International Institute for
Applied Systems Analysis
IIASA www.iiasa.ac.at

Capacity Modeling in a Stripping Bay Simulation Study

Mazel, B.

IIASA Working Paper

WP-75-097

1975

Capacity Modelling in a Stripping Bay
Simulation Study

B. Mazel

August 1975 WP-75-97

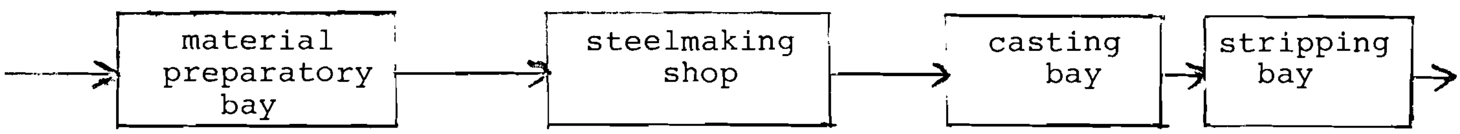
Capacity Modelling in a Stripping Bay
Simulation Study*

B. Mazel

Description of the Situation

The model of a steelplant with steel making, plate and sheet rolling and rod drawing facilities will be considered and described.

The annual production will be approximately 200 thousand tons to be increased using the same steelworks equipment. The production should rise by increasing the weight of a melt by sixteen tons (by enlarging the capacity of pouring ladles) and by increasing the output in the furnaces by approximately 7% in an hour (intensification of the production by increased oxygen supply). The problem consists of answering the question as to how the change in production will influence the work of the casting bay and the stripping bay. Let us consider that there are some organizational difficulties in the material flow and therefore some losses occur due to insufficient capacity.
The material flow in the steelworks will be represented by the scheme:



The steelmaking shop is equipped with five furnaces of the type Maerz-Boehlens, all of them with capacity of 200 tons. The casting takes place in one of the available mould-trains. The full number of these mould-trains is 14 with 28 moulds in average on each.

In the stripping bay there are three stripper cranes of 250 tons each which can functionally substitute for each other, i.e. to carry out both stripping and depositing of the moulds.

---

* Realized in cooperation with the Institute INORGA, Praha, CSSR (14)

A very important part of the stripping bay is a cooling bank to lay the stripping moulds on. The maximum capacity of this bank is 565 moulds.Through the bay goes the line with the capacity of three trains for transporting the bogies.

The majority of production functions and all preparatory functions are made in the stripping bay, i.e. fettling, exchange of mould bottom plates, placing of sheet billets and placing the moulds. For other sorts of material all preparatory works are made in other parts of the steelworks and only the moulds are placed in the stripping bay. The transport of the material between particular bays is carried out by mould-trains carried by Diesel- electric locomotives.

We can divide the production into two main groups according to the quality of the steel. One is presented by teeming unkilled steel and the other by the up-teeming of killed steel. Only a small part of the production is done in any other way, e.g. unkilled steel with up-teeming and killed by teeming.

The level of the production is influenced by the fact that every part of the production has its own working rhythm which causes the irregularities in the material flow.

Objectives of the Simulation Model

The problem of how to increase the production by technological improvements has been found. There is then another problem if some slow down occurs in the auxiliary parts of the steelworks, i.e. by the casting bay and stripping bay. The increase of the production assumes that it will not influence the throughput of the steelworks, i.e. that no delay of the transport and circulation of the bogies will occur.

Problems to be Solved in the Model by Simulation

(i) estimate the number of mould trains to cover the transport requirements for the planned volume of material

(ii) investigate the efficiency of cranes in the stripping bay

(iii) investigate the capacity of the cooling bank

(There exist some physical size limitations for making reconstructions of the stripping bay by increasing the capacity of the cooling bank.)

The objective of the problem is to build a model which will respect the technology of the process with the possibility of verifying discussed variations of changes in the production, i.e. in the number of individual machines, changes in the organization of the work etc.

Methodology for Constructing Individual Models

The problem arises from a relatively complicated server-queuing system where the serving channels are formed by individual components e.g. stripping bay, casting bay, rolling mill etc. Theoretically the study is based on a multiple server queuing problem. According to complexity of the problem and a great number of factors influencing the solution, it is very difficult to find some ready model or described analytical method. We decided to use a simulation technique which is recommended in the literature for solving such problems. A very significant factor for constructing such a simulation model seems to be compilors for simulation languages being very suitable for solving queuing problems on computers (GPSS, SIMULA, SIMSCRIPT, SIMON, CSL etc.). The problem could be solved as a single model reflecting the process of the stripping bay. It was decided to use an iterative way, i.e. to give precision to the simulated model step by step. Therefore a model described here as Model I. will represent the reality in rough features, but will take in charge the influence of the environmental process of the stripping bay. Model II. will represent the reality of the stripping bay in more detail, resulting from the Model I.

Input Data for the Models

The following have been used as input data:
-statistical measurements, organized directly inside the process during a week period
-mathematical-statistical informations evaluated from the

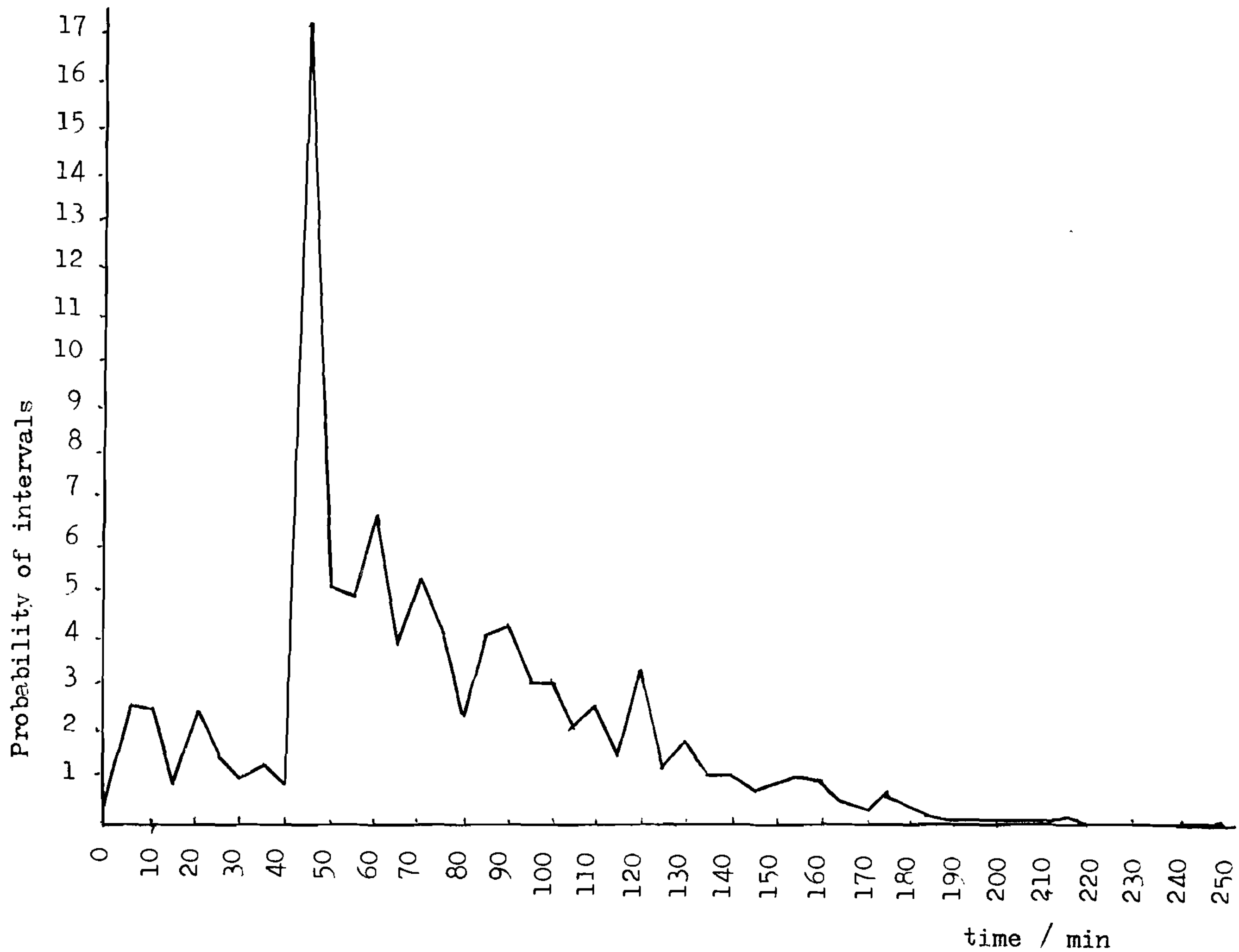


Figure 1 : Intervals between tapping

production sheets (averages and relative frequency distribution) -some results from the Model I. as inputs for the Model II.

As results from the statistical measurements some time indications of duration intervals of individual operations have been received.

Time Observations

Time intervals between individual tapping of iron from all five furnaces (see figure 1 indicating probability of intervals between tapping). specified time for placing of teemed ingots, time for stripping of one set of ingots and time spent in the rolling mills etc. Data indicating the time intervals of individual operations are either by an average and a spread or by a distribution function of probable duration of the operation.

Model I

The circulation of bogies will be described by figure 2. There will be some simplification introduced:
- the production of only two qualities will be foreseen (the teeming of the killed steel and up-teeming of non-killed steel)
- transport difficulties influencing the production capacity will not be considered
- some components of the model are not very realistic

(i) The rolling-mill is considered here only for completing the cycle of the bogies circulation. The production of the rolling-mill represents here all activities from the moment when the bogies leave the stripping bay until arriving for the operation "ready for up-teaming", or until they comeback to the stripping bay.

(ii) In the stripping bay no capacity limitations for stripping cranes will be considered and no mentioned activity has priority to another.

The formulated Model I was written in the language GPSS/360 for the IBM 360/40 computer. The simulation language first generates in the interval of 85 minutes considered in the number of bogies (in our case fourteen). These 85 minutes represent the average time for the tapping of one of the five furnaces. The bogies go through the operating facilities by series parallel mode where the time intervals are given empirically by ascertaining an average and a spread. The sampling of the time is followed by sampling a random number from the interval E < 0; 1 , where by suitable function transformation we receive relevant, corresponding time. Into the model some blocks are included containing statistical information about queues which are formed ahead of some serving facilities. Queue No. one, formed before the teeming bay is very important. The number of mould trains waiting in this queue must not be lower than one (in the moment of tapping one of the five furnaces) because such a situation occurs that the melting process must wait for the bogie. The time unit for the modelling will be one minute. For later simulation and better analysis an ascending reduction for hours and days will be done.

The first generator for mould trains stops after 1,190 minutes (14x85). Up to this this time the number of bogies needed will be generated. This generator can be used not only in running-in period of the model, (in reality the production flow starts with the placing of the moulds on the bogies) but the different numbers of trains we can put in the program according to the requirements of the experiment.

Another generator simulates the formation of melts according to the probability distribution time intervals of the tapping which are empirically ascertained.

The teeming into the moulds on the train will be realized in such a way that both will be synchronized with the movements of different transactions: the melting process will wait for the bogies (Generator No.2) or bogies will be waiting for the tapping (Generator No.1). The real synchronization will be achieved either when the bogies wait for melting or vice-versa.

Model II

This model will answer another question indicated by the objectives for the study: to simulate the function of stripping cranes.

It was necessary to make some simplifications here:

(i) Only two functions of cranes are identified: an active one for placing the moulds and for stripping; and break-downs.

(ii) The arrival of mould trains into the stripping bay will be considered by the same distribution function as generated for tapping of the furnace for Model I, but there are double requirements for the stripping bay: a mould train will be occupied during the positioning of moulds again while the ingots are stripped. That is the reason why the random values sampled from this distribution function are doubled.

(iii) Half of the generated mould trains will be occupied for stripping and the other half for positioning the moulds.

Schematically the problem will be shown by the picture

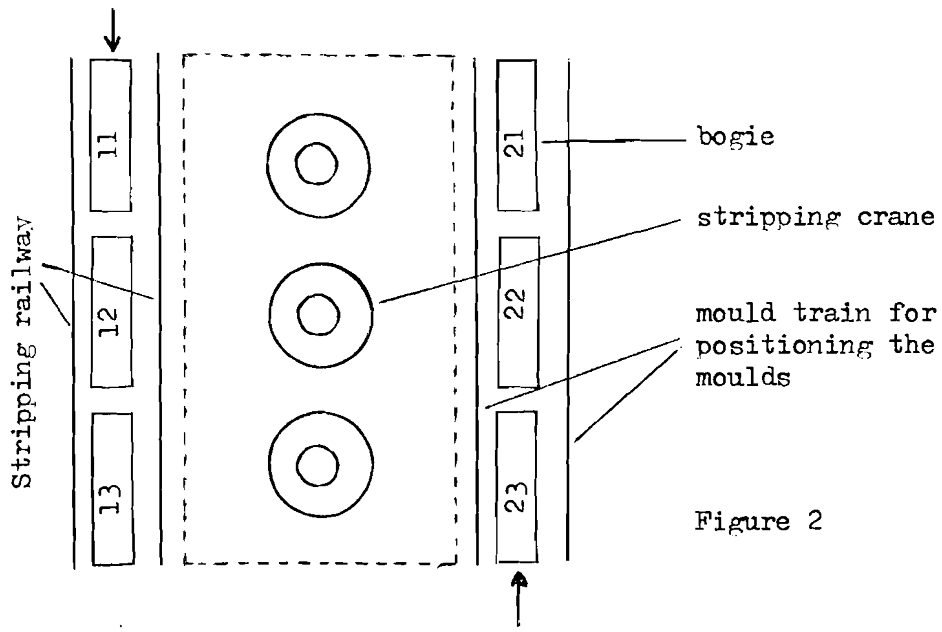


Figure 2

The trains for stripping and positioning are divided into three parts so that the three trains can be located here at the same time. In the model the sections are realized by six working units in series. Every mould train can be served by one - three cranes with the restriction that the outstanding cranes (here one and three) cannot be used on the opposite side of the bay (crane No.1 for trains 13 and 23, crane No. 3 for trains 11 and 21).

The model operates with requirements representing the mould trains. For better express reality i.e. several trains can work for one train at the same time, it will be useful that one requirement will represent one ingot.

The language GPSS/60 provides a possibility for this transformation. The original train comes into the block SPLIT where a number of copies will be reproduced from the original requirement as needed. In our study we use fourteen because a double ingot forms a unit. These copies will be unified again into one transaction (in the ASSEMBLE block) after processing as a complete train.

The strategy for specifying a priority for selection of the sequence of requirements will be explained. It will be assumed that the stripping has higher priority than the positioning of the moulds according to the temperature loss and economic loss as well since the ingots in the soaking pits must be reheated. For that reason there is a device enabling a break to be made in the work on the train which is occupied by placing the moulds and pass to the train ready for stripping.

The information concerning the breakdowns of the cranes will be inserted into the model by a special generator. This generator, according to the empirically compiled distribution function, creates random breakdowns with higher priority than stripping. The choice of the "crane under a breakdown" could occur in any of the three cranes with the same probability. If a breakdown occurs, the function of the crane will be immediately interrupted for a certain time period chosen from the empirical distribution of time for breakdown duration.

Validation of Models

A very important phase of the simulation technique procedure is the validation of the model. One common criteria for validation of a model is coincidence of results gained by observations of the behaviour of the model and reality. This common criteria must be specified for each case very precisely. For the construction of our model more precise goals have been presumed. Thus it seems to be necessary to evaluate some criteria for testing the validity of the model. For Model I it was mentioned that determinate criterion were:

- the coincidence of total time period for circulation of mould trains both teemed and up-teemed
- characteristics of queus arised before the blast furnace teeming bay and a stripping bay compared with the real figures

Significant criteria for Model II were:

- the time behaviour for the throughput of mould trains in the stripping bay and the average efficiency of individual cranes

All criteria mentioned here proved to be sufficient for validation of both Models I and II.

The problem of validity is tied up with the question of the time we need for simulation. If the time is too short, the results are distorted by the running-in of the model. If the time is too long, excessive computing time is required with a negative influence to the economy of the study.

To determine the minimum running-in time required, we can go out from the existing number of nodes. As a node, we understand the source of random quantities, the servicing points (components of the model), but also the queues arised before some components. In our Model I we use practically only one generator (No. 2) of random quantities because the other generator (No. 1) is determined and after a relatively short time stops itself. Besides a constant number of nodes in the model, the running time is influenced by the number of possible routes of requirements and the value of probability. The routes with small probability have much longer running-in characteristics and are therefore the weakest spots of the model.

The investigation of the running-in time of the model could be shown on some characteristics of the model. The running-in time would be measured by the number of mould train circulations, i.e. the time from when the train leaves the teeming bay until it comes back again. Under our consideration are:

- the average time for circulation ($\overline{t}$) divided according to the different kinds of teeming and the standard deviation (Δ_t)
- the average utilization of selected, in series, working, servicing facilities
- the average time for one train spent in queues which could be a weak chain-link of the model

Tables four and five indicate the case where the system consists of fourteen mould trains where 20% of all melting is done by teeming and 80% is done by up-teeming. The time is indicated in minutes and the servicing facilities utilization in one fraction (e.g. the utilization on 54.5% is indicated on the table as 0.545). (Note: The dotted line means that further ex-

Number of circu-lations	Time of mould train circulations				Average utilization of servising facilities		
	upteeming		teeming				
	$\bar{t}$	Δ t	$\bar{t}$	Δ t			
50	1243,8	172	702,4	248	0,565	0,288	0,176
150	1288,3	224	873,2	230	0,419	0,243	0,181
600	1272,5	191	878,2	198	0,512	0,308	0,180
800	1277,9	189	874,6	192	0,553	0,335	0,177
800	1288,8	208	892,5	174	0.593	0,364	0,168
800	1277,6	186	879,8	154	0.522	0,329	0,176

Figure 3

number of circulation	Before the teeming bay	Before the stripping bay		Before the teeming
		positioning	stripping	
50	423,7	0,9	0,00	60,2
150	544,2	1,9	0,06	30,1
600	547,0	2,8	0,20	80,3
800	545,5	2,7	0,19	82,6
800	553,8	3,1	o,15	95,1
800	544,8	2,1	0,15	92,6

Figure 4 : Average time for one train spent in queues

product mix	number of trains				
	13	14	15	16	17
70 ; 30	x	1674(1)	1716(1)	1662	1722
75 : 25	1675	1660(1)	1657(3)	1676	x
80 : 20	1704	1703	1722	x	x
70 : 30	x	1843(30)	1754(3)	1843(5)	1742(5)
75 : 25	1823(49)	1858	1828(5)	1875(31)	x
80 : 20	1808	1820	1826	x	x

Figure 5 : Proportion of product mix to the number of trains

periments with 800 circulations were carried out with different initial values of the random number generator with the reset of statistical files)

In further experiments in which all circulations will pass through the model 800 times, the time was taken as a sufficient period for a simulation experiment. Some distortion of final statistical data during the running-in period has been removed by repeating the first 200 circulation from the beginning, thus every experiment is now limited by a time of 1,000 circulations.

Experimenting on the Models

The final analysis of the simulation model and its behaviour in different conditions will now take our interest. The experiments must be held in the following different ways:

- the influence of different numbers of trains on the volume of the production has been investigated
- how the change of sorts will influence
- the acceleration of intervals
- tapping (increasing the production)
- last but not least the behaviour of the model during an artificially prepared breakdown situation

For calculations of one year's production some simplifications have been made by considering uniform production during the other eleven months as in the first month. The results are shown in Figure five. Each item on the table represents a realized proportion of the chosen sorts of products- present and increased production. Figures indicate a combination of number trains and sorts where no delay of the melting process for the train could occur. Some items with figures in brackets indicate how tapping must be detained for insufficiency of the transport.

We can conclude from these figures that for the basic ratio of sorts-products 80:20, the increasing of production can be realized without any technological or organizational breakdown by using 13-16 trains. For the ratio of 70:30 the situations where we insert 16 or 17 trains are more favorable, but only under the presumption that the production will not increase. We can say that the model is more sensitive to changes in produced sorts than to considered numbers of trains in circulation.

Product mix	13 a	13 b	13 c	13 d	14 a	14 b	14 c	14 d	15 a	15 b	15 c	15 d	16 a	16 b	16 c	16 d	17 a	17 b	17 c	17 d	
70:30	x	x	x	x	473,0	6,5	1	12	465,4	6,5	3	12	414,0	5,6	119	14	548,0	7,7	1	14	Standard production
75:25	445,8	6,1	0	10	483,4	6,5	1	12	588,0	7,9	1	13	600,8	8,3	0	14	x	x	x	x	
80:20	448,6	6,3	0	11	530,6	7,4	0	12	594,8	8,4	0	13	x	x	x	x	x	x	x	x	
70:30	x	x	x	x	311,2	4,6	30	11	456,1	6,4	3	12	414,0	5,6	119	13	529,3	7,6	5	14	Increased production
75:25	331,2	4,9	49	10	377,4	5,7	0	11	467,7	6,9	5	12	432,3	6,6	31	13	x	x	x	x	
80:20	400,8	5,9	0	11	456,9	6,8	0	11	530,6	7,8	0	12	x	x	x	x	x	x	x	x	

(number of trains: 13, 14, 15, 16, 17)

Figure 6 : Chosen characteristics of the queue No 1
Before the teeming bay

a – avarage time (in min,) for one train spent in queue
b – average number of trains in queues
c – number how many times was queues = 0
d – max. number of trains in queues

Other interesting remarks could be obtained by investigation of the dependence of sorts and trains on the production volume with the average time which the trains spend waiting in the longest queues, namely in front of the steelwork and the teeming bay. The queue in front of the teeming bay (Figure 6.) is most effective on consideration about the production of higher quality sorts (by teeming). Unusual increase of the waiting time for the trains in front of the teeming bay and decrease of the waiting time for casting necessitates (for 16 trains and the ratio of 70:30) a decrease in production or delay of melting. Table No. Six indicates the waiting time average in 400 minutes. When the average waiting time is shorter, the melting process will be delayed by the transport, e.g. in sorts with ratios of 75:25 and 70:30 it will be more than 50-80 minutes.

Some Remarks Regarding the Construction of the Model

The performance of one simulation experiment, i.e. 200 ÷ 800 circulations lasted approximately three to five minutes on the IBM 360/40 computer. In this time all necessary changes are included into the model due to both changes in sorts of products and number of trains. The simulation language GPSS/360 was shown to be very flexible for this purpose.

Conclusions

The described simulation method has shown many advantages in comparison with other methods for decision making as to how to increase the production effectively with no other investments. In this study, which was practically applied to an important steelwork in the CSSR, the expected objectives have been fully validated by increasing the production by 200 thousand tons of steel in a short time.

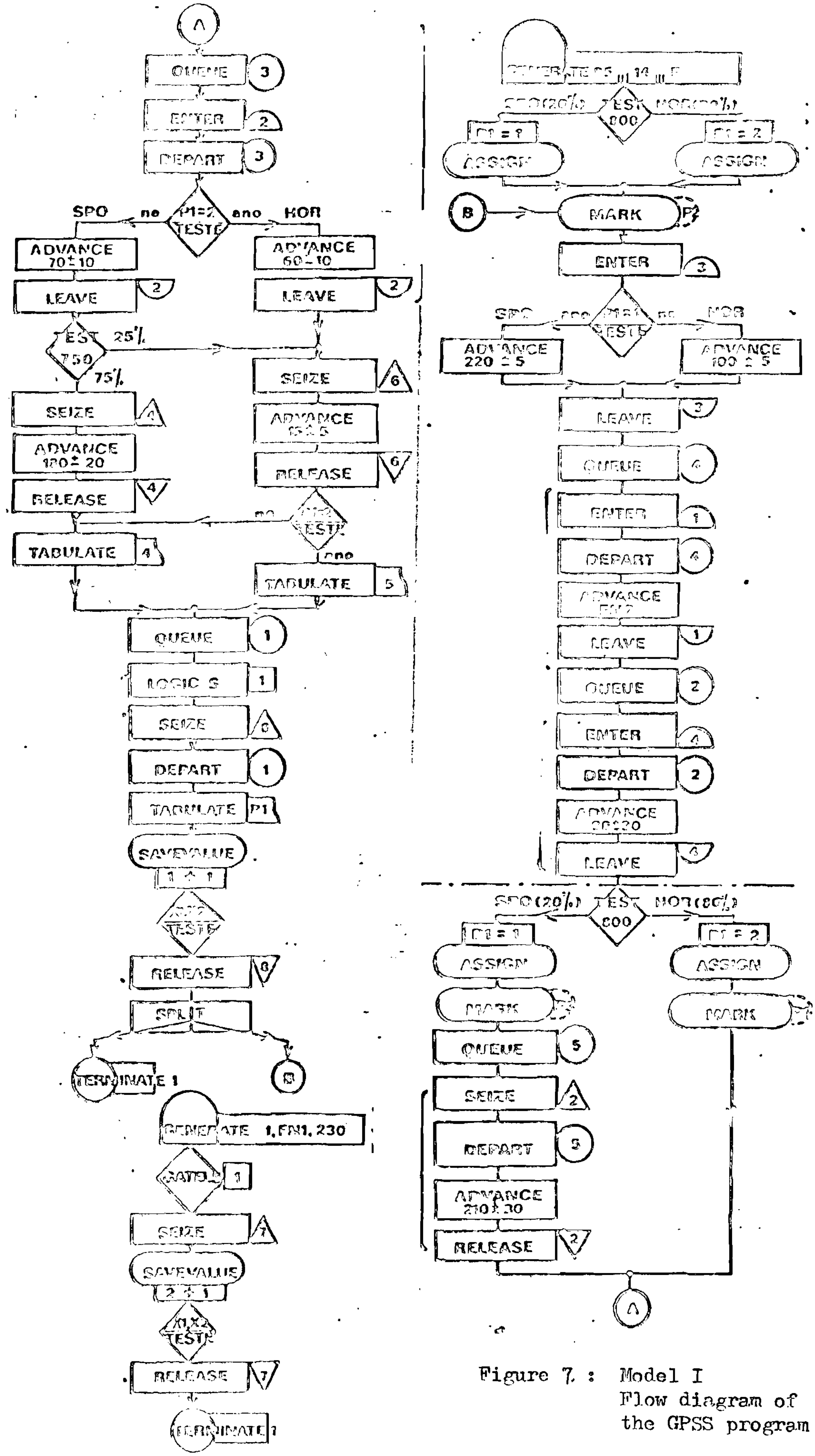


Figure 7. : Model I
Flow diagram of
the GPSS program

References

(1) Belostockij, A.A., Bragin V.I. Production Process Control Alogrithms Based on the Symbolic Model of the Object, Industrial Cybernetics Problems, Trudy CNIKA, 1969.

(2) Belostockij, A.A., Kagramanov, A.K. Investigating a Project Operations Control System by the Statistical Modelling Method, Nauka, 1971

(3) Buxton, J.N. Simulation Programming Languages, Proceedings of the IFIP Working Conference on Simulation Programming Languages, 1968

(4) Cheliustkin, A.B. Automation of Rolling Mill Production Processes, Metallurgia, 1971

(5) Cheliustkin, A.B. System-Based Production Control, Integrated Production Control Systems in Metallurgy, Nauka, 1971

(6) Colella, O'Sullivan, Carlino Systems Simulation, Lexington Books, 1974

(7) Dutton, J.M., Starbuck, W.H. Computer Simulation of Human Behaviour, J. Wiley

(8) Emshoff,J.,Sisson, R. Design and Use of Computer Simulation Models, McMillan

(9) Epstein, V.L. Mathematical Mode of Information Flows and the Determination of the Information Base in Automated Production Control Systems, Production Control, Nauka, 1967

(10) Fishman, G.S. Concepts and Methods in Discrete Event Digital Simulation, J. Wiley, 1973

(11) Golan, J., Phillips, D.T. SNAP Stochastic Network Analysis Program, Purdue University, USA, 1974

(12) Golenko, D.I. Statistical Methods in Economic Systems, Statistika,1970

(13) Hammersley, J.M., Handscomb, D.C. Monte Carlo Methods, J. Wiley, N.Y., 1971

(14) INORGA Kol. Rozpracovani simulacnich metod propotreby automatizovanych systemu rizeni, INORGA, 1973

(15) Jones, G.T. Simulation and Business Decision, J. Wiley

(16) Kopelovitch, A.P., Belostockij, A.A. Automation of Production Operations Control, Trudy CNIIKA, Issue 19, 1968

(17) Krouzek, Mojka, Splichal Simulace a jeji pouziti, INORGA, 1973

(18) Martin, F.F. Computer Modelling and Simulation, Hughes Ground Systems, J. Wiley, 1968

(19) Mize, J.H., Grady, Cox J. Essentials of Simulation, W. Grant Ircson

(20) Naylor, T.H. Computer Simulation Experiments with Models of Economic Systems, J. Wiley, N.Y., 1971

(21) Naylor, T.H., Balintfy, J.L., Burdick, D.S., Kong Chu Computer Simulation Techniques, J. Wiley, N.Y., 1966

(22) Poetzel, J. Simulationsmodell (Grobblechstrasse), Montnische Hochschule, Leoben, Austria, 1969

(23) Pritsker, A.A. GASP IV Simulation Language, J. Wiley, 1974

(24) Reitman, J. Computer Simulation Applications, J. Wiley, 1971

(25) Schriber, T.J. Simulation Using GPSS, J. Wiley, 1974

(26) Smith, D.H., Stevenson, R.W. A Simulation Model of Continuous Casting Steelmaking Complexes, BISRA, London

(27) Tocher, K.D. The Art of Simulation, Van Nostrand, Princeton, N.J., 1963

(28) Tocher, K.D. The Role of Models in Operational Research, The Journal of the Royal Statistical Society,London, 1961

(29) Tocher, K.D. Mathematical Models in the Steel Industry, The Iron and Steel Institute, London, 1969

(30) Tocher, K.D. An Integrated Project for the Desigin and Appraisal of Mechanized Decision-Making Control Systems, United Steel Co.,Ltd., Sheffield

(31) Wauters, J. Waiting Line and Simulation Models in Machine Interference, University Te Leuven, 1974

(32) General Purpose Simulation System V Manuals (IBM)

(33) Mathematical Models in Metallurgical Process Development, The Iron and Steel Institute, London