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Model for the Optimum Planning of Production in Crude-Oil Processing

The paper presents a mathematical-economic model for the planning of production at an enterprise, industrial group and ministry level, at the level of the respective subbranch and branch for various planning periods.

To apply it at the level of a petrochemical plant and at that of the crude-oil processing branch, a Monte Carlo type algorithm and the FELIX C-256 computer were used.

The model presented is conceived as a production planning instrument at an enterprise, industrial group and ministry level and at the level of the economic subbranch and branch. It is based on the analysis of technological processes relying on the principles of the systems theory (the delimitation of the system and of the component subsystems-the economic units, the technological installations implied in the respective process, the identifying of the main technological relations, etc.).

The economic-mathematical model is a component part (subsystem) of the information system, respectively of the informatic system for planning production in crude-oil processing, a system which can be adapted and applied at various levels. The model provides a program deck adequate to the demands of electronic processing on the FELIX C-256 computer.

Considering that for the application of the system, information is necessary, information which already exists in the current information systems, the experimeting of the program deck could be easily implemented at the level of the Teleajen petrochemical plant and at that of the State Planning Committee, the results obtained being appreciated as positive, a fact which has led to its utilization in the planning activity.

The model is taking into account the present planning methodology in which a number of plan variants are worked out within acceptible limits.

Thus, the production capacities, the resources necessary for the carrying out of the production processes, the finished production, etc. are envisaged by lower and upper variation limits, these limits — lower and upper — may coincide, being determined exogeneously to the model.

The computation system conceived in this way can be used in the activities of working out the production plan proposals for various planning periods, mainly aiming at the best use of the production capacities. The new capacities planned to be put into operation in the respective period can also be included. In this case, information is supplied on the investment plan, a fact which confers on the model additional values for securing a correlation between production and investments. The model can also be used for the substantiation of decisions on the efficiency of the import and export of raw materials and finished articles, by taking into account the net currency contribution, etc.

A simulation algorithm was used for solving the model, namely by giving the variation limits of all order variables, a set of possible solutions is obtained.

In the following, to specify, to an ever greater extent, the model's variables and relationships and for a more complete explanation of the possibilities of using it, we shall present the model for the crude-oil processing subbranch.

Figure 1 represents the block scheme of the electronic data processing which has the following processing modules:

— the module for the random determination of possible solution to the presented model (a Monte Carlo type algorithm for determining the possible solutions is used within the computation model);

— the module for the determination of the values of the economic indices which are the objective functions of the model;

— the module for selecting the solutions by taking into consideration the values of the objective functions that have already been chosen. This module contains techniques for choosing the possible solutions in keeping with the planner's objectives.

In the following, we briefly present the main variables and relations of the model.

Figure 2 represents a simplified graph corresponding to the respective technological process, in which:

1. The nodes represent the processing installations L_i^j and the resources necessary for processing. The latter can be:

— raw and related materials, semi-products not ready for delivery (inputs of the processing process for each installation), noted with $R_{i,\,r(v)}^{j,\,s(v)}$;

— semi-products or finished products (outputs corresponding to each processing process) noted $\bar{R}_{i,\,\alpha(u)}^{j,\,\beta(u)}$.

2. The arces represent the processing technological order of the oil products.

The nodes are disposed on two types of levels, namely:

a) Levels of an even order, in case they represent processing technological installations (for example, levels 2, 4, 6, ... in Fig. 2);

FLOW CHART OF DATA ELECTRONIC PROCESSING SYSTEM PLANC

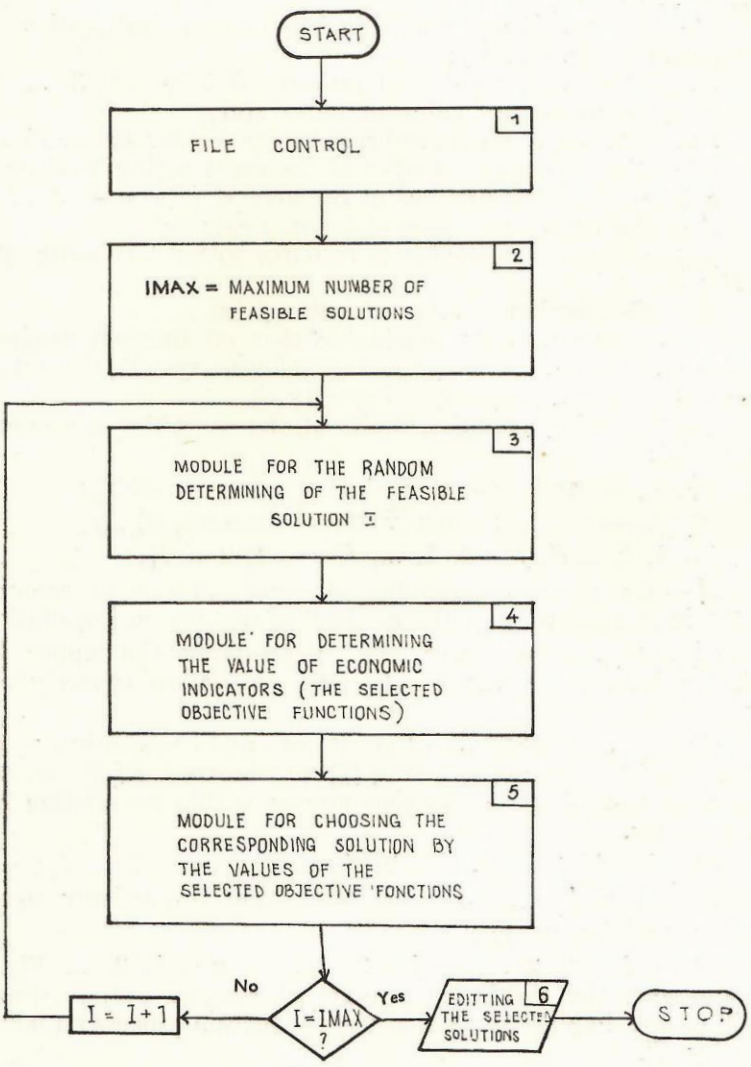

Fig. 1

b) Levels of an odd order corresponding to resources $R^{j,\,s(v)}_{i,\,r(v)}$ and $\bar{R}^{j,\,\beta(u)}_{i,\,\alpha(u)}$ (for example, levels 1, 3, 5, ... in Fig. 2).

In the following, the notations are used, as follows:

j — processing level ($j = 2,\ 4,\ 6, ..., J$);

J — the maximum value of index j;

i — the order of the processing installations within the level j($i = 1, 2, ... I^j$);

I^j — the maximum number of processing installations which are to be planned within level j;

$s(v)$ — the level number of resource R ($s(v) = 1, 3, ..., S$);

S — the maximum value of index $s(v)$;

$r(v)$ — the order number of resource within level $s(v)$ $r(v) = 1, 2, ..., R^s$);

R^s — the maximum number of resources within level $s(v)$;

$\alpha\ (u)$ — the level number of resource $\bar{R}$ ($\alpha(u) = 1, 3, ..., A$);

A — the maximum value of index $\alpha\ (u)$;

$\beta\ (u)$ — the order number of resource within level $\alpha(u)$, ($\beta(u) = 1, 2, ..., ..., B$);

B — the maximum value of index $\beta\ (u)$.

It is conventionally considered that all finished products are meant for consumption outside the given technological system, this external consumer being outlined in a graph by a capacity C^j_i.

The following variation limits of the variables are considered within the model:

$R^{j,\,s(v)}_{i,\,r(v)m}$ — the maximum value of resources $R^{j,\,s(v)}_{i,\,r(v)}$;

$R^{j,\,s(v)}_{i,\,r(v)M}$ — the maximum value of resource $R^{j,\,s(v)}_{i,\,r(v)}$;

$i = 1, 2, ... I^j,\ j = 2, 4, ..., J,\ v = 1, 2, ... I^j_i$;

I^j_i — the maximum number of inputs of various resources necessary for the implementation of the production process on installation L^j_i;

$C^j_{i,m}$, $C^j_{i,M}$ — the lower and respectively the upper limits of the variation interval of variable C^j_i (the production capacity of installation L^j_i);

$c^{j,\,s(v)}_{i,\,r(v),m}$ and $c^{j,\,s(v)}_{i,\,r(v),M}$ — the lower and respectively upper limits of the specific consumption [1]) $c^{j,\,s(v)}_{i,\,r(v)}$ of resource $R^{j,\,s(v)}_{i,\,r(v)}$ necessary for the implementation of the production process within installation L^j_i of the planned capacity.

$C^j_i,\ i = 1,\ 2, ... I^j,\ j = 2,\ 4, ..., J;\ v = 1,\ 2, ..., I^j_i$;

$p^{j,\,\beta(u)}_{i,\,\alpha(u),m}$ and $p^{j,\,\beta(u)}_{i,\,\alpha(u),M}$ — the lower and respectively upper limits of fraction (efficiency) $p^{j,\,\beta(u)}_{i,\,\alpha(u)}$

where $i = 1,\ 2, ..., I^j,\ j = 2,\ 4, ..., j,\ u = 1,\ 2, ..., E^j_i$,

E^j_i represents the maximum number of various outputs (resources) as a result of the implementation of the production process on installation L^j_i of capacity C^j_i.

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[1]) In this paper, by specific consumption we mean the quantity of resources necessary for the production of a resource unit (output) $\sum_{v=1}^{E^j_i} C^j_i p^{j,\,\beta(u)}_{i,\,\alpha(u)}$

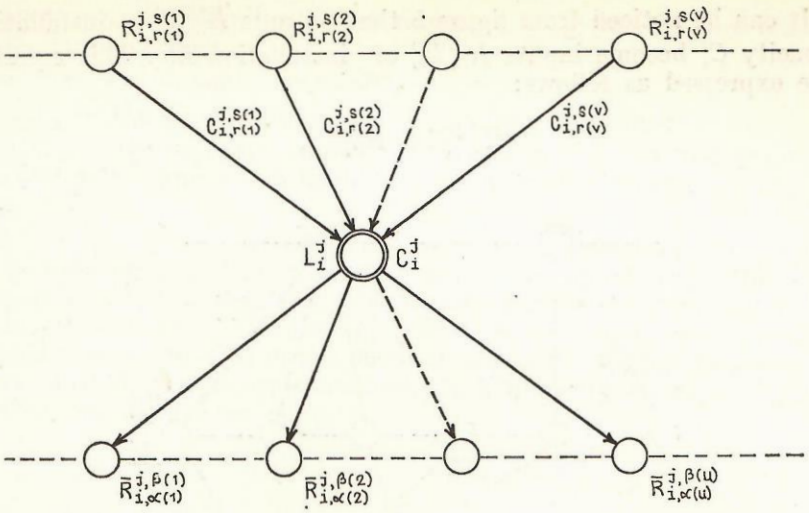

Fig. 3

Figure 3 outlines input $R^{j,\,s(v)}_{i,\,s(v)}$, capacity C^j_i, the outputs $\bar{R}^{j,\,\beta(u)}_{i,\,\alpha(u)}$ and the specific consumptions $c^{j,\,s(v)}_{i,\,r(v)}$ of resources $R^{j,\,s(v)}_{i,\,r(v)}$, wherefrom it can be noticed that

$$R^{j,\,s(v)}_{i,\,s(v)} = c^{j,\,s(v)}_{i,\,r(v)} \cdot \sum_{u=1}^{E^j_i} \bar{R}^{j,\,\beta(u)}_{i,\,\alpha(u)} \tag{1}$$

for $v = 1, 2, \ldots, I^j_i$ which represents an equilibrium condition of the outputs necessary for the production process L^j_i.

Figure 4 outlines capacity C^j_i and efficiency $p^{j,\,\beta(u)}_{i,\,\alpha(u)}$, wherefrom it is noticed that:

$$\bar{R}^{j,\,\beta(u)}_{i,\,\alpha(u)} = C^j_i p^{j,\,\beta(u)}_{i,\,\alpha(u)} \tag{2}$$

for $u = 1, 2, \ldots E^j_i$

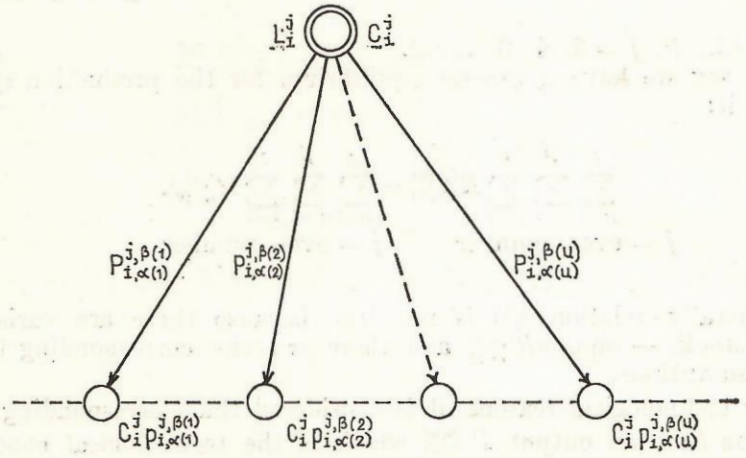

Fig. 4

It can be noticed from figure 5 that outputs $\bar{R}^{j,\,\beta(u)}_{i,\,\alpha(u)}$ of installation L^j_i of capacity C^j_i become inputs $R^{j',\,\beta(v)}_{i',\,\alpha(v)}$ of installation $L^{j'}_{i'}$. This equilibrium can be expressed as follows:

$$\bar{R}^{j,\,\beta(u)}_{i,\,\alpha(u)} = R^{j',\,\beta(v)}_{i',\,\alpha(v)}. \tag{3}$$

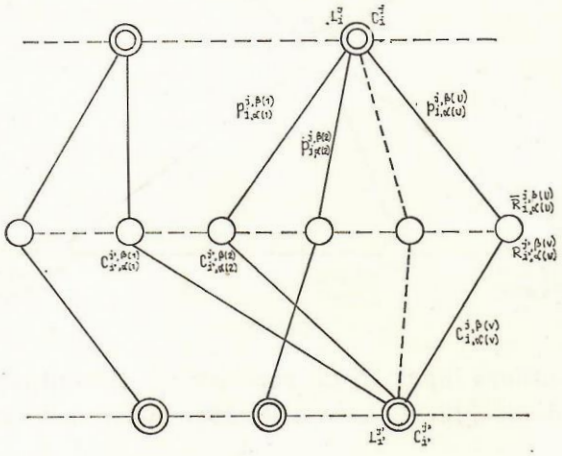

Fig. 5

Generally, we must verify the relations:

$$\sum_{u=1}^{I^{j'}_{i'}} \bar{R}^{j(i',j'),\,\beta(u)}_{i(i',j'),\,\alpha(u)} = \sum_{v=1}^{I^{j'}_{i'}} R^{j',\,s(v)}_{i',\,r(v)} \tag{4}$$

$i = 1, 2, \ldots, I^j$, $j = 2, 4, 6, \ldots, J$.

We say we have a general equilibrium for the production system as a whole, if:

$$\sum_{j=2}^{J}\sum_{i=1}^{I^j}\sum_{v=1}^{I^j_i} \bar{R}^{j,\beta(u)}_{i,\alpha(u)} = \sum_{j=2}^{J}\sum_{i=1}^{I^j}\sum_{v=1}^{I^j_i} R^{j,\,s(v)}_{i,\,r(v)}. \tag{5}$$

j = even number $\qquad$ j = even number

Generally, relation (5) is not true because there are variations of resource stocks — input s$R^{j,\,s(v)}_{i,\,r(v)}$ and there are the corresponding technological consumptions.

For technological reasons, it is considered that corresponding to any installation L^j_i is an output $\bar{R}^{j,\beta(u)}_{i,\alpha(u)}$ which is the technological consumption (the losses of resources-inputs $R^{j,\,s(v)}_{i,\,r(v)}$ during the transformation process).

If there is a variation in stocks of resources $R^{j,\ s(v)}_{i,\ r(v)}$ in this case relations (1) are no more verified.

For this, we introduce variables.:

$R^{j,\ s(v)}_{i,\ r(v),p}$ — the input-resources planned for processing;

$Cs^{j,\ s(v)}_{i,\ r(v),m}$ — the resource stock $R^{j,s(v)}_{i,r(v)}$ existing at the benginning of the planning period and which holds part of the maximum stocking capacity $Cs^{j,\ s(v)}_{i,\ r(v),M}$.

$Cs^{j,\ s(v)}_{i,\ r(v)}$ — the planned resource stock $R^{j,\ s(v)}_{i,\ r(v)}$ necessary for the production process on installation L^j_i. It should be noted that this stock may also be negative if input $R^{j,\ s(v)}_{i,\ r(v)}$ is insufficient for carrying out processing on installation L^j_i in the planned period. In this case, resource $R^{j,\ s(v)}_{i,\ r(v)}$, can be used if it is available in the form of a stock $Cs^{j,\ s(v)}_{i,\ r(v)m}$. Consequently this stock must decrease correspondingly to a quantity equal to $C^{j,\ s(v)}_{i,\ r(v)}$. It results that we have constraints:

$$0 \leqslant Cs^{j,\ s(v)}_{i,\ r(v)} + Cs^{j,\ s(v)}_{i,\ r(v),m} \leqslant Cs^{j,\ s(v)}_{i,\ r(v),M} \tag{6}$$

$i = 1, 2, ..., I^j$; $j = 2, 4, ..., J$; $v = 1, 2, ..., I^j_i$.

$$Cs^{j,\ s(v)}_{i,\ r(v)} = R^{j,\ s(v)}_{i,\ r(v)} - R^{j,\ s(v)}_{i,\ r(v),p} \tag{7}$$

$i = 1, 2, ..., I^j$; $j = 2, 4, ..., J$; $v = 1, 2, ..., I^j_i$.

Constraints (1) will be of the form

$$R^{j,\ s(v)}_{i,\ r(v),p} = c^{\ j,\ s(v)}_{i,\ r(v)} \sum_{u=1}^{E^j_i} \bar{R}^{j,\ \beta(u)}_{i,\ \alpha(u)}. \tag{8}$$

We can also outline constraints:

$$R^{j,\ s(v)}_{i,\ r(v),m} \leqslant \bar{R}^{j,\ s(v)}_{i,\ r(v)} \leqslant R^{j,\ s(v)}_{i,\ r(v),M} \tag{9}$$

$$\bar{R}^{j,\ \beta(u)}_{i,\ \alpha(u),m} \leqslant \bar{R}^{j,\ \beta(u)}_{i,\ \alpha(u)} \leqslant \bar{R}^{j,\ \beta(u)}_{i,\ \alpha(u),M} \tag{10}$$

$$p^{j,\beta(u)}_{i,\alpha(u),m} \leqslant p^{j,\ \beta(u)}_{i,\ \alpha(u)} \leqslant p^{j,\ \beta(u)}_{i,\ \alpha(u),M}, \tag{11}$$

$$c^{j,\ s(v)}_{i,\ r(v),m} \leqslant c^{j,\ s(v)}_{i,\ r(v)} \leqslant c^{j,\ s(v)}_{i,\ r(v),M}, \tag{12}$$

$$C^j_{i,m} \leqslant C^j_i \leqslant C^j_{i,M} \tag{13}$$

$i = 1, 2, ..., I^j$; $j = 2, 4, ..., J$; $v = 1, 2, ..., I^j_i$; $u = 1, 2, ..., E^j_i$;

$$\sum_{u=1}^{E^i_i} p^{j,\ \beta(u)}_{i,\ \alpha(u)} = 1 \tag{14}$$

$$\sum_{v=1}^{I^j_i} c^{j,s(v)}_{i,r(v)} = 1. \tag{15}$$

If an objective function (economic index), for example the gross production is added to the above constraints (2, 4, ..., 15), a non-linear programming model is obtained due to relations (2) and (8).

The presented model, with minimum adaptations, can be used for other technological processes as well.

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MODELE DE PLANNING OPTIMAL DE LA PRODUCTION POUR LE TRAITEMENT DU PETROLE

Les auteurs présentent un modèle économique-mathématique pour le planning de la production au niveau de l'entreprise, de la centrale industrielle, du ministère, de la sous-branche et de la branche respective pour différents horizons de planification.

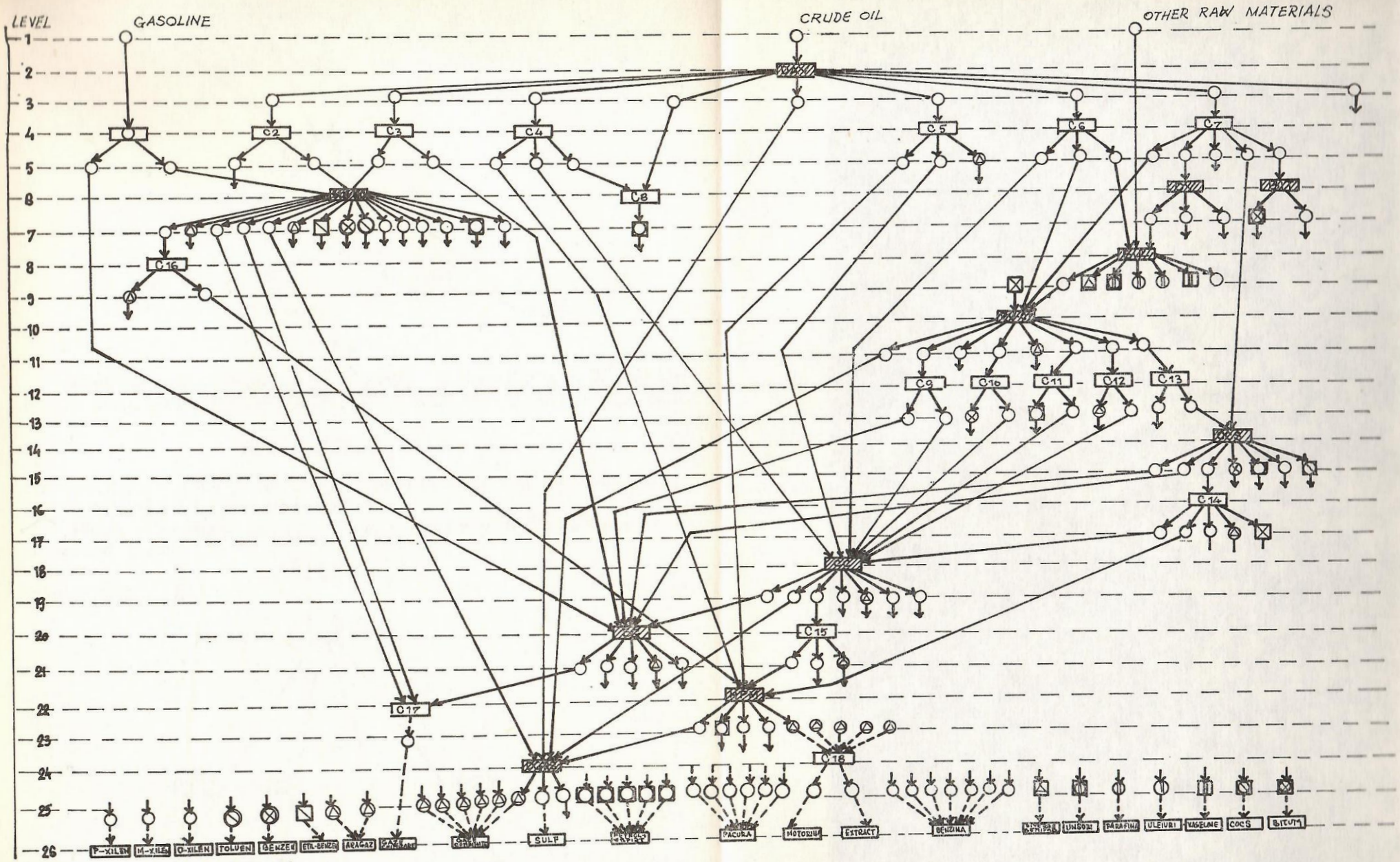
Pour l'application de ce modèle de traitement du pétrole au niveau d'un combinat pétrochimique et au niveau de la sous-branche on a utilisé un algorithme du type Monte-Carlo et l'ordinateur FELIX C-256.

МОДЕЛЬ ОПТИМАЛЬНОГО ПЛАНИРОВАНИЯ ПРОИЗВОДСТВА ПРИ ОБРАБОТКЕ НЕФТИ

Работа знакомит с экономико-математической моделью для планирования производства на уровне предприятия, промышленного объединения, министерства, на уровне соответствующей подотрасли и отрасли для разных горизонтов планирования.

Для её применения на уровне нефтехимического комбината и на уровне подотрасли нефтеобработки использован алгорифм типа Монте Карло и была использована вычислительная машина ФЕЛИКС С-256.

28.03.1976.



EXPLANATION:

- Plant
- Virtual plant
- Air and vacuum distilation
- Hydrofining
- Vacuum distilation for oil
- Bitum
- Viscousity reduction and thermal cracking
- Catalytic cracking
- Gas fractionation
- Hydrofining
- Gas desulfuration
- Oil block
- Carbon producing

EVEN RANK ORDER - Plants
ODD RANK ORDER - Resources
LEVEL 1 - Raw materials
LEVEL 26 - Finite products

- Technological consumption
- Medium oil circuit