts, with corresponding data processing.

5. OVEN HEATING

5.1 - Automatic operation by computer

In the beginning, oven heating was based on the traditional method by measuring the temperature of the walls with manual pyrometers. Given the antiquated aspect of this method, studies began in 1975, leading us to the development of an original process for automatic heating. The French acronym for this process is the "CRAPO" system (Chauffage avec Régulation Automatique de la Pause par Ordinateur). It was first put in operation in December 1982 ; it was described in detail in an earlier publication. We will now outline its main characteristics.

The main principle is the automatic adjustment at any moment and a priori of the addition of the heat necessary for coking. In order to carry out this task, the following elements are taken into consideration :

- the heat necessary for drying and coking the coal which depends, especially, on the fixed pushed coke temperature,
- the coal charge rate in the ovens,
- the characteristics of the heating gas (composition, calorific value and specific gravity)
- the sensible heat of the waste gases arising from the regenerators
- the heat losses of each battery.

The corresponding required data is used in the following equation which represents the hourly heat flow for each battery :

$$v.P = C . Q + v . F + 3 . p . A + C$$

Given :

v and P = mean hourly flow rate and net calorific value of the heating gas

C and Q = hourly flow rate and coking heat of wet coal blend

F and A = sensible heat of waste gases and of circulating air during the heating pause

S = hourly heat losses for each battery

p = duration of the pause (heat cut off)

Acquisition of this data and the different calculations are carried out constantly by the computer. Given set models and knowing the duration r of the inversing cycle and the instant heating gas flow rate V, it then deduces the duration of the heating pause which is to be applied at the beginning of each inversion according to the following equation :

$$p = r . (1 - \frac{v}{V})$$

The evolution of this pause is also displayed on a monitor (figure 5).

The final objective of the regulation is to push the coke at a pre-determined temperature as taken into account by the calculation model. In order to check that this objective is attained, the measurement of the temperature of the coke mass is controlled as given by three pyrometers mounted on the coke guide (figure 6.). There is then a return action in function of the deviation noted in relation to the target value.

The general flow sheet of this process is shown in figure 7.

Recently, a continuous measurement of the temperature of the gas in each ascension pipe was put into service in order to improve the system's performance (figure 8). With a basis depending especially on the moment which corresponds to the passage of its maximum temperature, very reliable information is thus acquired which allows us :

- to improve the individual adjustment of each oven,
- to have a more precise indication concerning the degree of coking with the possibility of anticipative corrective measures,
- to detect various abnormalities in oven operation

In order to take full advantage of this new information, a complementary calculation model has been developed and taken into account by the computer at the beginning of this year.

Since its start up more than three years ago, the CRAPO system has been operating regularly without incident. Optimization of heat consumption has been confirmed. At the present time, according to today's conditions (mainly the nature and moisture content of the coal and the weather conditions), this consumption rate is approximately 600 to 650 th/t of dry coal. Numerous developments and related uses have been made in the form of reports and screen displays. Two examples are given in figures 9 and 10. The first one is relative to the follow-up of the charging operations, the second is a synthesis of the coke plant results in the form of a daily report. This provides an important complement for the operation and daily surveillance of the coke plant. Moreover, from the point of view of the personnel, this step in the use of computers has been most fruitful and rewarding.

5.2 – Improvement in adjustments

Independently of the automatic heating of the batteries, studies are carried out to improve the existing regulation so as to ensure optimization of the oven heating process. We will cite two recent examples of works in progress and carried out in collaboration with the "Centre de Pyrolyse de Marienau" and "IRSID" :

- on the one hand, a theoretical study for establishing models of the transfer of mass and heat in the coke oven, undertaken in the context of a University thesis. This work will be prolonged with analyses of transitory phenomena which is very useful for programmed or non-programmed variations of the coke plant's operating rate.

- on the other hand, a theoretical and experimental study concerning the kinetics of gas consumption in the flues and the heat flow distribution according to height.
  The originality of the study lies especially in the fact that at this occasion a probe was perfected for measurement of the temperature of the flue walls. This has been named the "PYROFIL" probe (patented system) and includes a measuring head equipped with pencil pyrometer suspended from a steel rope (Fig.11). This flexible and non-cooled assembly allows us to establish, in a very useful way, the vertical temperature profiles of the flue walls during the combustion phase or during the waste gas descent phase. An example of a profile is given in figure 12.

6. TREATMENT OF THE GASES AND WATER

The gas processing line designed by the Koppers company includes the following workshops :

- separation of the collecting main waters
- condensation in the direct contact apparatus
- electrostatic de-tarring and de-dusting of the gas

. removal of volatile ammoniac in the packing washers by water absorption
. removal of naphthalene in a packing washer by absorption in fuel oil.
. extraction of purified gas downstream from the treatment plant. The exhausters are driven by a speed multiplier-variator and an electric motor.

Particular care has been taken for the purification of the water before emptying into the sea. The following measures should be noted :

. the volatile ammonia contained in the ammonia-liquor from the washers is extracted by steam stripping in two towers

. total ammonia content (volatile and fixed) of the collecting main waters is also removed by stripping in a third tower, but in the presence of soda so as to eliminate the fixed ammonia as well.

This supplementary precaution was taken beginning in 1976 upon request of the "service des Mines" governmental agency in view of avoiding the phenomenon of eutrophization of the sea.

The vapors which exit the two groups of towers are incinerated in a furnace. A recovery boiler is placed in the circuit and provides approximately 5 to 6 tons per hour of medium pressure steam.

Before emptying into the sea, the residual waters are treated in installations designed by the Degremont company which include :

. an 18,000 m3 homogenization lagoon,
. a pre-decantation and a floculation tank
. a tank for biological treatment by activated sludge
. a settling tank
. a final water aeration lagoon followed by natural lagoons with a residence time of approximately one month before emptying into the sea,
. a mud settling lagoon.

This sophisticated treatment system provides good quality water and meets the requirements of the environmental agency (Table II).

All of the installations described, as well as the collecting main water decantation, the storage of tar, ammoniac water and fuel oil are monitored, managed and remote-controlled from the control room. The introduction of computers is being studied and will be operational next year.

7.THE CONTROL LABORATORY

The laboratory was designed for very complete analyses of the characteristics of coals, coke and by-products (gases, tar, waters).

During the last few years, great efforts have been made for modernizing and automating certain tests such as the following :

- petrographic analysis of coal carried out automatically by a texture analyzer system,
- immediate analysis of coal and coke (moisture, ash and volatile matter index) carried out simultaneously and automatically using a MAT 400 (LECO) machine which treats 19 samples in 4 hours.
- elementary analysis of coal, coke and fuel oil which is handled by a single apparatus (CARLO-ERBA) capable of making approximately 20 to 30 complete analyses per day (C, H, S, N, O).
- the measurement of the calorific value of the coal, coke and fuel oil automatically in an adiabatic calorimeter,
- chromatographic analyses of the gases and liquids made on automatic chromatographs coupled with integrators.

IV. HUMAN RELATIONS

Productivity, regularity of operation and the quality of work and the results depend on the leaders who enlist the cooperation and participation of all.

In this spirit, the coke plant at SOLMER has always been interested in the human aspect of work. Numerous projects have been undertaken in this direction. The main lines are given in figure 13.

The following provide some examples :

. a calling into question of the organization of the maintenance section and creation of cells in direct relation with production,
. the creation of a technical section working on problems of progress but also involved in the daily operation of the coke plant,
. an important effort in training and education at all levels,
. Permanent information for the personnel:
    . weekly bulletins
    . monthly meetings.
. Group work has been developed and numerous problems thereby solved in groups of 5 to 10 persons in the spirit of circles of quality called "Groupes Eurêka" at SOLMER,
. consultation of the personnel for defining objectives and fixing "Quality Action Plans" (PAQ) once a year.

V. PRESENT PERFORMANCE OF THE COKE PLANT

The numerous endeavors for progress which have just been described have enabled a plant which was already efficient to attain a very high level of results in both productivity and quality.

Table III provides a synthesis for the last two years.

Upon examination, the following essential points can be underlined :

. productivity has considerably advanced, now reaching a level which has rarely been attained for a plant comprised of a group of ovens associated with its set of machines ; the high level of reliability of the latter is the main reason.

. the thermal level of the batteries remains reasonable given a wall temperature of less than 1,300°C for a coking time of 16 hours. Moreover, the great regularity of the charging/pushing operations also shows the tendancy towards a mastering of the operating conditions of the ovens.

. heat consumption is at a relatively low level considering, especially, the high work rate. The automatic heating operation with the CRAPO process has provided a source of great progress in this field.

- the quality of the coke in regards to both its physical and chemical characteristics has been perfectly, continuously mastered. This quality thus meets the requirements of the two blast furnaces which are well-known for their excellent results. We should emphasize the low moisture level of the coke combined with its great regularity which is essential for modern blast furnaces which have a very low consumption level (approximately 450 kg per ton of pig iron at SOLMER).

- the relatively low volatile matter content of the blend and the high coking rate require extra-careful surveillance in regards to both swelling pressure on the walls and coke shrinkage. For this reason, tests are regularly carried out with the assistance of the "Centre de Pyrolyse de Marienau" using a pilot oven with a movable wall.

- in a similar line of thought, which concerns the permanent endeavor for preserving the batteries, these levels of performance are of course realized while maintaining continuous surveillance of the state of the ovens and the related tools of coke production.

CONCLUSION

The actual operation of the coke plant meets SOLMER's objectives which is to attain a high level of productivity and cost-effectiveness while constantly improving the quality of the products. Such an ambition can be realized only if there is joint action in the social domain of motivation and participation of all the personnel.

Only in these conditions can we hope to maintain a viable world-scale level of competitivity.

CHARACTERISTICS OF SOLMER ' S OVENS

CARACTERISTIQUES DES FOURS DE SOLMER

NOMBRE	Number	:	2 batteries of 72 and 36 ovens 2 BATTERIES DE 72 ET 36 FOURS
CONSTRUCTEUR	Builder	:	DELATTRE LEVIVIER - OTTO
TYPE		:	COMPOUND - UNDERJET

34 CARNEAUX JUMELES PAR PIEDROIT

34 coupled flues per heating wall

DIMENSIONS A CHAUD :

Total height	HAUTEUR (SOLE A VOUTE)	:	7,59 M
Working height	HAUTEUR UTILE	:	7,22 M
Length face to face	LONGUEUR ENTRE ARMATURES	:	16,67 M
Working length	LONGUEUR UTILE	:	15,81 M
Average width	LARGEUR MOYENNE	:	438 MM
Oven taper	CONICITE	:	76 MM
Oven center distances	ENTR'AXE	:	1,4 M
Thickness of wall liners	EPAISSEUR DES PANNERESSES	:	100 MM
Oven-roof thickness	EPAISSEUR DE LA COUVERTURE	:	1,7 M
Working volume	VOLUME UTILE	:	50 M3

Table I

BIOLOGICAL WASTE WATER TREATMENT

TRAITEMENT BIOLOGIQUE DES EAUX

RESULTATS EN MG/L

RESULTS IN MG / L

	Before AVANT TRAITEMENT Treatment	After APRÈS TRAITEMENT Treatment	after aeration APRÈS basins LAGUNAGE (REJET EN MER) (SEA EFFLUENT)
PHENOLS PHENOLS	290	0,19	0,10
CYANURES CYANIDES	6	1,0	0,11
SULFOCYANURES SULFOCYANIDES	110	2	2
AMMONIAC LIBRE FREE AMMONIA	50	42	44
AMMONIAC FIXE FIXED AMMONIA	115	130	142
D.C.O. C.O.D.	2080	400	206
MATIERES EN SUSPENSION SUSPENDED SOLIDS	-	135	15

Table II

RESULTATS CARACTERISTIQUES

OPERATIONAL DATA

	ANNEE 1985 YEAR 1985	YEAR 1986 ANNEE 1986 TRIMESTRES 1.2.3. QUARTERS 1,2,3
PRODUCTION		
pushings / day NOMBRE DE DEFOURNEMENTS/JOUR	156,4	158,9
Dry coal input (t/d) CHARBON SEC ENFOURNE (t/j)	5860	5941
Dry coke production (t/d) COKE TOTAL SEC PRODUIT (t/j)	4611	4710
COKING CONDITIONS **CONDITIONS DE CARBONISATION**		
coking time average DUREE DE CUISSON (h) - MOYENNE	16,35	16,12
standard deviation - ECART TYPE	0,58	0,42
heating wall temperature TEMPERATURE DE PIEDROIT (°C)	1276	1281
heat consumption CONSOMMATION THERMIQUE (th/t charbon sec) (th/t dry coal)	643	632
MELANGE , BLEND		
HUMIDITE (%) Moisture	7,2	7,4
volatile matters (on dry basis) INDICE DE MATIERES VOLATILES/SEC	23,7	23,9
bulk density (on dry basis) DENSITE DE CHARGEMENT/SEC	0,75	0,75
BLAST FURNACE COKE **COKE DE HAUT-FOURNEAU**		
Moisture HUMIDITE (%)	2,8	2,3
I 10	19,0	19,1
I 40	42,9	42,9
C.S.R.	57,7	58,9
ash CENDRES (%)	10,5	10,8
sulphur SOUFRE (%)	0,65	0,58
alkalis ALCALINS (% dans les cendres)	2,01	1,78

Table III

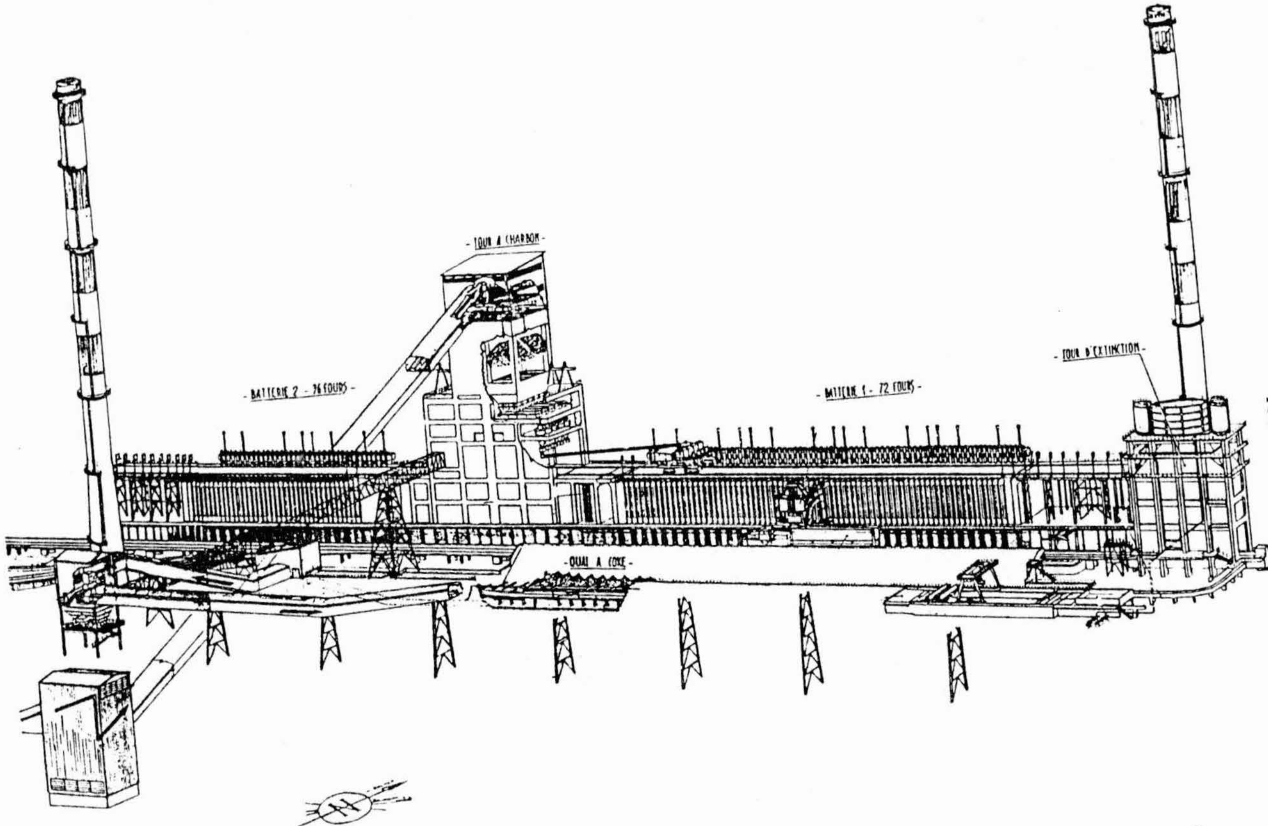
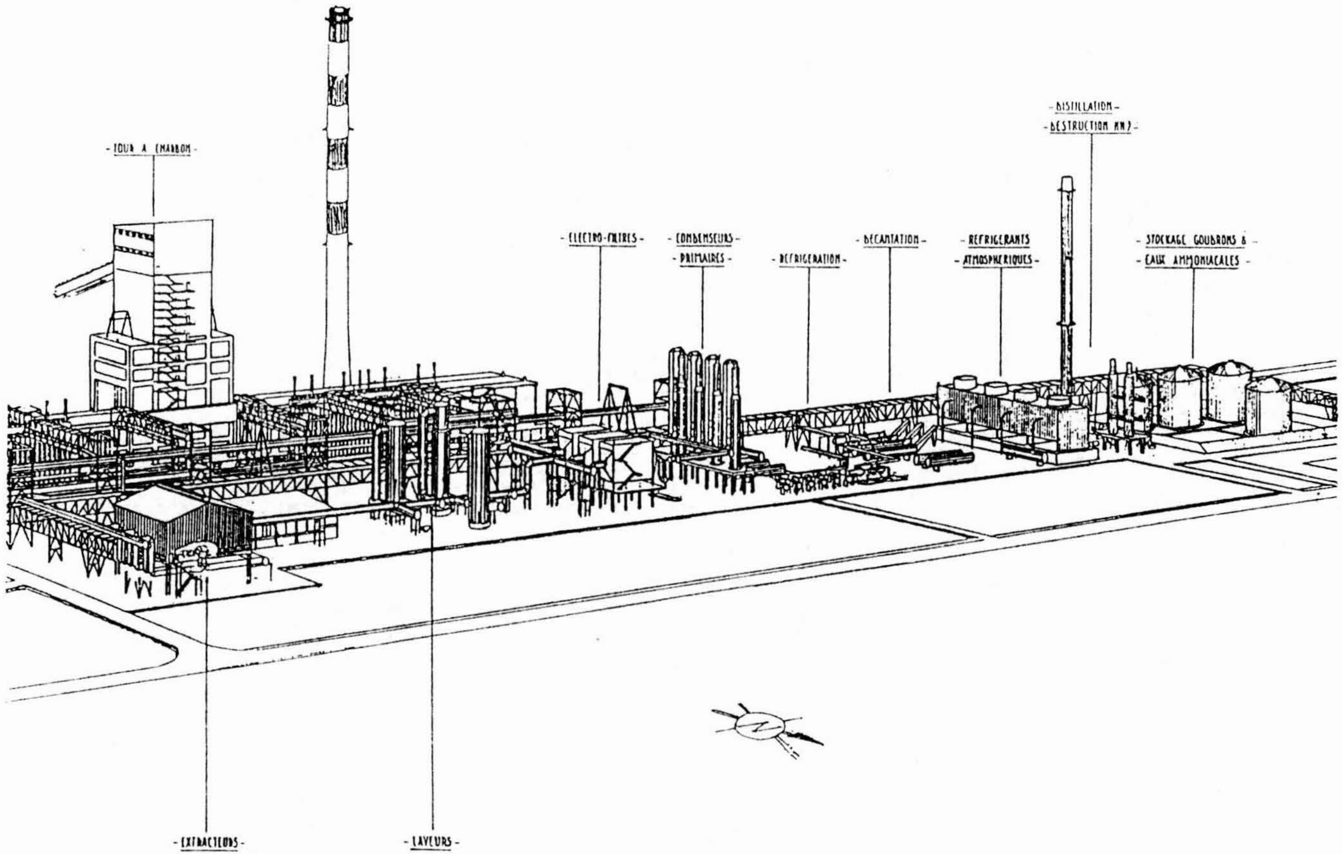


Fig. 1

VUE DES BATTERIES - COTE COKE



TRAITEMENT DU GAZ

Fig. 2

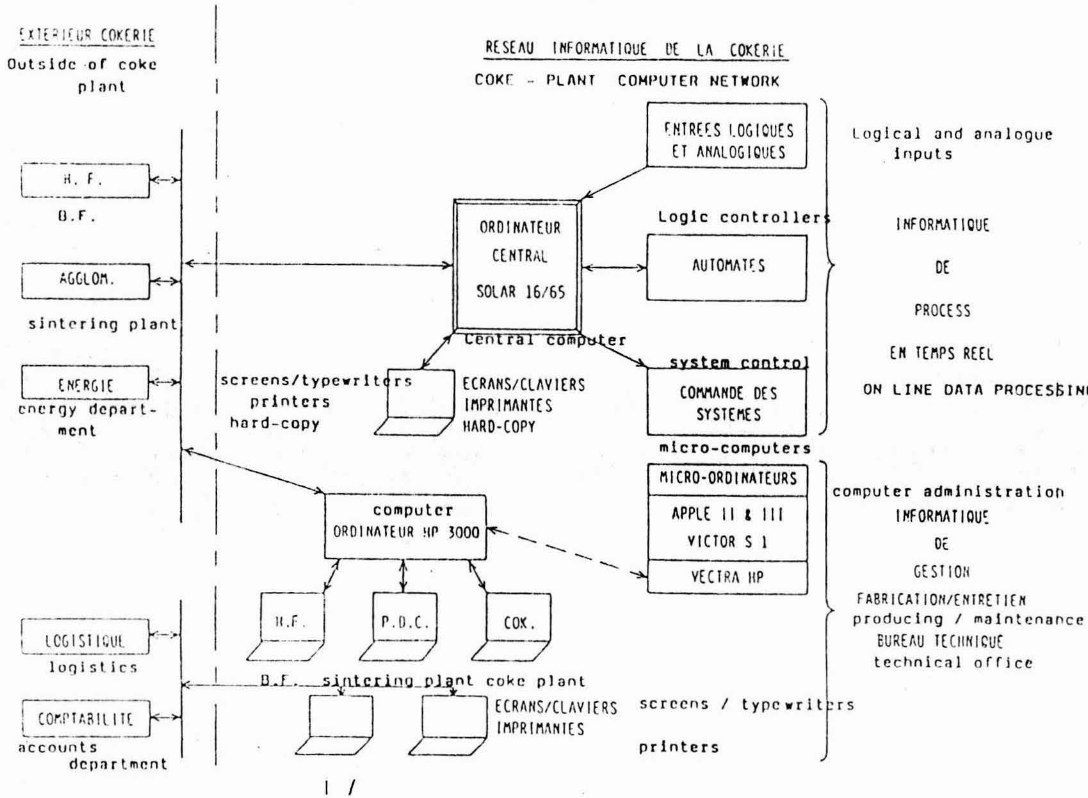

EXTERIEUR COKERIE
Outside of coke plant
RESEAU INFORMATIQUE DE LA COKERIE
COKE - PLANT COMPUTER NETWORK
ENTREES LOGIQUES ET ANALOGIQUES
Logical and analogue inputs
H. F.
B.F.
ORDINATEUR CENTRAL SOLAR 16/65
Central computer
Logic controllers
AUTOMATES
INFORMATIQUE DE PROCESS EN TEMPS REEL
ON LINE DATA PROCESSING
AGGLOM.
sintering plant
ENERGIE
energy department
screens/typewriters printers hard-copy
ECRANS/CLAVIERS IMPRIMANTES HARD-COPY
system control
COMMANDE DES SYSTEMES
micro-computers
MICRO-ORDINATEURS
APPLE II & III
VICTOR S 1
VECTRA HP
computer administration
INFORMATIQUE DE GESTION
computer
ORDINATEUR HP 3000
FABRICATION/ENTRETIEN
producing / maintenance
BUREAU TECHNIQUE
technical office
H.F.
P.D.C.
COK.
LOGISTIQUE
logistics
B.F. sintering plant coke plant
COMPTABILITE
accounts department
ECRANS/CLAVIERS IMPRIMANTES
screens / typewriters
printers

Fig. 3

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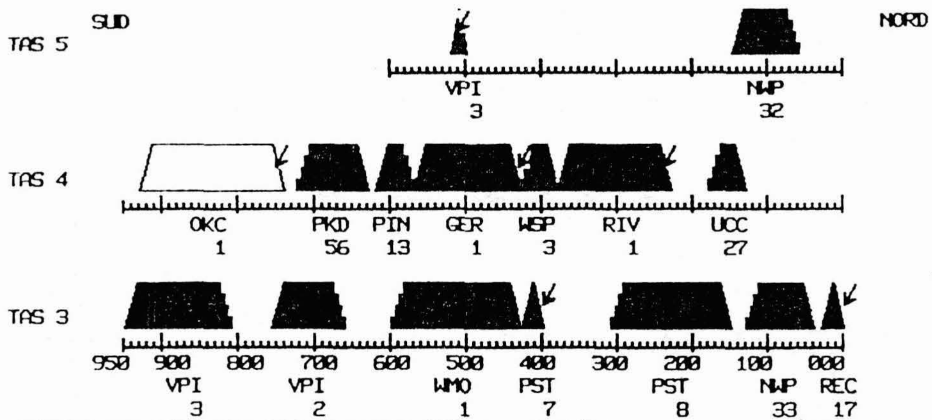
V2H COKERIE SITUATION CHARBON PARC PRIMAIRE AU 27-11-86 A 11H19



NATURE		TAS	NORD	SUD	TON RECP	TON REST	I	NATURE		TAS	NORD	SUD	TON RECP	TON REST
PST	7	3	401	430	50344.	3461.	I	VPI	2	3	663	760	45063.	22723.
PST	8	3	150	310	44337.	44337.	I	VPI	3	3	810	950	44846.	44846.
WSP	3	4	380	430	45825.	2511.	I			5	500	520		
GER	1	4	430	570	59575.	59575.	I	PIN	13	4	570	620	10601.	10601.
OKC	1	4	740	930	59848.	59848.	I	REC	17	3	0	30	2000.	2000.
UCC	27	4	130	180	53101.	5148.	I							
RIV	1	4	230	380	50687.	50687.	I							
PKD	56	4	630	725	85115.	26251.	I							
NWP	32	5	61	150	66688.	20191.	I							
NWP	33	3	40	130	85901.	24205.	I							
WMO	1	3	430	600	62828.	50784.	I							

COKERIE

Fig. 4

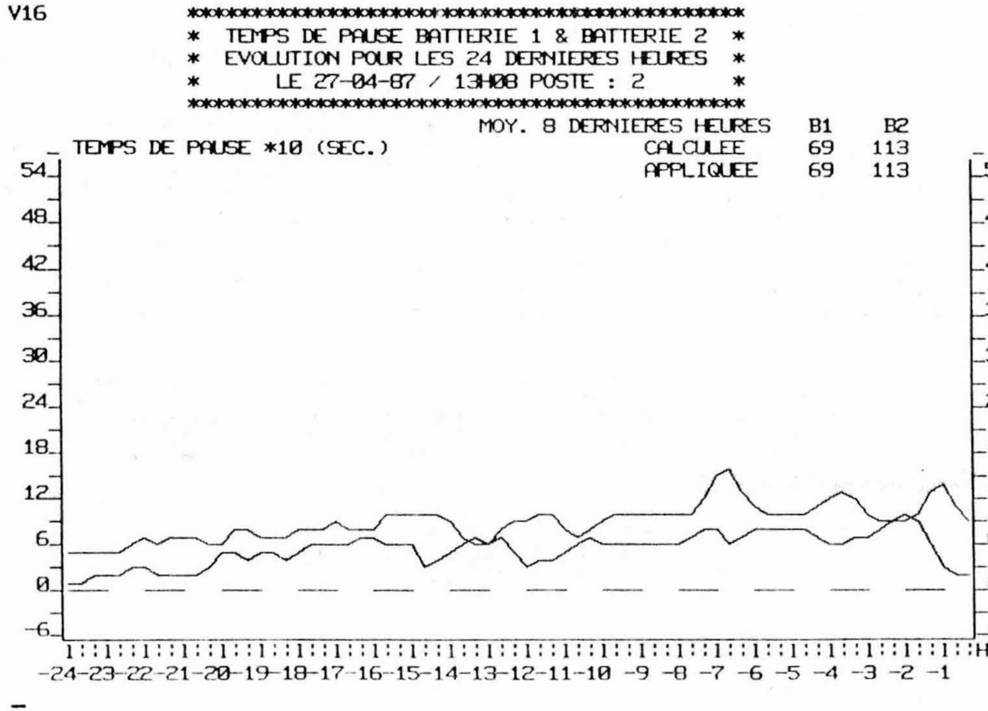


FIGURE 5 : EVOLUTION OF THE HEATING PAUSE FOR 24 HOURS

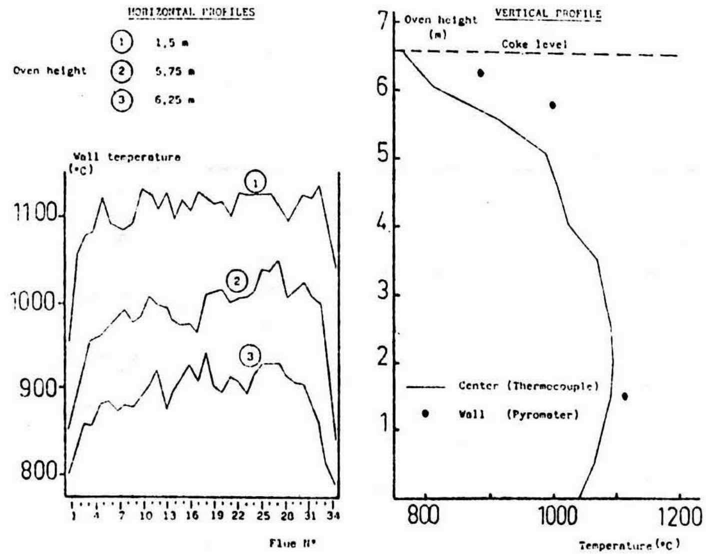


FIGURE 6 : COKE TEMPERATURE PROFILES GIVEN BY THE COKE-GUIDE PYROMETERS

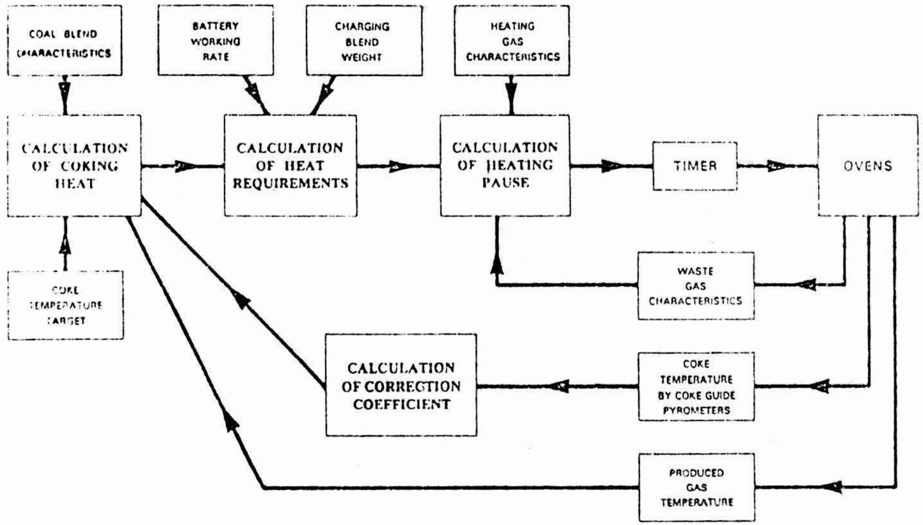


FIGURE 7 : FLOW SHEET OF THE CRAPO SYSTEM

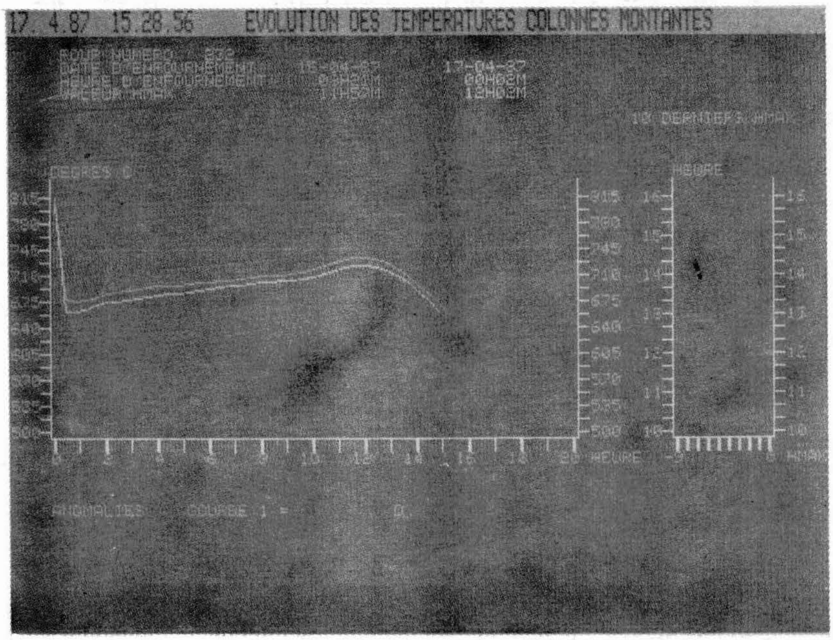


FIGURE 8 : GAS TEMPERATURE IN THE ASCENSION PIPE

SUIVI DES DEFOURNEMENTS ET ENFOURNEMENTS POSTE 2

DATE: 14-05-87 HEURE: 21-00-12

ALLURE 162 DUREE VISEE 15H55 POIDS DE REPALAGE 210KG

	NUMERO FOUR	ENFOURNEMENT PRECEDENT	DEFOURNEMENT	DUREE CUISSON	ECART	ENFOURNEMENT	HEURE DEFOURN. PREVISIONNELLE	TONNAGE FOUR	SILO
1	156	21H19	13H15	15H56	00H01	13H17	05H14	41.78	1
2	161	21H28	13H30	16H02	00H07	13H34	05H27	41.70	1
3	171	21H36	13H33	15H57	00H04	13H39	05H34	41.78	1
4	201	21H51	13H42	15H51	00H04	13H46	05H41	41.80	1
5	206	21H58	13H51	15H53	00H02	13H55	05H50	41.76	1
6	211	22H05	13H57	15H54	00H01	14H03	05H58	41.80	1
7	153	VIDE	VIDE	VIDE	VIDE	14H13	06H08	41.78	1
8	216	22H40	14H17	15H37	00H18	14H21	06H16	41.56	1
9	221	22H46	14H36	15H50	00H05	14H40	06H35	41.70	1
10	226	22H55	14H44	15H49	00H06	14H48	06H43	41.70	1
11	231	23H02	14H53	15H51	00H04	14H57	06H52	41.66	1
12	236	23H09	15H07	15H58	00H03	15H11	07H06	41.48	1
13	103	23H36	15H13	15H37	00H18	15H17	07H12	41.78	1
14	108	23H45	15H31	15H46	00H09	15H35	07H30	41.74	1
15	113	23H52	15H37	15H45	00H10	15H41	07H36	41.94	1
16	118	23H59	15H44	15H45	00H10	15H48	07H43	42.02	1
17	123	00H06	15H51	15H45	00H10	15H55	07H50	42.18	1
18	128	00H12	15H56	15H44	00H11	16H00	07H55	42.14	1
19	133	00H19	16H07	15H48	00H07	16H11	08H06	42.18	1
20	138	00H26	16H13	15H47	00H08	16H17	08H12	42.16	1
21	143	00H32	16H23	15H51	00H04	16H27	08H22	41.90	2
22	148	00H38	16H29	15H51	00H04	16H33	08H28	41.80	2
23	158	00H49	16H36	15H47	00H08	16H40	08H35	41.82	2
24	163	00H56	16H45	15H49	00H06	16H49	08H44	41.90	2
25	168	01H02	16H55	15H53	00H02	16H59	08H54	41.76	2
26	203	01H19	17H00	15H41	00H14	17H04	08H59	41.86	2
27	208	01H24	17H12	15H48	00H07	17H16	09H11	41.84	2
28	213	01H31	17H18	15H47	00H08	17H22	09H17	41.94	2
29	218	01H37	17H26	15H49	00H06	17H30	09H25	42.06	2
30	223	01H45	17H32	15H47	00H08	17H36	09H31	42.00	2
31	228	01H51	17H41	15H50	00H05	17H45	09H40	41.86	2
32	233	01H57	17H47	15H50	00H05	17H51	09H46	41.30	2
33	105	02H05	[illegible]	15H51	00H04	18H00	09H55	41.84	2
34	110	02H16	18H13	15H57	00H02	18H17	10H12	42.12	1
35	115	02H26	[illegible]	15H56	00H01	18H26	10H21	42.10	1
36	120	02H32	18H31	15H59	00H04	18H35	10H30	42.18	1
37	125	02H38	18H40	16H02	00H07	18H44	10H39	42.08	1
38	130	02H44	18H48	16H04	00H09	VIDE	VIDE	VIDE	H
39	135	02H50	18H48	15H58	00H03	18H52	10H47	42.22	1
40	140	02H59	19H02	16H03	00H08	19H06	11H01	42.26	1
41	145	03H05	19H11	16H06	00H11	19H15	11H10	42.28	1
42	150	03H10	19H17	16H07	00H12	19H21	11H16	42.28	1
43	155	03H15	19H22	16H07	00H12	19H26	11H21	42.20	1
44	160	03H22	19H27	16H05	00H10	19H31	11H26	42.26	1
45	165	03H28	19H33	16H05	00H10	19H37	11H32	42.20	1
46	170	03H35	19H45	16H10	00H15	19H49	11H44	42.18	1
47	205	03H51	19H50	15H59	00H04	19H54	11H49	42.30	1
48	210	03H58	19H59	16H01	00H06	20H03	11H58	42.28	1
49	215	04H04	20H06	16H02	00H07	20H10	12H05	42.22	1
50	220	04H10	20H20	16H10	00H15	20H24	12H19	42.18	1
51	225	04H17	20H26	16H09	00H14	20H30	12H25	42.26	1
52	230	04H24	20H32	16H08	00H13	20H36	12H31	42.26	1
53	235	04H31	20H38	16H07	00H12	20H42	12H37	42.32	1

DUREE DE CUISSON MOYENNE 15H54 ECART TYPE 00H00

TONNAGE MOYEN PAR FOUR 41.99 ECART TYPE 0.22

NUMERO TREMIE	1	2	3	4	5	6	7	8	9	10
POIDS MOYEN	8.54	8.51	8.40	8.41	8.36	8.49	8.51	8.31	8.43	8.34
TOLERANCES	0.26	0.34	0.36	0.26	0.22	0.53	0.13	0.30	0.33	0.21
CORRECTION	1.002	1.001	1.000	0.999	1.000	0.999	0.999	1.001	0.996	1.006

SOLMER COKERIE Fig. 9

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                         ******************************************************
                         * R A P P O R T   J O U R N A L I E R   C O K E R I E *
                         ******************************************************

ALLURE : 162 F/J                    DUREE DE CUISSON VISEE : 15H55                 JOURNEE DU 22-09-86 (DE 5H A 5H)

*************** PRODUCTION *************************** CONSOM. THERMIQUES ************************ TEMPERATURE COKE ***********
*                  * P1 * P2 * P3 * TOT *(EN TH/T)           *% FOUR * / SEC *COK+HFE* (VISEE: HFE 1020   * CYCLE* CYCLE* JOUR *
*                                       *                    *       *       * /SEC  *         COK 1050)  *  -2  *  -1  *      *
* ENFOURNEMENT     * 55 * 53 * 54 * 162 *               HFE  *  95.9 * 625.9 *       *                                         *
*                  *    *    *    *     * BATTERIE 1         *       *       * 625.3 *                HFE * 1005.* 1034.* 1025.*
* DEFOURNEMENT     * 54 * 54 * 53 * 161 *               COK  *   4.1 * 612.0 *       *  BATTERIE 1        *      *      *      *
*                  *    *    *    *     *                                            *                COK * 1020.* 1015.* 1022.*
* DUREE CUISSON    *15H52*16H05*15H44*15H54*            HFE  * 100.0 * 630.0 *       *                                         *
*                  *    *    *    *     * BATTERIE 2         *       *       * 638.2 *                HFE * 901.*  993.*  897.*
* ECART-TYPE       *00H05*00H13*00H00*00H16*            COK  *   0,0 *   0.0 *       *  BATTERIE 2        *      *      *      *
*                                       *                                            *                COK *   0.*    0.*    0.*
* NO DU DERNIER FOUR ENFOURNE EN P3 236 * BATTERIES     HFE  *  97.3 * 630.5 *       *                                         *
*                                       *                    *       *       * 630.0 ******* TEMPERATURE GAZ AUX COLONNES *******
* NO DES FOURS VIDES  A  (5H)   116   0 *  1 ET 2       COK  *   2.7 * 612.0 *       *                                         *
*                                       *                    *       *       *       *                HFE * 12H36* 12H14* 12H22*
*************** MELANGE ***************               COKE+HF *  97.3 * 635.2 *      * MOMENT * BATT 1    *      *      *      *
*                                       *                                            *        *       COK * 12H47* 12H55* 12H56*
*NO DE FORMULE A 5H:5743 DEPUIS LE:20-09**** PAUSE (EN SEC). **** CHALEUR DE COKEFACT ** DU    *                                *
*                                       *                    *  SUR HUMIDE           *        *       HFE * 12H33* 12H39* 12H47*
* POIDS HUMIDE CARBONISE /FOUR:  40.51T * BATTERIE 1   68.   *                       * MAXIMUM* BATT 2    *      *      *      *
*                                       *                    *     403.TH/T          *                COK * 00H00* 00H00* 00H00*
*ECART-TYPE 0.16T   REPALAGE/FOUR:0.30T * BATTERIE 2  101.   *                       *                                         *
*                                       *                    ** CHALEUR DE REACTION *********** TEMPERATURE PIEDROITS **********
*GRANU: (0.2: 17.0 (2: 65.4   H20:  7.2 ****** HF ENRICHI ***** + ECART BOUCLAGE     * (FOND DE CARNEAUX)  * J-2  * J-1  * JOUR *
*                                       *                    *                       *                                         *
* MV/S : PREVUES 23.5  REELLES J-1 23.4 * IV VISE  A 5H  885 *     40 TH/T           *                HFE * 1282.* 1288.* 1292.*
*                                       *                    *                       *  BATTERIE 1        *      *      *      *
************* QUALITE COKE ************* TAUX D' ENRICHISSMT ***** GAZ PRODUCTION ****                COK * 1272.* 1291.* 1283.*
*                  * P3 * P1 * P2 *             BATT 1  5.9*                         *                                         *
*                                 *                         * DEBIT VOL(NM3/H)  83.7*                HFE * 1275.* 1281.* 1279.*
* HUMIDITE         * 2.7* 2.2* 2.4*             BATT 2  6.4*                         *  BATTERIE 2        *      *      *      *
*                  *    *    *    *                         * PCI(KCAL/NM3)   4516.  *                COK *   0.*    0.*    0.*
* I 10             *19.2*19.6*19.2* PCI JOURN. HF   680.*                            *                                         *
*                  *    *    *    *                         *                       ********** CORRECTION CONS. THERM. *********
* I 40             *41.2*40.9*41.2*           HFE1 906.* H2 63.94 * CH4  24.23 * PROPORTIONNELLE    *CCLE-3*CCLE-2*CCLE-1*
*                                 *                         *          *             * (TH/T)SUR HUM.                          *
* CSR  (JOURNEE DU 21-09)   58.09 *           HFE2 915.* CO  5.91 *  N2   1.29 *                HFE * -0.1 * -1.4 * -2.0 *
*                                 *                                                  *  BATTERIE 1        *      *      *      *
* CSR  (JOURNEE DU XX.XX)   XX.XX ****************** CONTROLE COMBUSTION *******                COK * 12.0 * 10.5 * 10.5 *
*                                 *                         * BATT.1  *  BATT.2      *                    *      *      *      *
************** EXTINCTION ************                                               *                HFE *  2.2 *  1.2 * -0.3 *
*                  * P1 * P2 * P3 * CO2 NEUTRE (HFE) GAZ    *  26.93  *  26.70       *  BATTERIE 2        *      *      *      *
*                                 *                         *         *              *                COK *  0.0 *  0.0 *  0.0 *
* DUREE            * 69.* 72.* 68.*               FUMEES    *  XX.XX  *  26.58       *                                         *
*                  *    *    *    *                         *         *              *******************************************
* TEMP. BACHE      * 65.* 63.* 64.* O2 FUMEES               *  XX.X   *   3.38       * DERIVEE            *SERIEX*SERIEX*SERIEX*
*                                 *                         *         *              * (TH/T)SUR HUM.                          *
********* FONCTION EN DEFAUT ******* CO FUMEES              *  XX.X   *   0.00       *                HFE *  0.0 *  0.0 *  0.0 *
*                                 *                                                  *  BATTERIE 1        *      *      *      *
* PESAGE   0     PAUSE  B1 XXX  B2 XXX ********* BOUCLAGE (HFE1+HFE2/HF+COK) ********                COK *  0.0 *  0.0 *  0.0 *
*                                 *                                                  *                    *      *      *      *
* EXTINCTION   0. ENRICHI % TEMPS  96.4 *  METHANE :  99.7       THERMIES   100.2 *                HFE *  0.0 *  0.0 *  0.0 *
*                                 *                                                  *  BATTERIE 2        *      *      *      *
* ANALYSEURS(O/N):  1 N 2 N 3 N 4 N 5 N *          VOLUME    99.2                    *                COK *  0.0 *  0.0 *  0.0 *
*                                 *                                                  *                                         *
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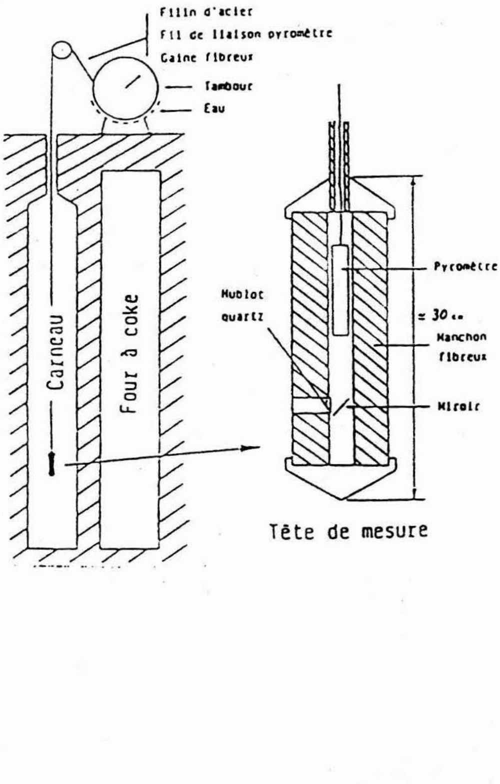
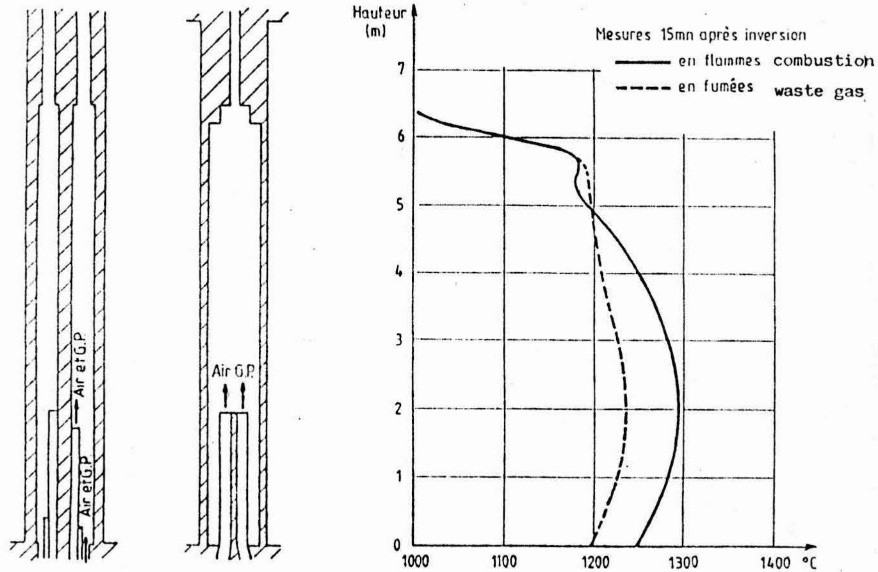
FIGURE 10 : DAILY REPORT



<u>FIGURE 11</u> : **DIAGRAM OF THE "PYROFIL" PROBE**



MESURES DE TEMPERATURES A LA SONDE PYROFIL DANS UN CARNEAU EN FLAMMES ET EN FUMEES

FIGURE 12 : TEMPERATURE PROFIL GIVEN BY THE "PYROFIL" PROBE

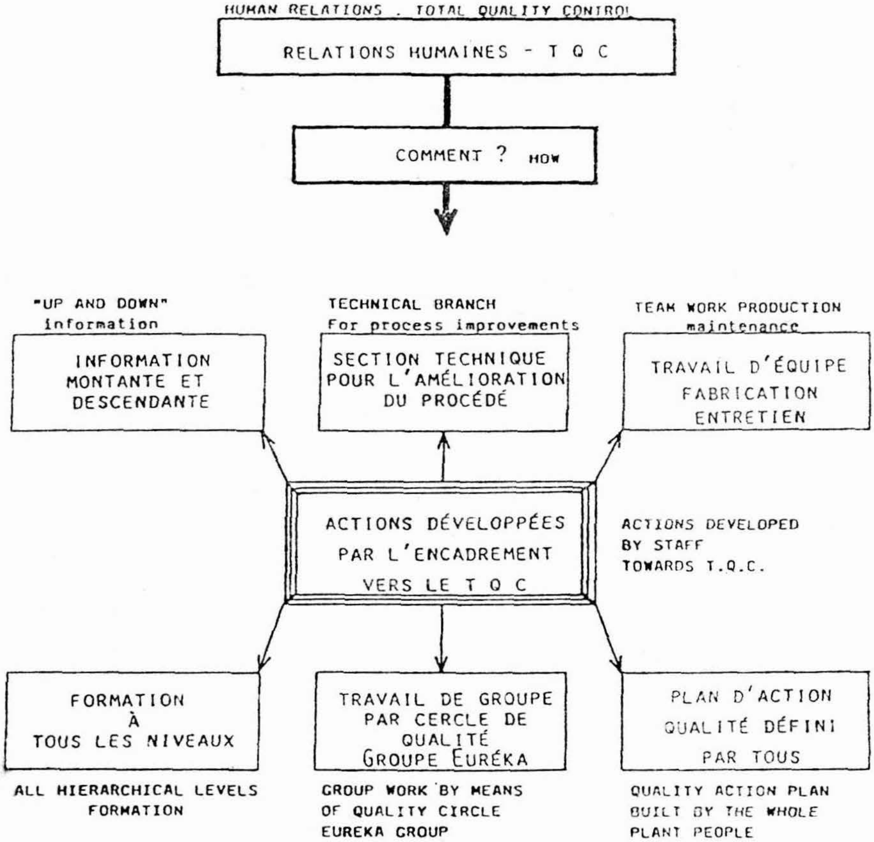

HUMAN RELATIONS . TOTAL QUALITY CONTROL
RELATIONS HUMAINES - T Q C
COMMENT ? HOW
"UP AND DOWN" information
INFORMATION MONTANTE ET DESCENDANTE
TECHNICAL BRANCH For process improvements
SECTION TECHNIQUE POUR L'AMÉLIORATION DU PROCÉDÉ
TEAM WORK PRODUCTION maintenance
TRAVAIL D'ÉQUIPE FABRICATION ENTRETIEN
ACTIONS DÉVELOPPÉES PAR L'ENCADREMENT VERS LE T Q C
ACTIONS DEVELOPED BY STAFF TOWARDS T.Q.C.
FORMATION À TOUS LES NIVEAUX
ALL HIERARCHICAL LEVELS FORMATION
TRAVAIL DE GROUPE PAR CERCLE DE QUALITÉ GROUPE EURÉKA
GROUP WORK BY MEANS OF QUALITY CIRCLE EUREKA GROUP
PLAN D'ACTION QUALITÉ DÉFINI PAR TOUS
QUALITY ACTION PLAN BUILT BY THE WHOLE PLANT PEOPLE

Fig. 13