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Some Aspects of the Use of Electronic Computers in Determining the Producing Capacity in Enterprises of the Engineering Industry

This paper deals with the elaboration of a calculation methodology concerning the producing capacity in the machine building enterprises, enabling to mechanize this calculation. It also deals with some aspects of the influence of the main manufacturing parameters on the producing capacity, stating the optimum poosibilities of the latter.

The rational use of equipment and production areas are the object of numerous studies and researches which are being carried on in the field of scientific organization of production and labour.

Among these studies an important place is held by the solving of some problems related to the correct and maximum operative determination of the producing capacity indicator of the highest importance in the planning and organization of the processes of production. This paper presents a new methodology enabling to determine the producing capacity of the enterprises for machine building and the mechanization of calculations and the application of the linear programmation, with a view to utilising the producing capacity, based on the criterion of the maximum loading of the equipment.

It is well known that the engineering industry is that industrial branch whose products include the largest number of units (sub-aggregates, bench marks, spare parts) separately made to the last stage of the manufacturing process (the assembly).

Besides, the enterprises of the above branch carry on their activity on basis of a heterogenous process of production including — in the technological as well as in the auxiliary processes — numerous elements specific to other industrial branches. Under these conditions, the determination of the producing capacity requires complex calculations involving thorough studies. Owing to the specific character of the industrial branch, the producing capacity calculations of the enterprise influence a large number of closely interrelated production units, in connection with the conditions imposed by the technological process, the volume of production, the number of assortments and the system of manufacture. We have to mention that the mathematical relations of calculations used at present differentiate particularly with

the conditions imposed by the stage of manufacturing process and the homogeneity of the output.

Besides, we should also take into account the effects of the adopted working conditions on the producing capacity.

In the following, we shall first demonstrate that these differentiations do not prevent the setting up of a unitary methodology for the whole enterprise, which would permit and particularly ensure the efficiency of the mechanization of the calculations of capacity.

1. POSSIBILITIES OF ADAPTING A GENERAL FORMULA OF CALCULATION

The general relation of the producing capacity calculation as stated in the specialized literature and frequently used in practice, is:

$$C = \frac{F}{t} \cdot K \tag{1}$$

where:

F = availabilities of production units (available time of the machine, productive area, serviceable volume);

t = consumption per piece of conventional unit (time/piece or m^2/piece)

K = coeficient of correction, taking into account, in the first place, the average degree of performance.

1. MODIFICATIONS IN THE GENERAL RELATION OF CALCULATION DEPENDING ON THE TECHNOLOGICAL STAGES AND ON THE HOMOGENEITY OF OUTPUT

According to the manufacturing stage, the productive units of the enterprise have distinct structural features which have a direct influence on the parameters taken into consideration in determining the producing capacity. The primary processes, for instance, (casting, forging, moulding, etc.) are determined by the fact that such sections use heat as the principal means for the changing of shape, dimensions of the internal structure of the semi-finished goods. In the same way, in the sections where the mechanical process is carried on, the characteristic features are determined by the use of motion and mechanical power for the technological transformation of objects while in the assembly sections, the essential factor lies in the modification of the site. This explains why, in the calculation of the producing capacity, essential specific elements intervene which should be taken into account, such as: *size of the production area, complexity degree of the product, duration of heating, cooling, force of impact, etc.* As regards the homogeneity of output, it should be pointed out that its effect is taken into consideration when determining *conventional units of calculation.*

Without developing here the entire problem, we shall further demonstrate that all these characteristic features can be included, with all the necessary precision used in mathematical formulas, without fundamentally modifying the initial data of the problem (relation 1).

For the foundries, the relation previously shown becomes:

$$Ct_i = \frac{S_i\, q_i}{t_i} \tag{2}$$

where: S = (m^2) = casting area

q = (t/m^2 year) = average annual production of a square meter of area.

t = (t/pc; t/cu) = consumption per piece or per conventional unit.

i = the workshop or section referred to (steel, cast iron, non-ferrous metals, etc.)

As regards the values of q, it should be mentioned that their calculation must take into account the typical structure of the production degree of complexity, in relation to the capacity of the smelting aggregates, of the workshops preparing the earths, of the moulding workshops, etc.

For the sections of forging and mechanical processes, the relation remains formally the same, but the significance of its terms changes.

a) *Forging sections*

$$Cf_i = \frac{F_i}{t_i} \cdot K \tag{3}$$

where:

Cf_i = (t/year; pc/year) = producing capacity of the workshop or section;

F_i (hours-machine/year) = available time of the workshop, section or group of machines i;

t_i = (hours-machine/ton, hours-machine/pc) = time allotted to the forging of a ton or of a piece.

It must be observed that in this case, the values F_i refer only to the forging aggregates belonging to the same group, while the values t_I are determined by taking into consideration the complexity of the pieces to be forged and should be correlated with the duration necessary for reheating, running the machines during processing, auxiliary operations, etc.

b) *Mechanical processes sections*

$$Cg_i = \frac{F_i}{tu_i}\, K_i \tag{4}$$

where:

Cg_i = (pc/year; uc/year) = producing capacity of the group of machines i

F_i = (hours-machine/year) = available time for group i

tu_i (hours-machine/pc) = unit tine for the interchangeable group of machines i.

It follows therefore that for the mechanical processes sections, the producing capacity can be directly determined, at section or workshop level, only when such sections include interchangeable machines.

For the assembly sections, the calculation of the producing capacity should take into consideration, as principal elements, the area necessary for the assembly of a quantity of products and the total duration of the assembly. In this case, the general relation of calculation should be changed as follows:

$$Cm_i = \frac{F_i \cdot Sm_i}{s_i \cdot tc_i} \cdot K \tag{5}$$

where:

F_i (hour/year) = available time for section, workshop or assembly i;
Sm_i (m^2) = the available assembly area for the production unit i;
s_i (m^2/pc) = area necessary for the assembly of a unit;
tc_i (hour-norm) = average duration of the assembly cycle.

The examples of adjustment shown above can be extended, practically without any distinction, to all the basic and auxiliary processes taking place in enterprises with the exception of those specific to other industries (producing and transformation of electric and thermal power, regeneration of emulsions, oils, transport, etc.)

2. MODIFICATIONS OF THE GENERAL RELATION CALCULATION DEPENDING ON THE WORKING CONDITIONS

As can easily be seen, each of the above formula contains, as an essential element of calculation, the total value of availabilities. A more detailed analysis of the relation gives us the opportunity to ascertain that, no mater its form of expression, this value has a complex structure. Thus, for a group of machines, it can be expressed as follows:

$$F_i = \sum_{i=1}^{p} m_i \cdot f_i \tag{6}$$

where:

m_i = number of interchangeable machines in group i
f_i = available element of a machine with the same characteristics.

Its value f_i differs, however, from one machine to another depending on a series of constructive and technical organization factors. In general, its value f_i results from the relation:

$$f_i = Z_p \cdot h \cdot K_s \left(1 - \frac{\alpha}{100}\right) \tag{7}$$

where:

Z_p = number of working days in a year;
K_s = number of daily continuous working periods;
h = number of hours in a period;
α = coefficient of technological interruptions (repairs and maintenance).

Similarly, it can be demonstrated that the values of S and F in the relation of calculation for foundries and assembly sections, have also a complex structure depending on the imposed working conditions. The above reasons — extended also to the other terms of the expression — have led to the introduction of the notions: technical capacity (C_T) and regime capacity (C_R)[1]: The differentiation of the notion of capacity has numerous implications with regard to increasing the possibilities in the use of these indicators in planning and organization of output in enterprises.

II. WAYS OF DETERMING SOME MATHEMATICAL PATTERNS OF CALCULATION WITH REGARD TO THE PRODUCING CAPACITY PER ENTERPRISE

1. WORKING OUT OF THE MATRIX OF CALCULATION

The reasons stated above attest the fact that, whatever the stage may be, both the manufacturing system and the working conditions of a production unit, the principal factors on which depends the volume of the producing capacity, are the same. At the same time, they throw into relief the necessity of taking into consideration, as primary conditions for the working out of the capacity calculation: the degree of homogeneity of output for simple units (machines, aggregates), and for complex units (groups of machines, workshops, technological lines, sections), the condition of interchangeability should also be added to the latter. We must also point out that in case of automatic lines, we should bear in mind the variations in the continuous running period (R_0). It is obvious however that in case of several automatic lines, each should be considered as an independent unit and calculated similarly to the groups of interchangeable machines.

All the observations which have been examined up to now enable us to conclude that the initial data can be systematized in a general calculation table. We shall mark: U_i the simple and complex units taken into consideration; N_f the number of manufactured products of each type; F_i the availabilities of the production units; T_{ij} the consumptions; Cun_{ij} the capacities

[1] Homoş, St. Bîrlea, Gh. Mărgărit — Bulletin of the Polytechnic Institute, Bucharest, January — March 1961, page. 48. Whenever we meet in this paper a variable marked R, it will refer to the planned values, while the variables marked T will express technical or optimum parameters of the respective variables. For instance $t_{R_{ij}}$ expresses the time consumption for each product (j) in each group of machines (i) determined on basis of the planned rate of output existing in a section, whilst $t_{T_{ih}}$ expresses the consumption time per each product (j), in each group of machines (i) determined on basis of the production quotas unified per branches and on the results obtained by the front rankers.

(for natural units) and Cuc_i for conventional units. With the help of the above marks, the calculation standard table can be written out as follows:

Table No. 1

Production units / *Products*	U_1	U_2	U_3....	U_i.....	U_k
N_1	t_{11}	t_{21}	t_{31}...	t_{i1}...	t_{k1}...
N_2	t_{12}	t_{22}	t_{32}...	t_{i2}...	t_{k2}...
N_3	t_{13}	t_{23}	t_{33}...	t_{i3}...	t_{k3}
.					
.					
.					
N_j	t_{1j}	t_{2j}	t_{3j}...	t_{ij}...	t_{kj}
.					
.					
.					
N_p	t_{1p}	t_{2p}	t_{3p}...	t_{ip}...	t_{kp}
Availabilities	F_1	F_2	F_3...	F_i....	F_k
Capacities	Cuc_1	Cuc_2	Cuc_3...	Cuc_i...	Cuc_k
	Cun_{11}	Cun_{21}	Cun_{31}...	Cun_{i1}...	Cun_{k1}
	Cun_{12}	Cun_{22}	Cun_{32}..	Cun_{i2}..	Cun_{k2}
	.				
	.				
	.				
	Cun_{1j}	Cun_{2j}	Cun_{3j}..	Cun_{ij}..	Cun_{kj}
	.				
	.				
	.				
	Cun_{1p}	Cun_{2p}	Cun_{3p}..	Cun_{ip}..	Cun_{kp}

2. INTERPRETATION OF THE INITIAL DATA

The system of data included in the matrices can be interpreted and used, if need be, for the working out of the following calculations:

a) *Determining of the producing capacity for each unit U_i, and drawing up of the balance of capacity per section, and enterprise.*

b) *Determining of the "harmonization" values for the terms* F_i *in case of a given range of goods.*

c) *Determining of values* N_j *or* Cun_{ij} *for which the system fulfills the optimum conditions with regard to diverse criteria.*

We shall now state some methods of performing calculations in the above-mentioned categories.

In determining the producing capacity for each *unit U_i*, the application of the calculation formula previously shown differs according to the homo-

geneity of the output. Generally, where the situation is similar to that stated in the previous matrices, we shall proceed as follows:

— We shall determine firstly the values for each group i:

$$Q_i = \sum_{j=1}^{p} N_j \cdot t_{ij}$$

Then we shall determine the coefficients of structure a_{ij} according to the relation

$$a_{ij} = \frac{N_j t_{ij}}{\sum_{j=1}^{p} N_j t_{ij}} \tag{8}$$

— We shall determine the average pondered time allotted to the conventional units in group *(i)*

$$tuc_i = \frac{\sum_{j=1}^{p} t_{ij} \cdot a_{ij}}{\sum_{j=1}^{p} a_{ij}} \tag{9}$$

On the above basis we shall establish the producing capacity of conventional units:

$$Cuc_i = \frac{F}{tuc_i} \cdot K_i \tag{10}$$

these conventional units can then be transformed into natural units with the help of the relation

$$Cun_{ij} = Cuc_i \cdot a_{if} \cdot \frac{tuc_i}{t_{ij}} \tag{11}$$

We must notice that this case has a general significance, since when values N_j are expressed in pieces (plan targets set at the beginning of the basic period), the calculation can be simplified as follows, by introducing the value of Cuc_i (10) in the last expressions, we obtain:

$$Cun_{if} = \frac{F_1}{t_{ij}} \quad K_i \; a_{ij} \qquad \text{and}$$

$$Cun_{ij} = \frac{F_i}{\sum_{j=1}^{p} N_j t_{ij}} \tag{12}$$

As can be observed, the value $K_i = \frac{E_i}{\sum_{j=1}^{p} N_j t_{ij}}$ is an invariant in relation to group i, which we call the coefficient of the production potential, expressing the ratio between the necessaries and the producing availabi-

lities; from this it follows that if we know the values N_j, we can calculate the producing capacity directly in natural units with the help of relation:

$$Cun_{ij} = Q_i N_j \cdot K_i \tag{13}$$

where Q_i represents the total time needed for the processing of all the planned products.

This relation is quite important, particularly when turning to mechanized calculation. It is obvious, however, that it can only be applied on condition that the values (N_j) expressed in natural units should be known.

The determination of the values of "harmonization" in case of a given range of goods implies that the terms of the first matrix in Table 1 are known and we are asked to find the values F_i for the respective groups of equipment.

The solving of the problem is only possible if we work in conventional units convertible per entire section.

As for the optimum utilization of the capacity, the given matrices can offer the possibility of establishing various mathematical patterns whose structure firstly depends on the criterion of optimum utilization.

The statements expounded above will be further illustrated by an example regarding the calculation of the technical capacity and the working conditions of the mechanical processing sections within the framework of the machine building enterprises.

III. EXPERIMENTAL APPLICATION OF THE ESTABLISHED MATHEMATICAL RELATIONS

The calculations have led to three variants: *a)* with the help of electric calculating machines; *b)* with the help of a machine using punched cards; *c)* with the help of an electronic computer.

The main purpose of the experimental calculations made through the three above variants is:

— to verify the calculation methods and formulas previously shown;

— to verify the algorism on which the machines are being used in the mechanization and automation of calculations;

— to determine the time necessary for the performance of calculations and its analysis, by way of comparison;

VARIANT A. CALCULATION OF THE TECHNICAL CAPACITY AND THE WORKING CONDITIONS OF A MECHANICAL PROCESSING SECTION, WITH THE HELP OF ELECTRIC MACHINES

— determination of the most rational variants in the making of calculations and of the necessary technical means.

In order to make the experimental calculations of the technical capacity and working conditions, we have chosen an average-sized mechanized section which produces a diverse range of goods.

The production conditions of this mechanized processing section are those of a serial production unit where complete sets of spare parts are si-

multaneously turned out for 5 types of machines. The production pattern corresponds to the principle of technological specialization.

In conformity with the exposed general methodology, the determination of the producing capacity of a mechanized processing section with a diverse range of goods, begins with the calculation of the technical capacity and working conditions for each machine-tool or for each group of machine-tools of the same type. The calculation can be made either by using the system of natural units or that of the conventional comparable units. In the example we have chosen we have used both methods. In the case of the mechanical processing section, the natural units are complete sets of spare parts for each of the products manufactured in the plant. Obviously three methods can be used to the same purpose: calculation in conventional units and then their transformation in natural units; direct calculation in natural units when we are given the duration of the total time which may be apportioned to the manufacturing of each product; direct calculation in natural units when the quantities to be manufactured are known (N_j and N'_j).

On comparing the three methods we may conclude the following with regard to the calculation of the producing capacity of the mechanized processing section in natural units:

1) Although the calculations, whatever method was chosen, referred to an average-sized section, they proved to be complicated.

2) The second and third methods, although implying less work, can be applied only under certain conditions (when values a_{ij} respectively N_j are known).

3) In all three cases we can obtain the capacity values only in natural or conventional units for each interchangeable group within the framework of the section (each U_i). For these reasons, the determination of the producing capacity of the entire section or of the enterprise suppose the drawing up of balances of capacity which also require elaborate work.

4) Whenever the conditions or initial data are altered, the calculations have to be wholly or partially done over again, which doubtlessly leads to the increase of the involved sollicited work.

5) The volume of calculations in order to determine the capacity per entire enterprise increases in accordance with the number of basic sections or groups of units of heterogeneous output.

6) All three methods offer but a partial possibility to utilize the manufacturing process or to determine the supplementary values for F_i when considering narrow places.

Starting from these conclusions, we have elaborated a method for the determination of the working conditions per section, in comparable conventional units between the groups of machines (i).

It is obvious that the first condition in working out such a method is to observe some proportionalities between values N_j, N_{j+1} and values Cun_{ij}, $Cun_{(i+1)j}$. The mathematical formulation of this principle is:

$$\frac{N_j}{N_j + 1} = \frac{Cun_{ij}}{Cun_{(i+1)j}} \tag{14}$$

This calculation method of the producing capacity in conventional units differs from those shown above, in that the resulting data, although not

expressed in natural units, may become comparable and the production units (per group i) are simplified.

Comparison may be obtained on condition that the values a_{R_i} expressing the structure coefficients per homogeneous groups of machines (i) planned should be calculated on basis of the relation:

$$a_{R_i} = \frac{N_j \sum_{j=1}^{p} \frac{t_{R_{ij}}}{Kn_i \cdot Kp_i}}{\sum_{j=e}^{p} \sum_{i=1}^{k} \frac{t_{R_{ij}}}{Kn_i \cdot Kp_i} \cdot N_j} \tag{15}$$

The average pondered time consumption per conventional unit (tc_i), exactly as in the other cases, is calculated by means of the relation:

$$tc_{R_i} = \sum_{i=1}^{k} \frac{t_{R_{ij}}}{Kn_i \cdot Kp_i} \cdot a_{R_i} \tag{16}$$

By making calculations for all the groups of machine-tools (i) with the help of the above relation, we have obtained centralized results which, together with the allotted duration for each group of machine-tools, are used to calculate the producing capacity of a section by means of the relation:

$$Cuc_{R_i} = \frac{F_{R_i}}{tc_i} \tag{17}$$

The data being expressed in conventional units comparable between the groups of machines, permit to determine the narrow places, the capacity reserves and the technical organizatory measures necessary to the harmonization of the production capacities of the groups of machine-tools within the framework of the respective section.

With that end in view, we should recommend the use of the following methodology:

1. The narrow places are determined starting from the capacity expressed in conventional units comparable between group of machines i (i = 1, 2, 3...k). Theoretically, a number of narrow places marked L_i, where $i \geqslant o$ will result. For these narrow places we shall always have $Cuc^{(c)} \geqslant Cuc_i$, where $Cuc^{(c)}$ is the capacity of the leading equipment or group of equipment. The difference $(Cuc^{(c)} - Cuc) = \Delta c_i$ gives the lack of capacity.

If we took into consideration the fact that $\Delta c_i = \frac{Fn_i}{tuc_i}$, where:

Fn_i = the necessary fund for group i (hours/machine);
t_i = the necessary fund in group i for the production of a conventional unit;
$m_i^{(s)}$ = the number of supplimentary equipment in group i,
it follows:

$$Fn_i = \Delta c_i \cdot tuc_i \text{ (hours/machine)}$$

$$Fn = f_i m_i^{(s)} = Z_p \cdot K_s h \cdot \left(1 - \frac{\alpha}{100}\right)$$

$$m_i^{(s)} = \frac{Fn_i}{Z_p \cdot K_s h \left(1 - \frac{\alpha}{100}\right)}$$

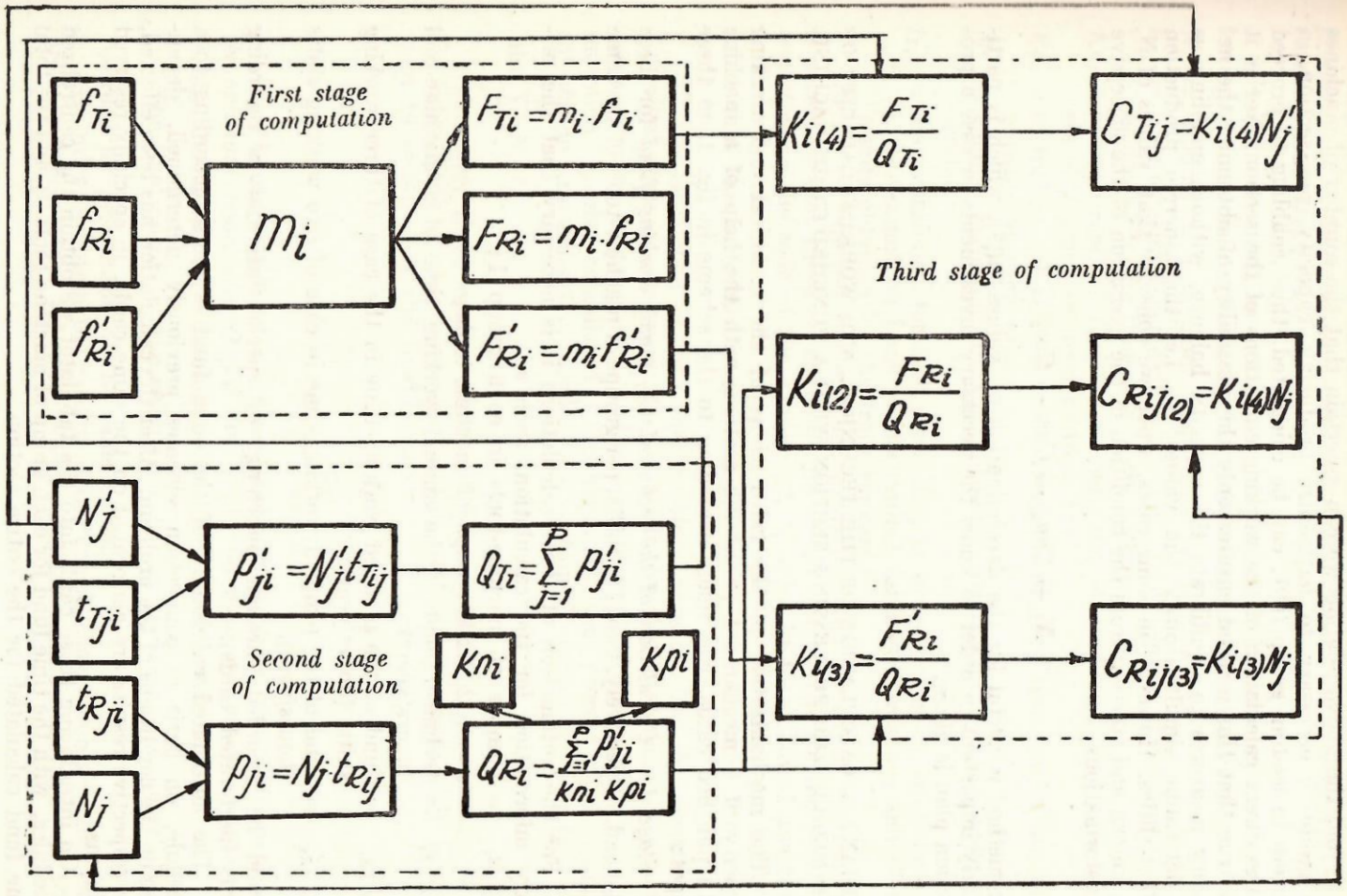

First stage of computation
f_{Ti}
f_{Ri}
f'_{Ri}
m_i
$F_{Ti} = m_i \cdot f_{Ti}$
$F_{Ri} = m_i \cdot f_{Ri}$
$F'_{Ri} = m_i f'_{Ri}$
$K_{i(4)} = \frac{F_{Ti}}{Q_{Ti}}$
$C_{Tij} = K_{i(4)} N'_j$
Third stage of computation
$K_{i(2)} = \frac{F_{Ri}}{Q_{Ri}}$
$C_{Rij(2)} = K_{i(4)} N_j$
$K_{i(3)} = \frac{F'_{Ri}}{Q_{Ri}}$
$C_{Rij(3)} = K_{i(3)} N_j$
N'_j
t_{Tji}
$P'_{ji} = N'_j t_{Tij}$
$Q_{Ti} = \sum_{j=1}^{P} P'_{ji}$
Second stage of computation
t_{Rji}
N_j
$P_{ji} = N_j \cdot t_{Rij}$
K_{ni}
K_{pi}
$Q_{Ri} = \frac{\sum_{j=1}^{P} P'_{ji}}{K_{ni} K_{pi}}$

Fig. 1

From the above relation we can ascertain that the number of machines for group ik necessary to harmonize producing capacity per section, in relation to leading group ($i^{(c)}$), can be calculated, thus enabling to proceed to the direct calculation of the working conditions of the section. Nor is it less true that this method ensures only the possibility of obtaining the necessary measures to equilibrate the capacity balance, without enabling us to determine simultaneously the values N_1, i.e. the concrete production potentialities. However, in some cases, when we consider that values of N_j are known and starting from the condition of the execution of the successive transformations:

$$N_j \rightarrow Cun_{uj} \rightarrow Cuc_i \rightarrow Cuc_i^{(c)}$$

the method is useful for the determination of values $m(_i^{(s)})$, which is particularly important in order to know the necessary investments in case a production plan is given.

VARIANT B. CALCULATION OF THE TECHNICAL AND WORKING CAPACITY OF THE MECHANIZED PROCESSING SECTION WITH A PUNCHED CARDS MACHINE.

The mechanization of the calculations of the technical and working capacity of a mechanized processing section, with the help of a machine with punched cards, was made according to the scheme in fig. 1, in three stages:

Stage I — Calculation of the technical (F_{T_i}) *and working fund* for three (F_{R_i}) and, respectively, two (F'_{R_i})shifts, per groups of machine-tools of the same type.

For the automation of these calculations it is necessary that the primary information for the calculation, such as:

(a) m_i = number of machine-tools in each group I;
$i = 1, 2, 3...$ k groups of machine-tools;

(b) f_{T_i} = technical fund of the annual working time of a machine-tool (hours/years);

(c) f_{R_i} = fund of the planned working time in the case of three working shifts (hours/year);

(d) f'_{R_i} = fund of the planned working time in case of two working shifts (hours/year),

should be recorded, through punching, in special information recording cards (perforated cards).

The automated calculation of the time fund is made according to a schedule, on basis of connection schemes previously determined, depending on the conditions of the problem. After the calculation has been effected, the respective results are perforated on the same cards, in specially reserved columns.

On introducing these cards into the tabulator we obtain the centralized schedules, with the time fund for each group of machine-tools (i) and the total time fund calculated for the entire section.

Stage II — Determination of the total hours/machine necessary for processing of complete sets of spare parts for all the products in each group of machine-tools (Q_{R_i} ; Q_{T_i}).

In order to effect an automated calculation, it is necessary that the following primary information should be recorded on punched cards;

N_j = volume of each assortment j, as per section plan.

$t_{R_{ij}}$ = time consumed per each product j, in each group of machine-tools i, according to the time rate in the section;

Kn_i = average coefficient of the carrying out of working rates by the workers of a group of machine-tools i;

Kp_i = coefficient of the transformation of average time rates into progressive average rates;

N'_j = volume according to the optimum assortment, for the respective section;

$t_{T_{ij}}$ = time consumed for each product j, in every group of machine-tools i, determined on basis of the unified rates per branches and of the results obtained by the front rankers.

Before introducing the punched cards into the electronic computer it is necessary that these cards should be sorted out on the sorting machine, according to the code of the equipment, in order to be classified according to the order number of the groups of machine-tools. It should be borne in mind that the perforated cards bearing coefficients Kn_i and Kp_i should come last.

a) *The calculation of the hours/machines necessary for the execution of the initial planned assortment* (R_{R_i}) is made by the machine with punched cards according to programme and to some connection schemes for the commutation panels, established beforehand. In the process of automated calculation, intermediary results are obtained (product $N_j \cdot t_{R_{ij}}$) and also $\sum_{j=1}^{p} N_j \cdot t_{R_{ij}}$

However, these results must not be recorded by perforation, as for the simplifying of the operations on the perforating machine it is sufficient to record only the final results:

$$Q_{R_i} = \frac{\sum_{j=1}^{p} N_j \cdot t_{R_{ij}}}{Kn_i \cdot Kp_i}$$

b) *The calculation of the hours/machines necessary for the execution of the optimum assortment* (Q_{T_i}) is also made on basis of punched cards; (the results should not be corrected by coefficients Kn_i and Kp_i).

The final results of the calculation $Q_{T_i} = \sum_{j=1}^{p} N' \cdot t_{R_{ij}}$ are automatically recorded by perforation of the same cards.

In order to obtain the results of the calculations, these punched cards are introduced into a tabulator which totalizes them up and presents them centralized in tables.

Stage III — Determination of the coefficients of the technical and production capacites for each group of machine-tools $K_{i_{(2)}}$ $K_{i_{(3)}}$ $K_{i(4)}$*) *and of the technical and production capacities* ($C_{T_{ij(6)}}$; $C_{R_{ij(2)}}$; $C'_{R_{ij(3)}}$*)

In order to effect these calculations, the following are used:

a) the punched cards comprising the final results with regard to the time fund (F_{T_i} ; F_{R_i} ; F'_{R_i})

b) the punched cards comprising the final results with regard to the time consumption necessary to the processing of a complete set of spare parts, for all the products of each group of machine-tools Q_{R_i};

c) the punched cards showing the final results regarding Q_{T_i};

d) the punched cards showing the initial data regarding the quantities of products as per 1) optimum assortment (N'_j) and 2) initial production schedule (N_i).

We wish to state precisely that before introducing the cards in the punching machine, they should be sorted according to the code of the group of machine-tools.

These calculations are also carried out according to a programme and connection scheme for commutation panels established beforehand.

The results of the calculation are automatically recorded by the punching of new cards and come out from the tabulator in tables.

VARIANT C. CALCULATION OF THE TECHNICAL AND WORK CAPACITIES OF THE MECHANIZED PROCESSING SECTION, WITH THE HELP OF ELECTRONIC COMPUTERS.

The solving of the problem regarding the automatic calculation of the technical and work capacities of the mechanized processing sections with the help of electronic computers implies the following:

Stage I — Formulation of the problem

The technical and work capacities of a mechanized processing section should be determined by the direct method (the relations of calculation have previously been given).

Stage II — Elaboration of the algorism of the problem

The following elements should be borne in mind in the elaboration of the algorism:

— a complex system of indicators of the production capacity should be ensured;

— a maximum precision of the obtained results should be ensured,

— introduction of the initial data and of the working programme of the electronic computers; the solving and obtaining of results in the minimum of time.

The algorism on whose basis the present experiment was carried out was the following:

*) Explanation of the respective symbols is given in Fig. 2.

Table Nr. 2

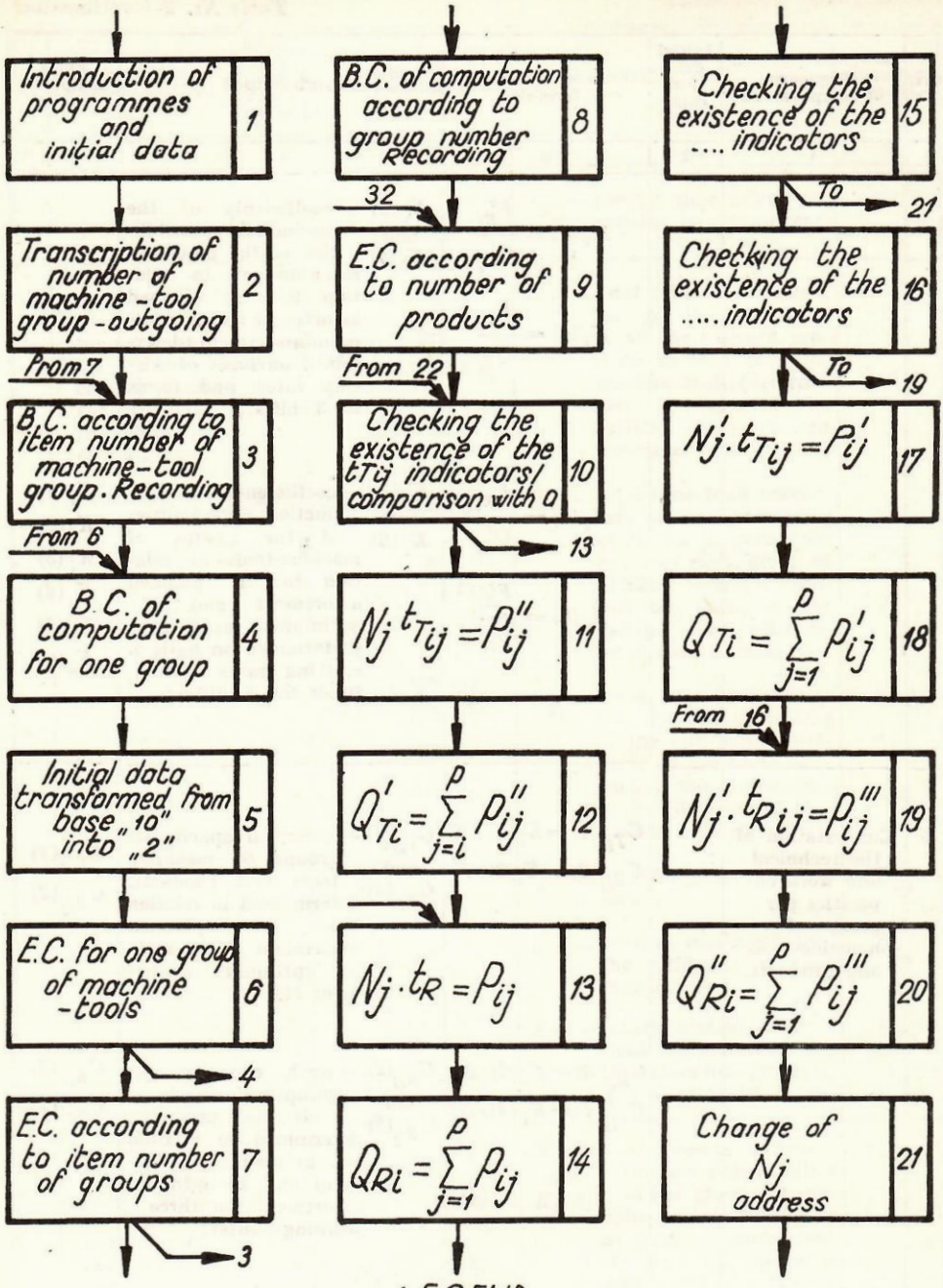
Crt. Nr.	Sequence of computations	Initial data for computer	Computation formula	Symbols used	Final computer results
0	1	2	3	4	5
1	Computation of the annual technical and work fund per groups of machine-tools.	f_{T_i}	$F_{T_i} = m_i \times f_{T_i}$	f_{T_i} — technical fund of the annual working time of a machine-tool;	
		f_{R_i}	$F_{R_i} = m_i \times f_{R_i}$	f_{R_i} — fund of the annual working time of a machine-tool (for three shifts);	
		f'_{R_j}	$F'_{R_i} = m_i \times f'_{R_i}$	f'_{R_j} — fund of the annual working time of a machine-tool (for two shifts);	
		m_i		F_{T_i} Technical fund of the working time of a group of similar machine-tools;	
				F_{R_i} and F'_{R_i} — annual working time funds of a group of similar machine-tools (for three and respeetilely two working shifts);	F_{T_i} F_{R_i}
				i — order number of the groups of similar machine-tools;	F'_{R_i}
2	Computation of the time fund necessary for the processing of each type of product in each group of machine-tools.	N_j	$P_{ij} = N_j t_{R_{ij}}$	N_j — quantity, in pieces, of each kind of product according to the initial production plan.	
		N_j	$P'_{jj} = N'_j t_{T_{ij}}$		
		$t_{T_{ij}}$	$P''_{ij} = N_j t_{T_{jj}}$	N'_j — quantity, in pieces, of each kind of product, according to the optimum assortment;	
		$t_{R_{ij}}$	$P'''_{ij} = N'_j t_{R_{ij}}$	j — order number of the products; $j = 1, 2, 3, ..., p$	
				$t_{T_{ij}}$ — technical time rates in the processing of each product (j) and for each group of machine-tools (i), determined on basis of the unified rates per branch;	

Table Nr. 2 (continuation)

Crt. Nr.	Sequence of computations	Initial data for computer	Computation formula	Symbols used	Final computer results
0	1	2	3	4	5
				$t_{R_{ij}}$ — present time rates existing in enterprises;	
3	Computation of the total time fund necessary for the processing of all the products in each group of machines.	Kn_i Kp_i	$Q_{R_i} = \frac{\sum_{i=1}^{p} P_{ij}}{Kn_i \cdot Kp_i}$ $Q'_{R_i} = \frac{\sum_{j=1}^{p} P'''_{ij}}{Kn_i \cdot Kp_i}$ $Q_{T_i} = \sum_{j=1}^{p} P'_{ij}$ $Q'_{T_i} = \sum_{j=1}^{p} P''_{ij}$	Q_{R_i} — total time fund necessary for the processing of all the planned products in each group of machine-tools, (determined on basis of the existing rates planned assortment); Q'_{R_i} — total time fund necessary for the processing of all the planned products in each group of machine-tools, (determined on basis of the existing rates and optimum assortments); Q'_{T_i} — total time fund necessary for the processing of the optimum assortment of products in each group of machine-tools, (determined on basis of technical rates); Q_{T_i} — ditto for planned assortment; Kn_i — average coefficient for the fulfilment of the time rates; Kp_i — transformation coeficient of the average time rates into progressive average rates	Q_{R_i} Q'_{R_i} Q_{T_i}
4	Computation of the coefficients of the production potentialities for each group of machines.		$K_i(1) = \frac{F_{T_i}}{Q'_{T_i}}$ $K_i(2) = \frac{F_{R_i}}{Q_{R_i}}$	$K_i(1)$ and $K_i(4)$ — coeficients of production potentialities of the groups of machine-tools in relation to a) planned assortment (1) and b) optimum assortment (4) (determined on basis of technical rates and technical time fund);	

Table Nr. 2 (continuation)

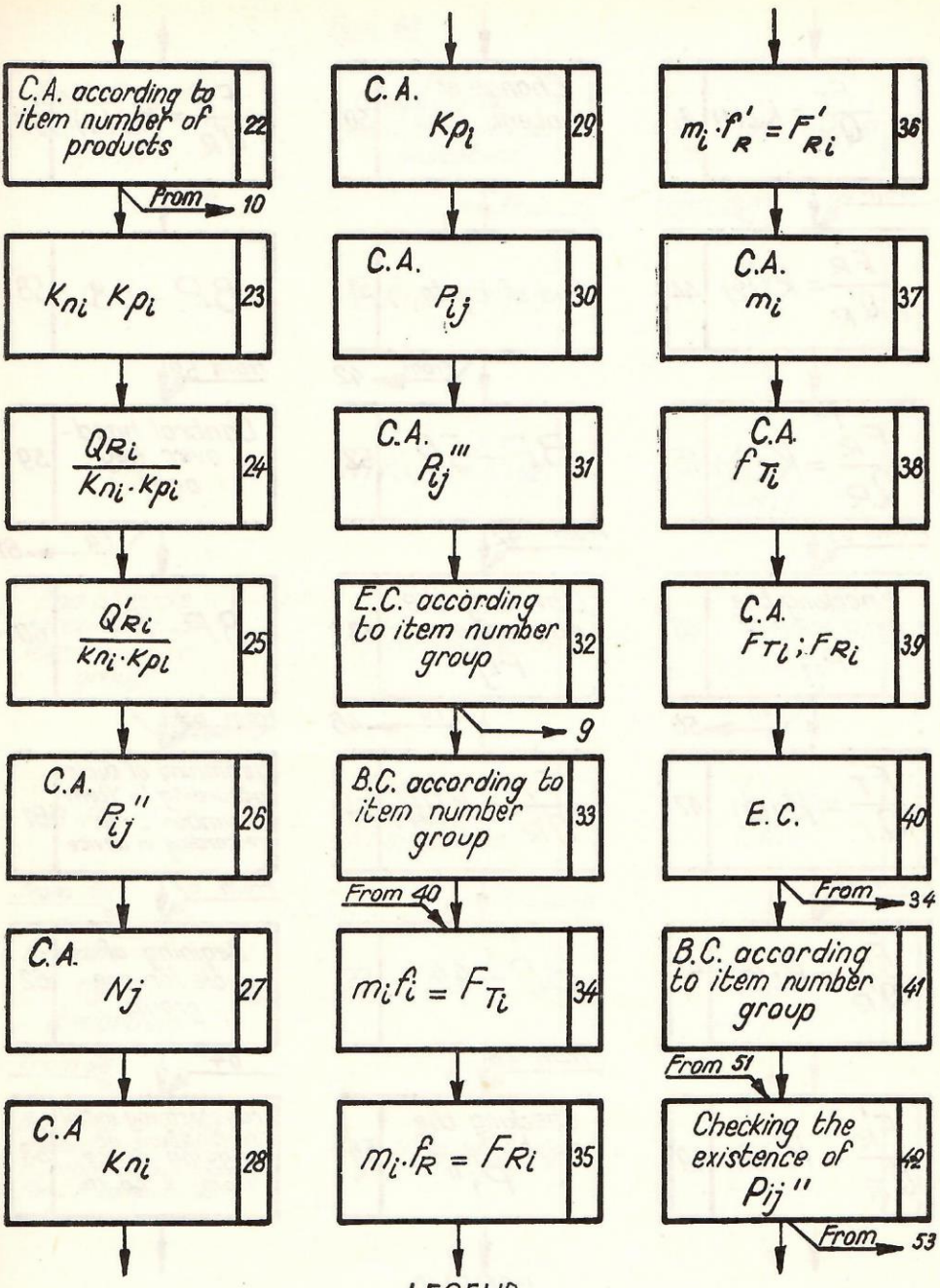
Crt. Nr.	Sequence of computations	Initial data for computer	Computation formula	Symbols used	Final computer results
0	1	2	3	4	5
			$K_i(3) = \frac{F'_{R_i}}{Q_{R_i}}$ $K_i(4) = \frac{F_{T_i}}{Q_{T_i}}$	$K_i(2)$ and $K_i(5)$ — coefficients of the production possibilities of the groups of machine-tools in relation to: a) planned assortment and b) optimum assortment (determined on basis of existing rates and funds for 3 shifts);	
			$K_i(5) = \frac{F_{R_i}}{Q'_{R_j}}$ $K_i(6) = \frac{F'_{R_i}}{Q'_{R_i}}$	$K_i(3)$ and $K_i(6)$ — coefficients of the production potentialities of the groups of machine-tools in relation to: a) planned assortment and b) optimum assortment (determined on basis of existing rates and funds for 2 shifts);	$K_i(1)$ $K_i(2)$ $K_i(3)$ $K_i(4)$ $K_i(5)$ $K_i(6)$
5	Computation of the technical and work capacities per groups of machine-tools and products.		$C_{T_{it}}(1) = K_i(1) \cdot N$ $C_{R_{ij}}(2) = K_i(2) \cdot N_j$	$C_{T_{ij}}(1)$ and $C_{T_{it}}(4)$ — technical capacity per groups of machine-tools and products, determinend in relation to: a) planned assortment (1) and b) optimum assortment (4);	$C_{T_{ij}}(1)$ $C_{R_{ij}}(2)$
			$C_{R_{ij}}(3) = K_i(3) \cdot N_j$ $C_{T_{ij}}(4) = K_i(4) \cdot N'_j$	$C_{R_{ij}}(2)$ and $C_{R_{ij}}(5)$ — work capacity per groups of machine-tools and products, determined in relation to: a) planned assortment and b) optimum assortment (for three working shifts);	$C_{R_{ij}}(3)$ $C_{T_i}(4)$
			$C_{R_{ij}}(5) = K_i(5) \cdot N'_j$ $C_{R_{ij}}(6) = K_i(6) \cdot N'_j$	$C_{R_{ij}}(3)$ and $C_{R_{ij}}(6)$ — ditto. (for two working shifts).	$C_{R_{ij}}(5)$ $C_{R_{ij}}(6)$



LEGEND

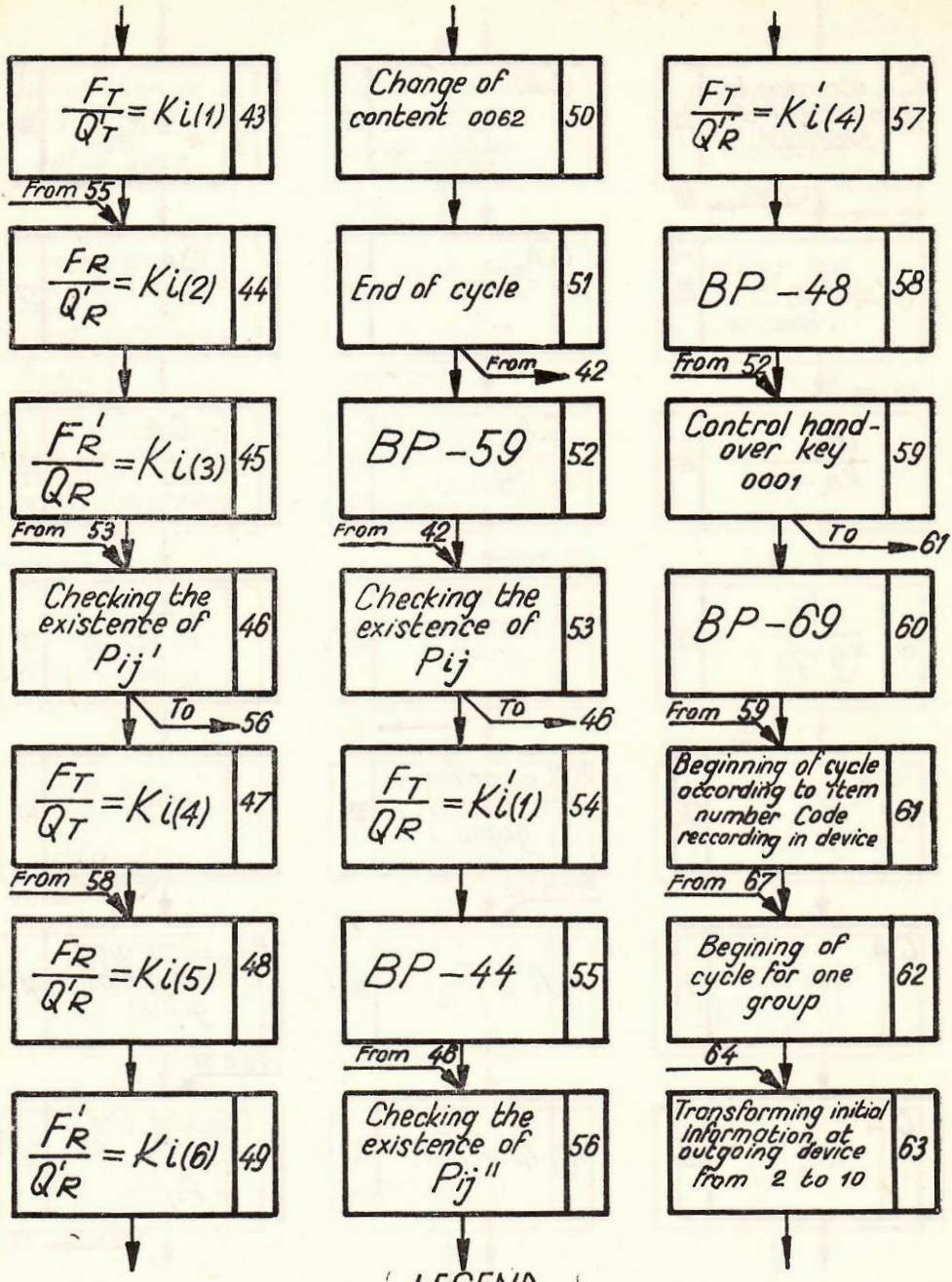
B.C. = beginning of cycle
E.C. = end of cycle
m.t. = machine - tools

Fig. 2



LEGEND
C.A. = change of adress
E.C. = end of cycle
B.C. = beginning of cycle

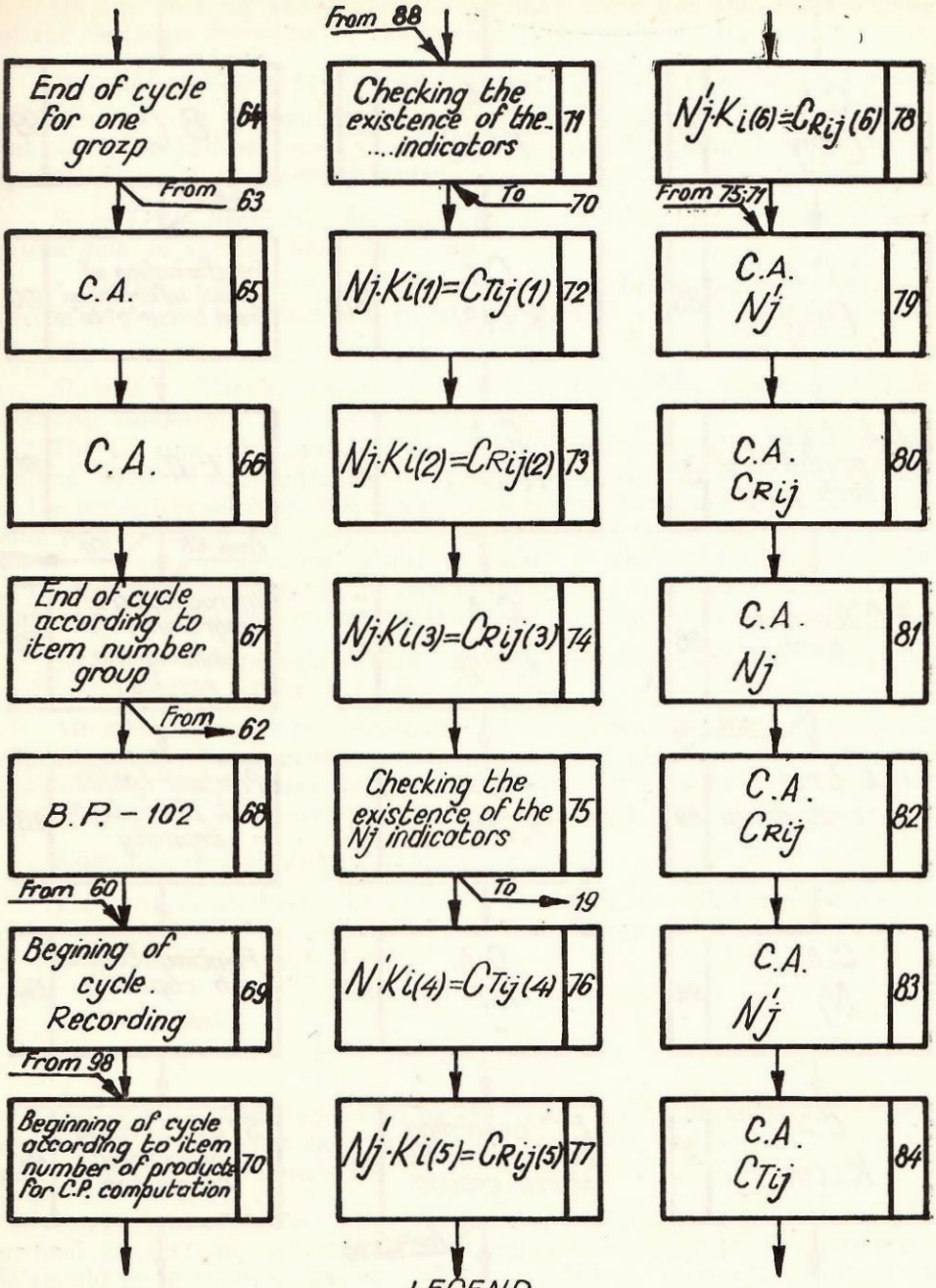
Fig. 3



LEGEND

C.A. = change of address

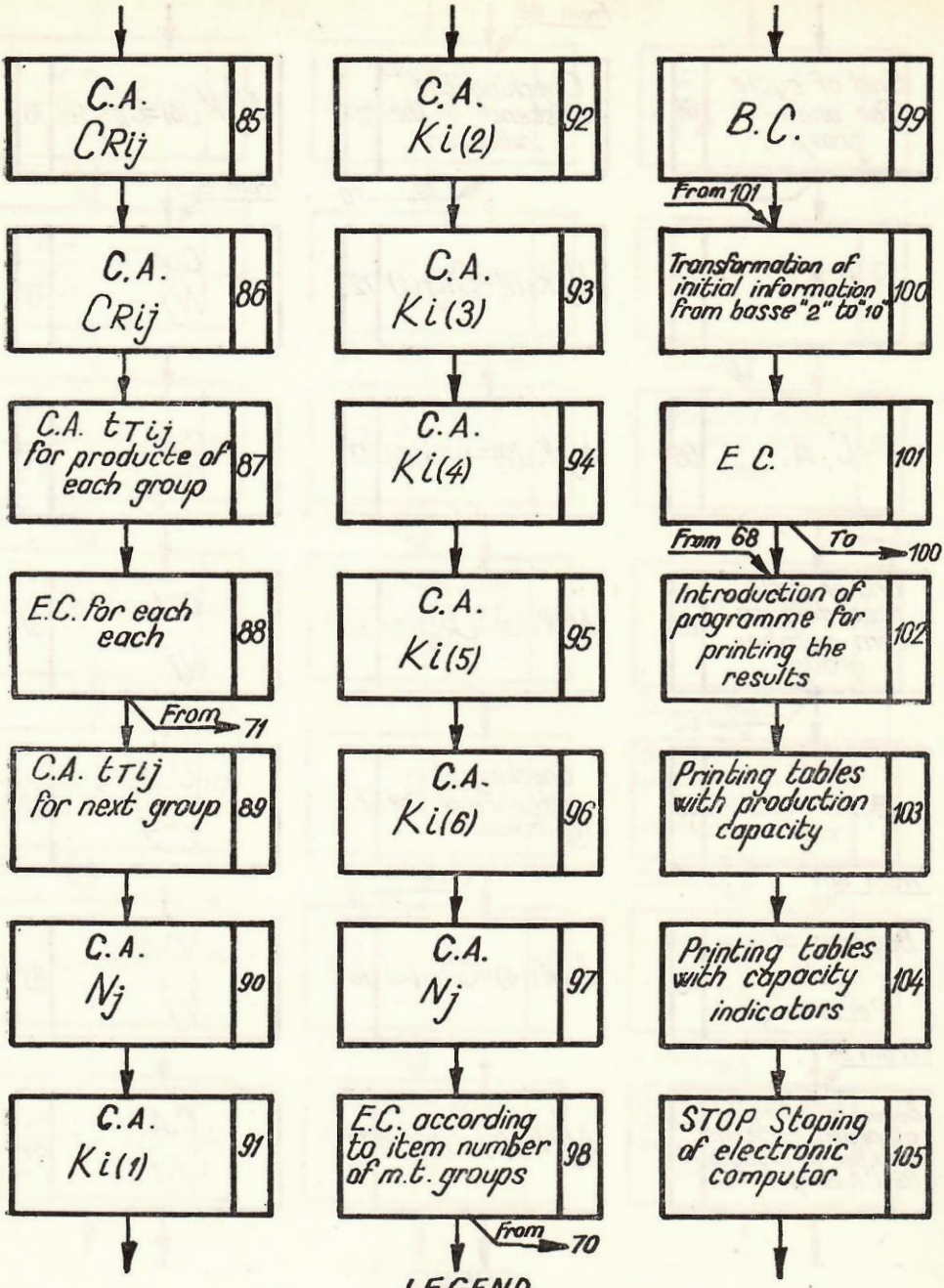
Fig. 4



LEGEND

C. A. = change of address

Fig. 5



LEGEND

C.A. = change of address
E.C. = end of cycle
B.C. = beginning of cycle

Fig. 6

On the basis of above algorism we may work out the block-scheme of the electronic computer or the solving of the problem (fig. 2—6).

Stage III — Making up of the working programme of the electronic computer.

The working programme of the electronic computer or the working out of the calculation consists of numerically coded commands, recorded in special forms, in a successive order.

Stage IV — Recording, by punching, of the calculation programme and initial data in special informative cards.

A number of 120 cards has been punched for the solving of the problem pertaining to the technical and work capacities of a mechanized processing section.

Stage V — Checking up and correcting of the working programme of the electronic computer.

The working programme of the electronic computer should be checked up and corrected during the solving process of a given problem. In the case of the present problem it was necessary to correct five times the initial working programme of the electronic computer. Four times the determination of the working programme lacked necessary precision (through the fault of the person responsible for the setting up of the programme); and another time one of the internal circuits of the electronic machine went out of order.

Stage VI — Automatic calculation of the technical and work capacities and obtainment of results in centralized tables.

After having made the automatic calculation of the technical and work capacity of the mechanized processing section, a series of indicators have been obtained which are centralized in tables, directly by the printing device of the electronic computer.

Stage VII — Analysis of results.

The analysis of the results obtained by automatic calculation is a compulsory stage since some results which do not correspond to the contents of the problem may also appear.

FINAL CONCLUSIONS

Out of the analysis and working out of the results obtained by the mechanized and automatic calculation of the technical and work capacity we may conclude the following:

1) *Precision of results.* After checking up 185 final results obtained by manual calculations, 116 i.e. 63 per cent were proved to be inaccurate. It should be mentioned that the difference between the results obtained by manual and automatic calculation, oscillates on an average between 10 and 100 units (products or complete sets of spare parts). Taking into consideration the fact that the volume of output for the various products varies

between 100—5,300 pieces and that the work capacity varies between 200—10,000 pieces, the error proceeding from manual calculations oscillates between 1—5 per cent, which is very much for a scientific planning.

2) *Reduction of time consumption for calculations*

The time consumption — in hours — for the making of the calculations necessary, for determining the technical and work capacities of the mechanized processing section, in the three variants, is shown in table No. 3.

Table No. 3

Crt. Nr.	Contents of the executed work	Calcul. made with simple electronic computers	In experimental conditions, using:		When using ready made programmes (for the critical case involving the solving of 7 problems with:	
			machines with punched cards	electronic computers	machines with punched cards	electronic computers
1	Systematizing of the primary information required by the calculation	1	2	1	2	1
2	Recording in cards of the initial data with punching machine	—	1	2	1	0.71
3	Setting up of the working programme and of the block scheme	—	104	120	14.85	17.15
4	Adjustment, checking up and correction of the working programme	—	5	7	0.715	1
5	Calculations and lists with results	154	0.666	0.033	0.666	0.033
6	Working out and analysis of results	—	1	0.23	1	0.25
	TOTAL	155	113.666	130.283	20.23	20.14

Comparing the results obtained through experimentation, we have found that the time consumption for the mechanized calculations with the help of machines with punched cards represents 73.4 per cent of the time consumed by manual calculations and 85.6 per cent of that by automatic calculations. At first sight, the reduction in time consumption seems non-essential, but it must be borne in mind that the total time includes also the time necessary for the preparatory operations which will not be repeated in the case of similar problems (working out and checking up of the working programme and block-scheme, recording in special cards of the working programme of the electronic computer, etc.).

Practically, when ready-made working programmes are used for this kind of problems, a considerable reduction of the time consumption takes place through the mechanic or automatic calculations.

When there are seven similar problems (i.e. 7 sections of mechanized processing with a serial production), the total time consumption per problem is the same for the last 2 variants (approximately 20 hours). This time also includes the quota of the initial consumption for the working out of programmes, recording of cards, etc. Therefore, in the case of the solving of 7 problems, the time spent for calculation is reduced 7.75 times, as compared to the time spent with manual calculations.

The studies show that the efficiency of the calculating machines increases with the number of similar problems. For instance, if the number of problems which are to be solved on basis of the same programme, is fifty, the time consumption per solved problem with a calculating machine will be 35.6 times shorter, as compared to the manual method; in the case of 100 problems, the reduction will be 50.5 times.

3. The considerable increase in speed of calculation enables to obtain capacity indicators in a theoretically unlimited number of variants, before the planned period. This is important in planning, chiefly in the cases where it is necessary to recalculate the producing capacities owing to changes which have taken place in the foreseen initial programme.

4. Automation of the calculations to determine the technical and working capacity enables the solving of a given problem in various variants. This is important, particularly in the case of various variants in the designing of new projects regarding constructions, reconstructions, modernizations, re-equipping and enlargement of existing plants and sections.

5. Mechanization offers the possibility of an unlimited use of the initially elaborated working programme of the electronic computer on condition of its being further worked out with the purpose of obtaining a standard programme for the solving of the capacity problems, whatever the numerical limits between which the initial calculation information oscillates (number of groups of machine-tools and number of the various products to be concomitantly manufactured on these machines).

6. The experimental results have shown that it is possible to make corrections and calculations of the technical and working capacity of mechanized processing sections, over a short period of time (month, quarter); this would enable us to determine the producing capacity dynamics in the course of one year and, on this basis, to follow up the evolution of the results of the production plan.

7. The use of the electronic computers, on a large scale, in the working out of the production process in general, and for the mechanization and automation of calculations, is subject to the drawing up of a unique system of indexing of the designs, structure of products, spare parts and components and also finished products, technicological equipment, etc. It is also subject to the scientific organization of the technical economical normative work within the framework of the enterprise.

The experimental calculations made and the comparative analysis of the results obtained in the case of the three variants under study have emphasized the fact that the introduction and use of electronic computers ensure an operative and complex determination of the producting capacity in the machine building enterprises and offer new possibilities for its maximum utilization.

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CERTAINS ASPECTS DE L'EMPLOI DES CALCULATEURS ÉLECTRONIQUES POUR LA DÉTERMINATION DE LA CAPACITÉ DE PRODUCTION DANS LES ENTREPRISES CONSTRUCTRICES DE MACHINES

La détermination de la capacité de production dans les entreprises de l'industrie mécanique, en fonction du caractère spécifique de leur structure de production, exige des calculs complexes, signifiant un volume important de travail. La méthodologie de calcul élaborée propose un systeme de liaisons assurant dans les constitutions d'un assortiment donné, homogène ou hétérogène, l'obtention simultanée des solutions pour plusieurs variantes en fonction des conditions établies au début.

Dans ce but, on a élaboré l'algoritme du problème qui permet d'obtenir simultanément six indices et on a effectué les calcules expérimentaux avec des machines à cartes perforées et avec des calculateurs électroniques. L'étude presente les résultats comparatifs obtenus, le temps nécessaire pour la préparation et la réalisation des calculs, ainsi que les possibilités d'application de cette méthode pour l'obtention des différents indices qui caractérisent la capacité de production et la façon dont il convient de l'appliquer.

Les auteurs traitent ensuite de certains aspects de l'influence des principaux paramètres de la fabrication sur la capacité de production et présentent les possibilités de son optimisation. A titre d'example, on a choisi les données d'une section d'usinage des pièces nécessaires à des machines agricoles et on a effectué les calculs respectifs, en analysant ensuite les résultats obtenus.

ОТДЕЛЬНЫЕ АСПЕКТЫ ПРИМЕНЕНИЯ ЭЛЕКТРОННЫХ КАЛЬКУЛЯТОРОВ ДЛЯ ОПРЕДЕЛЕНИЯ ПРОИЗВОДСТВЕННЫХ МОЩНОСТЕЙ НА ПРЕДПРИЯТИЯХ МАШИНОСТРОИТЕЛЬНОЙ ПРОМЫШЛЕННОСТИ

Определение производственных мощностей на предприятиях машиностроительной промышленности в зависимости от специфики их производственной структуры требует проведения сложных расчетов, являющихся очень трудоемкими. Разработанная методика расчета предлагает систему связей, обеспечивающих при данном ассортименте продукции —

однородной или разнородной, одновременное получение решений для нескольких вариантов в зависимости от первоначально заданных условий.

С этой целью был разработан алгоритм задачи, позволяющий одновременно получать 6 показателей, и были проведены экспериментальные расчеты на счетно-перфорационных машинах и электронных калькуляторах. В статье приводятся полученные сравнительные результаты, затраты времени на подготовку и проведение расчетов, а также и возможности применения метода при получении различных показателей, характеризующих производственную мощность и способ ее использования.

Затем рассматриваются отдельные аспекты влияния важнейших параметров производства на производственную мощность и указываются возможности ее оптимизации. Для примера были выбраны данные по цеху обработки путем резания и были проведены соответствующие расчеты, результаты которых рассматриваются.