MAFLOS-A GENERALIZED MANUFACTUPING SYSTEM SIMULATOR

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SUMMARY

Manufacturing systems are very complicated, so it is very difficult to grasp the actual behaviour of the manufacturing processes in detail. Even if we obtain a new idea of the scheduling algorithm or the process layout, it takes a long time until the idea is put into practical use, because it is difficult to prove the actual validity of the idea.

The simulation technique is valid to solve this bottleneck. However, the conventional simulators lack the ability to simultaneously simulate the material flows and the control systems' behaviour.

In this papers, the authors analyze the functions of manufacturing system in the following factors:
(a) equipment layout (b) control system, (c) material, (d) operation.
According to the analysis, we present a new type simulator which is named "MAFLOS".

MAFLOS is characterized by the following features.
(a) MAFLOS has seven kinds of unit-element to describe the equipment layout of the manufacturing system. The simulation model is therefore generated by combining these unit-element.
(b) MAFLOS can simultaneously simulate the material flow and the control system behaviour.

1. INTRODUCTION

Manufacturing systems are very complicated, so it is very difficult to grasp the actual behaviour of the manufacturing processes in detail. Even if we obtain a new idea of the scheduling algorithm or the process layout, it takes a long time until the idea is put into practical use, because it is difficult to prove the actual validity of the idea. Simulation[2] is one of the best methods to examine the validity of such idea.

Conventional simulators such as GPSS, SIMSCRIPT etc., which are generally used to solve queueing problems[3][4], lack the ability to simulate the control systems' behaviour. Hence, the conventional simulators are not convenient for simultaneously investigating the material flow and control system.

In this paper, the authors will present MAFLOS (Material Flow Simulator: a new type simulator for manufactiring systems). MAFLOS has the function to simulate the control systems' behaviour, the process layout and the material flow.

2. ACTIVITY OF MANUFACTURING SYSTEM

We now consider the activity of the manufacturing system shown in Figure 1 as an example. In this syst m, the materials are manufactured in the sequence which follows:
(1) The materials which arrived from external system are loaded in the "container."
(2) The containers are transfered to the central "storage" by the "handling machines" and the "conveyor."
(3) The central handling machine transfers the containers from the central storage to the local storages which are located beside the "production machines." The containers are transfered according to the sequence of the work schedule for the production machine.
(4) The handling machine selects a material which is demanded by the production machine, from the container.
(5) The selected material is put on the production machine.
(6) The production machine works on the material.
(7) The handling machine returns the worked material to the container.
(8) The central handling machine sends back the container to the central storage. The container stays at the central storage until another production machine requests it.
(9) The materials flow through production machines according to the manufacturing sequence individually given. The manufacturing sequence for each material is predetermined.
(10) The finished materials are taken away by the conveyor and the handling machines.

following two sets of data:
(a) The state of materials.
(b) The state of unit-equipment.
For example, the manufacturing time at the production machine is calculated according to time standard in data set (a) and probabilistic disturbance (if necessary). The carrying time of a handling machine is calculated according to the present position of the handling machine, in data set (b), and the present position of material, in data set (a), and position where the material should be transfered, in data set (b).

3.4.2 Confirming function for the starting conditions

Proceeding the start of an operation, the confirmation of the starting condition must be done. As for the starting condition, there are two cases.
(a) Synchronization of materials: Before the start of assembling operations, all parts that are needed to assemble must be put together.
(b) Propriety of the manufacturing sequence: Before the start of manufacturing operations, whether the operation is on the correct manufacturing sequence or not must be examined.

4. THE STATE OF THE MANUFACTURING SYSTEM

4.1 The state description of the manufacturing system

The state of manufacturing system is described by the state of the materials and the state of the unit-equipment. MAFLOS has the function to describe the following state of the manufacturing system.
(1) The state of materials.
  (a) The present position.
  (b) The progress on the manufacturing sequence.
  (c) The classification of material quality: a good material or no good material.
  (d) The classification of materials in waiting state: the material waiting the operation in the unit-equipment or the material waiting the scheduling in the control system.
(2) The state of the unit-equipment.
  (a) The state of operation of the unit-equipment.
  (b) The progress on the work schedule.
  (c) The name of the material on the unit-equipment.
  (d) The present location of the unit-equipment.

The transition diagram in the state of the operation for the production machine is shown in Figure 4.

The items deciding the state of each unit-equipment are shown in Table 2. A sign "O" in Table 2 denotes that the state is necessary for defining the state of unit-equipment.

4.2 Events inducing the state change

The state of the materials and the unit-equipment in the MAFLOS is changed by the following events.
(a) The start and the end of the working hours.
(b) The operation completion of the unit-equipment (handling machine, production machine, conveyor).
(c) The occurrence of the disturbance (the troubles at the unit-equipment, the manufacturing failure etc.).

5. THE STRUCTURE OF MAFLOS

5.1 The discription of the model of the manufacturing system

The simulation model is generated by feeding the information shown in Fig. 5, to MAFLOS. Shown in Table 3 and Table 4 are the partial input data for the model shown in Figure 1.

5.2 Output (simulation reports)

MAFLOS prepares the following output items for simulation reports.
(1) The interim simulation reports at arbitrary time.
  (a) The state of materials.
  (b) The utilization rate of storages.
An example is shown in Table 5.
(2) The final simulation reports.
  (a) The lead time of each product.
  (b) The rate of operation of the unit-equipment (the handling machines, the production machines, the conveyors).
  (c) The work schedules of the unit-equipment (if necessary).
An example is shown in Table 6.

The output items can be easily extended.

5.3 The program structure of MAFLOS

The whole structure of program is shown in Figure 6. The simulating program for the operation of H/M, P/M and C/V is controlled by the time advance routine and renews the state of the unit-equipment and the state of the materials. If it is necessary to run the scheduling programs, the supervisory routine initiates the scheduling programs. The scheduling programs regenerate the work schedule in accordance with the new situation.

6. CONCLUSIONS

The fundamental factors which characterize the manufacturing systems are the following four items:
(a) equipment layout.

3. DESCRIPTION OF MANUFACTURING SYSTEM IN MAFLOS

In MAFLOS, we classified the factors which characterize the manufacturing systems' behaviour into the following four categories.
(a) equipment layout
(b) control system
(c) materials
(d) operations
We will describe each category in the following sections.

3.1 Equipment layout

The equipment layout is defined by the following two items.
(a) The functions of each unit-equipment.
(b) The connections between unit-equipment.

3.1.1 Classification of unit-equipment

Unit-equipment is classified into the following seven classes according to their functions.
(a) Production machine (P/M): the material are manufactured by the production machines, taking the machine tools as an example.
(b) Handling machine (H/M): a handling machine transfers the materials from one place to another. The crane which moves along the path is an example. Workers carrying the material are also regarded as the handling machines.
(c) Connector (C/N): a connector is a simplified handling machine.
(d) Rail (R/L): a rail is a path along which the handling machine is guided.
(e) Conveyor (C/V): a conveyor is a carrying machine as the belt conveyor or the overhead conveyor.
(f) Conveyor Guide (C/G): a conveyor guide is a path along which the conveyor is guided.
(g) Storage (S/G): a storage is a unit-equipment which stocks the materials.

3.1.2 Expression for the unit-equipment and their connection

In the simulator-MAFLOS, the unit-equipment represents as shown in Table 1. The main parameters which specify the ability of the unit-equipment are also shown in Table 1.

The connection between unit-equipment A and B is defined by the pair (A, B). If A and/or B have some substate, the pair must include the index of substate as position or coordinate.

The manufacturing system which is shown in Figure 1 is expressed as shown in Figure 2 by using Table 1.

3.2 Control system

MAFLOS has the functions to simulate the control system with respect to
(a) Material flow detection
(b) Scheduling

3.2.1 Material flow detecting function for synchronizing the material flow and the control system.

Material flow detecting function is important for obtaining the information of material flows. When the material passes through the predetermined point in the layout of the manufacturing system, the information about the material flow is transmitted to the control system. The material flow detecting function in MAFLOS are classified into the following two items.
(a) Material flow detecting function for incoming materials.
(b) Material flow detecting function for material being removed.

3.2.2 Scheduling function

The production machines work on the materials according to the work schedule. The work schedule is regenerated according to the scheduling algorithm suited for the controlled manufacturing process. Scheduling programs can be incorporated into MAFLOS and the timing the scheduling in MAFLOS can be selected in the following three manners:
(a) When the material flow is detected by the material flow detecting function.
(b) When workers cannot maintain the work schedule previously given.
(c) When a given period of time passes.

3.3 Material

MAFLOS can accept the following information about the materials in relation to the production machine and the handling machine.
(1) As for the production machine.
  (a) Information of the product structures as shown in Figure 3.
  (b) Information of the manufacturing sequence for each product.
  (c) Information of production planning.
(2) As for the handling machine.
  (a) Information of the carrying unit, for example container or pallet, for each operation of the handling machine. However, the quantity to be carrying can be changed by scheduling within the carrying unit.

3.4 Operation

In MAFLOS, the operation of each unit-equipment is evaluated by the time elasping in the operation, therefore the function to calculate the operation time is required. The confirming function (the starting conditions are complete or not) is also required in order to evaluate the scheduling results.

3.4.1 Calculation of the operation time

The amount of time for each operation of a unit-equipment is calculated from the

(b) control system.
(c) material.
(d) operation.

The authors analyzed these fundamental factors in detail, and consequently proposed a new type simulator MAFLOS.

MAFLOS is characterized by the following features:

(a) MAFLOS has seven kinds of unit-elements to describe the equipment layout of the manufacturing system. The simulation model is therefore generated by combining these unit-elements.
(b) MAFLOS can simultaneously simulate the material flow and the control system behaviour.
(c) MAFLOS has "material flow detecting function" in order to synchronize the simulation of the material flow and the simulation of the control system behaviour.
(d) MAFLOS has "confirming function" in order to evaluate the scheduling results.

MAFLOS is suited for the design of the layout and/or the control system. This simulator is especially suited for the design of total manufacturing system including the control system and the layout.

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BIOGRAPHIES

Kazuyuki Mitome is a Researcher in the Central Research Laboratory of Hitachi, Ltd. He has been engaged in research for production control. He received the B.S. degree in Mechanical Engineering from the University of Kanagawa in 1965. He is a member of the Japan Society of Mechanical Engineers, the Institute of Electrical Engineers of Japan and the Society of Instrument and Control Engineers.

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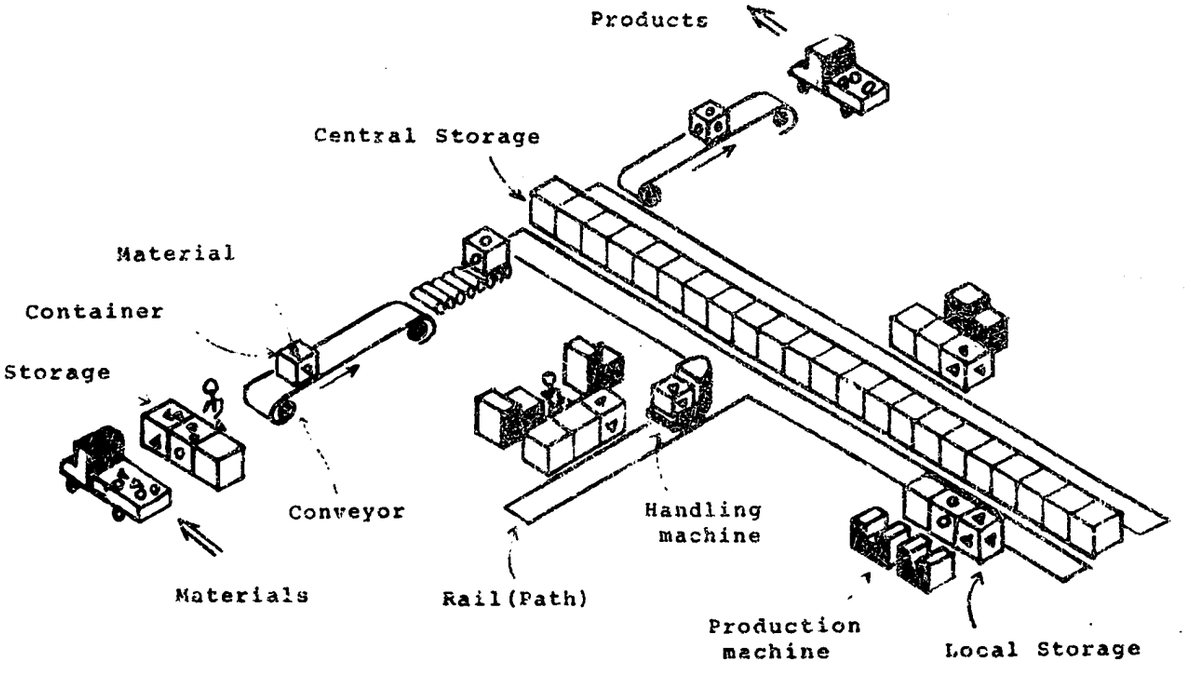


Fig. 1 Manufacturing system

Table 1 Symbols for unit-equipment

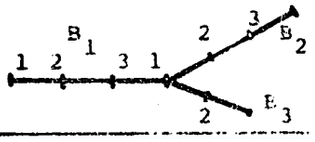
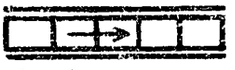
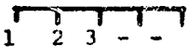
Unit-equipment	Symbol	Main parameter
Production machine		Manufacturing speed
Handling machine		Transfer speed Pick up and take down time
Connector		Rail NO.
Rail		Coordinate(Branch NO.,X,Z)
Conveyor		Conveyor speed Conveyor length Conveyor guide NO.
Conveyor guide		Coordinate (X)
Storage		Capacity (X,Y,Z)

Table 2 Items deciding the state of each unit-equipment

ITEM \ UNIT-EQUIPMENT	PRODUCTION MACHINE	HANDLING MACHINE	CONNECTOR	RAIL	CONVEYOR	CONVEYOR GUIDE	STORAGE
STATE OF MANUFACTURING	O	O	O	*	O	*	*
PROGRESS ON WORK SCHEDULE	O	O	*	*	*	*	*
MATERIAL NAME ON UNIT-EQUIPMENT	O	O	O	*	O	*	O
POSITION OF UNIT-EQUIPMENT	*	O	*	O	O	O	*

EXPLANATION: A SIGN "O" DENOTES THAT THE ITEM IS NECESSARY FOR DEFINEING THE STATE OF THE UNIT-EQUIPMENT

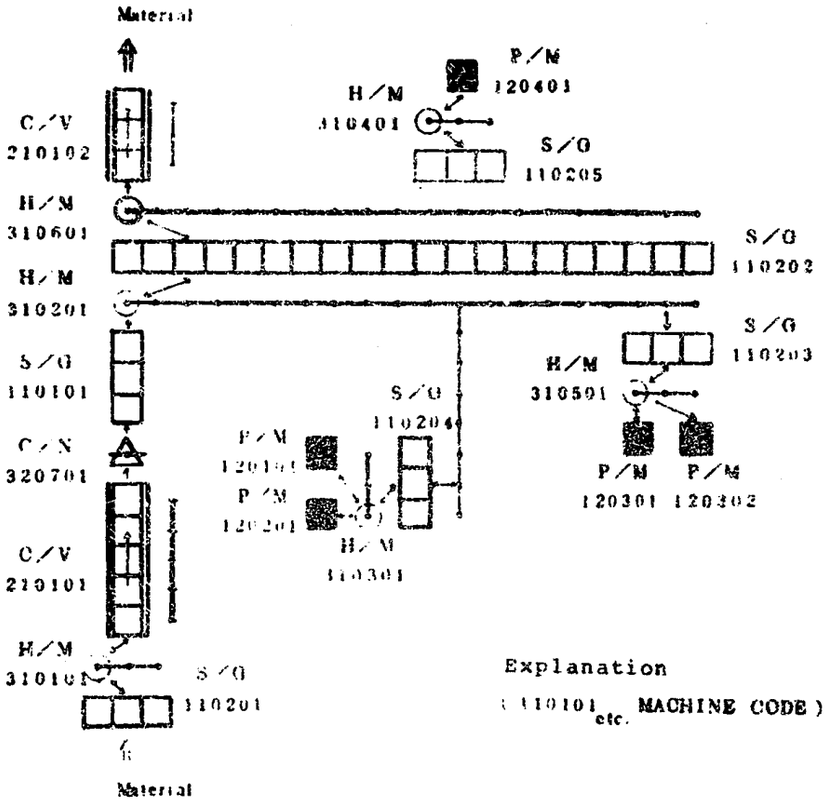


Fig. 2 Manufacturing system described by MAFLOS' symbols

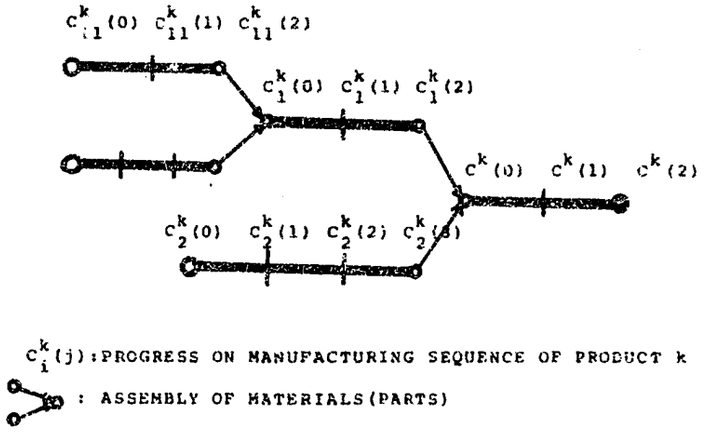


Fig. 3 Product structure

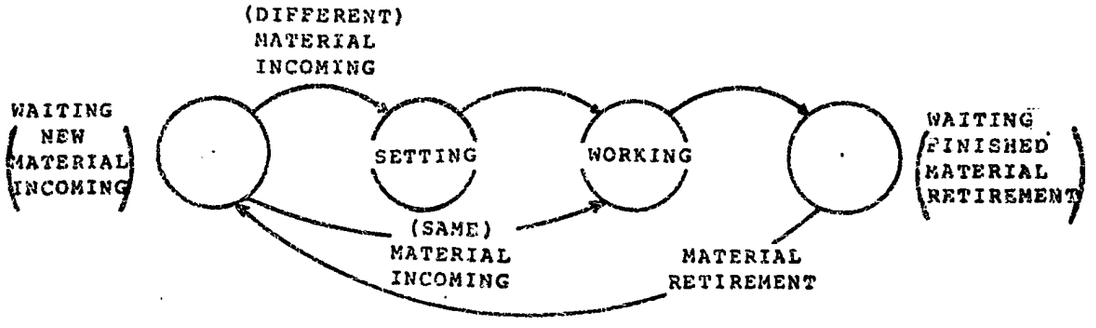


Fig. 4 Transition diagram in the state of the operation for the production machine

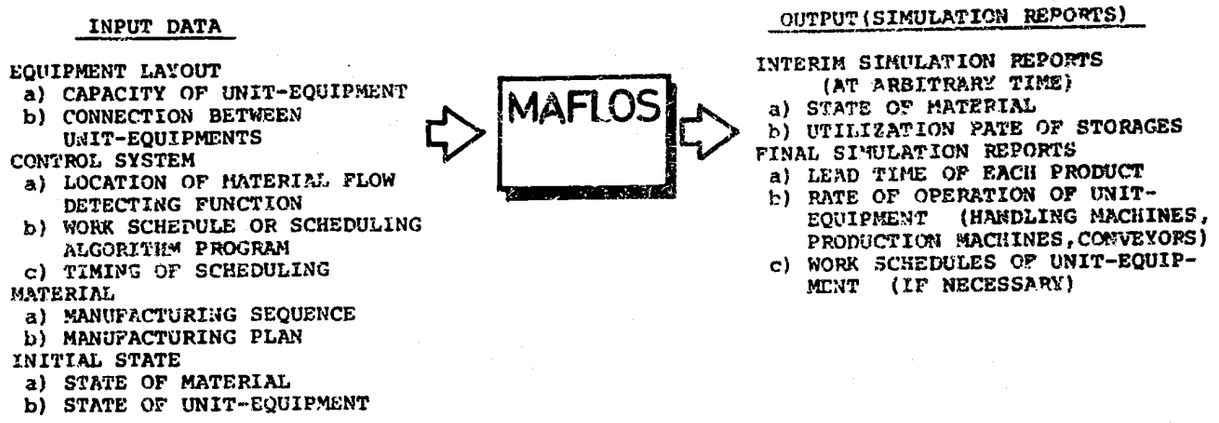


Fig. 5 Input data and simulation reports

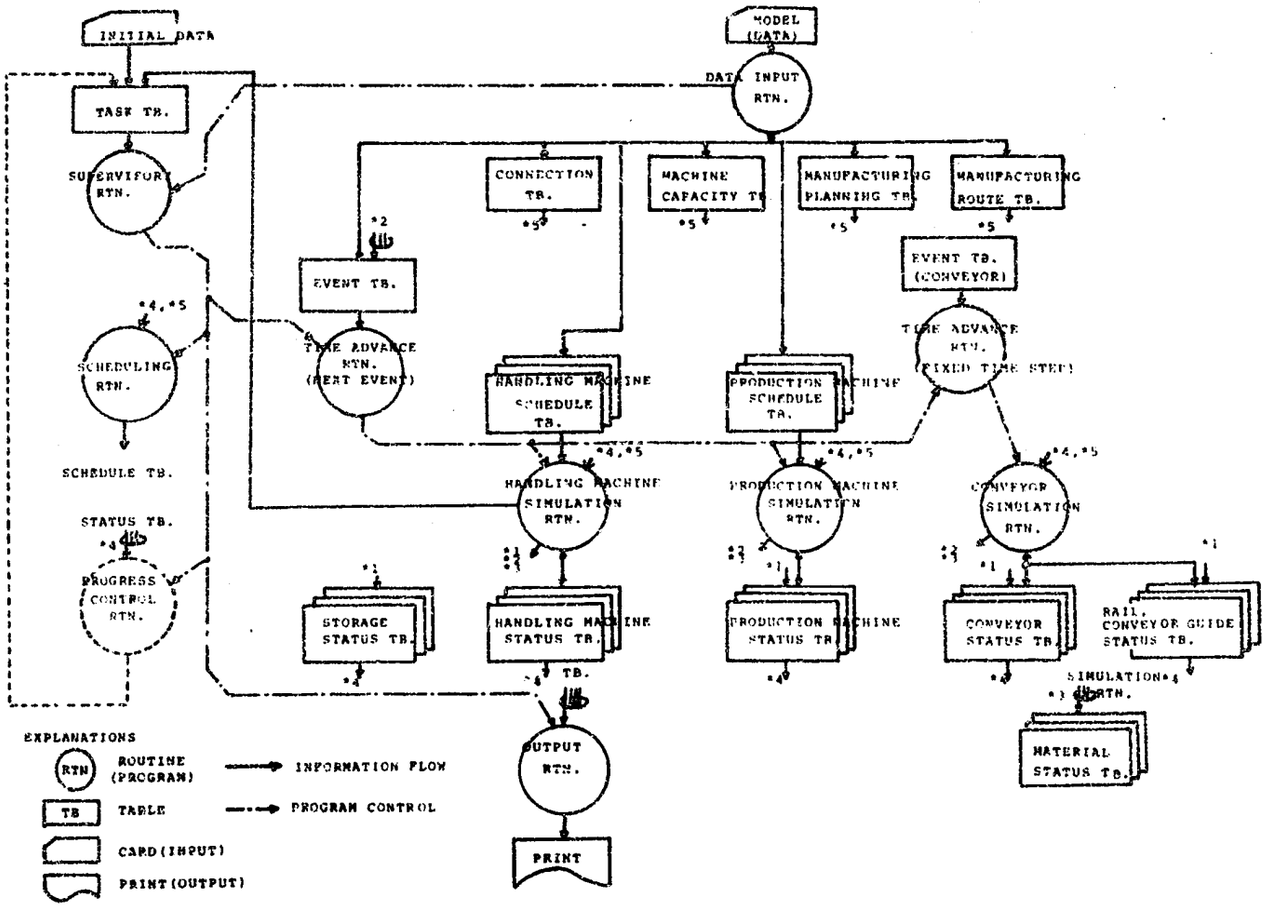


Fig. 6 Program structure of MAFLOS

Table 3 Input data format for unit-equipment

(partial input data for the model shown in Fig. 1)

```
                                                                    PAGE    6
$ ATTRIBUTE OF PROCESS ELEMENT                                      0
* STORAGE                                                           6
110101    3    1    1
110201    1    3    1
110202    1   20    1
110203    1    3    1
110204    1    3    1
110205    1    3    1
* PRODUCTION MACHINE                                                4
1    3    1
1    5
2    5
3    5
120101    0    1    1    4    0    0    0    1    1    2    0    0   10    0
0    0    0    0    0    0    0    0    0    0
2    3    1
1    5
2    5
3    5
120201
```

Storage NO.

Storage capacity (X,Y,Z)

Work center NO.

Production machine NO.

Production machine ability

Table 4 Input data format for connective relation

(partial input data for the model shown in Fig. 1)

```
                                                                    PAGE    9
$ CONNECTIVE RELATION BETWEEN PROCESS ELEMENT                       0
1    1
1    2    1    2    0    0    2
110201    0    1    1    1    1    1    2    1    1    3    1
210101    1  100    1    0    0    1    0    0    0    0    0
2    3
1   11    1    2    0    0    2
110202    0    1    1    1    1    1    2    1    1   12    1
110101    2    1    1    3    1    1    0    0    0    1    1    1
120301    0    1    1    0    0    0    0    0    0    0    0
120302    0    2    1    0    0    0    0    0    0    0    0
3    1
```

Rail NO.

Connective relation ([Rail NO. 1]&[Unit-equipment NO.110201])

Unit-equipment NO.

Table 5 Interim simulation report for the model shown in Fig. 1

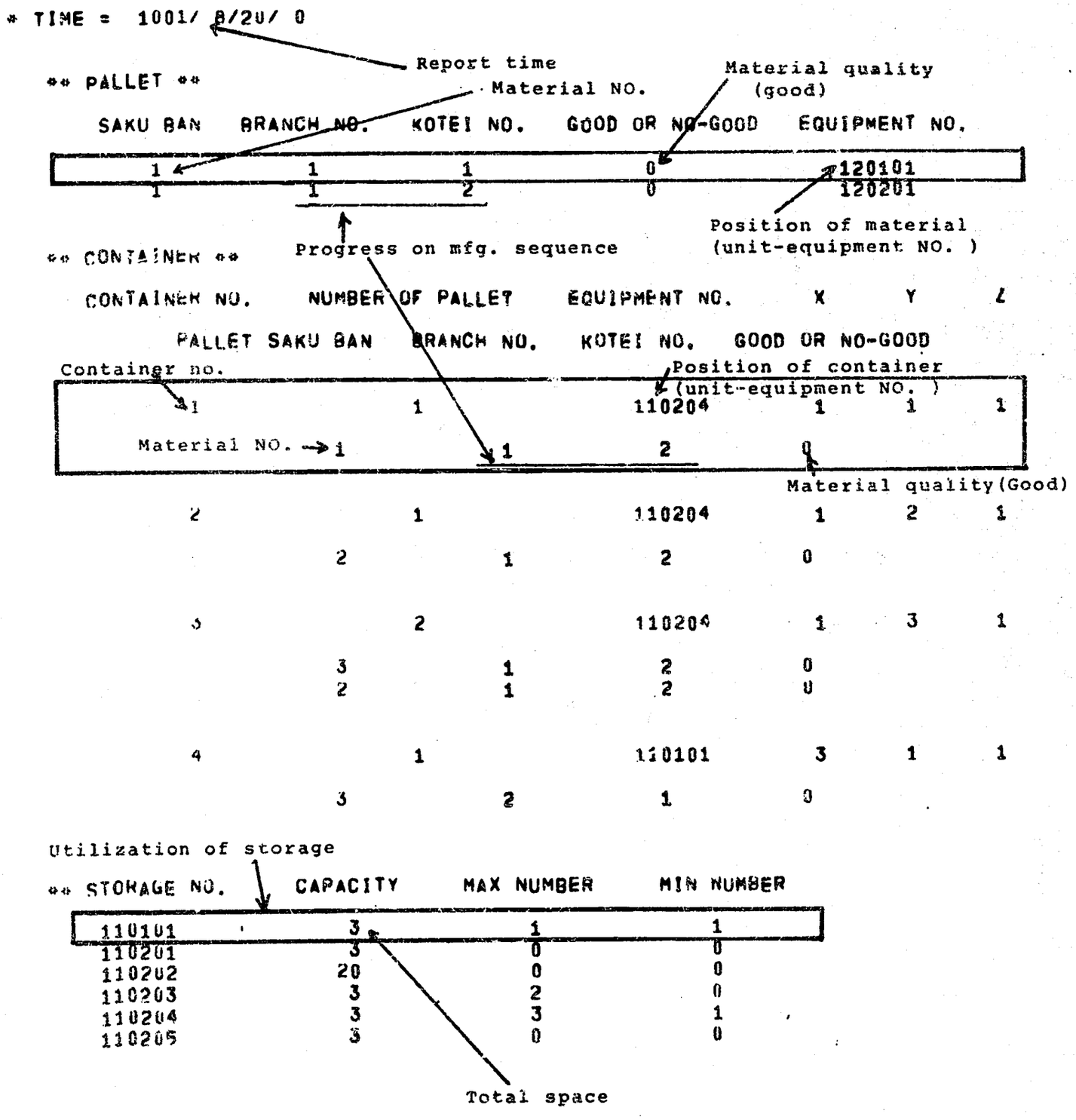


Table 6 Final simulation report for model shown in Fig. 1

** O U T P U T R E P O R T **

* MODEL NAME * K,A,MODEL *

* SUMULATION INTERVAL 1001/ 8/ 0/ 0 ------ 1001,10/30/ 0

* STATISTICAL TABLE 1 * NOUKI YOYUU *

Manufacturing finished time

JOB NO.	SEISAKU SU	KANSEI SU	NOUKI	KANSEI	NOUKI YOYUU	NOUKI
1	3	3	1001	1001	0	
2	2	2	1002	1001	1	
3	1	1	1003	1001	2	

* STATISTICAL TABLE 2 * KADOU RITSU (P/M) *

P/M NO.	SHUGYOU JIKAN WA (MINUTE)	KADOU JIKAN WA (MINUTE)	KADOU RITSU
120101	240	40	0.167
120201	240	40	0.167
120301	240	15	0.062
120302	240	25	0.104
120401	240	10	0.042

Rate of operation (Production machine)

Production machine NO.

Operation time

* STATISTICAL TABLE 3 * KADOU RITSU (H/M) *

H/M NO.	SHUGYOU JIKAN WA (MINUTE)	KADOU JIKAN WA (MINUTE)	KADOU RITSU
310101	240	1	0.004
310201	240	29	0.121
310301	240	11	0.046
310401	240	1	0.004
310501	240	5	0.021
310601	240	6	0.025

Rate of operation (Handling machine)

Handling machine NO.

* STATISTICAL TABLE 4 * KADOU RITSU (C/V) *

C/V NO.	UNPAN NOUHYOKU	UNPAN KOSU	KADOU RITSU
210101	300	4	0.013
210102	299	4	0.013

Rate of operation (Conveyor)

Conveyor NO.