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AUTOMATED SCHEDULING OF
MANUFACTURING RESOURCES

Technological Spinoff Report

Prepared by:
W. G. Hoppen

Published March 1974

Prepared for the
United States Atomic Energy Commission
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Bendix

**Kansas City
Division**

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W. G. Hoppen
Department 200**

Technological Spinoff Report

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AUTOMATED SCHEDULING OF MANUFACTURING RESOURCES

BDX-613-1077, UNCLASSIFIED Technological Spinoff Report, Published March 1974

Prepared by W. G. Hoppen, D/200

To effectively utilize manpower, equipment, and facilities in production, two major factors must be known: the current in-process status of product and the required date for the finished product. These provide basic information for determining the relative priorities of all product scheduled to move through a production facility. Three basic data files are used: the Requirements System, the Work-In-Process Status System, and the Automated Manufacturing Planning System. By automatically computing remaining production and inspection hours and comparing the results to required dates and resource capacities, it is possible to provide a daily priority plan for every production load center. The Automated Manufacturing Planning System produces these scheduling documents. This paper describes the automated process characterizations and control techniques which provide a five-day finite plan for 100 percent of the capacity of each load center in a manufacturing operation producing mechanical and electronic assemblies under contract for the U.S. Government and involving approximately 13,000 active part numbers.

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THE BENDIX CORPORATION

KANSAS CITY DIVISION

KANSAS CITY, MISSOURI

A prime contractor for the
Atomic Energy Commission
Contract Number AT(29-1)-613 USAEC

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INTRODUCTION

When considering the varieties of product that must move through the production process within any mechanical fabrication department, frequent priority decisions in allocating production resources are a daily necessity. The availability of accurate remaining production and inspection times and the current required dates for finished product are critical to the computation of relative priorities.

This paper describes a resource loading system which provides daily finite priorities for all designated load centers within mechanical fabrication departments. Weekly forecasts reflect load centers' capacity hours versus computed load hours for a period of five weeks. Monthly forecasts reflect load center load hours, capacity hours, and recovery or excess hours for the subsequent nine months. Monthly forecasts are based on raw schedule requirements only, rather than being a function of the in-process load. In addition to the load center forecasts, the system provides a weekly forecast by product identification number of expected completions for designated load centers for a period of five weeks. When no other considerations influence load center capacity factors, these forecasts serve as a trend indicator for capacity adjustments.

The production environment involves approximately 13,000 active part numbers and an additional 6,000 part numbers with potential requirements. Around 12,000 active jobs are being processed at a given time. Work-in-process information is supplied by about 5,000 transactions per day using 75 strategically located data collection units.

Automated loading of designated load centers has been successfully applied to printed circuit board fabrication, machining, and rubber and plastics molding departments for approximately 3 years.

REQUIREMENTS SYSTEM

True requirements are basic to optimizing mechanical fabrication resources. From this data, scheduling of production and procurement activities, impact analysis, forecasting of manpower and machine loading, and other budget information can be provided effectively. There are two practical systems for providing "true requirements:" Gross Requirements and Open (net) Requirements. The maintenance of gross requirements is heavily dependent upon manual postings to record cards, or which the majority are after-the-fact situations. Accurate and timely administration of this manual data results in optimum department headcounts. The Gross Requirements System satisfactorily supports scheduling of production and procurement activities but falls short of the minimal

support necessary to optimize mechanical fabrication resources. The "open," or net, requirements system addresses these deficiencies and will be discussed in following sections. Figure 1 is a flow chart for the inventory control systems.

OPEN REQUIREMENTS SYSTEM

The Open Requirements System (ORS) generally provides traceability for product through all inventory accountability points. These points include, but are not limited to, material and piece part stores, departmental in-process accounts including higher assembly levels, and monthly packaging and shipping accounts.

Relief from open build positions is generated as a result of transactions from any of the inventory accounts. Automatic updating of records is provided through data collection terminals in production, inspection, and packaging areas. Preplanned attrition information is accommodated automatically through the Open Requirements System and provides automatic generation of material requirements to lower assembly, material, and piecepart support. Attrition rates are integrated into computer records. Multiple configuration bills of material are also provided for in the Open Requirements System. This capability reduces the volume, and corresponding drawing changes, associated with echeloning engineering change orders to all product in the Open Requirements System.

The Open Requirements System provides total automatic traceability for material requirements and develops, on material, piece part, subassembly, and assembly bases, schedules which indicate quantity remaining to be built and date the quantity is needed. The information is provided on a daily, action only basis and can be traced through the use of cathode ray tube display stations. Computer records which are accessed for this information are updated three times daily. The requirements system also provides for the allocation of production material. Figure 2 shows the interaction between ORS and material allocations. The following paragraphs address material and job releases to the production departments.

MATERIAL AND JOB ESTABLISHMENT

Preliminary reviews of material requirements by product quantities can be accomplished in two ways: by physically moving materials from production stores to a staging area, which requires manual manipulation of material and review of documents to determine true shortages; or through the utilization of computer records associated with a job system, such as an Open Requirements System, which provides the traceability of information concerning material availability. The latter does not require the physical staging of material to effect an allocation of the material, but does provide hard copy allocation through the various inventory accounts.

Figure 1. Inventory Control Summary Flow Chart

Figure 2. Production Control Systems

MATERIAL AUTHORIZATION, ALLOCATION, AND RELEASE SYSTEM

The Material Authorization, Allocation, and Release System (MAARS) involves the control of inventory material through computer-generated bills of material, work in process data, and associated allocation records. As these jobs are individually released, job packets are produced and delivered to production stores where the jobs' allocated materials are accumulated and disbursed to the production facility, and data collection transactions are made to properly debit and credit productive inventory status. Materials disbursed from stores must be received in production departments and acknowledgement must be made through the job reporting system, which is the initiating step in reporting the work-in-process status of the production job throughout its tenure in the production environment.

WORK-IN-PROCESS SYSTEM

The Work-In-Process System (WIP) is used primarily to provide inventory status reporting of production jobs through production operations. This system also provides basic information for the Automated Manufacturing Planning System which will be addressed in subsequent sections of this paper. WIP also provides labor reporting and scrap material cost information to accounting departments.

Certain data bases are required to be available in order that the system function properly. These data bases are established from Production and Inspection Travelers which provide sequential operations, narrative instructions, equipment and material required, and inspection codes required during the process of the production item. The manufacturing operations master record is established from these documents and reflects standard hour information for each production operation associated with the production item. WIP data collection information (i.e., report point scrap, sales, and exception reporting) is transacted for these report points by job number.

Upon release of production jobs, operational reporting information becomes a part of the production job packet which, in turn, supports WIP status reporting. Production and inspection operations are used to parallel production activity and are required report points for reporting WIP status through data collection terminals. Basic transactions at given operations are in-work, completions, scrap, and sales.

All production jobs are moved through production processes in a continuous flow and each job has report points corresponding with the base data established as accountability points. The job quantities are established in department based on existing limitations

for the various products and with the prime objective of optimizing production activity. Exception reports are generated in order to maintain effective control of product inventory through WIP reporting. These exception reports are generated basically as a result of programmed edit routines monitoring job quantities, job status, and type of data collection transactions. There are other exceptions associated with sales and scrap transactions which are also treated accordingly.

WIP thus provides a data base for making known the remaining in-process time for any given product in the mechanical fabrication production system. The requirements system provides the basic information needed to determine need dates, and the combination of the two provides basic information necessary to support a relative priority plan which can be provided by the Automated Manufacturing Planning System. Figure 3 shows a functional chart for WIP.

AUTOMATED MANUFACTURING PLANNING SYSTEM

The Automated Manufacturing Planning System (AMPS) presently provides daily, weekly, and monthly production plans for 640 load centers located in 32 mechanical fabrication departments.

Process Characterizations

The system is based on known data (Figure 4) which is automatically pulsed by daily events and thus functions as a daily production inventory and gives the status of jobs within the production environment. The actual inventory status is the result of daily recorded transactions to four major support systems. The Open Requirements System provides the products' quantitative base for schedules; the Manufacturing Operations Master Record provides standard hours, cycle times, equipment codes, and associated operational sequence information; the Work-In-Process System provides the inventory position of each job; and the Material Authorization, Allocation, and Release System provides job material status plus the need date finished product is required to stores. Figure 5 is a functional chart describing AMPS.

The complementing programming required to take data from these four systems and provide a realistic production priority plan to mechanical fabrication departments considers the daily working environment. Production time lost during time required to prepare or "set up" complicated production equipment is not considered as an exception to the system. The system design resulted from consideration of the economical importance of getting the best utilization of lengthy equipment setups. As a result, other jobs for the same product that are in inventory at the load center, or that will be arriving at the load center during the run time of the production job occupying the load center, are planned to sequen-

Figure 3. Work In Process

Product Number
Production Job Number
Product Flow Time
Date Finished Product is Due in Stores
Department of Manufacture
Last Reported Job Status
Total and Remaining Product Process Time
Load Centers Product Must Pass Through
Number of Machines Within Load Centers
Number of Personnel Manning Machines
Number of Shifts Worked Each Load Center
Number of Days Worked per Week

Figure 4. AMPS Known Data

Figure 5. Automated Manufacturing Planning System

tially follow until there is a break in the availability of the product to the load center. The latter obviously could tie a load center up indefinitely and thus best illustrates that AMPS is a plan, not a "set-in-concrete" production schedule. The information must be considered as a representative priority plan for the load center, and personnel managing these load centers must be ever conscious of their relative production position with respect to breaking setups in favor of protecting the production mix of product.

AMPS Objectives

AMPS identifies manufacturing and inspection resources of personnel or machines that are required for each product. The application of each resource (load center) is scheduled according to the highest priority product consistent with schedule requirements. Resources are loaded to the limit of available capacity, and capacity variations at load centers due to manpower and machine availability are also accommodated.

AMPS develops and displays daily priority plans in occupation time by product and individual job at each load center for the current and four subsequent days (Figure 6). Weekly load center and weekly part number completion forecasts for the current and subsequent four weeks, constrained by capacity, are also provided (Figure 7). Monthly total load center forecasts indicate loads imposed by known future schedule requirements for six to nine months. The latter are not constrained by resource capacity or in-process status.

In addition to the normal scheduled product activities, AMPS accommodates the loading of development work and other special customer requirements.

System Features

Total load center identification within manufacturing and inspection, as required in the manufacture of mechanical or fabricated piece parts, is established. Current capacity limitations for each load center are established and include provisions for maintenance. Non-productive activity and inspection functions are identified by an expansion of the operational structure of production travelers and associated computer records.

The system designates each production traveler operation as a WIP report point and load center identification. Production traveler changes are incorporated into the computer record and are automatically established in each applicable WIP job. Load center occupation time for each operation is established in order to permit the automatic calculation of the total work by individual products.

Job priorities (Figure 8) based on in-process status and scheduled requirements are calculated by the computer program, which provides

FEB. 4, 1974

R921X1

DAILY LOAD CENTER SCHEDULE

DEPT 001 L.C. C845

PAGE 1

MACHINES	SHIFTS		1ST	2ND	3RD	DAYS	EXPER	DAILY-CAP	WEEKLY-CAP	DESCRIPTION
1	2	MEN	0.8	0.8	0.0	5	70.0%	12.4	62.0	9 SPDL GD
		FACILITY	0.8	0.8	0.0					

DAY 1

	PART NUMBER	PRIORITY	JOB NUMBER	QTY	RPT-PT	START	DAY	END	DAY
W	RR 123456-001	-39.68	73220155A	72	119S	07 06	1	08 06	1
	RR 123456-001	-39.68	73220155A	72	120A	08 06	1	08 30	1
W	234567-002	91.52	74007154A	72	050A	08 30	1	10 36	1
W	234567-002	144.52	74007157A	72	050A	10 36	1	13 12	1
	X 345678-003	-14.74	73299210A	28	259S	13 12	1	13 42	1
	X 345678-003	-14.74	73299210A	28	260A	13 42	1	18 36	1
	X 456789-004	-13.38	73353028A	18	169S	18 36	1	19 06	1
	X 456789-004	-13.38	73353028A	18	170A	19 06	1	20 42	1
	X 567890-005	-12.47	73353031A	16	169S	20 42	1	21 12	1
	X 567890-005	-12.47	73353031A	16	170A	21 12	1	22 12	1
	X 678901-006	-11.59	73353030A	16	169S	22 12	1	22 42	1
	X 678901-006	-11.59	73353030A	16	170A	22 42	1	23 42	1
Q	X 789012-007	-10.41	73353029A	16	169S	23 42	1	07 24	2

TOTAL CAPACITY HRS	12.4	TOTAL SCHEDULED HRS	15.6	125.8% CAPACITY SCHEDULED
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EXCESS LOAD NOT SCHEDULED	52.0
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Figure 6. Daily Load Center Schedule

FEB. 1, 1974

R1120X2

AMPS WEEKLY PART NUMBER FORECAST

DEPT 001

PART NUMBER RR 123456-001

WEEK OF			FEB. 3, -----			FEB. 10 -----			FEB. 17 -----			FEB. 24 -----			MAR. 3, -----		
LOAD	RPT	MFG	SCHED	SCHED	EXCESS	SCHED	SCHED	EXCESS	SCHED	SCHED	EXCESS	SCHED	SCHED	EXCESS	SCHED	SCHED	EXCESS
CENT	PT	DEPT	QTY	HOURS	HOURS	QTY	HOURS	HOURS	QTY	HOURS	HOURS	QTY	HOURS	HOURS	QTY	HOURS	HOURS
C000	009S	001	GENL DRILL	144	1.2	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
C000	010A	001	GENL DRILL	144	1.2	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
Z901	020A	001	IMP STAMP	144	.2	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
Z900	030A	001	HAND SAND.		.0	.6*	.0	.6*	.0	.6*	.0	.6*	.0	.6*	.0	.6	.6
J612	040A	001	MECH SCRUB		.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
J355	050A	001	AUTO CLEAN		.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
J000	060A	001	K P R		.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
G651	070A	001	EXPOSURE		.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
H000	080A	001	DEVELOP		.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
Z906	090A	001	EXAM RESIS		.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
H720	100A	001	ETCH		.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
J614	110A	001	REM. RESIS		.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0*	.0	.0	.0
C845	119S	001	9 SPDL GD	144	2.2	1.5*	72	1.1	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
C845	120A	001	9 SPDL GD	144	.6	.0*	72	.3	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
J612	130A	001	MECH SCRUB	72	.1	.1*	72	.1	.1*	.0	.1*	.0	.1*	.0	.1	.0	.1
H470	140A	001	GOLD IMM	72	.4	.0*	72	.4	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
G131	150A	001	SHEAR		.0	.1*	144	.2	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
B422	159S	001	GRTN MILL		.0	.0*	144	1.2	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
B422	160A	001	GRTN MILL		.0	.0*	144	7.6	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
Z903	170A	001	PICK/DEBUR		.0	.0*		.0	24.2*	72	12.1	12.1*	.0	12.1*	72	12.1	.0
B422	179S	001	GRTN MILL		.0	.0*		.0	.0*	72	.6	.0*	.0	.0*	72	.6	.0
B422	180A	001	GRTN MILL		.0	.0*		.0	.0*	72	2.3	.0*	.0	.0*	72	2.3	.0
C000	189S	001	GENL DRILL	72	.6	.0*		.0	.0*	72	.6	.0*	.0	.0*	72	.6	.0
C000	190A	001	GENL DRILL	144	3.2	.0*		.0	.0*	72	1.6	.0*	.0	.0*	72	1.6	.0
Z903	200A	001	PICK/DEBUR	144	40.2	.0*		.0	.0*	72	20.1	.0*	.0	.0*	72	20.1	.0
X110	230I	002	VISUAL INS		.0	10.2*		.0	10.2*	.0	15.3*	.0	15.3*	.0	20.4		
X413	240I	003	PM-2 MACH		.0	.0*		.0	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
B422	249S	001	GRTN MILL		.0	.0*		.0	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
B422	250A	001	GRTN MILL		.0	.0*		.0	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
Z903	260A	001	PICK/DEBUR		.0	.0*		.0	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
Z914	270A	001	PACKAGE		.0	.0*		.0	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
X110	290I	002	VISUAL INS		.0	.0*		.0	.0*	.0	.0*	.0	.0*	.0	.0	.0	.0
PART NUMBER TOTALS *				49.9	12.5		10.9	35.1		37.3	28.1		.0	28.1		37.3	21.1

Figure 7. Weekly Part Number Forecast

$P = \text{ORS JULIAN DUE DATE} - \text{CURRENT JULIAN DATE} - (\text{REMAINING PROCESS TIME} \times \text{LOAD FACTOR})$

$\text{REMAINING PROCESS TIME} = \text{REMAINING LOAD CENTER OCCUPATION TIME}$

$\text{LOAD FACTOR} = \frac{\text{FLOW TIME}}{\text{TOTAL LOAD CENTER OCCUPATION TIME}}$

EXAMPLE:

ORS DUE DATE = DAY 161

TODAY = DAY 130

REMAINING PROCESS TIME = 50 HOURS

FLOW TIME = 150 DAYS

TOTAL LOAD CENTER OCCUPATION TIME = 300 HOURS

$P = 161 - 130 - (50 \times \frac{150}{300})$

$P = 31 - 25$

$P = +6$

Figure 8 AMPS Priority Formula

a unilateral basis for determining relative job criticality at each load center. These priorities are expressed in plus or minus days. Development work order priority is elevated automatically when the work order delivery date is jeopardized. In-process manufacturing completion dates are computer calculated by operation based on job due dates. Recognition of reported disruptive events during processing results in the recalculation of affected loads.

Loading Process

The AMPS loading process is dependent upon several factors: schedule requirements contained in the Open Requirements System; staged or non-released jobs; the in-process location and status of product in WIP as of midnight each work day; remaining operations to be completed for product flow through various manufacturing and inspection load centers; and each manufacturing or inspection load center's occupation times as developed from job quantities, standard hours and/or cycle times, and experience factors. Inter- and intra-department transportation times are included.

Jobs scheduled to start production during the five-day loading period are included in developing loads for applicable load centers. WIP jobs currently reported as interrupted (Figure 9) and having an estimated clear date falling within the five-day loading period are also included in developing loads for applicable load centers. Both categories are also the subject of supplemental exception reports during their periods of dormancy.

The loading process uses the concept that the total quantity of the job will flow as an entity throughout the manufacturing process. When jobs are encountered having partial quantities reported at various stages of production, job loading will commence at the earliest reported operation and will continue until the total job quantity again flows as an entity.

Incapacitated load centers are reported separately, and the loading process discontinues forecasting to and beyond the affected load center. This capability eliminates the necessity of reporting individual production jobs into interrupt that are in inventory at the load center or that are forecasted to be at the load center during the down time.

Work is not planned for the first and last six minutes of each shift for any load center in order to provide for personnel "get ready" and cleanup times. Capability exists to continuously plan work across a load center through the normal lunch break periods. When the latter capability is not utilized, a lunch break allowance is made for each shift in planning load center work (Figure 10).

Setup operation time is not duplicated in the loading process when several jobs for the same product are consecutively available at a

ENGINEERING

- 30 - Production Traveler Not Available
- 31 - DSE Job Overload
- 32 - Process Development Overload
- 33 - N.C. Tapes Not Available
- 34 - Tooling Prove-In
- 35 - Process Engineering Problems Misc.
- 36 - Drawings Not Available
- 37 - Project Engineering Problems Misc.

QUALITY

- 38 - Inspection Traveler Not Available
- 39 - Gage Overload
- 40 - Test Equipment Not Available
- 41 - Test Equipment Overload
- 42 - Inspection Manpower Overload
- 43 - Inspection Problems Misc.
- 44 - Quality Process Engineering Problems

MANUFACTURING

- 45 - Tooling Down
- 46 - Capital Equipment Maintenance or Repair
- 47 - Capital Equipment Overload
- 48 - Gage Not Available
- 49 - Tooling Overload
- 50 - Manufacturing Manpower Overload
- 51 - Facilities Environmental Controls
- 52 - Manufacturing Problems Misc.

GENERAL

- 53 - Component Shortage - Purchased Material
- 54 - Component Shortage - Make Material
- 55 - Component Shortage - C Item/Returned Material
- 56 - Component Shortage - Material Recall
- 57 - Rework - ECN
- 58 - Rework - Manufacturing Error
- 59 - Rework - Processing Error
- 60 - Rework - Defective Purchase Material
- 61 - Rework - Defective Make Material
- 62 - Disposition Pending - Q103 Clearance - Purchased Mat'l.
- 63 - Disposition Pending - Q103 Clearance - Make Material
- 64 - Disposition Pending - ECN/NCM
- 65 - Disposition Pending - TMS
- 66 - Disposition Pending - Lab. Test
- 67 - Disposition Pending - Stop Order
- 68 - Disposition Pending - Insp. First Part or Plating
- 69 - Disposition Pending - Inspection, Courtesy Check
- 70 - Disposition Pending - Inspection, Qaip
- 71 - Qaip Overload
- 72 - Facilities Power Outage
- 73 - Facilities Miscellaneous Delay
- 74 - Job Priority Acceleration
- 75 - Job Priority Deceleration
- 76 - Job Lot Build-Up
- 77 - Tooling Not Available
- 79 - Miscellaneous

Figure 9. Interrupt Code Examples

First Shift

Total Hours	=	8.5
Ready to Start	=	-0.1
Lunch	=	-0.5
Ready to Stop	=	-0.1
Net Productive Hours	=	<u>7.8</u>

Second Shift

Same as First Shift.

Third Shift

Total Hours	=	7.0
Ready to Start	=	-0.1
Lunch	=	-0.3
Ready to Stop	=	-0.1
Net Productive Hours	=	<u>6.5</u>

Example: Daily Capacity Calculation

<u>Machines</u>	<u>Shifts</u>		<u>1st</u>	<u>2nd</u>	<u>3rd</u>	<u>Days</u>	<u>Daily Capacity</u>	<u>Weekly Capacity</u>
<u>2</u>	<u>3</u>	Men	<u>1</u>	<u>1</u>	<u>1</u>	<u>5</u>	<u>44.2</u>	<u>221.0</u>
		<u>Facility</u>	<u>2</u>	<u>2</u>	<u>2</u>			
<u>Machines</u>	<u>Shifts</u>		<u>1st</u>	<u>2nd</u>	<u>3rd</u>	<u>Days</u>	<u>Daily Capacity</u>	<u>Weekly Capacity</u>
<u>2</u>	<u>3</u>	Men	<u>2</u>	<u>2</u>	<u>0.5</u>	<u>5</u>	<u>34.5</u>	<u>172.5</u>
		<u>Facility</u>	<u>2</u>	<u>2</u>	<u>0.5</u>			
<u>Machines</u>	<u>Shifts</u>		<u>1st</u>	<u>2nd</u>	<u>3rd</u>	<u>Days</u>	<u>Daily Capacity</u>	<u>Weekly Capacity</u>
<u>2</u>	<u>3</u>	Men	<u>1</u>	<u>0.5</u>	<u>0.5</u>	<u>5</u>	<u>18.2</u>	<u>91.0</u>
		<u>Facility</u>	<u>1</u>	<u>0.5</u>	<u>1</u>			

Figure 10. Load Center Productive Hours

load center. Occupation times for inspection load centers utilizing sampling techniques are developed from computer stored statistical sample size information. When several jobs for the same product are consecutively available, the load center calculation of occupation is not duplicated for more than one sample quantity.

The capability exists to report production activities out of the normal sequence of operations. Operations reported in this manner are not loaded when production is completed sequentially to that operation and hours expended in out-of-sequence activities are relieved from the remaining time forecast.

System Maintenance

The introduction of new product, new load centers, load center capacity changes, and other variable factors requires continuous updates to computer-stored data bases.

Due to the lack of history in many system-critical areas, the initial feed and continuing monitoring of load center information, in-process time factors; added operations for setup, and inspection operation expansion is of paramount importance. As history is captured and system analysis is defined for machine performance, continued system monitoring will be reduced and, in some cases, eliminated.

In summary, every conceivable activity having a potentially significant impact on the accuracy and reliability of the loading process must be identifiable for purposes of analysis and corrective action where necessary. The original system design is intentionally flexible to facilitate required control techniques that are effective and yet do not compromise the system intent. Control techniques will be discussed in the following paragraphs.

AMPS Control Techniques

Monitoring and control of the data base elements and the accuracy of collected data are accomplished in two basic ways. First, variable information, (i.e., load center capacity elements and load center status, etc.) is verbally communicated to a control group which, in turn, converts the information to input data to the appropriate computer record. Second, built-in edit routines automatically distribute exception messages to control group organizations for analysis and corrective action.

Daily load center plans provide the user with certain descriptive information which is used as a monitoring tool. Information included is number of machines, number of shifts being worked, number of personnel per shift, number of work days authorized, experience (efficiency) factor, and information reflecting the number of hours available in excess of the load center daily

capacity. The latter information is only relative to the daily and weekly capacity factors. It does serve as a short range overload indicator which, if pronounced, can be offset by appropriate adjustments to the load center's various capacity factors. The same information is available for long range analysis in a load center monthly forecast which reflects an unconstrained load for the authorized schedule period against the capacity of record.

Additionally, load centers temporarily out of service for more than one working day are established as being in "down" status. Production Control, in conjunction with the responsible manufacturing or inspection supervisor, determines the necessity of adjusting load center capacity elements and the supervisor calls a control group to insert the adjustment into the record. The manufacturing or inspection supervisor having administrative responsibility for load centers going out of service communicates the information to the same control group for appropriate action input to the record.

Control groups receiving computer generated exception reports analyze the discrepancies indicated; determine and initiate the required corrective action; and advise, as necessary, the affected organizations of preventive measures (Figure 11). The AMPS job exception report is distributed to Production Control and serves as notification of discrepancies in WIP job records that seriously impair the AMPS loading process. The discrepancies include, but are not limited to, the following messages.

- Released job not loaded due to incomplete information.
- Authorized job past due for scheduled release.
- Released job with no quantities in a reported status.
- No estimated clear date for job reported in interrupt.
- Inspection operation with no cycle time, job not loaded.
- Set-up operation with no cycle time or standard hours, job not loaded.
- Job quantity spread over more than 2 operations, should be split.
- Priority cannot be calculated, job not loaded.

The AMPS loading exception is distributed to Production Control and serves as notification of discrepancies in WIP job records that affect the loading of jobs in AMPS. The discrepancies include, but are not limited to, the following messages.

Figure 11. Remote Input Control

- Invalid condition, two consecutive setups, change WIP.
- Invalid condition, setup department and department of next operation not the same, change WIP.
- Invalid department, no stored data, contact control group or change WIP.
- Invalid load center, no stored data, contact control group or change WIP.

In addition, each of the two major support systems, ORS and WIP, have companion edit programs which report discrepancies to Production Control for analysis of other problems which may seriously impair the AMPS loading process.

CONCLUSION

Early inquiries concerning similar systems in other industries were fruitless. One large international corporation spent three years attempting to develop an automated priority loading system before finally aborting their project.

Development of the computerized systems described in this paper has provided the administrative tools for optimum utilization of resources. The resulting benefits are easily measurable.

Tangible results are evident in the reduction in numbers of Production Control and Manufacturing personnel required to administer productive operations, in the significant reduction of overtime utilization, and in a vast improvement in the reliability of material status information in all inventory control accounts. Intangible results are also evident in improved schedule performance of all configurations of product produced in the fabrication departments; an attitude of acceptance and the first job status reporting by bargaining unit employees; elimination of the "squeaky wheel" priority concept; the flexibility to handle emergency fabrication on a "sprint basis;" and the synchronization of customer schedules, computed priorities, and production sales.

GLOSSARY

- Authorized Job:** Computer assigned job number that initiates the material allocation inventory account consistent with current Bill of Material definition and required date. This entity remains as "authorized" until formal release to the production facility.
- Bill of Material:** Computer product definition which itemizes materials and component parts required for fabrication of the product configuration.
- Cycle Time:** General (time in decimal hours that a machine will expand to accomplish a traveler operation); Set-Up Oper's (elapsed time for equipment set-up); Insp. Oper. (elapsed time necessary to accomplish inspection operation); Run Time (time allocated to perform production operations).
- Development Work:** Operations performed in a production environment for other than normal requirements.
- Estimated Clear Date:** The date of record that released production job's interrupt condition is to terminate.
- Experience Factor:** Estimated efficiency assigned to load centers which functions to arithmetically reflect realistic load center capacity.
- Flow Time:** Number of work days required to complete the manufacturing cycle of specific product.
- Gross Requirements:** Schedule information which reflects, by product, the total customer requirements, whether quantities have been shipped, are in production, or have yet to be scheduled to production.
- Interrupt:** Reported production job status which designates reason for temporary loss of productive capability for the job.
- Job Factor:** Plastic packet which includes Work-In-Process document required to support material disbursement and Work-In-Process reporting.
- Load Center:** A work activity defined as a production worker, group of production workers, a machine, or a group of machines.
- Load Center Capacity:** Loadable work hours for each load center which are functions of number of machines, number of production workers assigned per shift, number of work days per week, and experience factor.

Machine Code: The unique number assigned to a machine.

Manufacturing Operations Master Record (MOMR): Computer record which includes production operations, associated equipment codes, and associated standard hours and/or cycle times.

Occupation Time: Function of set-up, cycle, and run times at individual load centers.

Open Requirements (ORS): Schedule information which reflects customer requirements remaining to be completed.

Priority: Relative priority of jobs concerning in-process status and scheduled completion dates reflected in plus or minus days.

Released Job: Physical accumulation and disbursement of allocated materials to the production facility. Reflects status change from "authorized" to "released" and is the initial step toward Work-In-Process reporting.

Requirements System: Mechanics for determining total quantities and need dates for all parts required to manufacture specific products.

Sampling Technique: Application of products's quality specification which provides the quantities less than total product quantities submitted for specified inspection functions.

Standard Hours: Time in decimal hours that a production worker will expend in accomplishing a task (traveler operation).

True Requirements: Specific product quantities and need dates which remain to be produced in support of customer requirements.

Work-In-Process System (WIP): Mechanics used to provide in-process production status of released jobs throughout the production process.