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OPTIMISATION OF THE USE OF ENERGY IN FACTORIES FOR THE MANUFACTURE OF FERTILISERS, WITH THE AID OF DATA PROCESSING - S.I.C.N.G. CASE STUDY

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I - INTRODUCTION

Our factory, which is composed of twelve manufacturing units, constitutes an open energy system which produces, distributes, consumes and exchanges energy of different forms with its environment.

The energy situation of the factory depends on several internal and external factors which are interrelated in a fairly complex way.

The object of saving energy presupposes a quantitative knowledge of the influence of various factors on the production and the consumption of energy in the factory.

The purpose of our work was to define a model which would describe this energy situation when various operating factors varied.

This model is currently used as a basis for the application of a program and a systematic control of the energy economy within our Industrial area at Thessalonika.

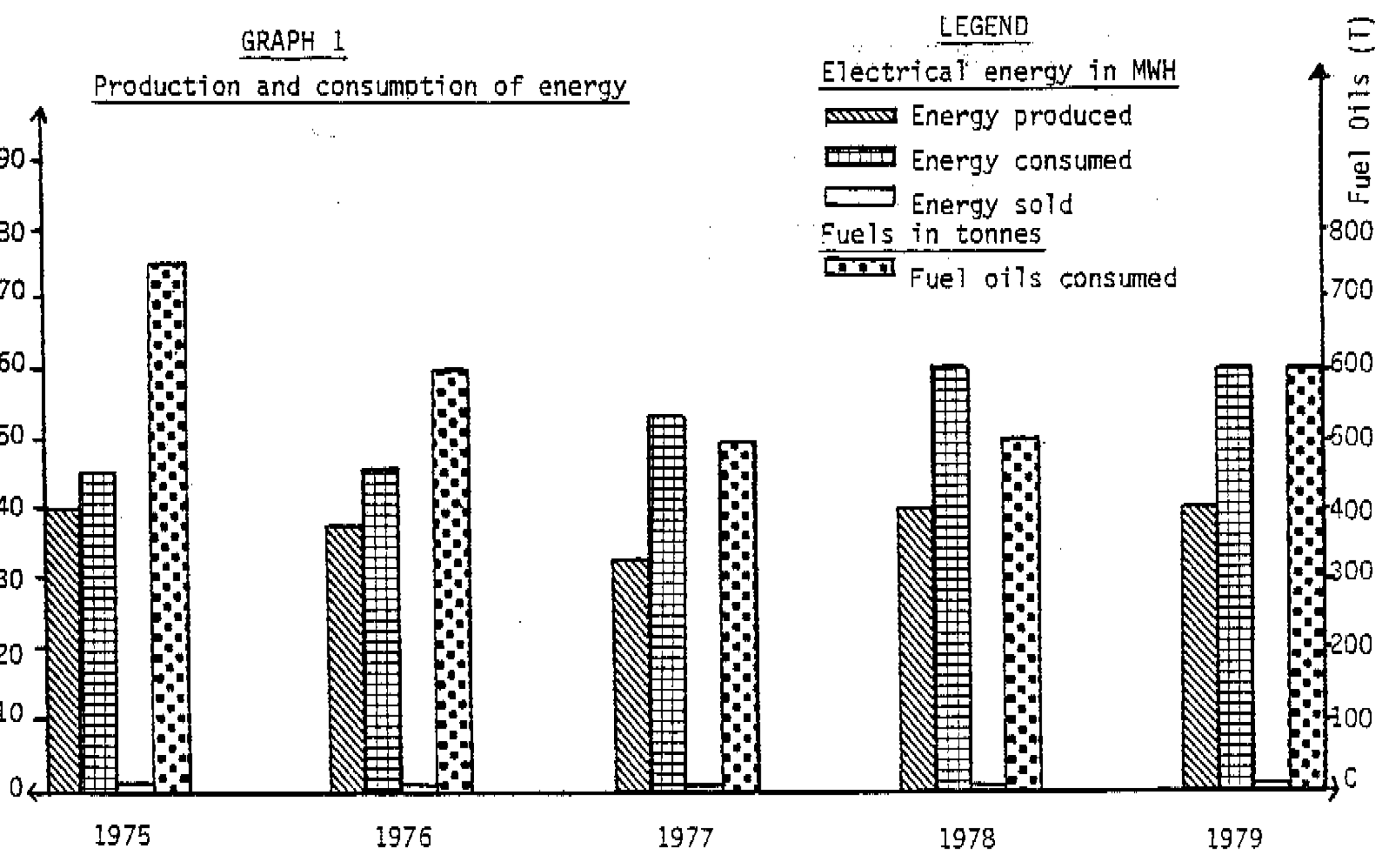
II - PRODUCTION, DISTRIBUTION AND CONSUMPTION OF ENERGY IN THE FACTORY

The attached plan No. 1658/I shows the energy circuit of the factory.

The graph 1 below shows the production and the consumption of electrical energy together with the consumption of fuel oil by the factory for the period 1975 - 1979.

GRAPH 1

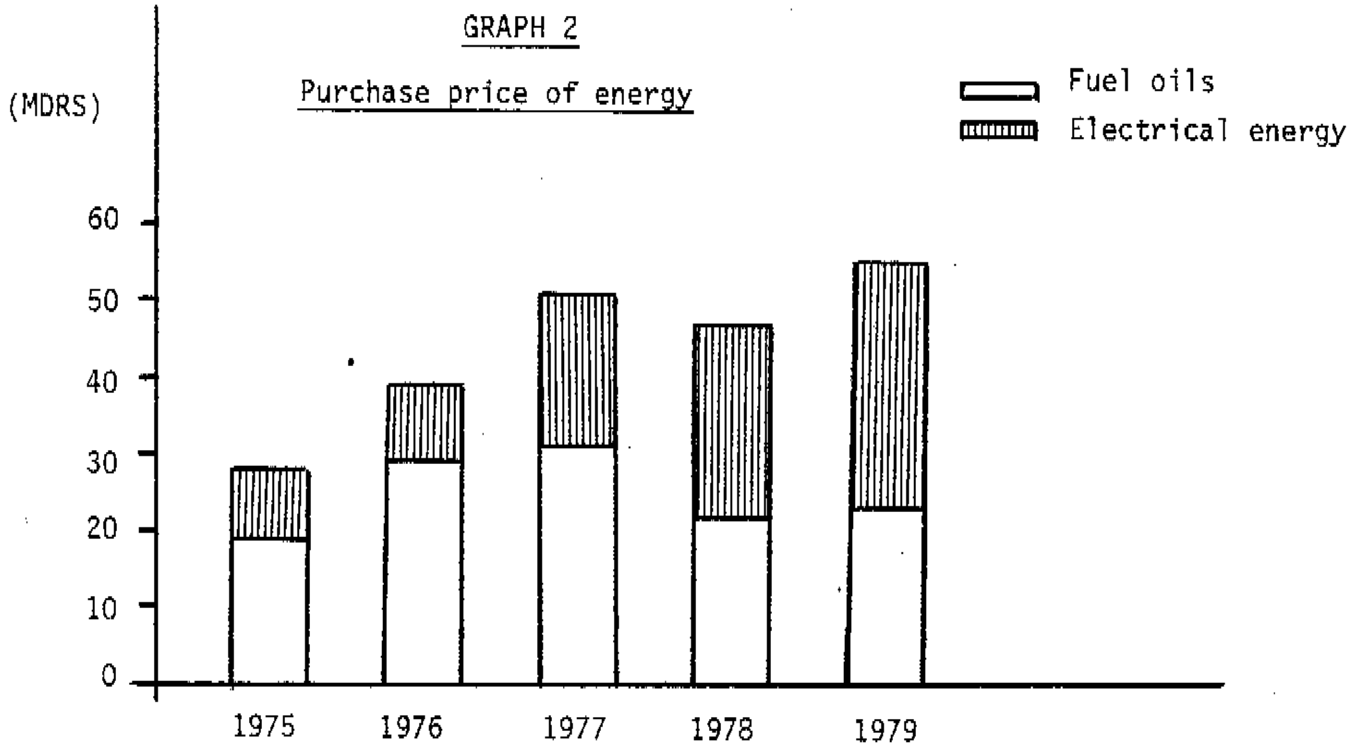
Production and consumption of energy



The graph 2 shows the total amounts paid to purchase this energy in this same period.

GRAPH 2

Purchase price of energy



III - EVALUATION OF THE PRODUCTION AND THE CONSUMPTION OF ENERGY IN UNITS

The production or the consumption of energy in a unit for the manufacture of a particular product depends essentially on its operating conditions. In other words:

$$E = F\ (P)\ ,\ \text{in which}$$

E = energy produced or consumed
P = production

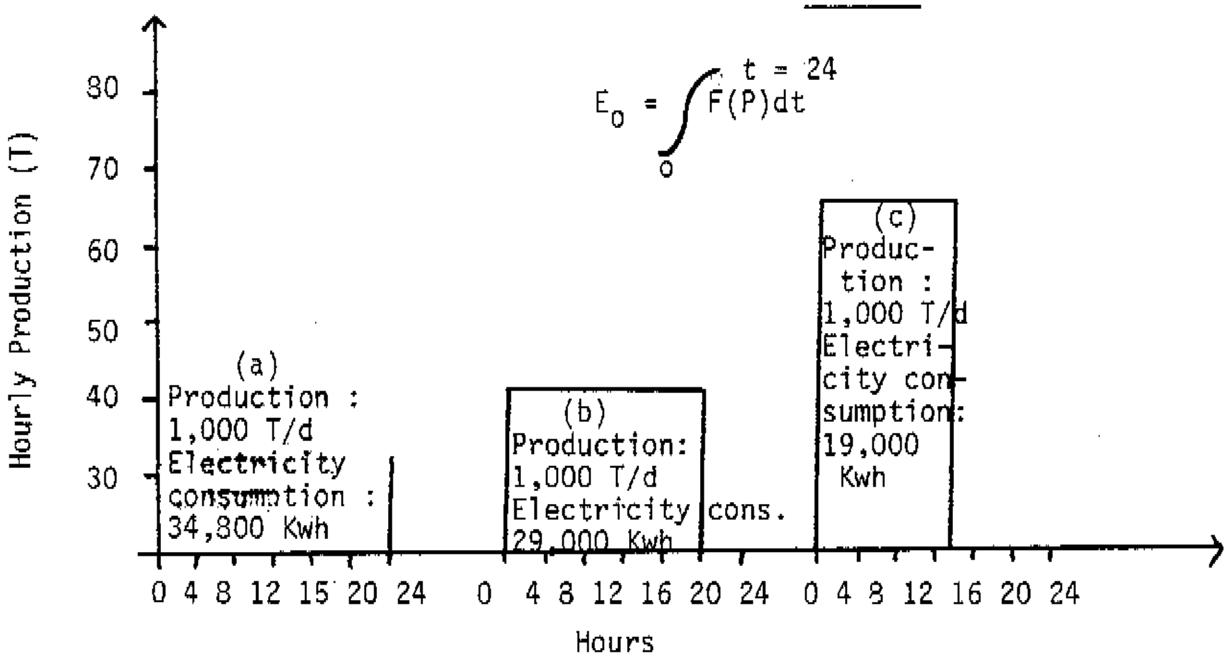
The amounts of energy produced or consumed in a unit during a period t will be:

$$E = \int_0^t F\ (P)\ dt$$

The integral shows us that this amount of energy depends not only on the amount P of products manufactured, but also on the procedure which has been followed in order to manufacture it.

The chart 1 below shows, by way of example, the amount of energy consumed during one day in order to manufacture 1,000 tonnes of a particular product, in a unit with a maximum capacity of 1,800 T/d, when different production schedules - (a), (b), (c) - are imposed. For example, to a first approximation, the power consumed by the unit, assumed to be 1,450 KW, is considered to be virtually independent of its operating conditions in the range from 1,000 to 1,800 T/d.

CHART 1



The development of an energy model for the whole of the factory presupposes the possibility of representing the main energy flows, in the unit and between the units, in an analytical form. The difficulties of this representation depend essentially on the processes examined, the existing measuring instruments (number, precision) and the possibility of deliberately varying the operating conditions of the units in order to obtain experimental measurements. Certain assumptions are unavoidable.

The attached graphs 3 and 4, together with Table 1, give the production and the consumption of energy in the units of the factory, as a function of their operating conditions.

The results of an elaborate study made it possible to integrate all the data concerning the production, the distribution and the consumption of energy in the factory. These data were collated from the supply contracts of the units, the plans, the equipment specifications, the operating schedules of the units and the experience of the operators. The main difficulty encountered during this study was the inadequacy of the measuring instruments installed for measuring the energy flows, and this imposed the need to make a considerable number of assumptions.

IV - DEVELOPMENT OF THE ENERGY MODEL OF THE FACTORY

IV-I : THE MODEL OF THE ENERGY BALANCE

The graphs 3 and 4, together with Table 1, enable us, within the assumptions made, to draw up an energy balance in the factory, as a function of the operating conditions of the units,

The attached Table 2 gives the analytical expressions of the above items of information.

This table is a mathematical model which describes the energy situation of the factory when the different factors (modes of operation, operating programs of the units) vary.

This mathematical model gives the instantaneous energy balance of the factory. In the case where we are interested in the energy balance of the factory during a certain period of time t, during which operating conditions of the units vary, we must divide this period t into a number of sub-periods n, each corresponding to a stable operating situation of the units, i.e.:

$$t = t_1 + t_2 + \ldots\ldots\ldots + t_i \ldots\ldots\ldots + t_n$$

so as to be able to integrate the analytical expressions contained in the table.

Transfer of the model to our computer

Having given the operating conditions of the units and also the amounts of HP and LP steam sent to the unit heaters of the FERTILISER UNIT, the model developed informs us, by way of analytical expressions, of the energy flows circulating in the factory. Although the necessary calculations can be carried out manually, it is obvious that the use of a computer greatly facilitates this operation.

Our computer department currently has an NCR type computer at its disposal, which we used for this purpose.

The inputs into this program are:

a) The operating conditions of the units, Ri
b) The stable operating periods of the units, ti
c) The amounts of HP steam (V72, V73) and LP steam (U72, U73, U74) sent to the unit heaters of the FERTILISER UNIT.

The outputs are:

a) The amounts of HP steam (V), MP steam (Y) and LP steam (U) produced and consumed by the units of the factory.
b) The amounts of MP and LP steam required for heating.
c) The amounts of LP steam in excess (sent into the atmosphere) or deficit.
d) The total electrical energy consumed by the units.
e) The amounts of HP steam available for electrical energy production in the turbo-alternators (T/A).
f) The total electrical energy (nett) produced by the T/A.
g) The purchases and sales of electrical energy from and to HED.

The writing, coding and checking of the program required about one month's work by the staff of the computer department.

Cobol language was used.

The inputs into the computer are based on the daily "production sheet" of the factory.

IV-2 : CHECKS

A - Of the program

The final form of the program fed into the computer was checked on the basis of a series of tests, which confirmed that the results given by the computer are consistent with those obtained by manual processing of the data (inputs).

B - Of the energy model

The energy model gives the flows of the different forms of energy circulating in the factory, according to the various operating conditions of the units. By way of example, the attached computer print-out given in Appendix I shows these flows for 26.8.1980 within the period from 00h to 03h. For the model to be accepted, it must represent "actual conditions" with a certain degree of precision which we estimate to be sufficient for our calculations.

In our particular case, we estimated that a precision of the order of 10% is sufficient.

It should also be noted that a better approach becomes difficult not only because of the limitation of the possibilities of the model, but also because of the actual conditions themselves, which cannot be determined with great precision.

This is due to the limited precision of the measuring devices and means available to us, to the definition of the exact time of start-up, operation and shutdown of the units, and also to the changes with time of the operating parameters and the efficiencies of the units.

To check the precision of the model, we drew the graphs given in the attached Appendices 2.1 and 2.2, which show the daily amounts of electrical energy produced by the turbo-alternators, together with the amount consumed by the units, as they are determined by the measuring devices (dotted line) and by the model (continuous line) in the period from 1.7 to 31.7.1980.

A detailed analysis, on a daily basis, of the deviations in excess of 10% showed us that these deviations are substantiated up to this level.

V - USE OF THE ENERGY MODEL IN THE ENERGY SAVING OPERATION

The energy model developed is a very useful tool which can assist greatly in our energy saving efforts in the following areas:

1) The control of the production and the consumption of energy in the factory.
2) The control of the amounts of sulphuric acid produced.
3) The control of the change with time of the energy savings made by the factory, even when the operating conditions vary.
4) The definition, the evaluation and the economic viability of the energy-saving modifications and conversions to the existing circuits.
5) The definition and the evaluation of the investment for saving energy according to the estimated operating conditions of the factory and the prices of the different forms of energy.
6) The utilisation and the equivalence of the different forms of energy used.

It is obvious that the use of this data-processing tool presupposes an understanding of its physical concept represented by this model.

On this point, we can say that the model represents "an energy situation of the factory which is close to the ideal situation and which can be provided by the existing installations and circuits".

In the sections which follow, we will give a certain number of examples of the use of the model in the areas (1) to (6) above.

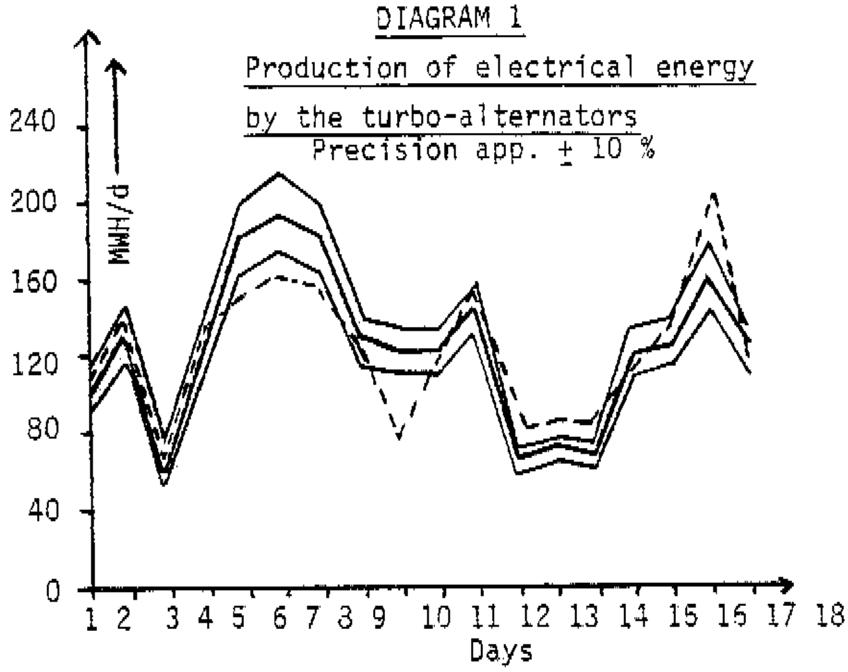
V.1 : CONTROL OF THE ENERGY PRODUCED AND CONSUMED IN THE FACTORY

The thick curve of diagram 1 gives the values of the electrical energy produced daily by the turbo-alternators, as calculated by the computer, in a 19-day period.

DIAGRAM 1

Production of electrical energy by the turbo-alternators

Precision app. ± 10 %



In Section IV.2, we estimated to a first approximation that the precision of the model is of the order of 10%. The dark zone in this diagram represents the range of this precision. The dotted line gives the corresponding actual value. Control of the electrical energy produced by the turbo-alternators passes through the following steps:

1) Measurement of the deviation:

$Ep = Epm - Epr$, in which

Epm = electrical energy calculated by the computer

Epr = actual electrical energy produced.

2) Analysis and explanation of the deviations in the case where

$$\frac{\Delta Ep}{Epm} > +10\%$$

3) Taking corrective action (instructions, modifications etc.) in order to avoid the deviations.

For example, on the 9th of the month, there is a substantial deviation, which could be due to:

a) The shutdown of one of the three T/A
b) The simultaneous operation of the three T/A at a time when only two would suffice.
c) A leakage of HP steam in one of the three condensers.
d) A wastage of the MP steam in the processes.
e) An over-estimation of the production of sulphuric acid.
f) Several other reasons and combinations of the above reasons or different reasons.

Checking is also necessary in the case where $\frac{\Delta Ep}{Epm} < -10\%$

The deviation on the 18th of the month belongs to this category. One explanation could be an under-estimated production of sulphuric acid.

The analysis of a series of deviations observed over a sufficiently long period of time can give us very useful data. In diagram 1, for example, we find that during the 5th, 6th and 7th of the month, there are deviations exceeding 10% when the T/A are running at a high speed. In the case where this is systematically observed, under normal operating conditions, only during the hot months of the year, one explanation would be a drop in the performance characteristics of the T/A because of the increase in the temperatures of the water and the air for cooling the condensers.

DIAGRAM 2

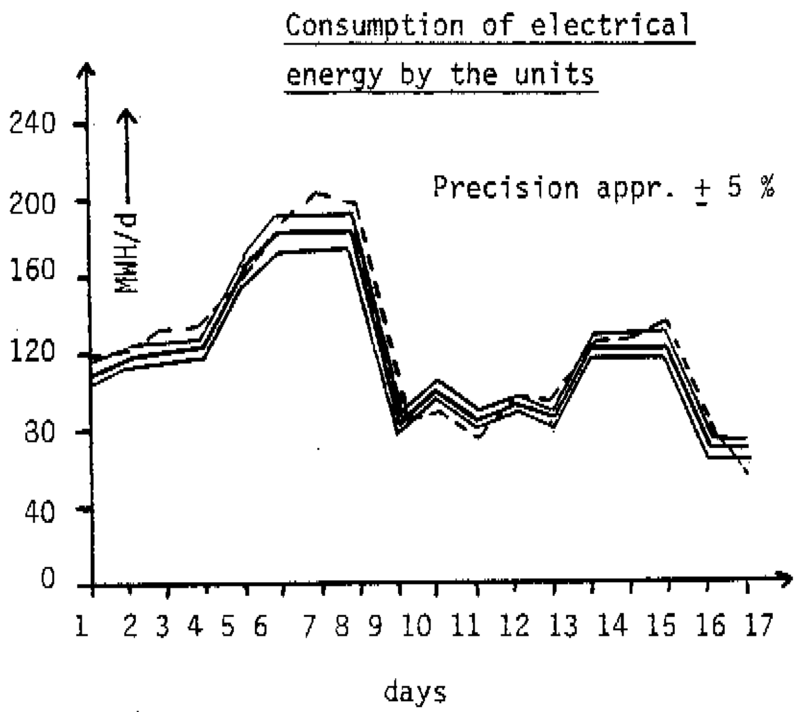
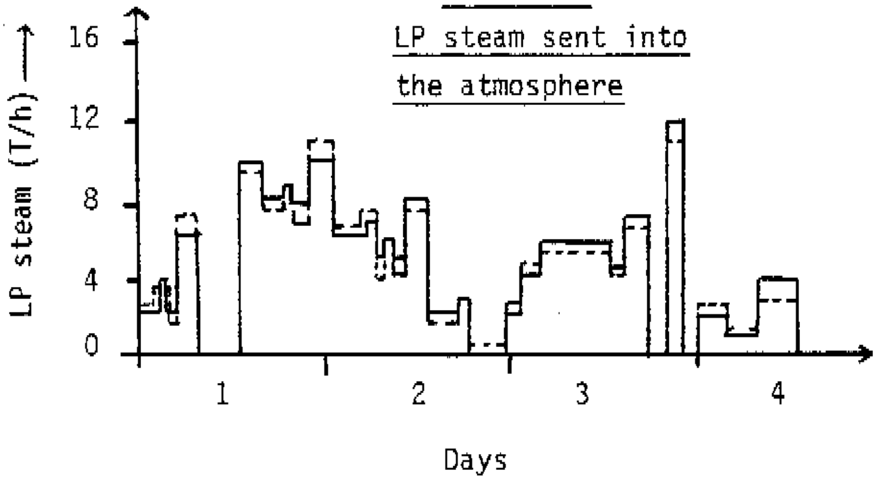


Diagram 2 gives the amount of electrical energy consumed daily by the units. The deviations shown are essentially due to the start-up and shutdown of the units, during which an amount of electrical energy is consumed without production. The checking in this case is based on the same principles as before.

DIAGRAM 3



In the same way, we can check the amounts of LP steam sent into the atmosphere (diagram 3), with the aid of a measuring instrument (e.g. a diaphragm) installed on the air pipe.

The model also offers us the possibility of controlling the change in the energy savings in the factory, with the aid of statistics. To compare two periods, say T1 and T2, it suffices to compare the average deviations (model minus actual) shown in these periods.

This same model also offers us the possibility of making energy predictions based on the existing predictions for the manufacture of the various products.

V.2 : THE FINANCIAL MODEL, DECISION MAKING

The financial model

The attached chart 2 shows the various energy flows passing through the limits of the factory, together with the main flows between the units. The flows in this chart are identified with the same symbols as in the computer print-out.

The price (Ci) of the energy used by the factory, in a stable operating period Ti, is given by the formula (3) below:

$$C_T = \left[L.p_L + F.p_F + E221(a)Pe_a - E221(v).Pe_v \right] . Ti \quad (3), \text{ in which}$$

L = heavy fuel oil (T/h)
F = fuel oil (diesel) (T/h)
E221(a) = electrical energy purchased from HED (Kwh/h)
E221(v) = electrical energy sold to HED (Kwh/h)
p_L, p_F, Pe_a, Pe_v = the corresponding unit prices (Drs/T and Drs/Kwh)
In the chart 2, we see that L = L1 + L2.

L2 is the amount of heavy fuel oil intended for the FERTILISER unit, which depends on the amounts of HP and LP steam sent into the unit heaters of this unit for heating the combustion and dilution air used in the drier.

This dependence is defined by the formula (4)

$$L2 = L2' - C_{LV} .(V72 + V73 + U72 + U73 + U74) \qquad (4)$$

in which L2 = the amount of heavy fuel oil (T/h) required to reheat the gases intended for drying in the drier, without using steam in the unit heaters, and
C = the coefficient of replacement of the heavy fuel oil by steam in order to heat the air to the same temperature.

A simple theoretical calculation shows that:

$$C_{LV} = (0.0575) . \frac{\text{T of heavy fuel oil}}{\text{T of steam}}$$

From the above, the formula (3) takes the form (3') below:

$$\boxed{Ci = \left[\left[L1+L2'-(0.0575)(V72+V73+U72+U73) \right] p_L + F.p_F + E221(a)Pe_a - E221(v).Pe_v \right] .TI} \quad (3')$$

The total price (C_T) of the energy used by the factory in a period of time T, composed of n sub-periods of stable operation, is obviously given by the formula (5)

$$C_T = \sum_{i=1}^{i=n} (C_i) \qquad (5)$$

Decision making

With the aid of the computer and on the basis of the operating conditions of the factory, whether actual or predicted, and also of the prices (actual,

predicted or time-dependent) of the different forms of energy used, the above financial model enables us to define and evaluate:
1) The investment in energy terms,
2) The conversions and the modifications of the circuits, and
3) The equivalence of the different forms of energy,
and to make decisions accordingly.

In the attached Appendix 3, some examples are given which show the use of this model in the areas described above.

It should also be noted that the models enable us, in all cases, to calculate the risk incorporated in each of the decisions to be made. For example, in the event of the installation of an M/B in the Anhydrous unit 2, the complete shutdown of the Anhydrous unit 1, the sudden increase in the price of the heavy fuel oil, or the need for continuous operation of the phosphoric acid concentration unit etc.

VI - <u>CONTROLLING THE ENERGY SAVINGS</u>

The energy model can inform us about the deviations existing between the ideal energy and the energy actually produced and çonsumed in the factory, but it cannot locate the equipment or the circuits responsible for these deviations. To be able to control the energy saving, it is necessary to have a certain number of instruments for measuring the main energy flows in the factory.

The plan No. S 1658/2 shows the points of the circuit where the installation of certain additional measuring instruments would permit an adequate check of the energy produced and consumed.

The choice of these points was made on the basis of the following criteria:

a) Centralisation of the data
b) Possibility of measuring the heat losses of the circuits connecting the units
c) Responsibility for checking the energy divided between different manufacturing sectors of the factory.

As regards the consumption of the electrical energy, in particular, it is essential to install a certain number of additional meters to enable the consumption of each of the units to be measured separately.

VII - <u>CONCLUSIONS</u>

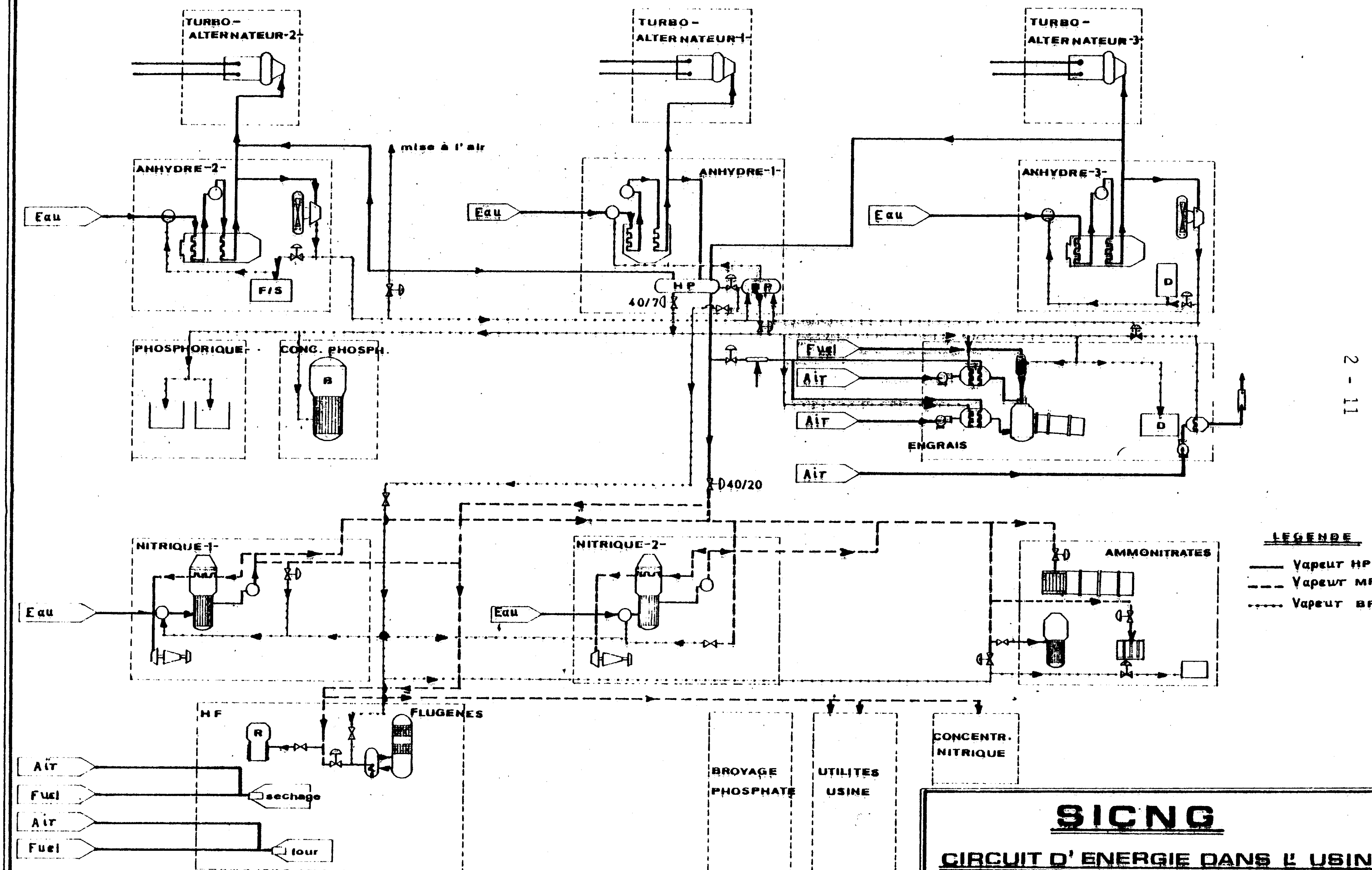
The model which has been developed of the energy balance of the factory, and which describes a situation close to the ideal situation, affords us the possibility of checking the production and the consumption of energy and also the change in the energy savings in the factory. With this model, and aided by our computer and by statistics, we are capable, on the basis of the estimated operating conditions of the factory, of defining and evaluating the investment and the modifications envisaged for saving energy. This enables us to optimise our decisions and to calculate the risks involved in the case where the future is probable and undetermined.

We note that this data processing tool is very useful for evaluating the different alternatives envisaged in the area of energy savings, but the final decisions must be made on the basis of other factors as well, namely the reliability and the flexibility of operation of the factory, the regulations and the restrictions of the authorities etc.

To control the energy savings in the factory, the installation of a certain number of instruments for measuring the energy flows is essential in order to have a complete series of primary and sufficiently precise items of information.

CAPTIONS OF FLOWSHEET PLAN 1658/1
(from left to right and top to bottom)

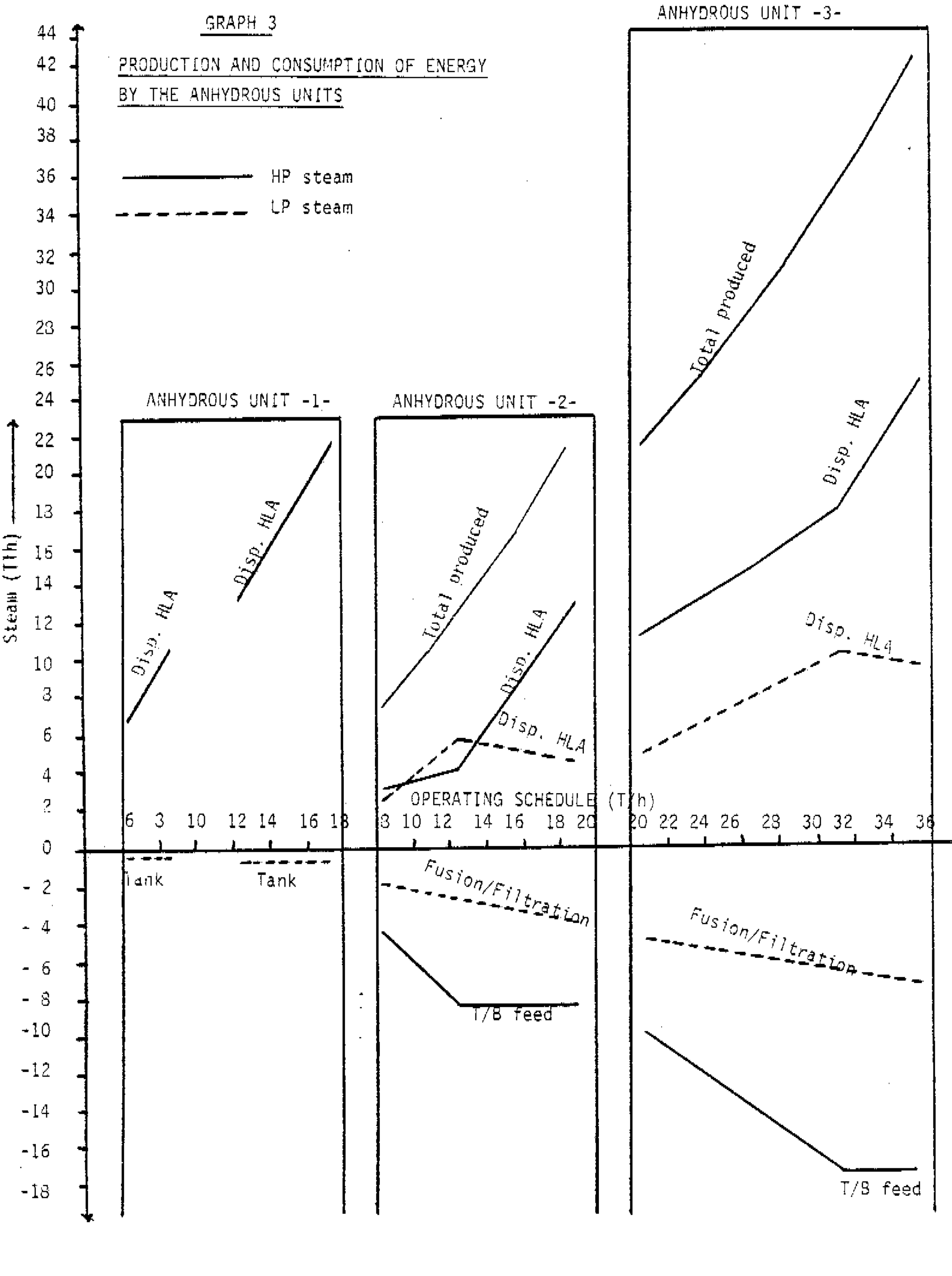
TITLE : ENERGY CIRCUIT IN THE FACTORY	TITRE : CIRCUIT D'ENERGIE DANS L'USINE
Turbo Alternator	Turbo-Alternateur
Anhydrous Unit	Anhydre
to the atmosphere	mise à l'air
Water	Eau
Phosphoric acid	Phosphorique
Phosphoric acid concentration	Conc. Phosphorique
Fertilizer Unit	Engrais
Nitric acid	Nitrique
Calcium ammonium nitrate	Ammonitrates
LEGEND : HP steam	LEGENDE : Vapeur HP
MP steam	Vapeur MP
LP Steam	Vapeur BP
Flugens	Flugenes
Phosphate grinding	Broyage Phosphate
Factory utilities	Utilités usine
Nitric acid concentration	Concentr. Nitrique
Drying	Séchage
Furnace	Four



SIÇNG

CIRCUIT D' ENERGIE DANS L' USINE

Plan 1658/1


GRAPH 3
PRODUCTION AND CONSUMPTION OF ENERGY BY THE ANHYDROUS UNITS
HP steam
LP steam
Steam (T/h)
ANHYDROUS UNIT -1-
ANHYDROUS UNIT -2-
ANHYDROUS UNIT -3-
OPERATING SCHEDULE (T/h)
Disp. HLA
Total produced
Tank
Fusion/Filtration
T/B feed

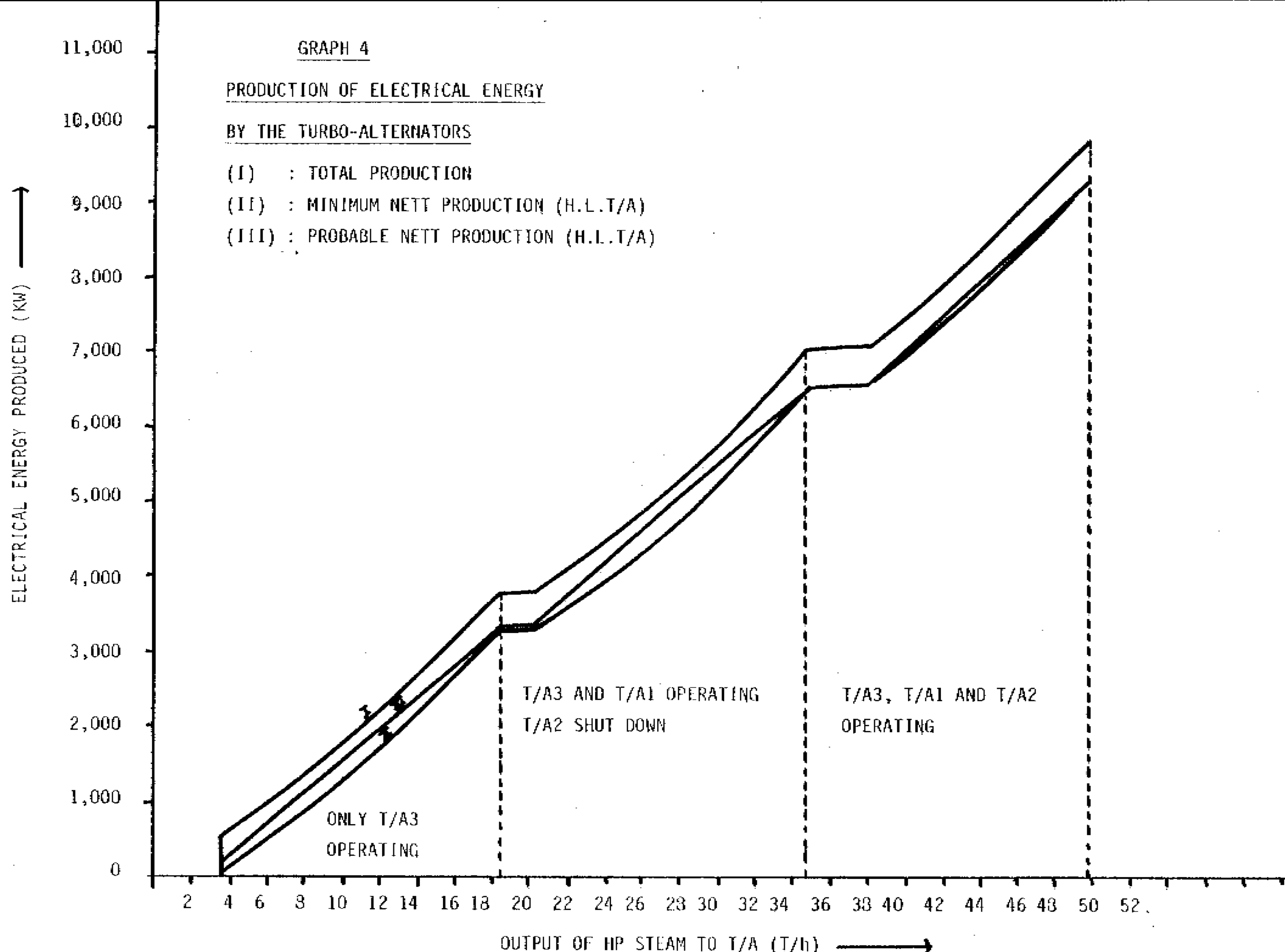

GRAPH 4
PRODUCTION OF ELECTRICAL ENERGY
BY THE TURBO-ALTERNATORS
(I) : TOTAL PRODUCTION
(II) : MINIMUM NETT PRODUCTION (H.L.T/A)
(III) : PROBABLE NETT PRODUCTION (H.L.T/A)
ELECTRICAL ENERGY PRODUCED (KW)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
ONLY T/A3
OPERATING
T/A3 AND T/A1 OPERATING
T/A2 SHUT DOWN
T/A3, T/A1 AND T/A2
OPERATING
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
OUTPUT OF HP STEAM TO T/A (T/h)

TABLE I

PRODUCTION(+) AND CONSUMPTION (-) OF ENERGY IN THE
VARIOUS UNITS (EXCEPT ANHYDROUS UNITS) OF THE FACTORY

UNIT	OPERATING SCHEDULE (R) (T/h)	STEAM (T/H) →			ELECTRICAL ENERGY (KW)	OBSERVATIONS
		HP	MP	LP		
PHOSPHORIC ACID						
1 Filter	Operating	-	-	(0.22)R	(- 500)	*Maximum theoretical values
2 Filters	Operating	-	-	(0.22)R	- 850	
PHOSPHORIC ACID CONCENTRATION	Operating	-	-	2 R	- 150	
FERTILISER	Operating				- 1,450	
Vats + Filters P.D.		-	-	- 1		
LP Heater units						
- for combustion		-	-	Ø to -1.23*		
- for dilution		-	-	Ø to -2.64*		
- for the platform		-	-	Ø to -4.42*		
HP Heater units						
- for combustion		Ø to -2.84*	-	-		
- for dilution		Ø to -6.10*	-	-		
NITRIC ACID 1	Operating	-	- 1.5	- 1.2	- 350	
NITRIC ACID 2	Operating	-	+ 2.5	- 0.8	- 350	
NITRIC ACID CONCENTRATION	Operating	-	- 0.7	-	- 25	
AMMONITRATES	Operating		- 7.5	- 1	- 700	
LIMESTONE GRINDING					- 300	
PROFLUOR (HF + Cl)	Operating	-			- 1,000	
HFA alone	Operating	-		- 0.3	- 700	
FL alone	Operating	-	- 0.5	- 1.4	- 700	
PHOSPHATE GRINDING	Operating	-	-	-	- 300	
DEGREMONT STATION	Operating	-	-	-	- 400	
FACTORY UTILITIES AND CONDITIONING	Operating	-	- 0.5	- 0.5	- 450	

TABLE 2

HOURLY ENERGY BALANCE OF THE FACTORY

Energy model

Reference	UNITS	OPERATING SCHEDULE R (T/h)	LIMITS	STEAM (T/h): High pressure (40 bars) (V)	STEAM (T/h): Medium pressure (20 bars) (Y)	STEAM (T/h): Low pressure (6 bars) (U)	ELECTRICAL ENERGY CONSUMED (kwh) (Ec)
1	ANHYDROUS UNIT 1						
1.1	1 line	R_{011}	$6.25 \leqslant R_{011} \leqslant 8.75$	$V_{011} = (0.0684)R_{011}^2+(0.6507)R_{011}$	-	$U_{011} = -0.4$	$E_{011} = 1000$
1.2	2 lines	R_{012}	$12.5 \leqslant R_{012} \leqslant 17.5$	$V_{012} = (0.0341)R_{012}^2+(0.6507)R_{012}$	-	$U_{012} = -0.8$	$E_{012} = 1500$
2	ANHYDROUS UNIT 2	R_{020}	$8.33 \leqslant R_{020} \leqslant 18.75$	$V_{020} = (0.0240)R_{020}^2+(0.7)R_{020}$	-	-	$E_{020} = 400$
2.1	Input T/B		$8.33 \leqslant R_{020} \leqslant 12.5$	$V_{021} = (0.9592)R_{020} - 3.49$	-	-	
2.2	Input T/B		$12.6 \leqslant R_{020} \leqslant 18.75$	$V_{022} = 8.5$			
2.3	Output T/B		$8.33 \leqslant R_{020} \leqslant 12.5$	-	-	$U_{023} = V_{021}$	
2.4	Output T/B		$12.6 \leqslant R_{020} \leqslant 18.75$	-	-	$U_{024} = 8.5$	
2.5	Consumption F/F		$8.33 \leqslant R_{020} \leqslant 18.75$	-	-	$U_{025} = (0.1919)R_{020}+0.4019$	
2.6	Steam available H.L.A.		$8.33 \leqslant R_{020} \leqslant 12.5$	$V_{026} = V_{020} - V_{021}$	-	$U_{026} = U_{023} - U_{025}$	
2.7	Steam available H.L.A.		$12.6 \leqslant R_{020} \leqslant 18.75$	$V_{027} = V_{020} - 8.5$	-	$U_{027} = 8.5 - U_{025}$	
3	ANHYDROUS UNIT 3	R_{030}	$20.83 \leqslant R_{030} \leqslant 35.42$	$V_{030} = (0.0119)R_{030}^2+(0.7786)R_{030}$	-		$E_{030} = 750$
3.1	Input T/B		$20.83 \leqslant R_{030} \leqslant 31.25$	$V_{031} = (0.7197)R_{030}-(4.99)$			
3.2	Input T/B		$31.26 \leqslant R_{030} \leqslant 35.42$	$V_{032} = 17.5$			
3.3	Output T/B		$20.83 \leqslant R_{030} \leqslant 31.25$	-	-	$U_{033} = V_{031}$	
3.4	Output T/B		$31.26 \leqslant R_{030} \leqslant 35.42$	-	-	$U_{034} = 17.5$	
3.5	Consumption F/F		$20.83 \leqslant R_{030} \leqslant 35.42$	-	-	$U_{035} = (0.1713)R_{030}+1.4326$	
3.6	Steam available H.L.A.		$20.83 \leqslant R_{030} \leqslant 31.25$	$V_{036} = V_{030} - V_{031}$	-	$U_{036} = U_{033} - U_{035}$	
3.7	Steam available H.L.A.		$31.26 \leqslant R_{030} \leqslant 35.42$	$V_{037} = V_{030} - 17.5$	-	$U_{037} = 17.5 - U_{035}$	

TABLE 2 (continuation I)

Reference	UNITS	OPERATING SCHEDULE R (T/h)	LIMITS	STEAM (T/h)			ELECTRICAL ENERGY CONSUMED (kwh) (Ec)
				High pressure (40 bars) (V)	Medium pressure (20 bars) (Y)	Low pressure (6 bars) (U)	
4	<u>ANHYDROUS UNIT SECTOR</u>						
4.1	Steam available H.L.S.	R_{040}		$V_{041} = (V_{011}+V_{012}) + (V_{026}+V_{027}) + (V_{036}+V_{037})$	-	$U_{041} = (U_{011} + U_{012}) + (U_{026} + U_{027}) + (U_{036} + U_{037})$	
5	<u>PHOSPHORIC ACID</u>						
5.1	1 Filter	R_{051}	none	-	-	$U_{051} = -(0.22)R_{051}$	$E_{051} = 500$
5.2	2 Filters	R_{052}	none	-	-	$U_{052} = -(0.22)R_{052}$	$E_{052} = 850$
6	<u>PHOSPHORIC ACID CONCENTRATION</u>	R_{060}	none	-	-	$U_{060} = -2R_6$	$E_{060} = 150$
7	<u>FERTILISER</u>	R_{070}	none	-	-	-	$E_{070} = 1450$
7.1	Vats + Filters + Preheaters	R_{071}			-	$U_{071} = -1$	
7.2	Unit heater for combustion (HP)	R_{072}		$V_{072} = \ldots$	-	$U_{072} = \ldots$	
7.3	Unit heater for dilution (HP)	R_{073}		$V_{073} = \ldots$	-	$U_{073} = \ldots$	
7.4	Unit heater for the platform	R_{074}			-	$U_{074} = \ldots$	
8	<u>NITRIC ACID 1</u>	R_{080}	$7.5 \leqslant R_{080} \leqslant 11.25$	-	$Y_{030} = -1.5$	$U_{080} = -1.2$	$E_{080} = 350$
9	<u>NITRIC ACID 2</u>	R_{090}	$7.5 \leqslant R_{090} \leqslant 10.80$	-	$Y_{090} = +2.5$	$U_{090} = -0.8$	$E_{090} = 350$
100	<u>NITRIC ACID CONCENTRATION</u>	R_{100}	none	-	$Y_{100} = -0.7$	-	$E_{100} = 25$
110	<u>AMMONITRATES</u>	R_{110}	none	-	$Y_{110} = -7.5$	$U_{110} = -1$	$E_{110} = 700$

TABLE 2 (continuation II)

Reference	UNITS	OPERATING SCHEDULE R (T/h)	LIMITS	STEAM (T/h) High pressure (40 bars) (V)	Medium pressure (20 bars) (Y)	Low pressure (6 bars) (U)	ELECTRICAL ENERGY CONSUMED (kwh) (Ec)
120	PROFLUOR (HF + FL)						($E_{121}+E_{122}$ together E = 1000)
121	HFA alone	R_{121}	none	-	-	$U_{121} = -0.3$	$E_{121} = 700$
122	FLUGEN alone	R_{122}	none	-	$Y_{122} = -0.5$	$U_{122} = -1.4$	$E_{122} = 700$
130	LIMESTONE GRINDING	R_{130}	none	-	-	-	$E_{130} = 300$
140	PHOSPHATE GRINDING	R_{140}	none	-	-	-	$E_{140} = 300$
150	DEGREMONT STATION	R_{150}	none	-	-	-	$E_{150} = 400$
160	FACTORY UTILITIES + CONDITIONING	R_{160}	none	-	$Y_{160} = -0.5$	$U_{160} = -0.5$	$E_{160} = 450$

TABLE 2 (continuation III)

170	TOTAL MP STEAM REQUIRED FOR HEATERS (T/h)	$Y_{170} = Y_{080} + Y_{090} + Y_{100} + (Y_{120} \text{ and } Y_{122}) + Y_{160}$	
180	TOTAL LP STEAM REQUIRED FOR HEATERS (EXCEPT ANHYDROUS UNITS) (T/h)	$U_{180} = (U_{051} + U_{052}) + U_{060} + U_{071} + U_{072} + U_{073} + U_{074} + U_{080} + U_{090} + U_{110} + (U_{120} + U_{121} + U_{122}) + U_{160}$	
190	EXCESSES (+) [to the atmosphere] or DEFICITS (-) OF LP STEAM	$U_{190} = U_{041} + U_{180}$	
200	TOTAL ELECTRICAL ENERGY CONSUMED BY THE UNITS (KWh)	$E_{200} = (E_{011} + E_{012}) + E_{020} + E_{030} + (E_{051} + E_{052}) + E_{060} + E_{070} + E_{080} + E_{090} + E_{100} + E_{110} + (E_{120} + E_{121} + E_{122}) + E_{130} + E_{140} + E_{150} + E_{160}$	
210	HP STEAM AVAILABLE FOR THE PRODUCTION OF ELECTRICAL ENERGY (T/h)	$V_{210} = V_{041} + \frac{Y_{170}}{1.16} + (\frac{U_{190}}{1.20}$ in the case where U_{190} is negative) + $V_{072} + V_{073}$	
220	TOTAL NETT ELECTRICAL ENERGY (KWh) (H.L.T/A) PRODUCED BY THE T/A E_{220}	LIMIT FOR V_{210}	VALIDITY OF THE FORMULA
		$0 \leqslant V_{210} < 3.5$	$E_{220} = 0$
		$3.5 \leqslant V_{210} \leqslant 18.5$	$E_{220} = 213\ V_{210} - 596$
		$18.5 < V_{210} \leqslant 20.4$	$E_{220} = 3344$
		$20.4 < V_{210} \leqslant 34.8$	$E_{220} = 219\ V_{210} - 1121$
		$34.8 < V_{210} \leqslant 38$	$E_{220} = 6500$
		$38 < V_{210} \leqslant 55$	$E_{220} = 237\ V_{210} - 2503$
221	PURCHASES OF ELECTRICAL ENERGY FROM HED (kwh)	$E_{221} = E_{220} - E_{200}$	

APPENDIX I

ENERGY BALANCE FOR THE PERIOD FROM 00.00 TO 03.00 HOURS PRODUCTION DATE 20/03/80

REFERENCE	UNITS	OPERATING SCHEDULE (R)	VALUE OF R(T/H)	S T E A M (T / H)			ELECTRICAL ENERGY	F U E L O I L S (T / H)	
				HP (V)	MP (Y)	LP (U)		BUNKER FUEL 1500	DIESEL OIL
010	ANHYDROUS UNIT 1								
012	2 LINE	R012	15.42	18.6		-0.8	1500		
020	ANHYDROUS UNIT 2	R020	16.00	17.3			0400		
022	INPUT T/B			8.5					
024	OUTPUT T/B					8.5			
025	CONSUMPTION F/F					3.5			
027	STEAM AVAILABLE HLA			8.8		5.0			
030	ANHYDROUS UNIT 3	R030	31.25	35.9			0750		
031	INPUT T/B			17.5					
033	OUTPUT T/B					17.5			
035	CONSUMPTION F/F					6.8			
036	STEAM AVAILABLE HLA			18.4		10.7			
040	ANHYDROUS UNIT SECTOR								
041	STEAM AVAILABLE HLS			45.8		14.9			
050	PHOSPHORIC ACID								
051	1 FILTER	R051	5.11			-1.1	0500		
052	2 FILTER	R052				0.0	0000		
060	PHOSPHORIC ACID CONCENTRATION	R060	3.00			-6.0	0150		
070	FERTILISER	R070	37.71				1450		
071	VATS + FILTERS + PREHEATERS					-1.0			
073	AE/ME FOR DILUTION			-2.0		0.0			
080	NITRIC ACID 1	R080	9.38		-1.5	-1.2	0350		
090	NITRIC ACID 2	R090	8.54		2.5	-0.8	0350		
110	AMMONITRATES	R110	25.77		-7.5	-1.0	0700		
121	HFA	R121	.62			-0.3	0700		
122	FLUGENS	R122	1.42		-0.5	-1.4	0300		
130	LIMESTONE GRINDING	R130					0000		
150	DEGREMONT STATION	R150	1.00				0400		
160	FACTORY UTILITIES CONDITIONING	R160	1.00		-0.5	-0.5	0450		

170	MP STEAM (T/H) REQUIRED FOR HEATERS		Y170 =	-7.5
180	LP STEAM (T/H) REQUIRED FOR HEATERS (EXCEPT ANHYDROUS UNITS)		U180 =	-13.3
190	EXCESS(+) (TO THE ATMOSPHERE) OR DEFICITS OF LP STEAM (T/H)		U190 =	1.6
200	ELECTRICAL ENERGY CONSUMED BY THE UNITS		E200 =	8000.0
210	HP STEAM AVAILABLE FOR THE PRODUCTION OF ELECTRICAL ENERGY (T/H)		V210 =	37.4
220	NETT ELECTRICAL ENERGY (KWH) (H.L.T/A) PRODUCED BY THE T/A (T/H)		E220 =	6500.0
221	PURCHASES (-) OR SALES (+) OF ELECTRICAL ENERGY (KHW) FROM OR TO HED		E221 =	-1500.0
222	PURCHASE (-) OR SALES (+) OF ELECTRICAL ENERGY IN THIS PERIOD	E221(T2-T1)	E222 =	-4500.0
223	PRODUCTION OF ELECTRICAL ENERGY IN THIS PERIOD	E220(T2-T1)	E223 =	19500.0
224	ELECTRICAL ENERGY CONSUMED BY THE UNITS IN THIS PERIOD	E200(T2-T1)	E224 =	24000.0
225	EXCESS (+) OR DEFICITS (-) OF LP STEAM IN THIS PERIOD	U190(T2-T1)	E225 =	4.8

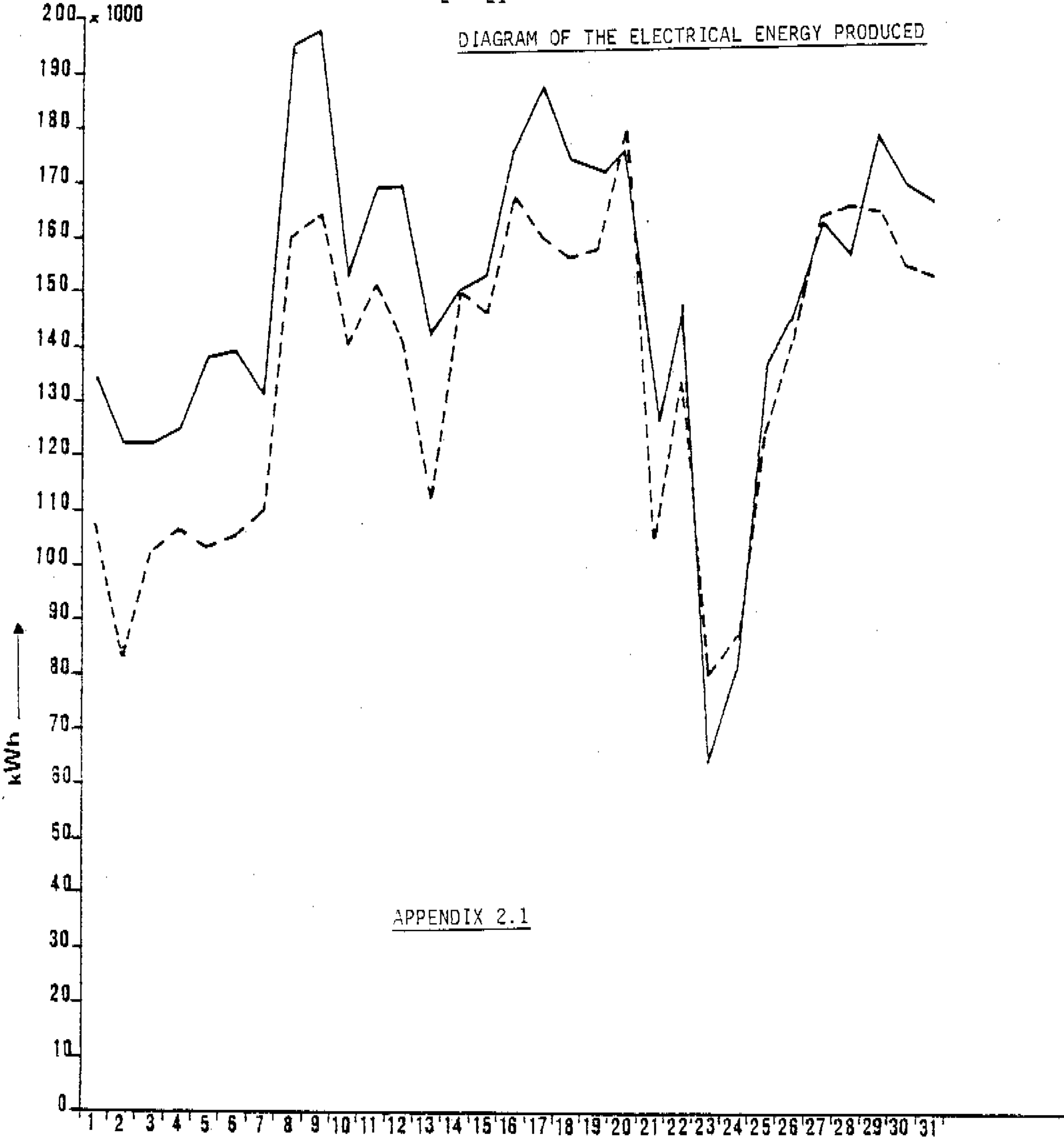


DIAGRAM OF THE ELECTRICAL ENERGY PRODUCED

APPENDIX 2.1

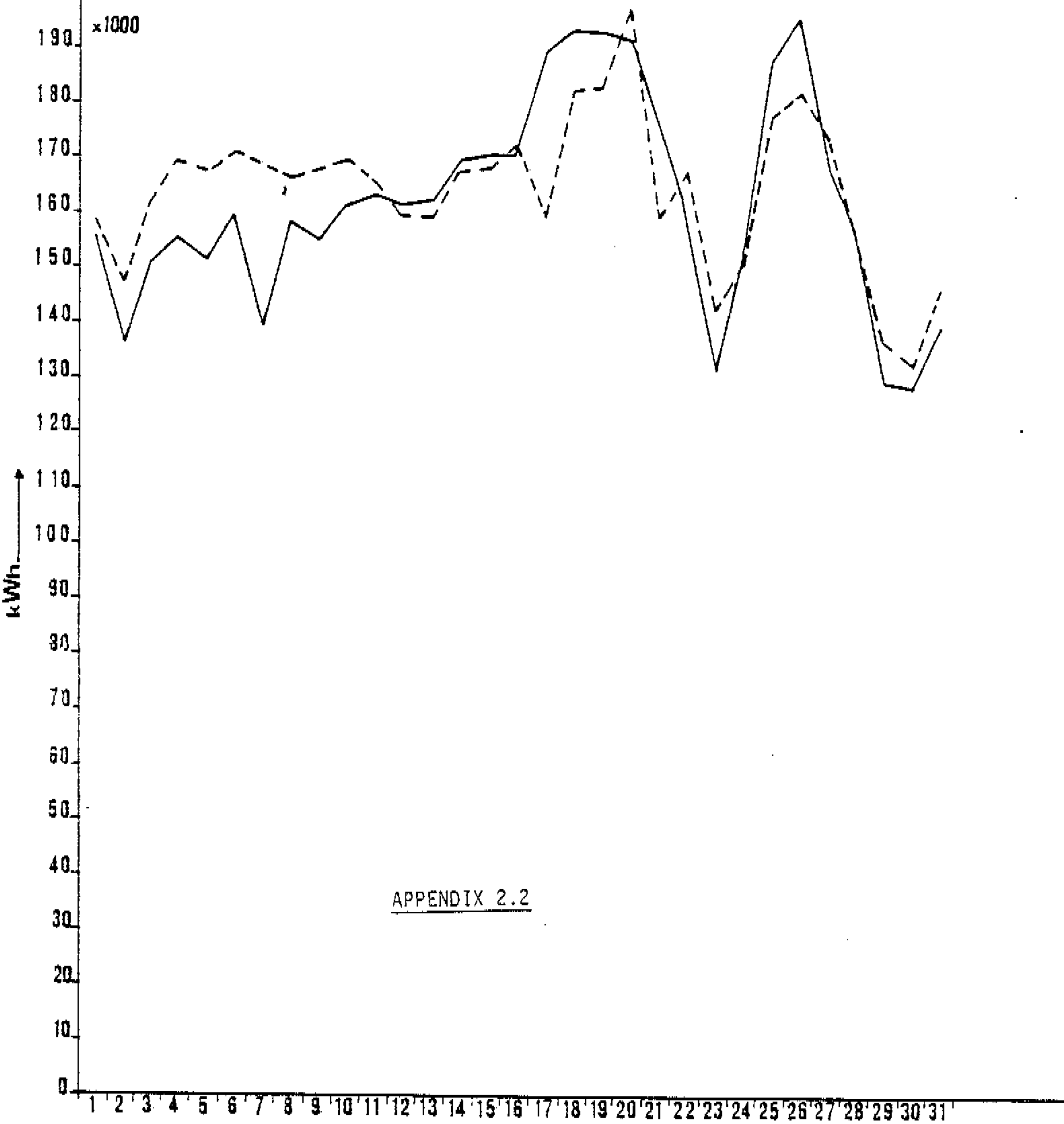
MONTH OF JULY 1980

MODEL :

PRODUCTION SCHEDULE :

TOTAL CONSUMPTION BY THE UNITS

APPENDIX 2.2



MONTH OF JULY 1980

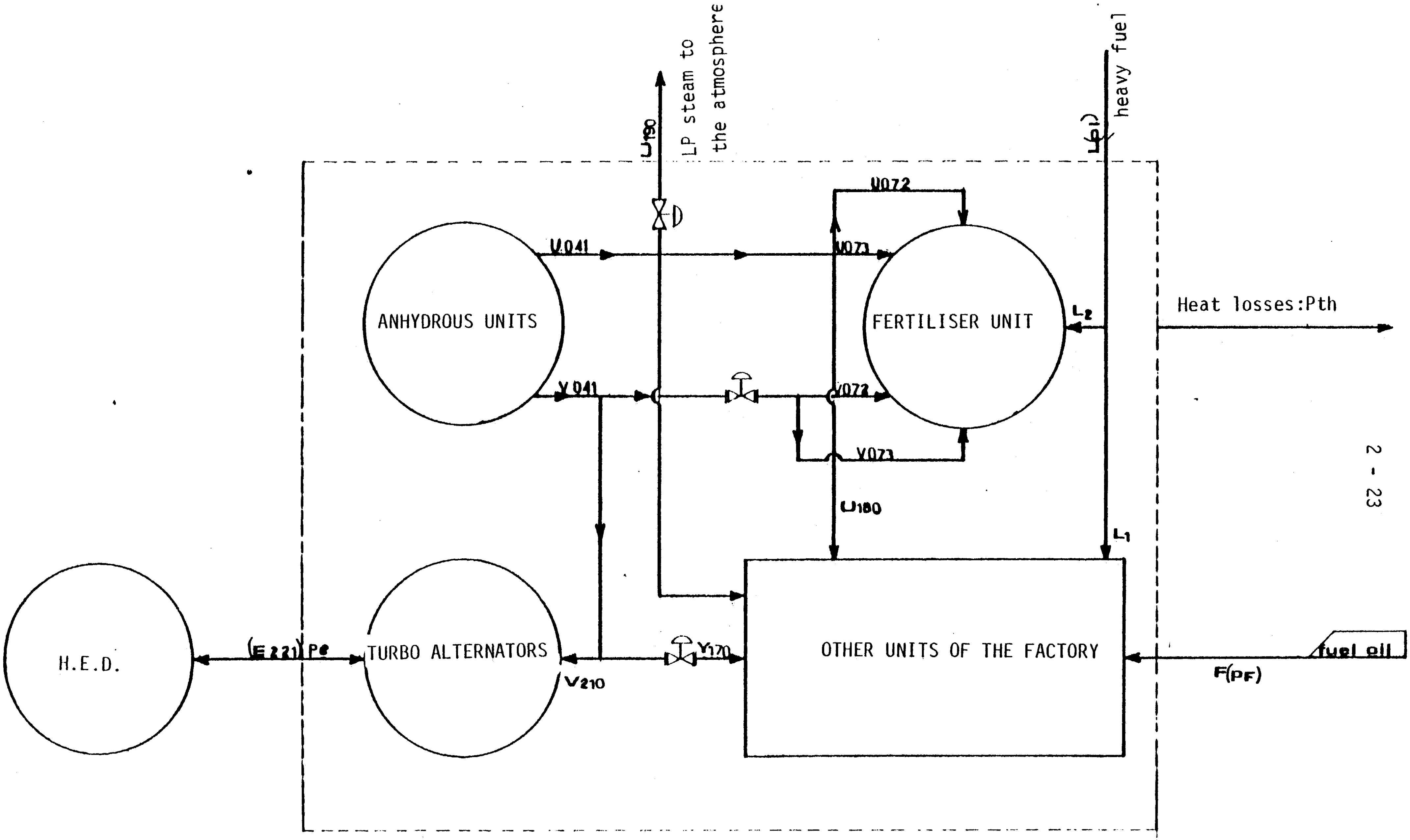
MODEL : ————

PRODUCTION

SCHEDULE : – – – –

CHART 2

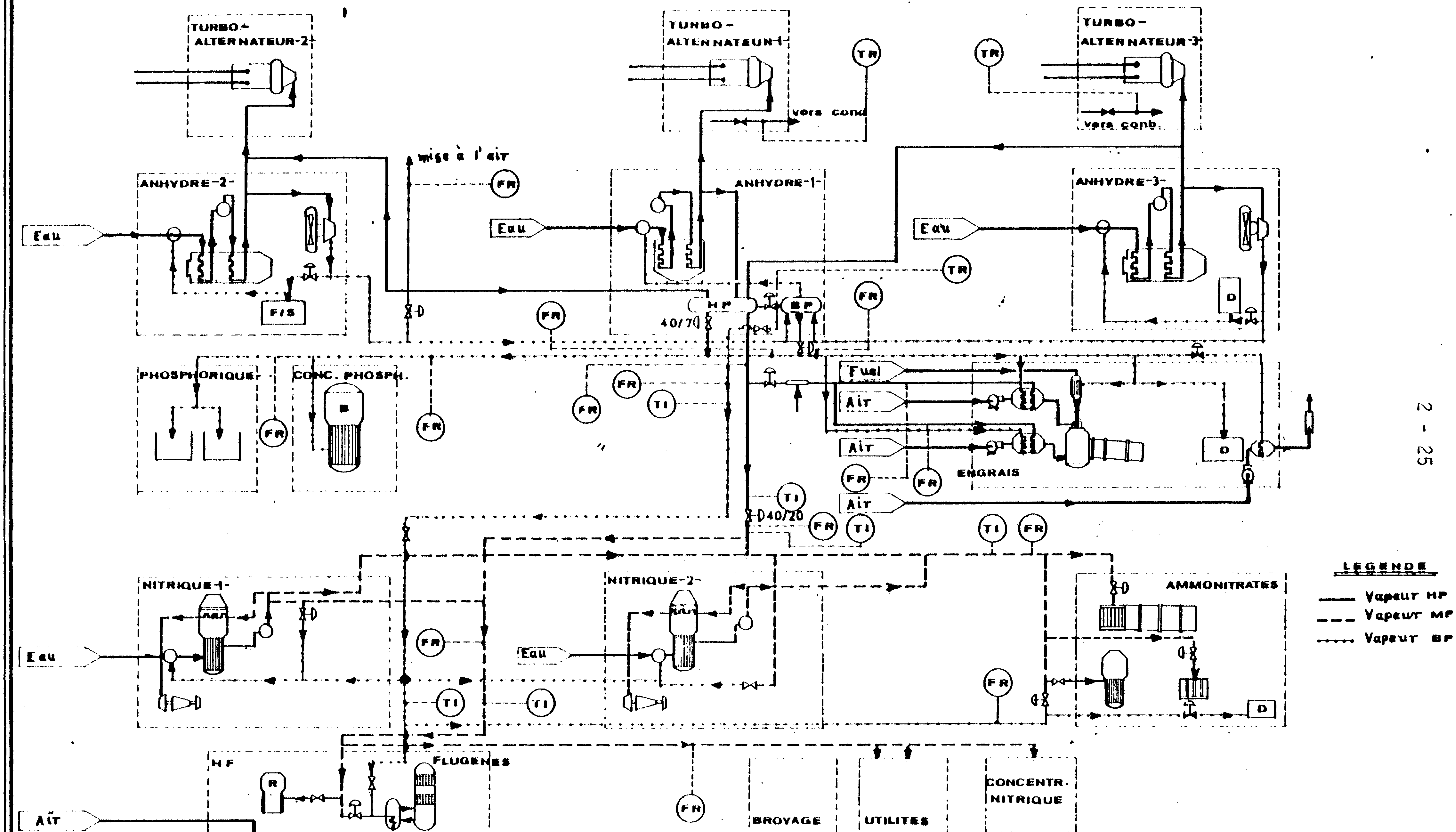
ENERGY CIRCUIT



CAPTIONS OF FLOWSHEET PLAN 1658/2

(from left to right and top to bottom)

TITLE : ENERGY CIRCUIT IN THE FACTORY	TITRE : CIRCUIT D'ENERGIE DANS L'USINE
Turbo Alternator	Turbo-Alternateur
to condenser	vers condenseur
Anhydrous unit	Anhydre
to the atmosphere	mise à l'air
Water	Eau
Phosphoric acid	Phosphorique
Phosphoric acid concentration	Conc. Phosphorique
Fertilizer Unit	Engrais
Nitric acid	Nitrique
Calcium ammonium nitrate	Ammonitrates
LEGEND : HP steam	LEGENDE : Vapeur HP
MP steam	Vapeur MP
LP steam	Vapeur BP
Flugens	Flugenes
Phosphate grinding	Broyage Phosphate
Factory utilities	Utilités Usine
Nitric acid concentration	Concentr. Nitrique
Drying	Séchage
Furnace	Four



SICNG

CIRCUIT D' ENERGIE DANS L' USINE

Plan 1658/2

APPENDIX 3

EXAMPLES OF USE OF THE MODEL

Example 1 : Investments

The schedules of the "energy balance of the factory" leave the computer department regularly every day, and certain data contained are recorded in special files which we have created for this purpose (memory). Amongst the other data collected, there are the amounts of LP steam sent into the atmosphere. We follow them systematically on a graph or on a table and, after a sufficiently long period - say 100 days - we find that these amounts are significant. This fact has attracted our attention and we envisage replacing the turbo-blower of the anhydrous unit 2 by a motor-driven blower or a motor-driven turbo-blower. The main question which must be answered is as follows:

"What is the expected benefit of this replacement?".

With the energy model and financial model, and with the aid of the computer, this question is easy to answer, either on the basis of the operating elements of the factory as available to us, or on the basis of these same elements rectified according to expectations (eg.: conversion of the anhydrous unit 1 to a sulphur unit, or longer operating time of the phosphoric acid concentration unit in the future, or higher price of the Kwh purchased etc.).

We can also optimise this investment as related to the unit heaters installed in the FERTILISER unit on the basis of these same elements (as above), as a function of the change in the expected price of the heavy fuel oil.

Example 2 : Modifications/conversions

Assume that a manufacturer, attracted by the energy saving campaigns, proposes a modification in a unit, consisting, for example, in a saving of 1 tonne of LP steam per hour of operation of his unit, having a price of 1,000,000 Drs; should this be carried out or not? Would this be an economically viable modification or would it result in an unnecessary increase in the amount of steam sent into the atmosphere?

Hitherto, there has been no means of replying to this proposition. With the models, the answer is simple. The procedure to be adopted for evaluating this proposition is as follows:

- Calling-up from the files of the computer (memory) the operating periods of the unit in question, with the values of the LP steam sent into the atmosphere during the corresponding periods, for a sufficiently long period of, say, one year.
- Separating out the periods for which the factory had a deficit of LP steam (negative values).
- Evaluating the benefit expected from the existence of a surplus of 1 tonne of LP steam per hour during these periods.
- Calculating the pay-out time of the modification envisaged, etc.

Example 3 : Equivalence of the different forms of energy

The HP steam can be used either for the production of electrical energy in the turbo-alternators, or for the heating of the air intended for drying the N.P.K. fertilisers.

The model gives us the possibility of deciding which way to use it, as a function of the purchase and sale prices of the Kwh and also of the price of the heavy fuel oil.

TA/82/2 Optimisation of the use of energy in factories for the manufacture of fertilizers, with the aid of data processing - SICNG - Case study, by D. MARAGOS, SICNG, Greece

DISCUSSION : (Rapporteur Mr. P. ORPHANIDES, PFI, Greece)

Q - Mr. E.G. PULLEN, The Phosphate Cooperative Company of Australia Limited, Australia

In graph 1. you refer to approximately 2 MWH (4%) of electric power excess to your needs being shown as sold.

1. We would be interested in comments as to what conditions apply to its sale

2. Whether it is only acceptable during periods of maximum demand by the Thessaloniki power distributors; and

3. The manner in which the energy sold is credited against the energy consumed.

A - 1. There is a signed agreement between SICNG and DEH for the purchase of residual active energy by the formulation P = (rate/kmh) = 0.0019 L (L = price/t lignite).

2. The total amounts sold, which we try to minimize, are purchased. The invoicing is done montly by SICNG on the basis of the lignite price given by DEH each time it changes.

3. There is no compensation between the amounts purchased and sold. The invoices (DEH and SICNG) are independent. In addition, prices of the kwh purchased and sold vary and have no direct relationships.

(Present price of kwh purchased: 0.893 by DEH, price of kmh sold by DEH = 4.9 Dr).