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COMPUTERIZED INTEGRATED PRODUCTION CONTROL SYSTEMS 1/

by

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SUMMARY

The production management work covers extensive areas of the production activities, but the present report refers mainly to the production control after the receipt of orders.

As a possible application of computers to the production control, comprehensive mechanization of data processing has been attempted in the past, and by the technical development of data telecommunication, real time processing of information, etc., the information system by means of on-line system has been introduced. Explanations of the production control system of the Kimitsu Works of Nippon Steel Corporation will be given hereinbelow, describing in what spheres the computers are actually utilized, and also their point of contact with the manpower of the works.

The computer system of the Kimitsu Works is an integrated information system comprising two units of off-line computers and seven units of on-line computers, with the functions of information gathering, information distribution, information accumulation, information processing, etc. Besides these computers, there are quite a number of process computers used for various operational control, but no explanation of them will be given here.

About 80% of the functions of the integrated information system of the Kimitsu Works is directly related to production control, and so this system as a whole may well be regarded as a system for the production control.

In this system, the above-mentioned production control information system and the men of the production control departments are systematically organized, forming an integrated production control system, the man and the computers sharing their functions as follows.

Functions to be executed by man:

(i) Judgements that cannot be standardized.

(ii) Optimum disposition of works, whose handling standards are not established.

(iii) Coordination between equipment efficiency and delivery terms.

Functions to be executed by computers:

(i) Disposition of works whose handling standards are established.

(ii) Accumulation and assortment of information (furnishing of data to help the judgement of man)

(iii) Operational instructions and records gathering.

The integrated information system are divided into four levels - A, B, C, and D - corresponding respectively to the following process control functions:

1. General planning, general control ..... A-level system
2. Production control for each process ..... B-level system
3. Operational instruction, data gathering ..... C-level system
4. Control by each process, data gathering ..... D-level system

The scope of application of computers, at present, to each of the aforementioned functions is described in the Report, but roughly speaking, in the planning field, computers are used for the accumulation of source data showing various standard values to be used for the planning, or for

the forecast of the outcome of the plan, whereas adjustment and decisions to the actual plans are left for the man to take care of. For the evaluation of the outcome of plans, computers are used in relation to the comparison with proper values at the time of planning and calculation of separation degree, or for the comparison with the separation limit, requiring only the help of manpower when such limit is exceeded. As to operational instructions and operation records gathering, the real-time-corresponding method with tracking system is adopted for the prevention of mistakes.

The computerization of process control, different from that in other departments which aims at statistic handling of records, is destined to carry out actual activities. The first prerequisite, therefore, is the standardisation of each system, for example, accounting system, quality control system, production control system etc. The system of the Kimitsu Works has been realised based on maintenance engineering and operations techniques aiming at stabilisation of operations, and standardisation of management cultivated by many years' experience at several of Nippon Steel's Works.

These computer systems at Kimitsu Works are applicable everywhere in the world, if the following conditions can fulfilled.

(1) System needs must be explicit before computerization which top management admits according to the individual circumstances.

(2) Well prepared masterplan and the detailed programme of computerisation must be made, including the training schedule of systems engineers and programmers.

Introduction

The integrated production control system by the full utilisation of computers at Nippon Steel's Kimitsu Works started with the operation of the heavy plate control system in Febraury 1968 and was expanded to its present state with the introduction of the large section control system in April 1972.

This production control system is based on the Kimitsu integrated information system to which many of the following descriptions will be devoted because any discussion of the former would be meaningless without dealing exhaustively with the latter.

Coupled with the integrated information system, the production control system can ensure an annual crude steel production and delivery of 10 million tons, while achieving satisfactory results in the exactitude of delivery time, the reduction of in-process inventory and the reduction in number of production control personnel.

The production control system and the integrated information system as viewed from aspects of production control will be described below.

Outline of Kimitsu Works

Located in the Kanto district, an area accounting for one-third of the Japanese steel demand, Kimitsu Works is among the largest steelworks in the country. It has an annual crude steel production of 10 million tons.

The works enjoys a plant layout which facilitates the smooth flow of traffic in the works.

It is also advantageously located on the coast. The products manufactured at this works cover almost all kinds of steel products including flat steels, wire rods, large sections, and pipe and tubes. The production plants are of the world's largest scale now capable of high-speed operation. The control system for the effective use of these groups of large mills is rationalized by the thoroughgoing utilization of computers.

Especially in its production control phase, it has coordinated processing functions by operating a computer system that provides integrated control from the receipt of orders to the shipment of products.

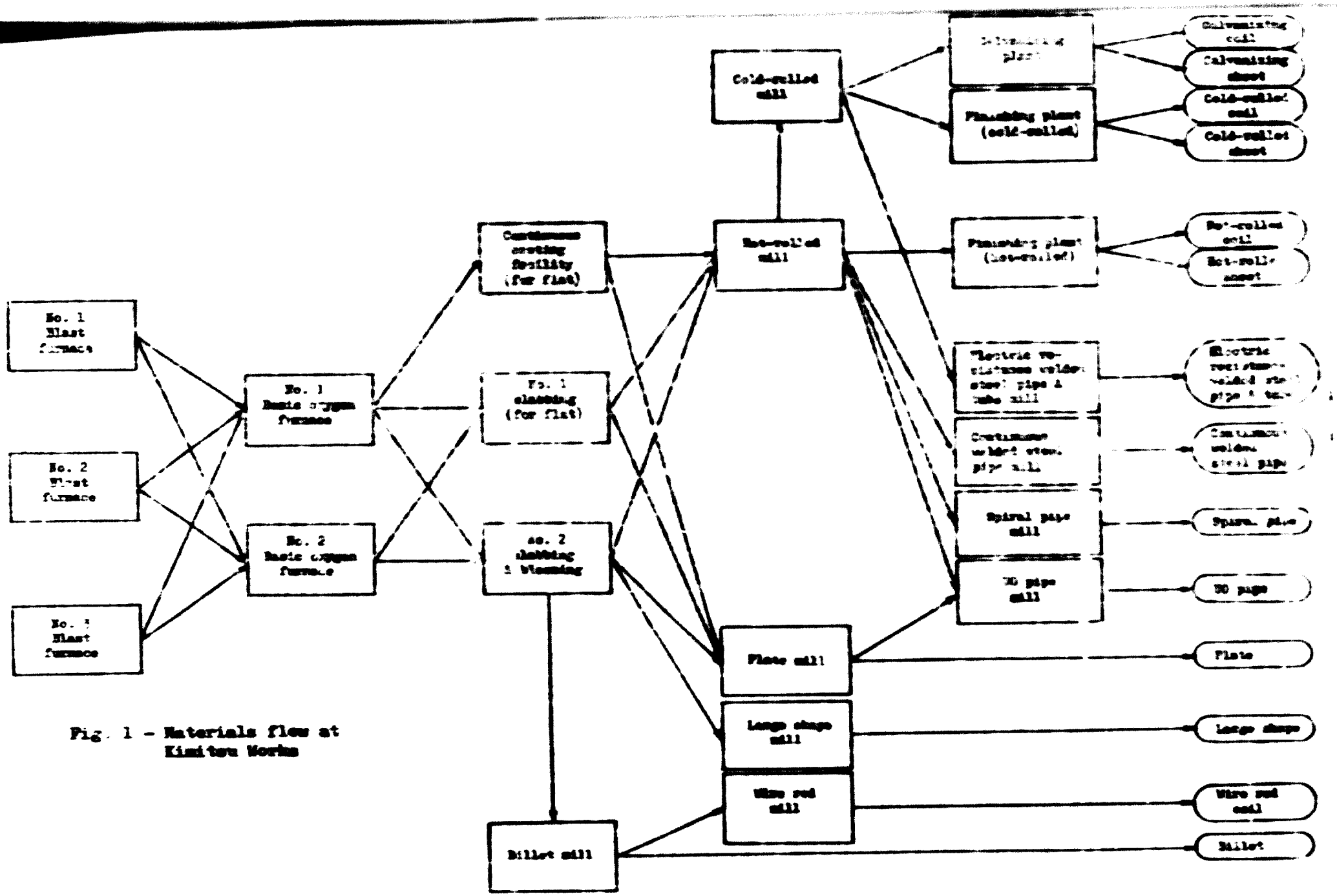
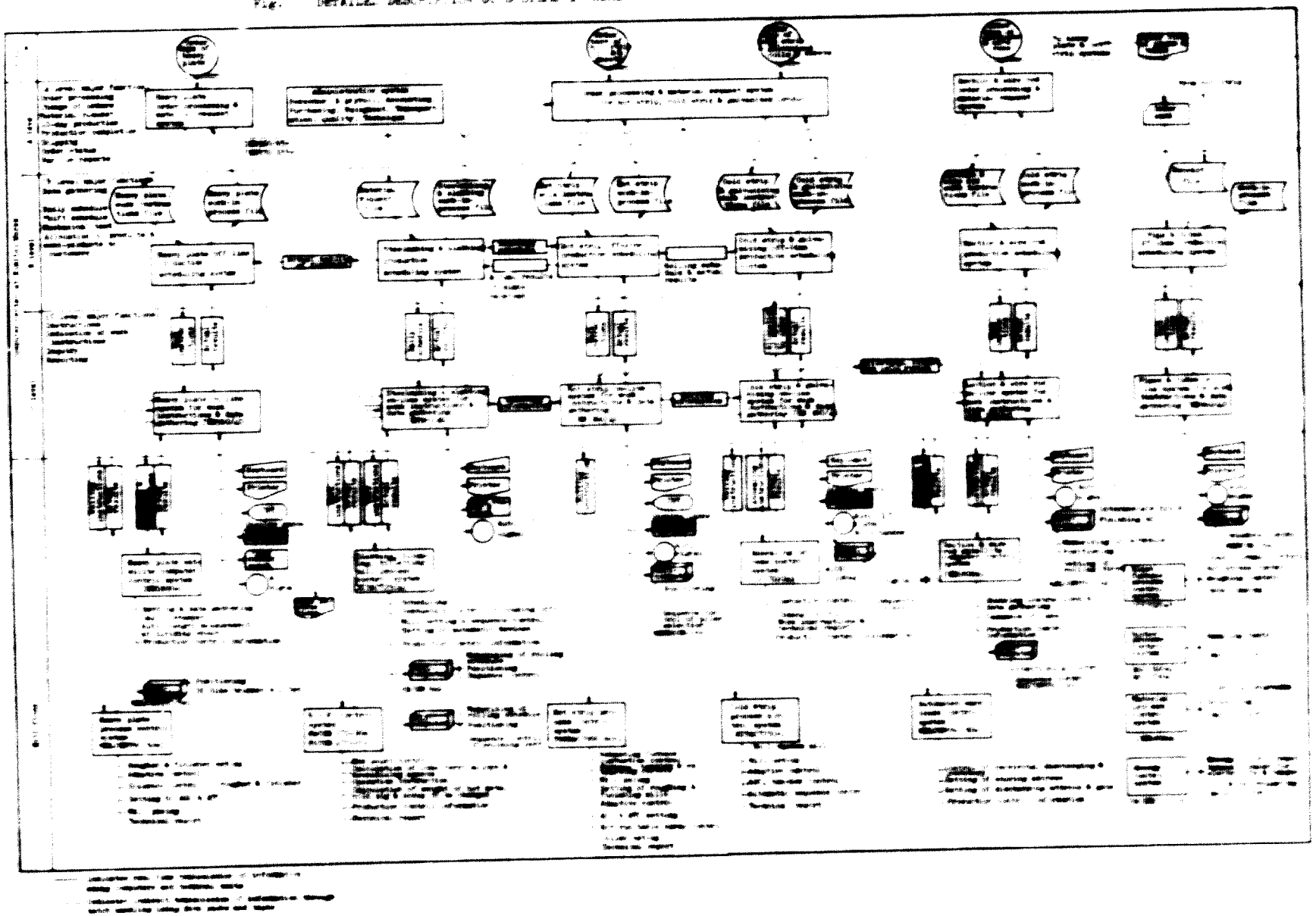


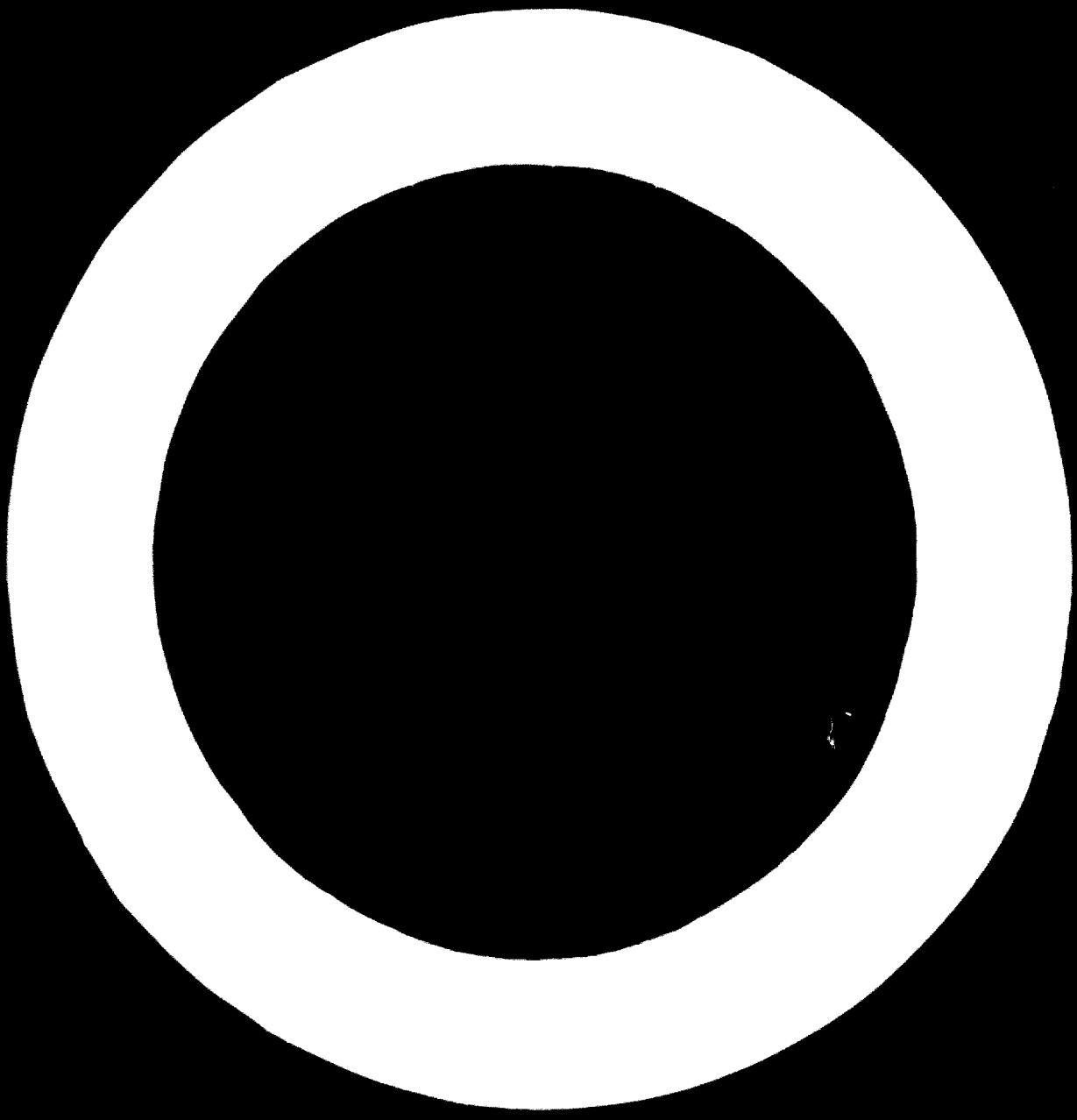
Fig. 1 - Materials flow at Kimitsu Works

Plant	Number	Capacity	Value for planning (remarks)
Coke batteries	No. 1 - 4	9,000 T/D	
Sinter plants	No. 1		
	No. 2	82,000 T/D	
	No. 3		
Blast furnaces	No. 1		2,705 m^3
	No. 2	23,000 T/D	2,884 m^3
	No. 3		4,063 m^3
Basic oxygen furnaces	No. 1	250 T/CH × 2/3	417 m^3
	No. 2	300 T/CH × 1/2	520 m^3
Continuous casting		75,000 T/M	Continuous casting of slab
			Second strand
Slabbing mills	No. 1	450,000 T/M	Slab
	No. 2	260,000 T/M	Bloom, Slab
Plate mill		180,000 T/M	
Hot-rolling		300,000 T/M	Max. 45T Coil
Cold-rolling	No. 1	200,000 T/M	Max. 60T Coil
	No. 2		Max. 45T Coil
Galvanising	No. 1	30,000 T/M	
	No. 2		
	EGI		
Spiral pipe	No. 1	11,000 T/M	
	No. 2		
UO pipe		25,000 T/M	
Electric resistance welded steel pipe & tube (special)		5,500 T/M	
Continuous welded steel pipe		20,000 T/M	
Wire rod		55,000 T/M	Max. 1.8T Coil
Large shape		80,000 T/M	

Table 1 Details of main items of equipment

Fig. DETAILED DESCRIPTION of SYSTEMS at KINITIC WORKS





The production control system at Kimitsu works

Although production control activities in a broad sense of the term cover a tremendously wide scope of activities, including plans for new equipment and facilities, personnel and raw materials planning, the production control activities after the receipt of orders will be mainly dealt with in this paper. The equipment and facilities at Kimitsu Works have unprecedentedly large scales and high speeds, as shown in Table 1. They form extremely complicated flows of materials, as indicated in Fig. 1, because a large product mix is manufactured. To keep these groups of large-scale mills in smooth operation, sound preliminary plant operation planning, correct and fast information gathering at the time of operation, and connection of the information to adequate coordinating functions from an integrated viewpoint are essential. In our production control system, the integrated control functions are satisfied by employing two off-line computers, seven on-line computers (of which one is for back up), and 20 process computers and connecting them to one another organically, as illustrated in Fig. 2.

These computer systems are integrated information systems that involve not only the information processing functions such as performed by conventional systems but also the information gathering, accumulation, distribution, and other functions. The systems contain enormous amounts of information; the total on-line system can hold about 200 million characters and the total off-line system about 2,200 million characters. Classified into the four grades of A, B, C, and D according to their application scopes and processing cycles as represented in Fig. 2, these information systems are carrying out high-efficient processing depending on the characteristics of the respective computers.

About 80 percent of the information systems are directly related with production control, so that it is no exaggeration to say that they are constructed

almost purely for production control purposes. Now the relationship between the information systems and the production control system will be discussed briefly with the system related to the hot strip lines as the example. It must be borne in mind in this connection that our production control system is after all a system which consists of an integration of human beings and computers. Basic planning, co-ordinating functions which are the parts to be fulfilled by intervention and judgement from all the existing conditions, are performed by human beings, while the part for which standardised processing methods have been established is assigned to information systems. As for other parts, the information systems furnish men with the information necessary for judging how the tasks should be carried out.

Integrated planning and control

The object of these is to give the appropriate general operation index of each plant and the production index of each order so as to control the complicated flow of production (material) in advance, to ensure smooth plant operations and to manufacture without fail all products by the delivery dates.

In order to accomplish the main object, we have the following four functions.

1. Preparation of the operation balance index for each process
2. Quality plan and material plan
3. Overall daily plan and overall evaluation
4. Control of standard values and planned values

These functions will be explained one by one in the following paragraphs (Fig. 2

1. Preparation of the operation index for each process

The operation conditions by processes and by days and the work-in-progress quantity can be determined appropriately, but it is difficult to calculate accurately the differences in the production and processing capacity and the respective necessary due to the differences of steel kinds and sizes and also to the repair and maintenance plans of the respective plants.

It is necessary to make preparations far in advance in order to realize this. As the nearest plan to this end, we now have the monthly plan. (Plans earlier than this will not be dwelt upon in the present paper.) In the monthly plan, the prospective values of demands by processes and by products are distributed to Nippon Steel's 10 works (function of the head office) and the prospects to be obtained from the result of this primary distribution are evaluated for each works. The balance is normalized based on the evaluation result, and then a redistribution plan is prepared at the head office. It serves as the monthly operation plan for Kimitsu works, and, based on the plan, the ten-day balance and daily operation balance are adjusted. As the result, the actual order processing and other subsequent processings are to be started. The part up to this point, however, has not yet been computerized because our operation scope which depends on various circumstances, including our policy toward each plant operation and the balance over the period of each plan, is subject to changes at each time of operation, making it difficult to obtain a uniformly applicable evaluation criterion.

This problem involves difficulties in standardizing the methods of operations and in computer processing logic, so that at least at the presently conceivable level it is considered preferable to entrust the tasks of this part to the overall judgment of human beings instead of computer processing.

2. Quality plan and material plan

For the orders distributed by the head office each works, the contents of each order and the manufacturing conditions for each order are checked, and manufacturing specifications are given to each order. After that, calculations of the materials necessary for each order are conducted in succession right from the terminal process. In this calculation process, the final amount of tapping and the tapping date are temporarily

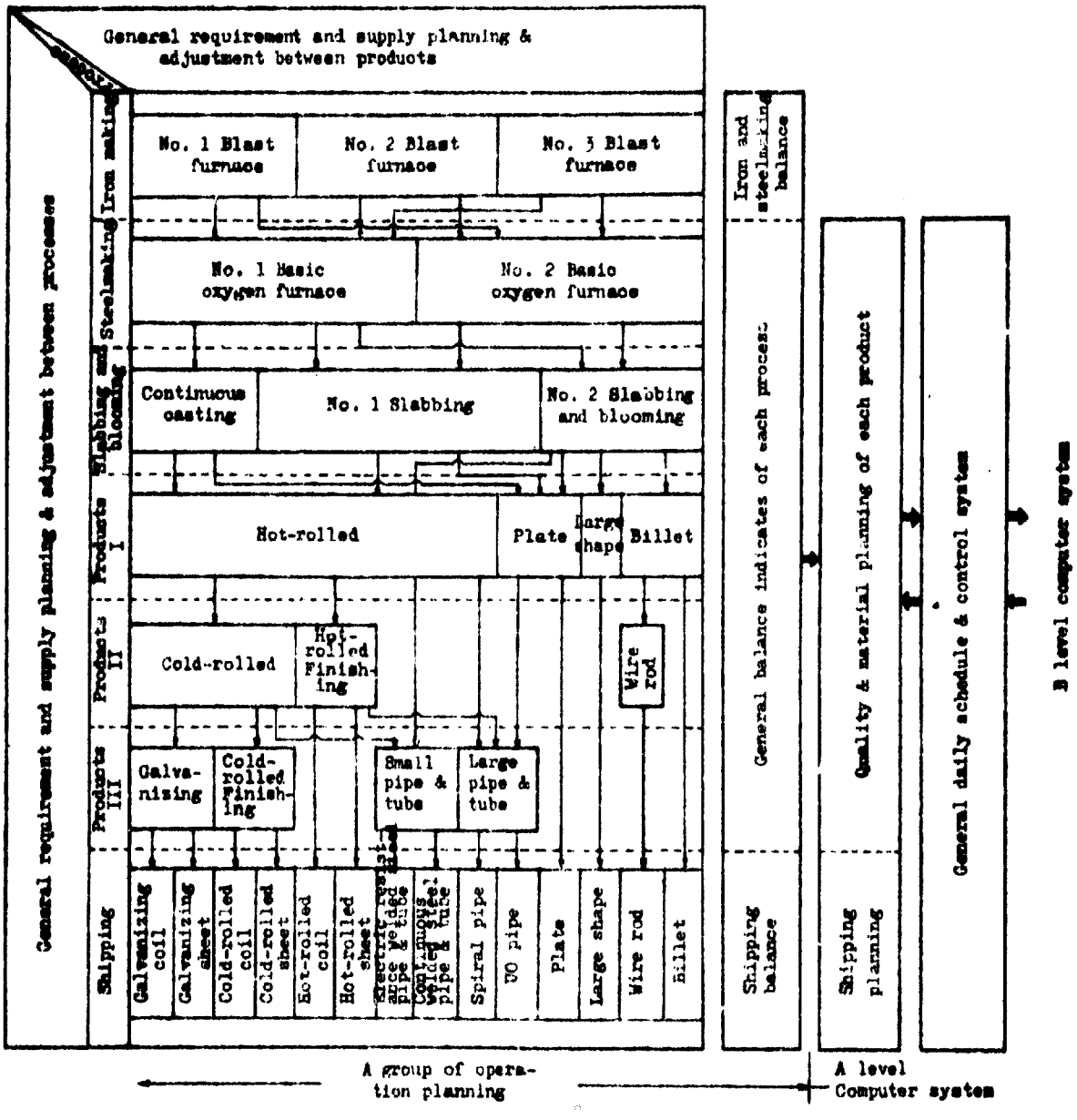


Fig. 3 - General planning and control system

decided in consideration of the delivery date, open-order slabs or blooms for each process and scheduling of procession, and while forming operation lots suitable for each process.

The results are checked in comparison with the process operation balance as the total quota, and, if large differences are detected, some measures to eliminate them must be taken. As such measures, the change of lot combination conditions and the change of processes to be passed may considered. In the worst case, it is necessary to change the delivery dates for orders after contacting the head office. The decision in this process rests on human beings, the conditions are changed by human judgment, and a material plan is made again by the computer system.

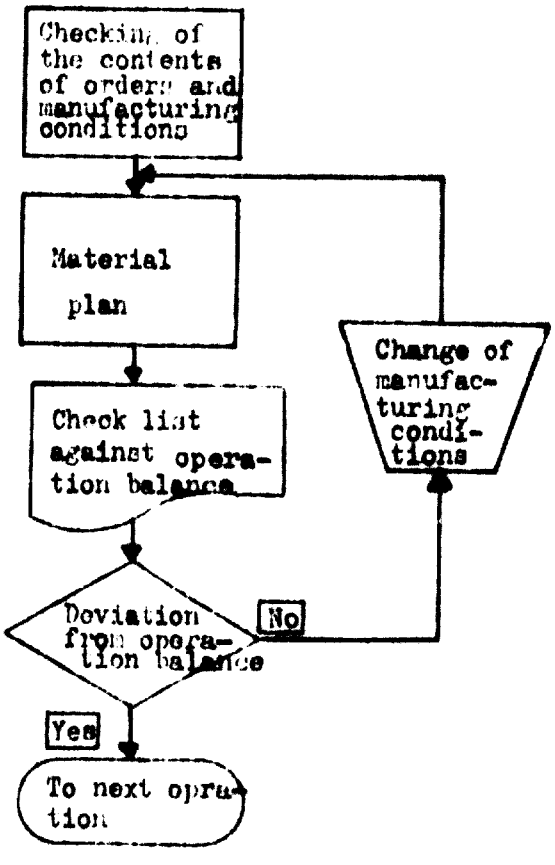


Fig. 4 Quality and material planning system flow diagram

3. Overall daily plan and overall evaluation

(1) Overall daily plan

Based on the overall balance index for each process (quantity quota by product kind and by processes involved) and the material plan (prepared in the unit of handling for each process), the expected dates of passing the respective processes are scheduled. To take the example of the system concerned mainly with hot strip lines, the expected dates of passing the respective processes are determined for each material unit from the expected tapping date, through the hot rolling date, to the date of each process of hot strip finishing one after another, in consideration of the operational conditions of the processes and thus the final shipping date is also decided.

The plan prepared here, in its nature, should be followed with first priority in the practice plan for each process.

The scheduled data for the respective processes by individual orders, which are scheduled from the result of the said plan, serve as the basis for the subsequent order status controls.

(2) Result evaluation and adjustment

The operation of each process is carried out based on the overall daily plan prepared in (1), and the system grasps the results integratedly and evaluates them so as to revise the plan or form a new plan. Factors which can change the said plan are considered to be the following.

i) Factor attributable to the efficiency difference of each process

ii) Change in yield of each process

iii) Material loss at each process

iv) Change in condition caused by trouble or the like of each process

v) Change in order conditions (such as delivery date and quantity)

In order to evaluate these factors, all work-in-progress and backlog of production for each process are collected, integrated, and their differences from the original plan are detected, and then whether or not the differences will affect the production plans for the subsequent processes is estimated. As a result, if the differences are not great, the plans of individual materials will be revised and, if they are estimated to affect largely the process balance, replanning stated in (1) will be performed.

4. Control of standard values and planned values

In preparing the plans discussed so far, various estimated values are used; whether or not those plans are carried into execution accurately depends solely upon the propriety of the various standard values or planned values employed in preparing them.

These values may be classified into the following items, and they are used suitably according to each stage of the plans.

(i) Efficiency values by processes and by divisions of product kinds (T/Hr)

(ii) Yield by processes and by product kinds (output/input)

(iii) Work ratio by processes and by product kinds (working hours/workable hours)

(IV) Passing quantity by processes and by work divisions (unit operation lot)

(v) Capacity by processes (time or quantity)

In addition to these items, the following are necessary for statistics at the stage of order and material plans.

(vi) Order volume by product kinds and sizes

(vii) Material consumption volume by product kinds and sizes

In order to make these values estimable at all times, various actual results are preserved in highly detailed forms for about six months. We have a perfect system ready to enable these data to bear changes in the units of various divisions. Of course, we always compare standard

values with actual values for detecting whether it is necessary or not to change each unit of division, and if necessary, we take the following measures;

(i) Deviation of actual values from standard values → revision of standard values

(ii) Large variations of values → change of division units

These actual result data contain values of various characteristics so that they are used for analysis of material characteristics in sectors other than the production control department, for example in the quality design department.

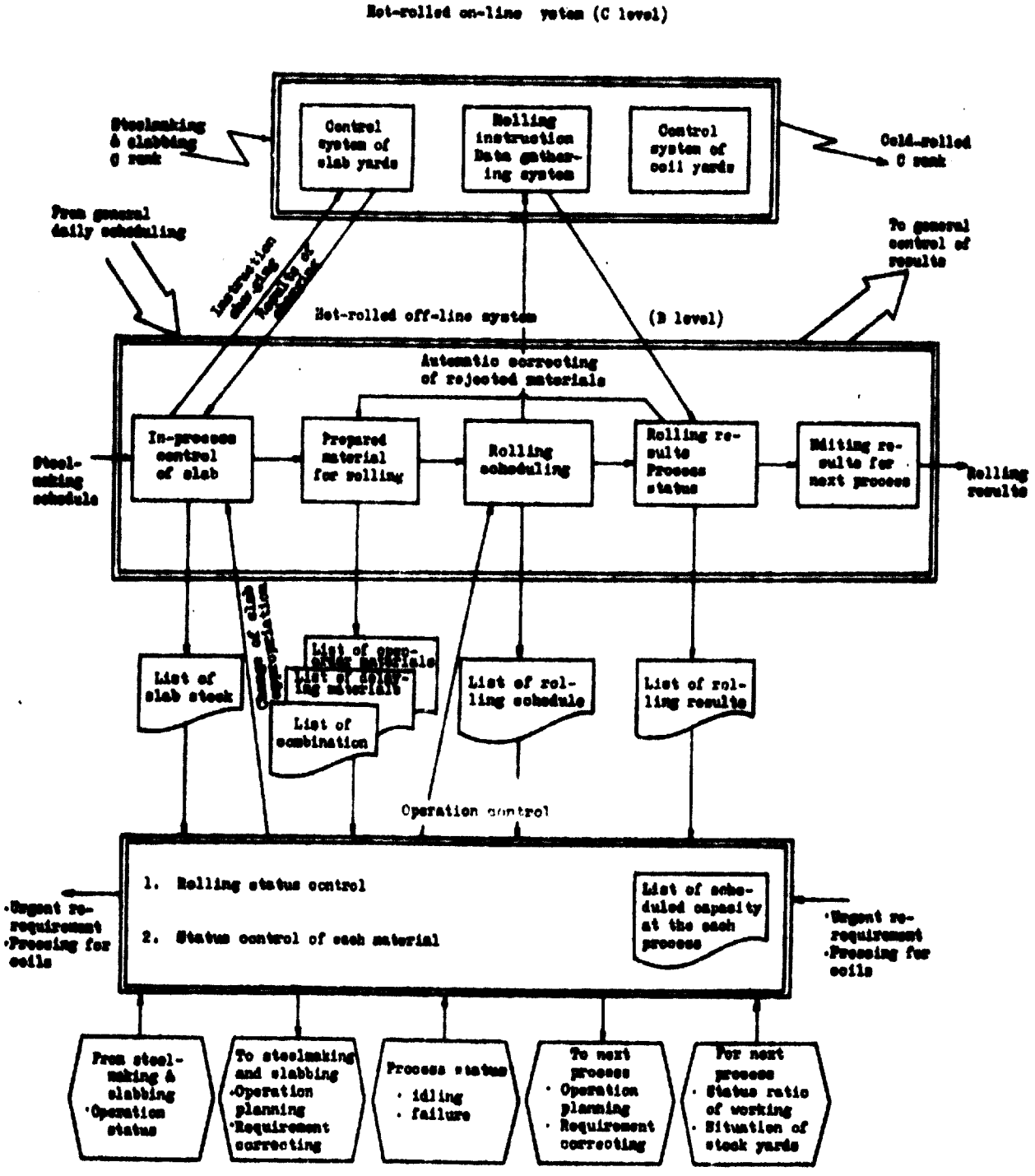


Fig. 5 - Operational control on the hot-rolled line

Operation control by processes

The overall operation balance for each process prepared in the overall plan and the scheduled date of passing each process for individual materials serve as the targets of control in controlling the operation of each process. However, when the operation plan for each process is put into practice, unexpected troubles often occur to make it sometimes impossible to carry out the operation according to the plan.

Such troubles are caused by various factors, which may be classified into two groups. Factors belonging to one group destroy the operation balance between processes. They are;

(i) Change in efficiency of production processes

(ii) Unexpected suspension of operation due to equipment breakdown

(iii) Limitation to manufacturing items due to equipment breakdown

Factors of the other group are not so large as to destroy the operation balance but are more or less embarrassing if the operation is seen in terms of orders. They are:

(iv) Change in yield of materials

(v) Material loss

(vi) Substitution of materials

(vii) Change in contents of orders

Various adjustments are necessary to cope with these factors, and the steps to be taken for the adjustments will be explained below with regard to the case of hot strip line operation control by way of example.

The hot strip line operation control comprises various information processing mechanisms operated by personnel in charge and computers, as shown in Fig. 5. The functions involved may be roughly classified into the following;

1. Control at the material stock
2. Actual operation plan
3. Rolling results control

1. Control at the material stage

To carry out the production of the line as planned, it is necessary to detect conditions not agreeing with the plan and to take proper measures to remedy them as early as possible. In order to do so, the control system for the hot strip line evaluates results with regard to the plan at the material receiving stage and makes an effort to obtain the materials required.

Usually the following lists are used as documents for controls at the material stage:

(i) Products-orders assignment list ..... for materials which have already reached the slab yard and been assigned to orders by the rolling schedule.

(ii) Behind schedule list ..... for materials which have failed to reach the slab yard as scheduled for some reason in the preceding process.

(iii) Open-order slab list ..... for materials which have reached the slab yard but are not directly assigned to the rolling plan. (These occur mainly during the operation lot formation at the steelmaking stage.)

The degrees of progress of individual materials are understood from these three lists, and at the same time the overall material supply condition is understood from the tabulation of these lists so as to estimate the supply of materials to the next process. Of course, in case a large deviation from the operation plan of a process is detected, the rebalancing of operation is done from time to time to maintain the balances with the preceding and succeeding processes.

2. Actual operation plan

Although the actual operation plan in normal cases can be carried out without any problem if executed according to the schedule, the plan is almost always subjected to some changes or other in various conditions. In order to absorb all such changes, therefore, our system makes it a rule to recheck the plan with the initial overall plan and to grasp the latest condition of the progress of production processes, the condition of each yard, and the condition of equipment, and we are able to manufacture according to the rolling plan matching these various conditions. The hot rolling process in particular has a number of subsequent processes, such as each process after cold rolling, the hot strip refining processes, and the processes related to pipe and tubes, as depicted in Fig. 3. Therefore, the material demand and supply adjustment at this stage is very important for maintaining the smooth operation of all these processes. This part of the work has highly difficult points to handle, such as the decision of the kinds of information to be required and the selection of the evaluation criteria, so that it is impossible to handle this part according to a fixed principle. For this reason, therefore, we now content ourselves with facilitating the operators' controls and interferences, and avoid making the computer system control the manipulator of operation. In this system the manipulator of operation (adjustment necessary for some reason or other) is generally done by the human being and the processing after how much manipulation should be done has been decided is performed by the computer system. So the system is a so-called man-machine system.

3. Rolling results control

The understanding and evaluation of rolling results are limited mainly to the degrees of the progress of operation and the losses of the individual materials. The work of the computer system consists the gathering of individual operation results by the on-line computers and the evaluation of the results by the off-line computers. Of the results evaluation, the evaluation of the degrees of the progress of operation must be made in consideration of the influences on other processes. Also it is impossible to gather all information necessary for this evaluation. So no direct evaluation of the degrees of progress is carried out. Individual materials are evaluated by using the scheduled dates prepared at the time of the overall plan. The work of the coordinators consists of the evaluation and adjustment of the said overall condition of progress and the arrangement of individual materials. In case the operation balance is greatly lost, the overall balance will naturally be planned again and the individual materials will also be replanned at this time. However, the problem is generally of the process balance and there are not so many materials requiring particularly quick handling so that the processing is carried out mostly within the scope of individual adjustment.

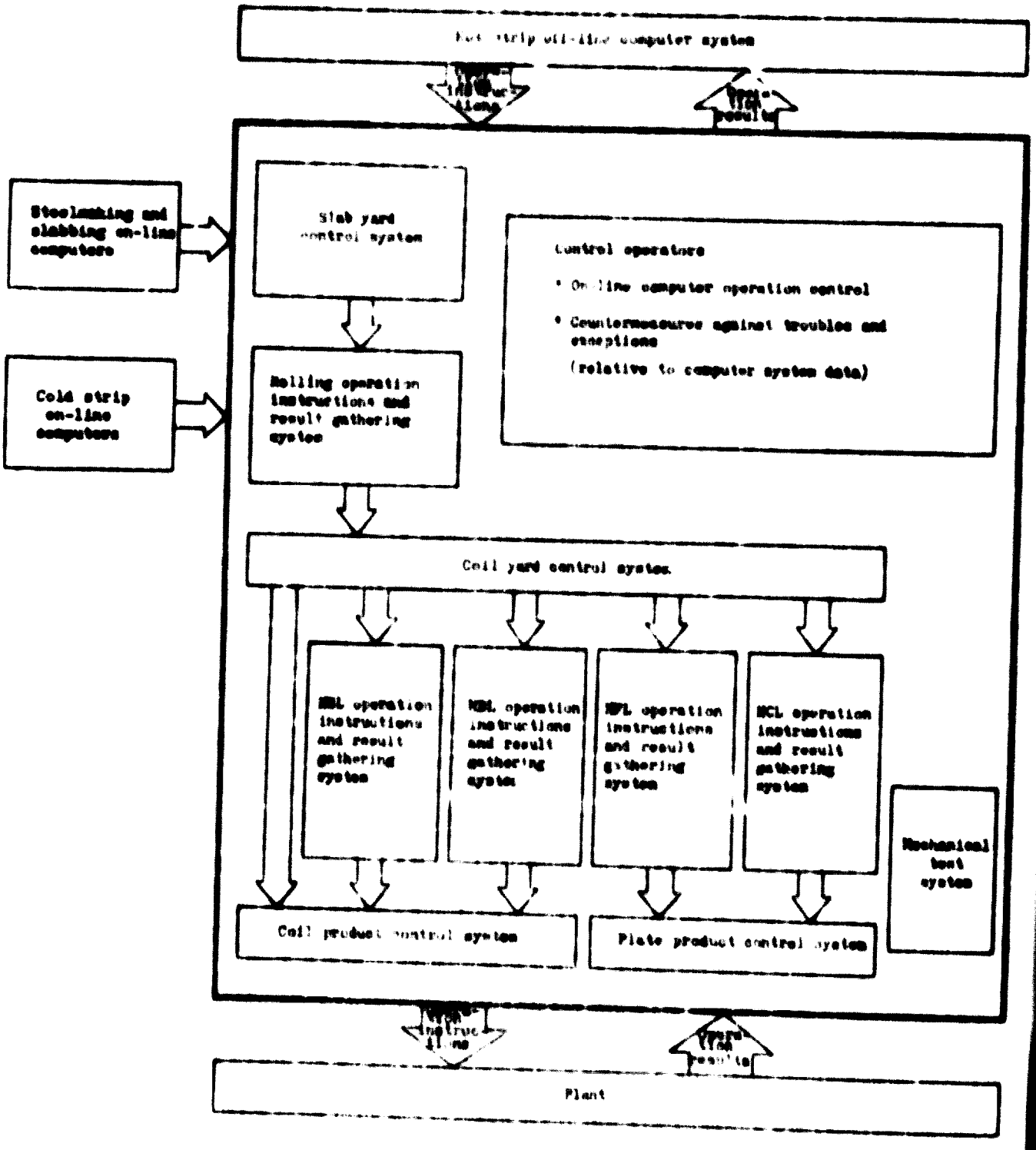


Fig. 6 - Function diagram of hot strip on-line system

Collection of operation results and inventory control.

The greatest feature of the production control system at Kimitsu Works is the introduction of the on-line system and the control systems based on it.

Generally the information for production control and coordination must be gathered as early as possible to ensure adequate processing, otherwise it is untimely and scarcely has the value of information in some cases. Also a huge information transmitting mechanism is required to organically connect the extremely large mills to one another. These requirements used to be met by telephones and pneumatic tubes in the past, but such communication means had their limitations in the volumes and timing of information they could transmit and in the integrated estimating functions and also required a large number of coordinators. In order to solve all these difficulties once and for all, the production control system at Kimitsu Works has introduced on-line information systems, which have the main functions of operation instructions, operation results gathering, inventory control, and yard control. To take the hot strip mill as an example, the on-line systems fall into the following two groups, as illustrated in Fig. 6.

One is the group of sub-systems mainly for inventory control and yard control, which are:

(1) Slab yard control system

(2) Coil yard control system

(3) Coil product control system

(4) Plate product control system

The other is the group of sub-systems mainly for operation instructions and operation result gathering, which are:

(5) Rolling operation instructions and result gathering system

(6) HSL operation instructions and result gathering system

(7) HDL operation instructions and result gathering system

(8) HFL operation instructions and result gathering system

(9) MCL operation instructions and result gathering system

(10) Mechanical test system

1. Inventory control system

As an example of the inventory control and yard control system, the hot strip slab yard control system will be discussed below.

The hot strip slab yard control system, as illustrated in Fig. 7, may be classified into the following three parts:

(1) Accepting yard determining part

(2) Inventory control and yard control part

(3) Delivery yard designating part

The basic functions of this slab yard control are the dividing of the slab yard into many sections having each address and the piling up of slabs for each such address.

(1) Determination of the accepting yard

Determining the accepting yard is the basis of the slab yard control. We take the system to reduce the necessity of re-piling and to raise the yard utilization as much as possible.

(2) Inventory control and yard control

The system can supply the slab yard control operators with information on every slab and information on every yard at all times for the convenience of actual slab control and coordinated yard control. The slab information is transmitted as it is to the hot strip off-line system to be used as information for operation controls and rolling plans.

(3) Delivery yard designation

Slabs are actually delivered one by one for rolling. So, it is only necessary to instruct the delivery operation by designating the yard number of the slab. In some cases different kinds of slabs are piled together at the same section, so not only the yard number but also which slab as counted from the top is instructed at the same time for assurance.

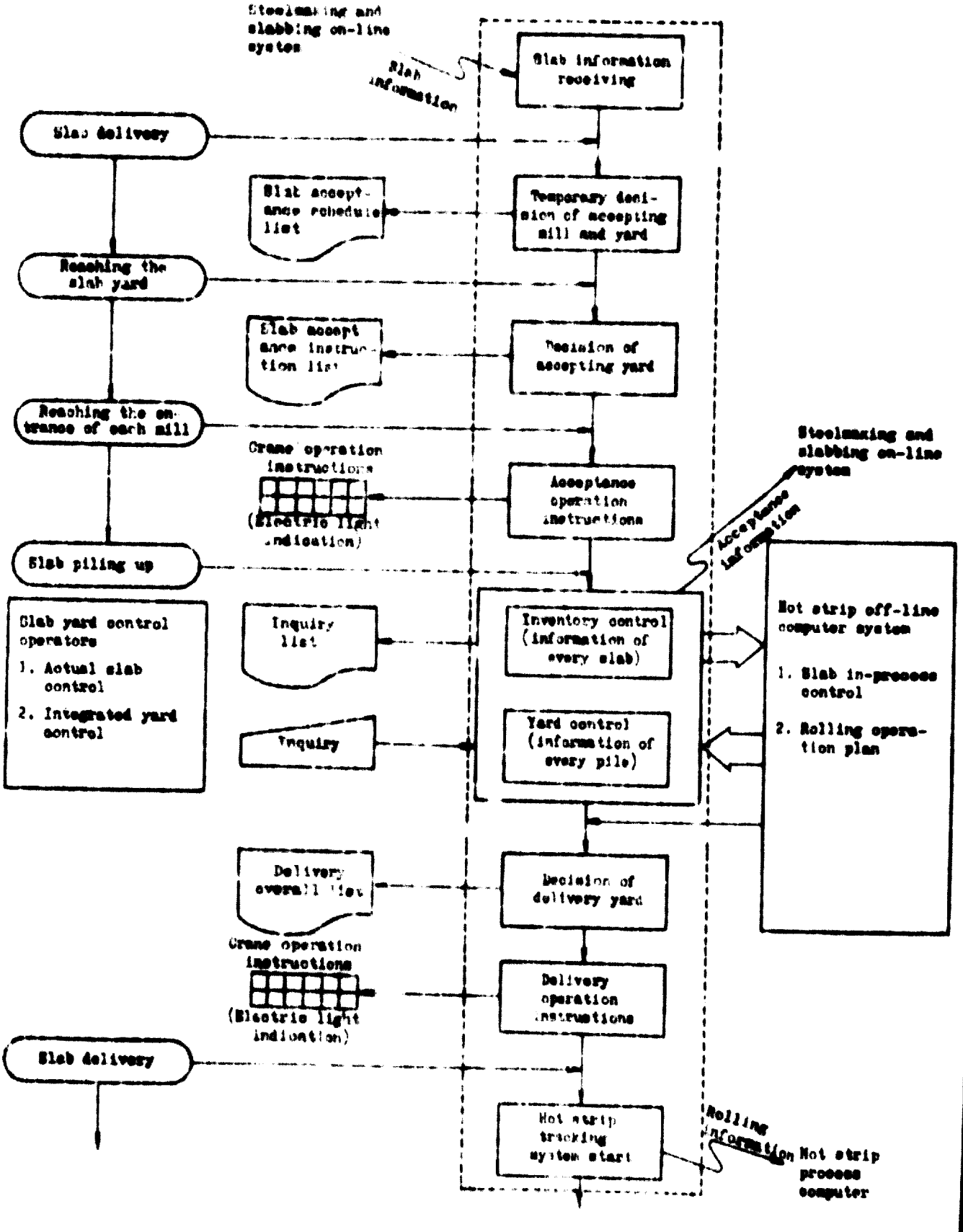


Fig. 2 - Hot strip slab yard control system

2. Operation instructions and result gathering system

The basic concepts of the operation instructions and operation result gathering system are the real-time operation instructions by the trucking system aiming at the lessening of the operation result gathering work and the improvement of the data accuracy gathering (to avoid input errors) and the thorough employment of the method of result gathering by the one-touch operation of push buttons. This system consists of the following three parts as represented in Fig. 8.

(1) Trucking system

(2) Each operation instructions system

(3) Result (data) collection system

(1) Trucking system

This system aims at the detecting where the actual materials (slabs and coils) are flowing, giving operation instructions in appropriate time and gathering the results of such operation.

(2) Operation instructions system

In the hot strip line, most of the work is automatically operated and automatically set by the hot strip process computer, as shown in Fig. 8. Unlike the operation instructions in other processes, therefore, the instructions in this process are not given to the operators but given to the computer. When the information of operation instructions is transmitted to the process computer, the instructions immediately serve as operation instructions. In other processes the operation instructions are generally given by the use of display tube, electric light display, CRT, punch cards, prints, etc. depending upon the case of use in each process. In case the contents of the operation instructions are complex and have a great many items of instructions, some processes use the documents prepared

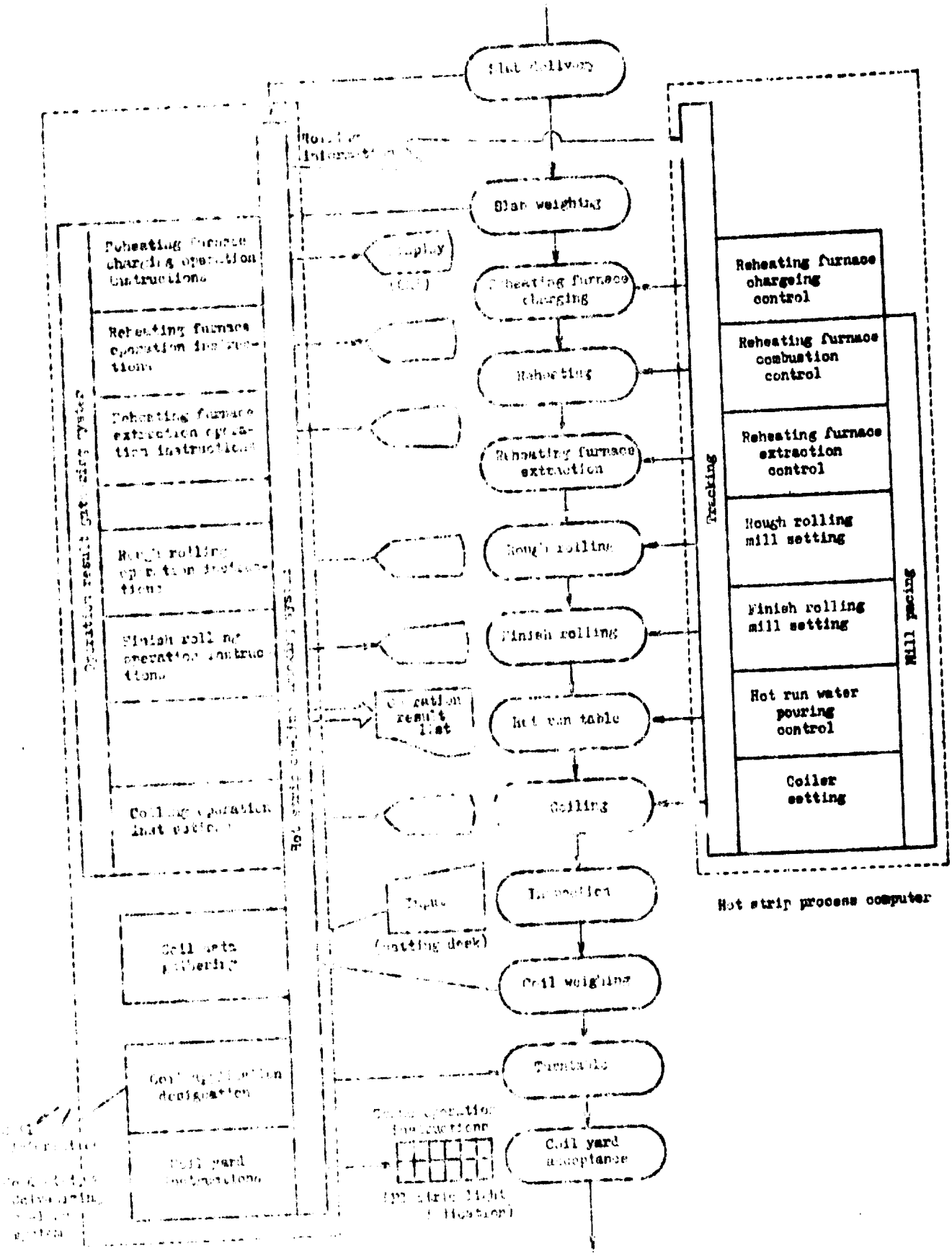


Fig. 3 - Hot strip mill operational instructions and result collecting system

in advance by the off-line computer, and on-line computer indicate only the number (used in the documents) for identifying the materials actually flowing. In the case of the hot strip line, most of the actual operation is carried out by the process computer as stated above, so that deviations of information are prevented by CRT display at every unit of equipment in order to positive-check the tracking by the process computer with that by the on-line computer and the tracking by the on-line computer with the actual materials.

(3) Operation result gathering system

Operation results corresponding to the real-time operation instructions in (1) and (2) are gathered in real time. Since it is only necessary to gather operation results just as instructed by the computer in most cases, the data gathering of the hot strip line is performed almost entirely automatically. The only case in which the computer operators are required to interfere with the computer operation and to set the respective items to gather the results is where an operational trouble has occurred.

3. Roles of the controller of on-line-computer (control operator)

To obtain smooth operation of the on-line system explained above, the back-up of operators is necessary. They are to play the roles of (1) controlling the operation of computers and (2) connecting abnormal or exceptional operation information to computer information.

(1) Control of the operation of computers

The most important role of the control operators is the control of the on-line system as a whole, covering everything from the center machines to the respective terminal display and setting equipment. As stated earlier, our on-line system is closely connected to the field-operation and the trouble and stoppage of the system directly lead to the

suspension of field operation. Although various back-up measures are being taken (for instance, the preparation of duplex computers), the judgment and operation of actual computer switching or the appropriate steps to be taken against trouble of each terminal equipment must necessarily be carried out by the control operators.

(2) Connection of abnormal or exceptional information to computer information

The Kimitsu integrated information system covers almost all kinds of information necessary for various controls, and for this very reason data errors in this system may have disastrous influence on each control. For instance, in the case of a deviation owing to a signal error in the tracking system, the field operator may find it but the judgment as to what extent it must be corrected or what must be done to correct it cannot always be entrusted to him. Our system is designed to permit real-time error detections and corrections of errors at the points of their occurrence, to the extent possible. Nevertheless, quick corrections or recoveries in case these steps are impossible must be made by the control operators.

Prospects for the future

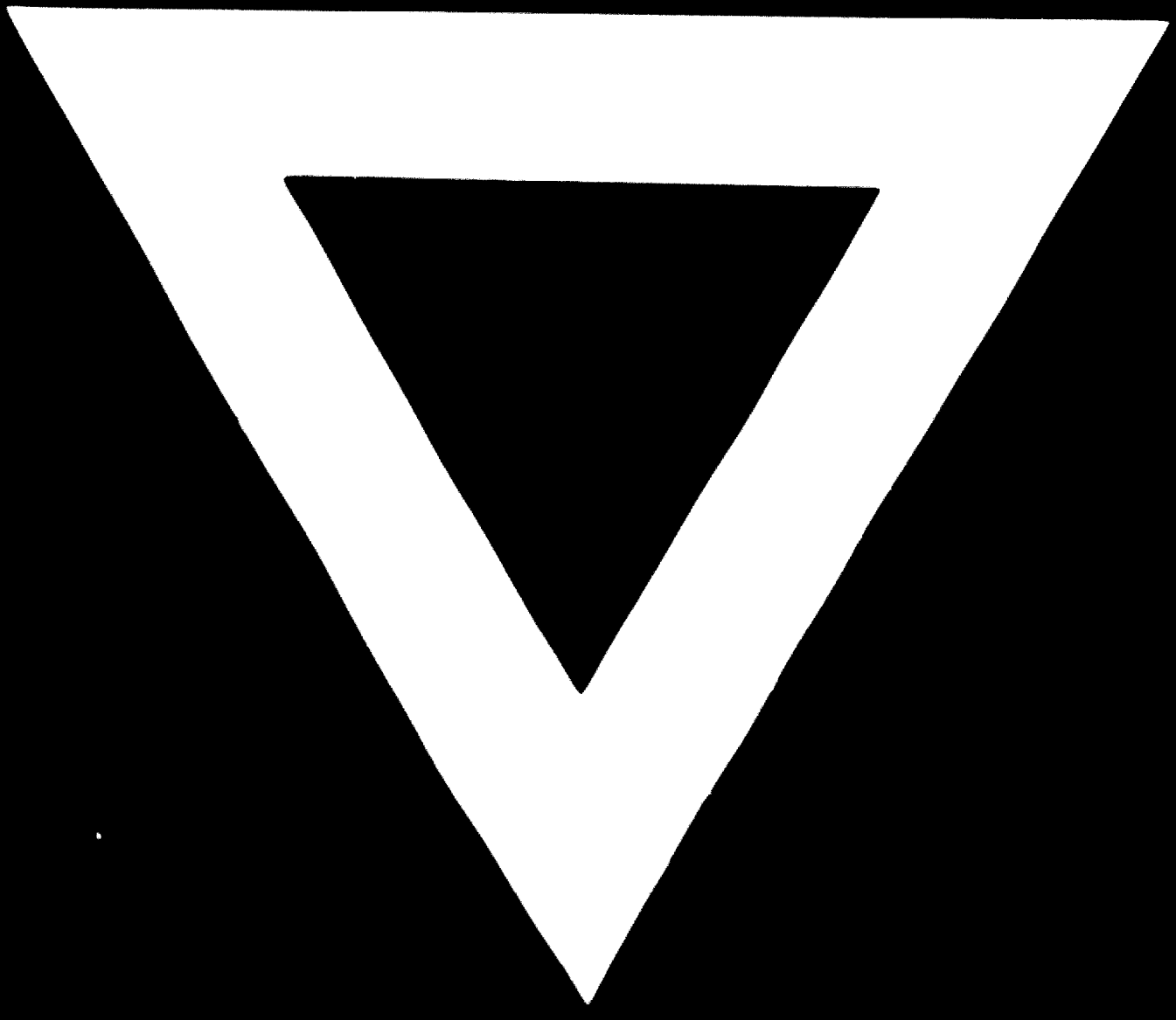
The production control system at Kimitsu Works is based on the Kimitsu integrated information system. As has been explained so far, it is a system combining the functions of men and computers. The judgment or estimation of the part whose processing has yet to be standardized, the optimization of the part for which no computer processing procedure for discovering optimality has yet been established, and the harmonization of equipment efficiencies with delivery dates for orders are the duties of the human being. On the other hand, the information processing of the part for which the processing procedure

by some fixed method or already been established (including the processing of abnormal information) and the arrangement of information for assisting the judgment of human beings on the functions to be shared by computers. However, the current level of computerization is supported by the standardization of control methods and the stabilization of plant operations realized in past years. If, therefore, the control level is raised or the operation stability is increased in the future, the system must also be improved correspondingly. It is also necessary to promote the development of the logics of the part still remaining uncomputerized owing to the difficulty of the logics (such part being related mainly with transportation and handling) No less important is the effort to realize still closer coupling of the production control system with the material, equipment, labor and other production preparation systems for the perfection of the integrated system.

The system at Kimitsu Works is applicable everywhere in the world, if the following conditions can be fulfilled.

(1) System needs must be explicit before computerization which top management admits according to the individual circumstances.

(2) Well prepared masterplan and the detailed programme of computerisation must be made, including the training schedule of systems engineers and programmers.



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