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MASTER

EQUIPMENT FORECASTING SIMULATION MODELS

FACILITIES

Facilities Planning

Ralph W. Hawes

THE DOW CHEMICAL COMPANY
ROCKY FLATS DIVISION
P. O. BOX 888
GOLDEN, COLORADO 80401

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Abstract. A general description is given of a computerized modeling technique used to determine future equipment requirements. The technique has application also in manpower forecasting and in determining purchase requirements.

Included is a simulation of a hypothetical product with related flow charts and illustrations of a computer modeling program.

INTRODUCTION

Simulating equipment requirements provide a technique for accurately predicting the ability of a production plant to meet future schedules.

The described technique consists of several computer programs which are merged to provide the desired output. Three output reports are obtained for each type of equipment: (1) *The Available Hours* Report, (2) *The Required Hours* Report, and (3) *The Capital Equipment Forecast* or Variance Report which identifies the quantity of machines needed and is developed from Reports 1 and 2.

Subservient reports generated during the running of the programs are used for reconciling input and output. Input involves a detailed study of each part to be produced to identify the necessary equipment and the hours required by this equipment.

Each product is represented by a simulation model which includes the fabrication, assembly, and inspection of all component parts and subassemblies. The models are written from detailed flow charts of each product, and coded in the language of the General Purpose Simulation System (GPSS). After each model program has been test-run and debugged, a production run which will contain models of all products can be made.

The individual product models are summarized, using utility programs written in FORTRAN. The *Available Hours Report, Required Hours Report,* and *Capital Equipment Forecast Report (variance)* are obtained by a combination of GPSS and FORTRAN programs.

DESCRIPTION

Input:

Accurately detailed input has considerable value and can be achieved by use of the described technique. As in all computer programs, the output is only as significant as the input. Therefore, data are obtained from the best available source.

1. Production Control:

   a. Production Control provides a list of current and former production items by part number and assembly configuration, commonly called the *Bill of Materials.*

   b. Scrap factors are used by Production Control to facilitate scheduling, and also in the simulation models.

   c. Lead times are supplied in weekly units for each part.

   d. Safety stock is added by Production Control to provide several extra production items to allow for loss by the customer where replacement would be necessary. These remain as shelf items.

   e. Future items which have not been assigned part numbers are given *look-alike* numbers. This is necessary in order to study future production items by comparing them with parts previously produced.

   f. Production Control supplies the production schedules for current and anticipated future production.

2. Industrial Engineering:

   a. MACHINE STANDARDS–Industrial Engineering provides the *Machine Standard Hours* required to make each part on a specific type of equipment. In many cases, the standard is equivalent to the direct-labor standard times, determined by time studies or other techniques.

   b. PERCENT PERFORMANCE–The worker will directly affect the time required on a piece of equipment; therefore, an efficiency factor must be applied to the machine standard. Exceptions include types of equipment that can operate unattended, except for loading and unloading. The *Percent Performance* for each work center is calculated by the Industrial Engineering group comparing *Actual* versus *Standard* hours.

c. AVAILABLE HOURS—The Industrial Engineering group determines the hours per shift that a worker is available for production work. The *Job Content Breakdown Report* provides these data. Machines or equipment not dependent on an operator will have availability calculated independently by a machine group.

d. FUTURE PRODUCTION—Industrial Engineering will estimate machine standards for future items using whichever technique would be applicable.

3. Product Engineering:

a. DEFINE—Product Engineering will define and describe items which may be in future production.

b. BEST ESTIMATE—Product Engineering will provide a best estimate of the time necessary to make any item which varies considerably in configuration or complexity that the standard times on existing look-alike parts cannot be used.

4. Facilities Engineering:

Facilities Engineering will provide the quantity and location of each type of equipment to be available at some predetermined time in the future.

Information will be changed as needed capability and technologies require revisions.

5. Shop Personnel:

a. Time required on special order work not appearing on a schedule is provided by shop personnel. Such work classified as *Cash Sales* has been relatively constant year to year.

b. Future production items are discussed with shop personnel to obtain the *best estimate* as to required machine times. Personnel also identify the process and equipment types which may be used on future items.

c. Shop personnel also provide Industrial Engineering the information needed in studies of *Machine Standard Hours.*

6. Research and Development:

Research and Development personnel assist to resolve questions on how an item may be built, to identify or supply data on machines to be used and to establish or define processes for use on future items.

7. Data Processing:

Data Processing provides the mechanics and support to program and run the models.

BUILDING THE MODEL

The products to serve as forecasting models must be determined. To show how a model may be constructed, a hypothetical product is selected. For example, a roller skate used as the model was analyzed, coded, and run with a flow chart prepared to designate each step. The procedures and data obtained for the roller-skate model illustrate the identical approach to be used if a production product were selected.

Constructing a model of each product has advantages. However some products, which may be *one-of-a-kind* or a special prototype, are not easily defined for purposes of building an appropriate model. To overcome such an obstacle, a procedure has been worked out to compensate for time spent on nonmodel products and is noted in Table I, *Available Hours Program. (See Hours for Special Orders.)*

Data required for production models can be compiled from various sources. Using the Roller Skate (No. 9000) as the product, a Flow Chart (Figure 1)[1] was prepared showing *Section A—Flow of Parts and Subassemblies* and *Section B—Flow of Operations. Section A* serves to prepare *Section B* from which *Coding* can then be done directly. Data were compiled also from the following sources:

Bill of Materials, Figure 2

Operation Process Sheet, Figure 3

Sketch of Parts, Figure 4

Machine Group Code Numbers, Figure 5

Flow Chart Construction:

To construct the Flow Chart, the following steps are proposed:

[1] Illustrations are grouped at end of text.

1. Determine the product configuration from the Bill of Materials (Figure 2) and the Sketch of Parts (Figure 4).
2. Construct the Flow of Parts and Subassemblies (Figure 1, Section A).
3. Construct Flow of Operations (Figure 1, Section B) by use of Operation Process Sheets (Figure 3).
4. Fill in all data required as per nomenclature given in Figure 1.

TABLE I. Available Hours Program.

Calculations for Required Machine Hours

Required Quantity = (Quantity of Parts X Scrap Factor) + Safety Stock

Required Hours per Machine Group (A) = (Required Quantity X Machine Standards) + Percent Performance

Calculations for Available Hours and Variance

Hours per Machine (C)

$$\text{Available Hours per Machine Group (B)} = \begin{pmatrix}\text{Available Hours per Shift} \times \text{Shifts per Day} \times \text{Days per Period}\end{pmatrix} \times \begin{pmatrix}\text{Quantity of Machine}\end{pmatrix} - \begin{pmatrix}\text{Hours for Special Orders}\end{pmatrix}$$

$$\text{Required Machines} = \frac{\text{Required Hours (A)} - \text{Available Hours (B)}}{\text{Hours per Machine (C)}}$$

Variance = Required Machines ± Available Machines

Lead Time:

General Purpose Simulation System (GPSS) is a time per event computer language. Lead times are programed into the models and will be evidenced by differences in part quantities within given time periods.

The quantities of finished assemblies in a specific time period (quarter) will usually be different from the hardware part finished within that same period because of lead times. Scrap factors and safety stock also influence this quantity.

Notice that the flow charts are constructed with the product to be shipped at the apex and all subassemblies and parts are extended from the final product. The flow procedure continues from the top to bottom, exactly opposite from the way in which a product is actually built. The reason for developing the flow chart (Figure 1) in reverse was to show that the final product is the controlling item on the schedule. The model is also coded and run in the same reverse method.

Machine Group Code Numbers can be applicable to several work centers. Therefore, both Machine Group Code Numbers and Account (work center) Numbers are necessary to identify a particular equipment capability. Usually equipment although identical is not interchangeable between work centers. A representative list of code numbers is presented in Figure 5, Page 12.

CODING AND RUNNING THE MODELS

The models are coded in GPSS language which provides a relatively simple tool for simulating the data identified by the flow charts. Although GPSS can provide statistical output on queuing facilities and storage usages, the data needed are tabulated in matrices.

The actual coding of the model is not explained in detail as a programer experienced in GPSS should have little difficulty following the logic. Figures 6 through 9 are excerpts from the GPSS run of the hypothetical product. Figure 10 is part of the actual matrix output.

The computer core must be reallocated to provide core for the blocks which are used in this simulation. A typical reallocation:

```
REALLOCATE VAR, 40, FSV, 80, HSV, 0,
           CHA, 0, GRP, 0, BVR, 0, FMS, 30

REALLOCATE HMS, 0, XAC, 100, BLO, 3000,
           FAC, 0, STO, 0, QUE, 0, LOG, 0

REALLOCATE TAB, 0, FUN, 6,
           MAC, 6, COM, 80000
```

The reallocate cards follow the *JCL* cards and must preceed the *SIMULATE* card noted in Figure 6.

The *FIRST FUNCTION* is the schedule of products to be shipped during each quarter. This sample schedule specifies a quantity of 10 products per quarter, each quarter until the internal clock reaches 79. At time 79, the quantity changes to 15. At clock time 82, the quantity changes to 20, etc. The function quantity could change each quarter if necessary.

The *DATE FUNCTION* identifies the column in the matrix output into which the statistics are to be placed (see Figure 10). This function also uses the clock as a timer. At clock times 5 and 10, the output is to be placed in Column 30. At clock time 14, the output is to be placed in Column 28, etc. Columns 1 through 28 accumulate the actual data for the 28 quarters studied.

Macro-notation is used consistently throughout the model. This reduces the coding significantly as only one, or possibly two, cards are necessary for each block on the flow chart. One card is needed for the Part Number statistics, another for the Machine Hours and Group.

ONE MACRO is used for the determination of part quantity by applying scrap factors and spares to the quantity specified either in the *First Function* table or in Parameter 5.

TWO MACRO calculates the Hours Required, by Machine Group, using the quantity calculated in the *ONE MACRO*.

FOUR MACRO is used to write the matrix output onto magnetic tape or disk for input into the *match and sum* programs.

Table I shows the calculations used in the models and in the *Available Hours* program.

Summary of Individual Models:

Upon completion of a model for each individual product, the model must be summarized to determine the entire plant requirements. Figure 11 is a flow chart showing the sequence of computer operations. The *Initial Match and Sum* is a program which will set up matrices for each work center and machine group to be summarized. The format is exactly the same as shown in Figure 10. At this point, the contents of all the matrices will be zero. A FORTRAN program will read data from both the *Initial Match and Sum* and the first model and place the contents of each matrix of the model into the appropriate matrix produced by the *Initial Match and Sum* program. The process is repeated for each model, each time accumulating the data to obtain a total summation.

After all the models have been run, an *Available Hours* matrix is introduced (see Figure 11). This model contains data which represent the actual hours each machine group has available. The data are provided by using the quantity of machines per work center, hours per shift the machines are available, the shifts per week, and weeks per period.

A FORTRAN program is utilized to make the required comparison of required machine hours and actual machine hours and thus produce the variance hours report.

By using a FORTRAN program for the final output, the format can be arranged to suit the users' specific needs. Currently in use are three different outputs, one for *Facilities Planning*, one for *Manufacturing*, and the third for *Production Control*.

Validation of the output is possible by using the matrix printouts of each individual model. Should there be any errors, the entire set of models do not have to be rerun if tapes are retained until validation has been determined. Thus duplication of effort can be eliminated and a savings in computer time realized.

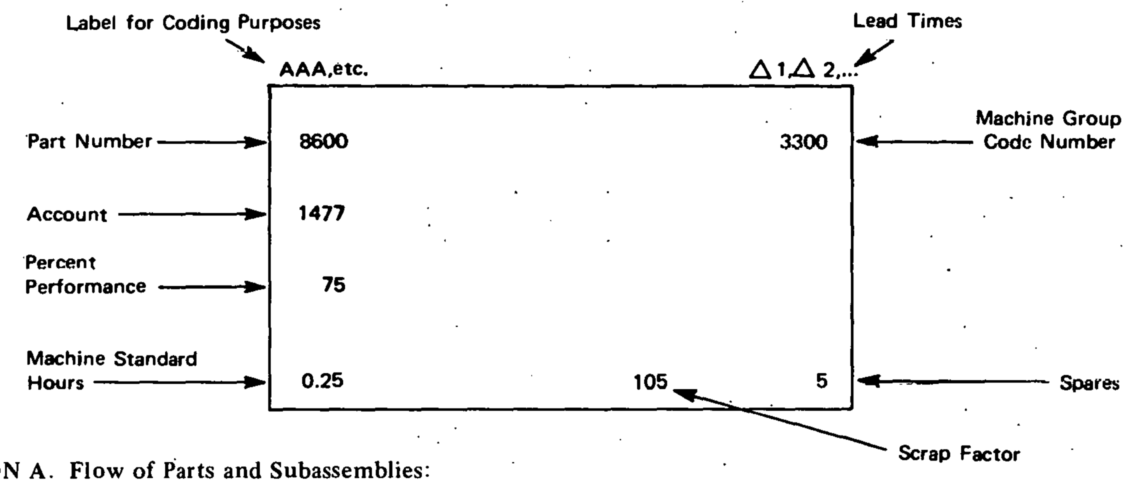
CONCLUSIONS

The use of computer simulation to provide a management tool is becoming increasingly important.

The equipment forecasting technique offers advantages because of ease in manipulation and in validation of data. Both manpower and computer time savings are achieved. The technique is relatively straight forward and comprehensible which allows for minimum error in interpretation and coding.

ILLUSTRATIONS

NOMENCLATURE:



SECTION A. Flow of Parts and Subassemblies:

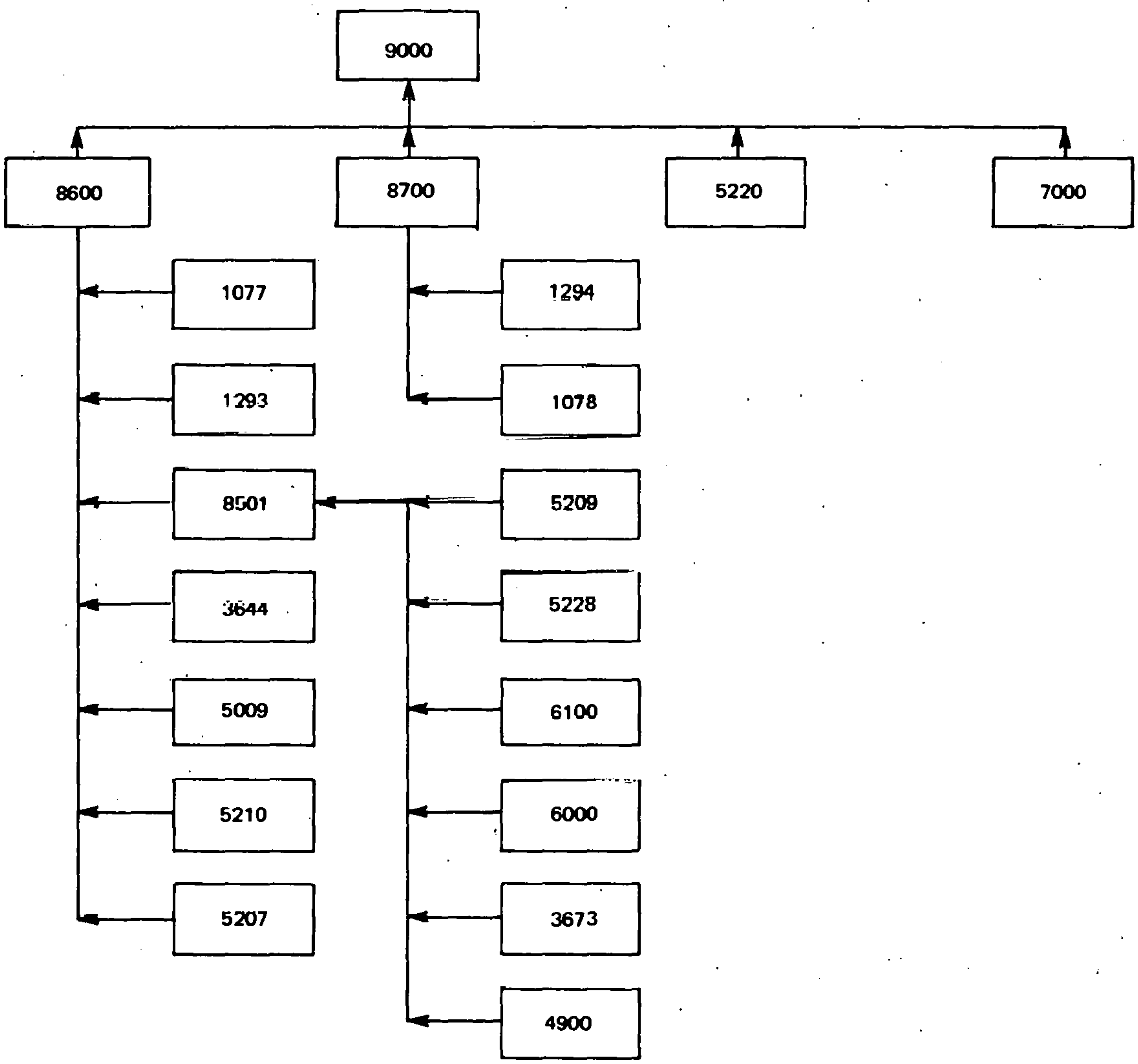
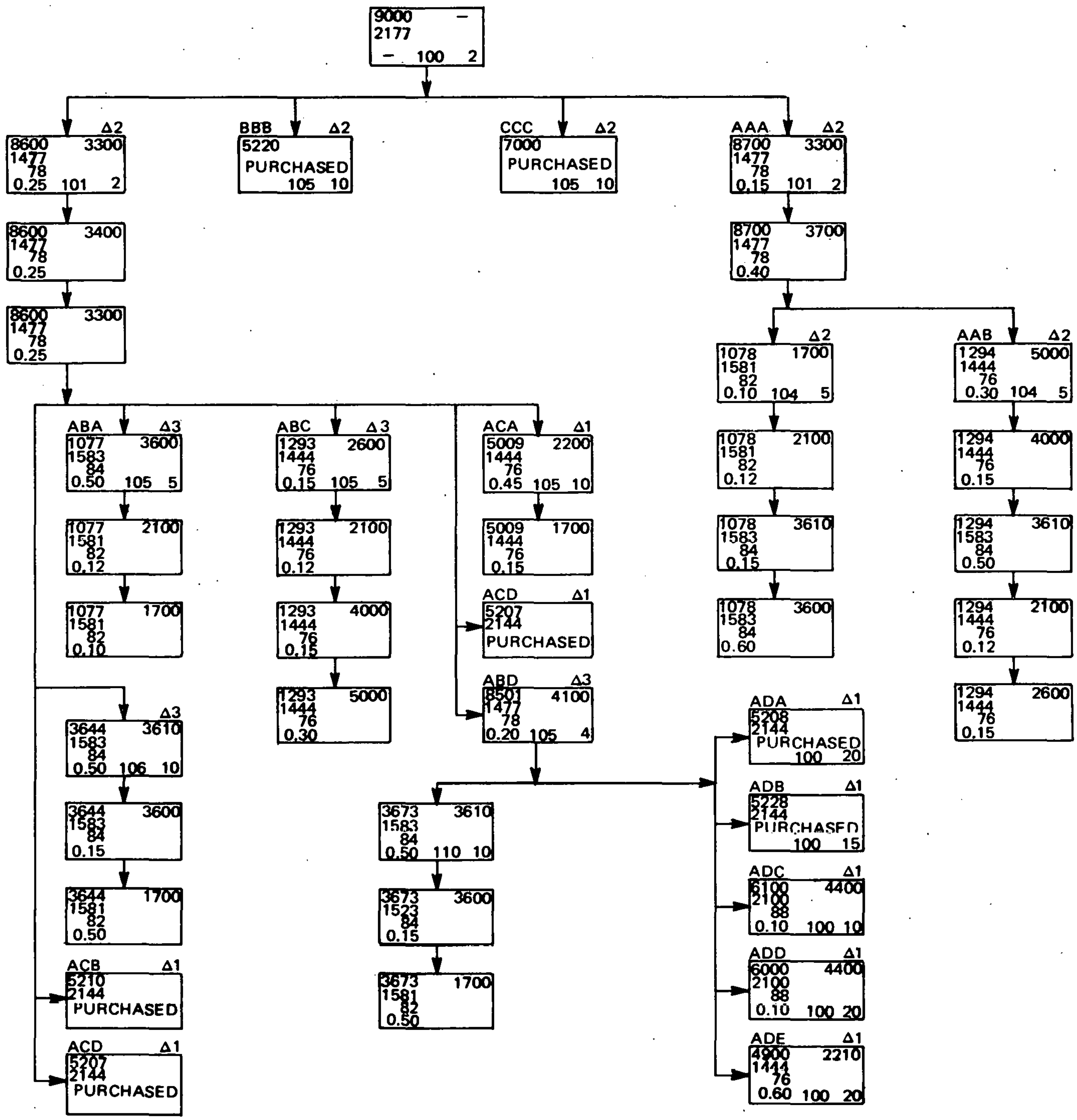


FIGURE 1. Flow Chart for Model. →

SECTION B. Flow of Operations:



(continued)

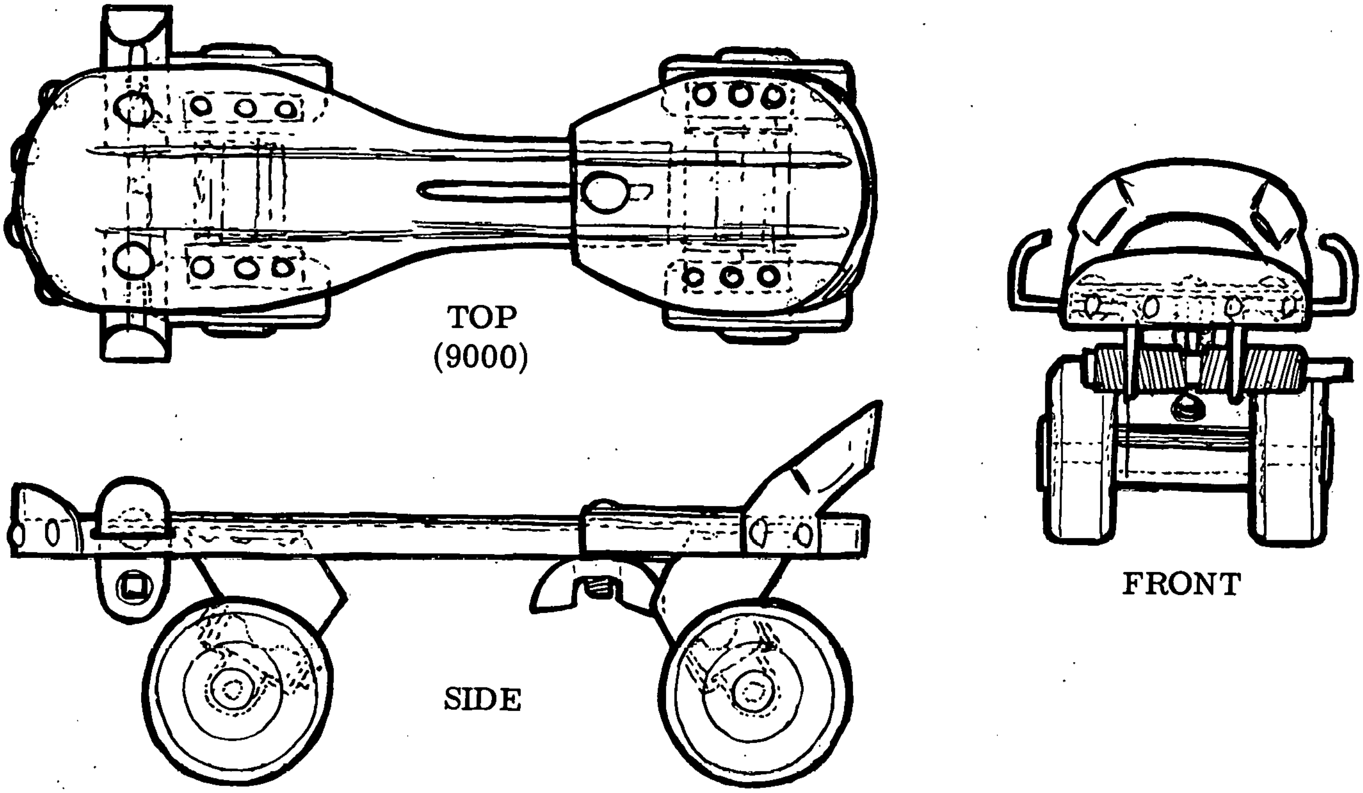
FIGURE 2. Bill of Materials.

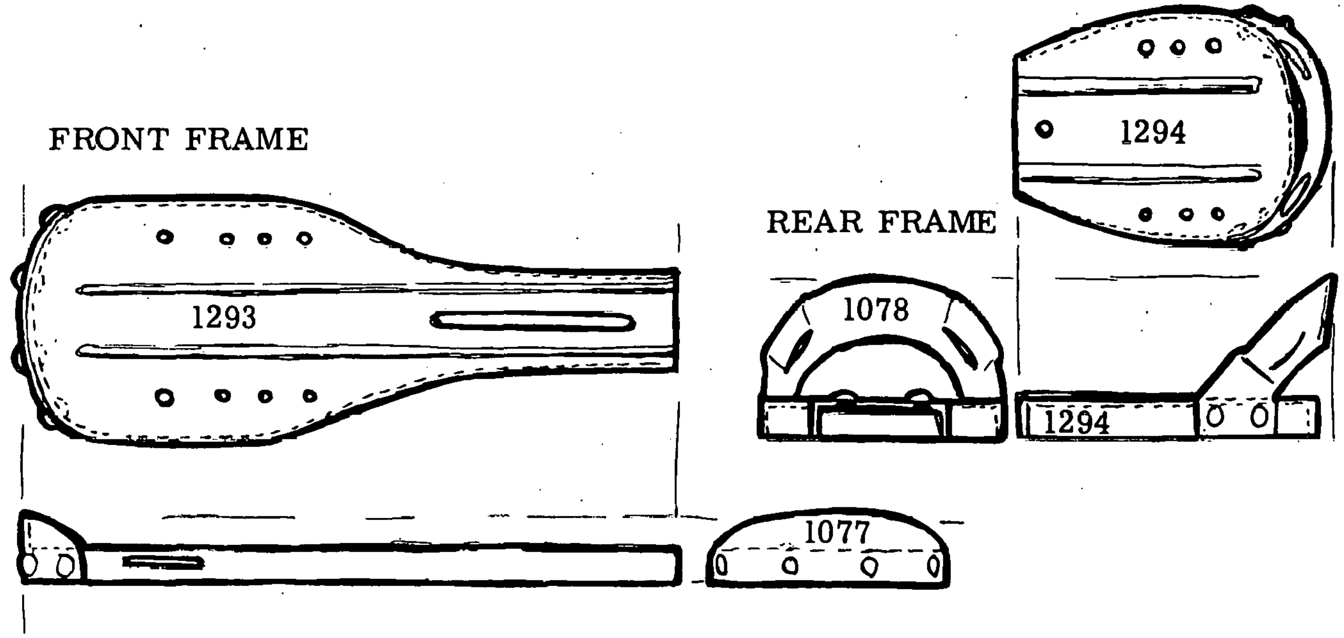
NAME OF PRODUCT: SKATE – ROLLER – STREET, NO. 9000.

Part No.	Quantity	Description
1077	1	Toe Plate
1078	1	Heel Plate
1293	1	Front Frame
1294	1	Rear Frame
5009	1	Adjusting Screw
3644	2	Toe Clamp
3673	2	Axle Frame
4900	2	Axle
6000	4	Wheels
6100	4	Bearing
5207	6	Rivet
5210	2	Shouldered Rivets
5220	1	Adjusting Bolt
7000	1	Strap with Buckle
5228	4	Axle Retainers
5209	4	Washers
8501	1	Wheel Subassembly 5209, 5228, 6100, 6000, 3673, and 4900
8600	1	Front Subassembly 1077, 1293, 8501, 3644, 5009, 5210, and 5207
8700	1	Rear Subassembly 1294 and 1078
9000	1	Final Assembly 8600, 8700, 5220, and 7000

FIGURE 3. Operation Process Sheet.

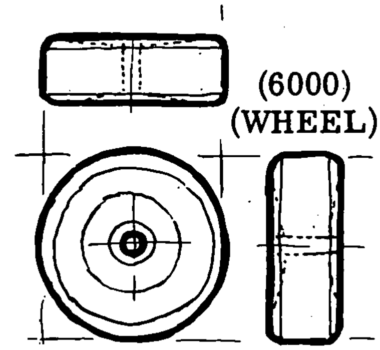
Part No.	Step	Work Center Account	Procedure	Machine Group	Standard Time
1077	1	1583	Cut and Form	3600	0.50
	2	1581	Drill 6 Places	2100	0.12
	3	1581	Dress Edges	1700	0.10
1078	1	1583	Cut and Form	3600	0.60
	2	1583	Punch Holes for Straps	3610	0.15
	3	1581	Drill 4 Places	2100	0.12
	4	1581	Dress Edges	1700	0.10
1293	1	1444	Cut Off Tube	2600	0.15
	2	1444	Drill	2100	0.12
	3	1444	Clean	4000	0.15
	4	1444	Paint	5000	0.30
1294	1	1444	Cut Off Tube	2600	0.15
	2	1444	Drill	2100	0.12
	3	1583	Punch Slot	3610	0.50
	4	1444	Clean	4000	0.15
	5	1444	Paint	5000	0.30
5009	1	1444	Turn Screw	2200	0.45
	2	1444	Dress	1700	0.15
3644	1	1583	Punch	3610	0.50
	2	1583	Form	3600	0.15
	3	1581	Dress	1700	0.50
3673	1	1583	Punch	3610	0.35
	2	1583	Form	3600	0.15
	3	1581	Dress	1700	0.50
4900	1	1444	Form Grind Axle	2210	0.60
6000	1	2100	Inspect Wheels	4400	0.10
6100	1	2100	Inspect Bearings	4400	0.10
Subassemblies:					
8501	1	1477	Assemble Axle Frame, Axle	None	–
	2	1477	Press Bearing in Wheels	4100	0.20
	3	1477	Assemble Wheels on Axle	None	–
8600	1	1477	Rivet Frame to Toe Plate	3300	0.25
	2	1477	Install Shouldered Rivets	3400	0.25
	3	1477	Rivet Wheel Assembly to Plate	3300	0.25
	4	1477	Assemble Toe Clamps	None	–
8700	1	1477	Weld Frame to Plate	3700	0.40
	2	1477	Rivet Wheel Assembly to Plate	3300	0.15
9000	1	1477	Assemble Skate	None	–
	2	1477	Install Strap	None	–
	3	2177	Inspect	None	–
	4	2177	Package	None	–



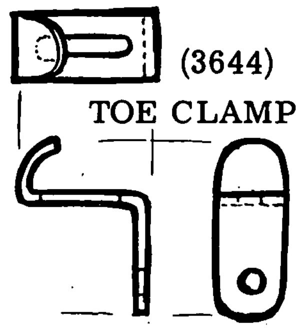


FIGURES 4(a) and (b). Sketch of Parts, Roller Skate Model No. 9000: Frames (a) and Parts (b). ⟶

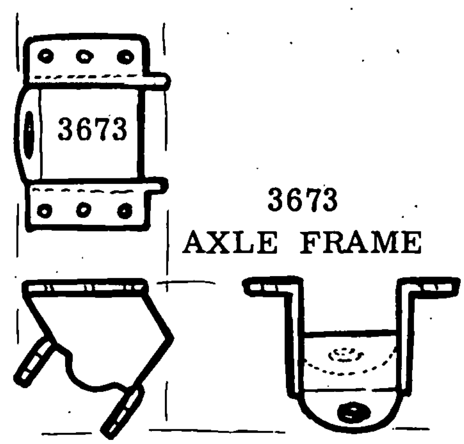
ADJUSTING SCREW
(5009)



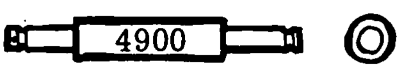
(6000)
(WHEEL)



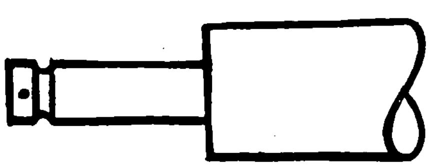
(3644)
TOE CLAMP



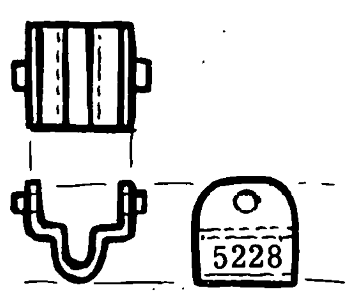
3673
AXLE FRAME



AXLE



AXLE DETAIL



AXLE HOUSING

(continued)

FIGURE 5. Machine Group Code Numbers.

1700	Buffer and Grinder	3600	Hydraulic Forming Press
2100	Drill Press	3610	Punch Press
2200	Threading Lathe	3700	Welder
2210	Contour Grinder	4000	Degreaser
2600	Cut-off Saw	4100	Arbor Press
3300	Riveting Machine	4400	Inspection Machine
3400	Hand Riveter	5000	Spray Booth

FIGURE 6. Sample General Purpose Simulation System Program.

```
*LOC    OPERATION  A,B,C,D,E,F,G            COMMENTS
        SIMULATE
* SAMPLE PROBLEM TO DEMONSTRATE THE CAP/CAB SYSTEM
*  CAP/CAB IS A SERIES OF EQUIPMENT FORCASTING MODELS
 FIRST FUNCTION     C1,D5        SCHEDULE OF PRODUCTS
1,10/79,15/82,20/86,15/89,10
 DATE  FUNCTION     C1,D32       SELECTS MATRIX COLUMN FOR OUTPUT
5,30/10,30/14,28/18,27/23,26/27,25/31,24/36,23/40,22/44,21/49,20/53,19
57,18/62,17/68,16/72,15/77,14/78,13/79,12/80,11/81,10/82,9/83,8/84,7
85,6/86,5/87,4/88,3/89,2/90,1/100,30/105,30
*
* COLUMN 30 IS A DUMMY COLUMN AND IS NOT NEEDED
*
 1      MATRIX      X,7,37       ACCOUNT 1444 LIGHT FABRICATION
 2      MATRIX      X,4,37       ACCOUNT 1477 ASSEMBLY
 3      MATRIX      X,2,37       ACCOUNT 1581 DRILL AND TRIM
 4      MATRIX      X,2,37       ACCOUNT 1583 HEAVY FORMING
 5      MATRIX      X,1,37       ACCOUNT 2100 INSPECTION
 6      MATRIX      X,20,37      PART REQUIRED
*
*        MATRIX OUTPUT SUPPLIES EXCELLENT DIAGOSTIC STATISTICS
*
*          TEST CLOCK TO DETERMINE IF SPARES SHOULD BE INCLUDED
*
*          CALCULATE THE QUANTITY OF PARTS REQUIRED
*
 ONE    STARTMICRO
        ASSIGN      33,#A        ACCOUNT NUMBER
        ASSIGN      34,#B        PART NUMBER
        ASSIGN      3,#C         SCRAP FACTOR
        ASSIGN      4,#D         SPARES
        TEST C      C1,90,#I     TEST AND LABEL FOR FALSE EXIT
        ASSIGN      6,0          SET PARAMETER TO ZERO
 #I     MSAVEVALUE  #G,#F,33,P33   PLACE ACCOUNT NUMBER IN COLUMN 33
        MSAVEVALUE  #G,#F,34,P34   PLACE PART NUMBER IN COLUMN 34
 PCS    VARIABLE    (P5*P3)/100+P4
        ADVANCE     #E           LEAD TIME DELAYS THE TRANSACTION
        MSAVEVALUE  #H,#F,FN$DATE,P5  PLACE QUANTITY IN SPECIFIC COLUMN
        MSAVEVALUE  #H,#F,31,P5       TOTAL QUANTITY IS PLACED IN 31
        ASSIGN      5,V$PCS
 ONE    ENDMACRO
*
*          CALCULATE MACHINE HOURS PER GROUP
*
 TWO    STARTMACRO
        ASSIGN      1,#A         PERCENT PERFORMANCE
        ASSIGN      2,#B         MACHINE STANDARD HOURS
        ASSIGN      33,#C        ACCOUNT NUMBER
        ASSIGN      34,#D        MACHINE GROUP
 EHR    FVARIABLE   ((P2*P5)/P1)*10   CALCULATION
        MSAVEVALUE  #G,#E,FN$DATE,V$EHR  PLACE HOURS IN SPECIFIC COLUMN
        MSAVEVALUE  #F,#E,33,P33         PLACE ACCOUNT NUMBER IN COLUMN 33
        MSAVEVALUE  #F,#E,34,P34         PLACE MACHINE GROUP IN
*                                        COLUMN 34
 TWO    ENDMACRO
```

```
BLOCK
NUMBER
        * MACRO TRANSFERS MATRIX STATISTICS TO DISK OR MAG TAPE
        *
         FOUR  STARTMACRO
               ASSIGN      35,#A        TOTAL ROWS IN MATRIX
               ASSIGN      36,39
               ASSIGN      38,#A
         #B    ASSIGN      39,37
         #C    ASSIGN      *39,#D       MATRIX NUMBER
               LOOP        39,#C        LABEL FOR LOOP
               WRITE       JOBTAl
               LOOP        38,#B        LABEL FOR LOOP
         FOUR  ENDMACRO
        *
        * THE MACRO CARDS ARE THE SAME FOR ALL MODELS
        *
1              GENERATE    1,,,,1,39,F
2              TEST LE     C1,100,FIN     TEST TO PREVENT RUNAWAY MODEL
3              ASSIGN      5,FN$FIRST     ENTER SCHEDULE DATA
        *
        * START OF ACTUAL MODEL CODING DATA
        *
         ONE   MACRO       2177,9000,100,2,0,1,6,6+,TEST1
4              ASSIGN      33,2177
5              ASSIGN      34,9000
6              ASSIGN      3,100
7              ASSIGN      4,2
8              TEST L      C1,90,TEST1
9              ASSIGN      4,0
10       TEST1 MSAVEVALUE  6,1,33,P33
11             MSAVEVALUE  6,1,34,P34
         PCS   VARIABLE    (P5*P3)/100+P4
12             ADVANCE     0
13             MSAVEVALUE  6+,1,FN$DATE,P5
14             MSAVEVALUE  6+,1,31,P5
15             ASSIGN      5,V$PCS
        *                             NO EQUIPMENT NEEDED IN THIS OPERATION
        *                QUANTITY OF PARTS ENTERED IN MATRIX NUMBER FIVE
        *
16             SPLIT       1,AAA   TRANSACTION SPLITS PER FLOW CHART
         ONE   MACRO       1477,8600,101,2,2,2,6,6+,TEST2
17             ASSIGN      33,1477
18             ASSIGN      34,8600
19             ASSIGN      3,101
20             ASSIGN      4,2
21             TEST L      C1,90,TEST2
22             ASSIGN      4,0
23       TEST2 MSAVEVALUE  6,2,33,P33
24             MSAVEVALUE  6,2,34,P34
         PCS   VARIABLE    (P5*P3)/100+P4
25             ADVANCE     2
26             MSAVEVALUE  6+,2,FN$DATE,P5
27             MSAVEVALUE  6+,2,31,P5
28             ASSIGN      5,V$PCS
        *                             PROCESS FOLLOWS THE FLOW CHART
        *
         TWO   MACRO       78,25,1477,3300,1,2,2+  RIVET FRAME
29             ASSIGN      1,78
```

FIGURE 7. Sample of Model Coding.

```
BLOCK
NUMBER
 473             MSAVEVALUE 1,2,34,P34

         TWO     MACRO      76,15,1444,2600,5,1,1+
 474             ASSIGN     1,76
 475             ASSIGN     2,15
 476             ASSIGN     33,1444
 477             ASSIGN     34,2600
         EHR     FVARIABLE  ((P2*P5)/P1)*10
 478             MSAVEVALUE 1+,5,FN$DATE,V$EHR
 479             MSAVEVALUE 1,5,33,P33
 480             MSAVEVALUE 1,5,34,P34

 481             TERMINATE  0
 482     BBB     SPLIT      1,CCC
         ONE     MACRO      2144,5220,105,10,2,4,6,6+,TES19
 483             ASSIGN     33,2144
 484             ASSIGN     34,5220
 485             ASSIGN     3,105
 486             ASSIGN     4,10
 487             TEST L     C1,90,TES19
 488             ASSIGN     4,0
 489     TES19   MSAVEVALUE 6,4,33,P33
 490             MSAVEVALUE 6,4,34,P34
         PCS     VARIABLE   (P5*P3)/100+P4
 491             ADVANCE    2
 492             MSAVEVALUE 6+,4,FN$DATE,P5
 493             MSAVEVALUE 6+,4,31,P5
 494             ASSIGN     5,V$PCS
 495             TERMINATE  0
 496     CCC     ADVANCE    0
         ONE     MACRO      2144,7000,105,10,2,5,6,6+,TES20
 497             ASSIGN     33,2144
 498             ASSIGN     34,7000
 499             ASSIGN     3,105
 500             ASSIGN     4,10
 501             TEST L     C1,90,TES20
 502             ASSIGN     4,0
 503     TES20   MSAVEVALUE 6,5,33,P33
 504             MSAVEVALUE 6,5,34,P34
         PCS     VARIABLE   (P5*P3)/100+P4
 505             ADVANCE    2
 506             MSAVEVALUE 6+,5,FN$DATE,P5
 507             MSAVEVALUE 6+,5,31,P5
 508             ASSIGN     5,V$PCS
 509             TERMINATE  0
 510     FIN     PRIORITY   0
        *                   THE MATRIX OUTPUT IS NOW PUT ON TAPE OR
        *                   DISK FOR SUBSEQUENT OPERATIONS
        *
         FOUR    MACRO      7,ZAZ,ZBZ,MX1(*38,*39)
 511             ASSIGN     35,7
 512             ASSIGN     36,39
 513             ASSIGN     38,7
 514     ZAZ     ASSIGN     39,37
 515     ZBZ     ASSIGN     *39,MX1(*38,*39)
 516             LOOP       39,ZBZ
 517             WRITE      JOBTA1
```

FIGURE 8. Sample of Model Coding.

```
BLOCK
NUMBER
 518               LOOP        38,ZAZ
           FOUR    MACRO       4,ZCZ,ZDZ,MX2(*38,*39)
 519               ASSIGN      35,4
 520               ASSIGN      36,39
 521               ASSIGN      38,4
 522       ZCZ     ASSIGN      39,37
 523       ZDZ     ASSIGN      *39,MX2(*38,*39)
 524               LOOP        39,ZDZ
 525               WRITE       JOBTA1
 526               LOOP        38,ZCZ
           FOUR    MACRO       2,ZEZ,ZFZ,MX3(*38,*39)
 527               ASSIGN      35,2
 528               ASSIGN      36,39
 529               ASSIGN      38,2
 530       ZEZ     ASSIGN      39,37
 531       ZFZ     ASSIGN      *39,MX3(*38,*39)
 532               LOOP        39,ZFZ
 533               WRITE       JOBTA1
 534               LOOP        38,ZEZ
           FOUR    MACRO       2,ZGZ,ZHZ,MX4(*38,*39)
 535               ASSIGN      35,2
 536               ASSIGN      36,39
 537               ASSIGN      38,2
 538       ZGZ     ASSIGN      39,37
 539       ZHZ     ASSIGN      *39,MX4(*38,*39)
 540               LOOP        39,ZHZ
 541               WRITE       JOBTA1
 542               LOOP        38,ZGZ
           FOUR    MACRO       1,ZIZ,ZJZ,MX5(*38,*39)
 543               ASSIGN      35,1
 544               ASSIGN      36,39
 545               ASSIGN      38,1
 546       ZIZ     ASSIGN      39,37
 547       ZJZ     ASSIGN      *39,MX5(*38,*39)
 548               LOOP        39,ZJZ
 549               WRITE       JOBTA1
 550               LOOP        38,ZIZ
 551               TERMINATE   1
                   START       1
                   END
```

FIGURE 9. Sample of Model Coding.

MATRIX FULLWORD SAVEVALUE 1

*REPORTING RECORD

COLUMN	1	2	3	4	5	6	7	8	9
*MACHINE HOURS									
ROW 1	19	29	29	29	29	41	41	41	29
2	46	46	46	56	64	64	54	46	46
3	59	88	88	88	88	124	124	124	88
4	118	118	165	165	165	118	118	118	118
5	58	58	58	70	80	80	68	58	58
6	58	58	58	70	80	80	68	58	58
7	118	118	118	141	160	160	137	118	118

COLUMN	10	11	12	13	14	15	16	17	18
ROW 1	29	29	29	29	145	116	174	145	116
2	46	46	46	46	230	184	276	230	184
3	88	88	88	88	440	352	528	440	352
4	118	118	118	118	590	472	708	590	472
5	58	58	58	58	290	232	348	290	232
6	58	58	58	58	290	232	348	290	232
7	118	118	118	118	590	472	708	590	472

COLUMN	19	20	21	22	23	24	25	26	27
ROW 1	116	145	116	116	145	116	116	145	116
2	184	230	184	184	230	184	184	230	184
3	352	440	352	352	440	352	352	440	352
4	472	590	472	472	590	472	472	590	472
5	232	290	232	232	290	232	232	290	232
6	232	290	232	232	290	232	232	290	232
7	472	590	472	472	590	472	472	590	472

						*WORK CENTER	*MACHINE GROUP		
COLUMN	28	29	30	31	32	33	34	35	36
ROW 1	116	0	647	0	0	1444	1700	0	0
2	184	0	832	0	0	1444	2100	0	0
3	352	0	1959	0	0	1444	2200	0	0
4	472	0	3256	0	0	1444	2210	0	0
5	232	0	1037	0	0	1444	2600	0	0
6	232	0	1037	0	0	1444	4000	0	0
7	472	0	2107	0	0	1444	5000	0	0

*Titles inserted, not computer output.

FIGURE 10. Matrix Output.

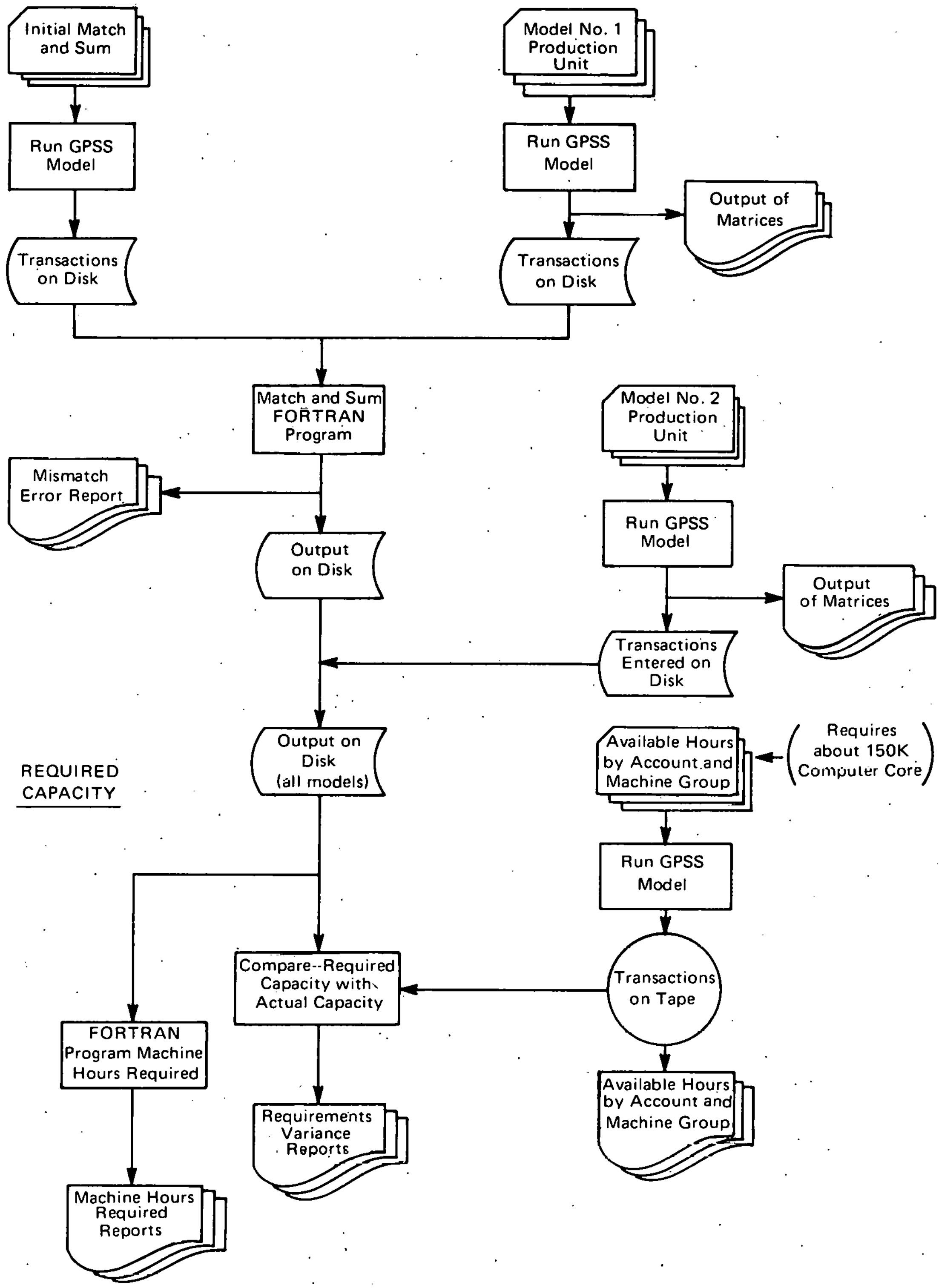


FIGURE 11. Basic Flow of Equipment Forecast Models.