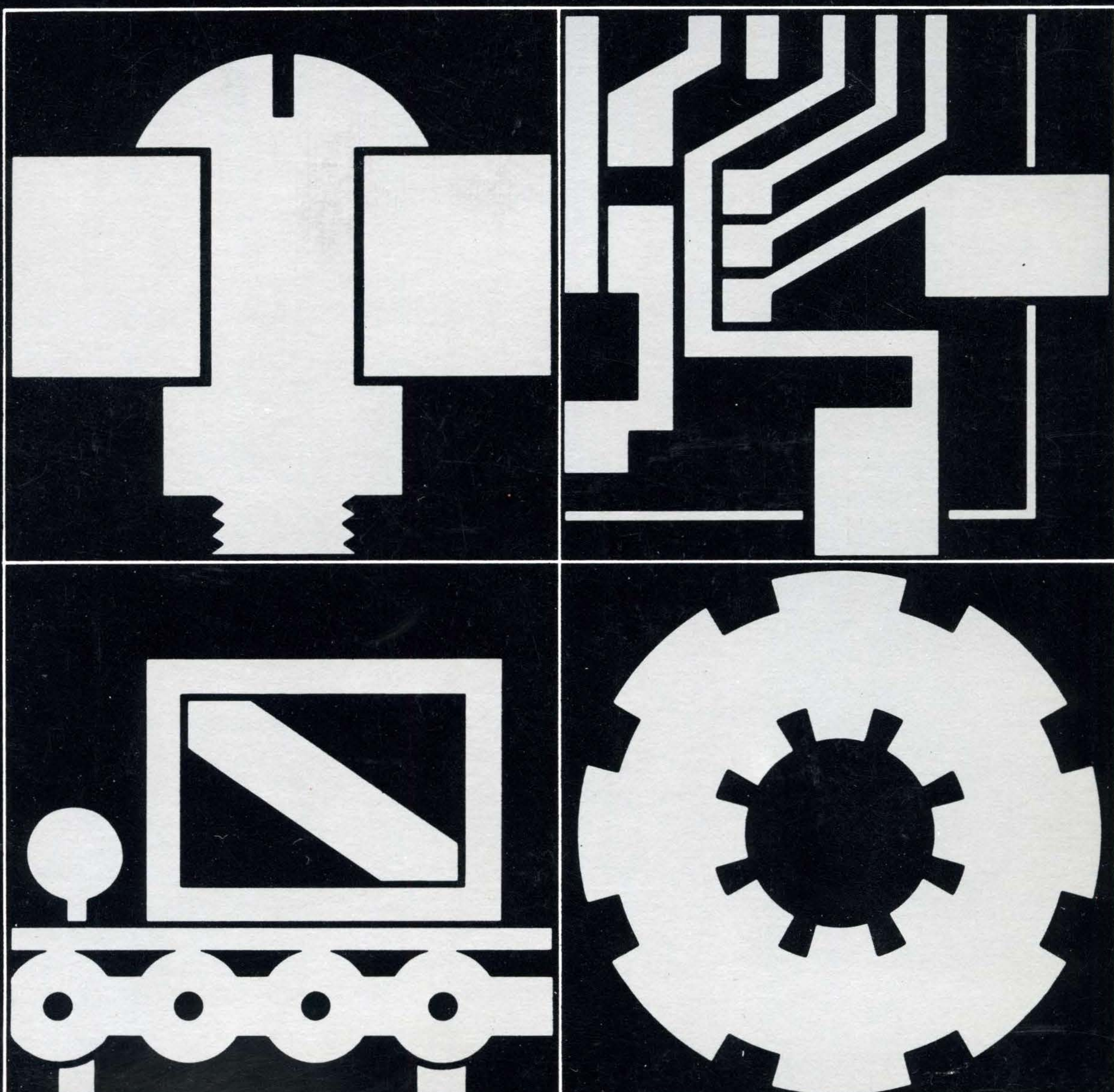
IBM

Communications Oriented Production Information and Control System

Volume VI

Chapter 8 Plant Monitoring and Control
Chapter 9 Plant Maintenance



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Foreword

COPICS (Communications Oriented Production Information and Control System) is a series of concepts that outline an approach to an integrated computer-based manufacturing control system. The concepts deal with problems common to most companies, from a forecast of customer orders, through development of the master production schedule, to production and shipment of the product. COPICS is involved, therefore, with allocation and control of most of the major resources of a company – plant, equipment, manpower, and materials.

COPICS evolved from the approach to manufacturing applications presented in the IBM publication *The Production Information and Control System* (GE20-0280). In COPICS those applications are defined from a communications point of view and have been expanded in scope.

The twelve COPICS chapters provide management with a guide for development of a dynamic online manufacturing control system that is terminal and communications oriented and event responsive. The chapters present the system's concepts in a manner designed to help develop a system that can truly respond to the requirements of all levels of operating personnel and management. Little knowledge of computers is assumed, although some prior exposure to computer concepts and familiarity with such terms as "program", "files", etc., is helpful. Emphasis is on what the problems are and *why* their solution is valuable. How specific problems are solved is discussed only at that level of detail required to assure managers that the solution is feasible. The computer is not, itself, the system, but is, rather, a tool to be used by the manager.

The COPICS concepts are oriented to production and related manufacturing applications. They are not concerned directly with other major areas, such as finance, marketing, and personnel, although the COPICS approach collects data that will be helpful to these areas.

Throughout the COPICS publications, distinction is made between a given COPICS concept, the corresponding chapter, and the corresponding plant department by the use of small capital letters, italics, and initial capital letters, respectively. For example, reference may be made to the COPICS concept PURCHASING AND RECEIVING, or to material in *Chapter 10, Purchasing and Receiving*, or to the plant departments called Purchasing and Receiving.

The complete system is presented in eight volumes containing, in all, 17 sections. The Management Overview section is also available as a separate publication, G320-1230. The contents and IBM order numbers of the eight volumes are as follows:

Volume I	G320-1974	Management Overview, System Requirements, Index, Glossary
Volume II	G320-1975	Chapter 1 Engineering and Production Data Control
		Chapter 2 Customer Order Servicing
Volume III	G320-1976	Chapter 3 Forecasting
		Chapter 4 Master Production Schedule Planning
Volume IV	G320-1977	Chapter 5 Inventory Management
Volume V	G320-1978	Chapter 6 Manufacturing Activity Planning
		Chapter 7 Order Release
Volume VI	G320-1979	Chapter 8 Plant Monitoring and Control
		Chapter 9 Plant Maintenance
Volume VII	G320-1980	Chapter 10 Purchasing and Receiving
		Chapter 11 Stores Control
		Chapter 12 Cost Planning and Control
Volume VIII	G320-1981	System Data Base

To obtain the complete set of eight volumes please order the IBM Bill of Forms number GBOF-4115.

Chapter 8. Plant Monitoring and Control

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Introduction

The business plans, procedures, and operations in manufacturing companies focus on one key objective – to maximize profits. Rising labor and nonlabor costs constantly complicate the attainment of this objective. Companies are often unable to raise prices and/or improve factory productivity enough to keep pace with these rising costs.

In reality, manufacturing management has just two ways to increase factory productivity. First, they can more effectively plan the factory's operation. Second, they can improve the implementation of these plans on the shop floor.

MATERIAL REQUIREMENTS PLANNING and MANUFACTURING ACTIVITY PLANNING address the significant manufacturing planning problems. These systems plan the use of manufacturing resources and materials before action begins in the factory. Once shop orders are released to the factory floor, implementation begins. PLANT MONITORING AND CONTROL addresses this implementation.

Manufacturing management historically has attacked productivity problems during execution with "faster, more efficient" machines. Mechanization alone, however, is not the total solution.

Productivity can also be improved during execution through increased control of shop floor activities. PLANT MONITORING AND CONTROL provides this increased control. It bridges the gap between manufacturing planning systems and the shop floor. PLANT MONITORING AND CONTROL provides manufacturing management with the information necessary to more effectively control factory resources, materials, and activities.

Shop floor control systems would be unnecessary if manufacturing activity occurred as planned. However, unplanned interruptions plague all factories – machines break down; workers are absent; scrap is excessive; materials arrive late. These expected but unplanned interruptions cause delays and inefficiencies that quickly "mushroom" throughout a factory.

PLANT MONITORING AND CONTROL improves the responsiveness of a factory to unplanned interruptions. Thus it vastly reduces delays and inefficiency due to minute-to-minute plant floor disturbances.

The key to improved factory responsiveness is faster and more effective shop floor communication. Many present shop floor systems are often slow, quickly obsoleted, and insensitive to changes. PLANT MONITORING AND CONTROL establishes a faster data communication link by selectively routing shop floor information to appropriate workers, managers, machines and departments.

However, PLANT MONITORING AND CONTROL is more than a communications network – it is also an information system. It uses manufacturing plans, current factory status, and logic to direct shop floor operation.

PLANT MONITORING AND CONTROL incorporates people, computers, shop floor terminals, and production machinery into one integrated system in order to:

- Issue directions to the shop floor based on planned activity
- Collect activity status information from the shop floor
- Compare activity status with the activity plan and identify exceptions
- Decide what corrective action should be taken
- Issue new directions to the shop floor based on this corrective action
- Highlight critical problem areas
- Summarize both current and historical snapshots of manufacturing activity

Many shop floor activities are manual operations. In these areas PLANT MONITORING AND CONTROL uses online computer terminals to communicate with workers and management, while in other shop floor activities, which are highly mechanized, plant floor equipment may be connected directly to the computer. Plant floor computers can be used to establish these direct machine links. In addition to monitoring machine activity, these computers can also be used to control machine operations.

Monitoring, control, and communications techniques will vary throughout a factory. Each department's requirements must be viewed individually. PLANT MONITORING AND CONTROL is the system that meets these requirements. In addition, it ties these individual systems into one cohesive, factory-wide monitoring and control system. Figure 1 illustrates the application of this concept to a typical factory.

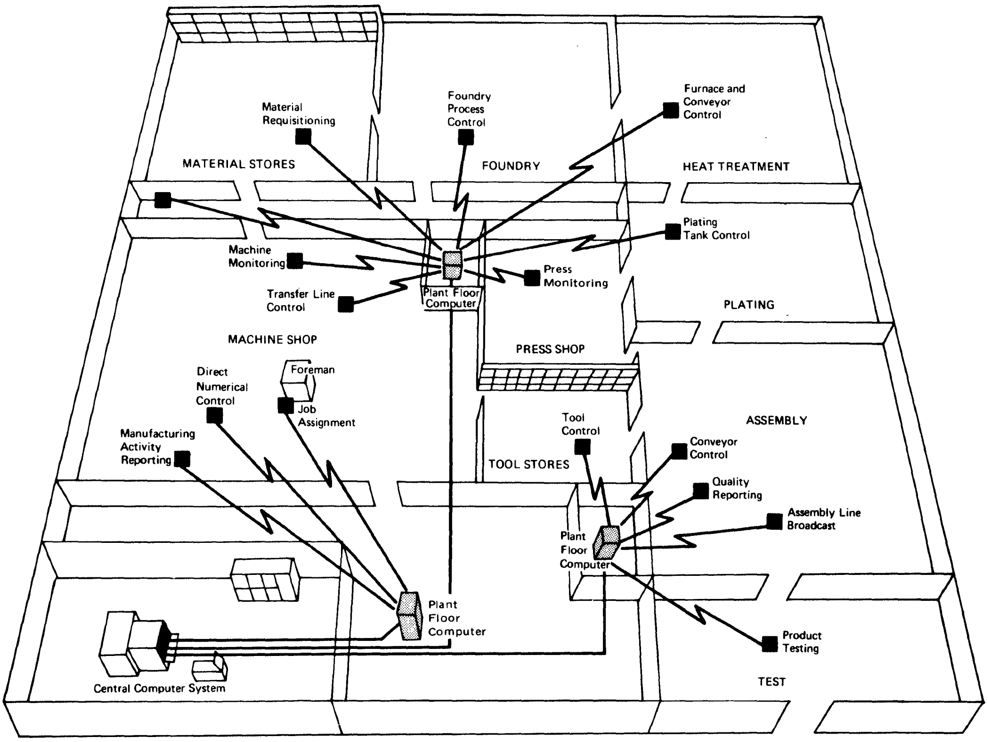


Figure 1. A plant communication system

Plant Communication Equipment

Types of equipment that can be used in a plant communication system include:

- Work area terminals
- Work station terminals
- Computer network (information and control systems)

The overall system is illustrated in Figure 5.

Work area terminal

This is the terminal from which the worker reports job completion and picks up his next assignment (Figure 2). It can read both a plastic badge that identifies personnel using the terminal, and a punched card that identifies the job. It can also, if desired, print hard-copy instructions concerning the job assignment. The terminal allows entry of variable information such as production quantities and storage locations. Personnel operating materials handling equipment can use these same terminals to report the location in which they placed the last move, and to receive their next assignment.

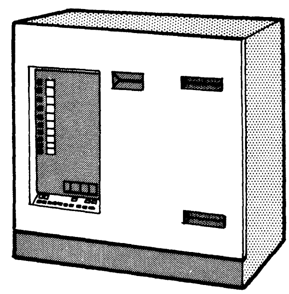


Figure 2. A work area terminal

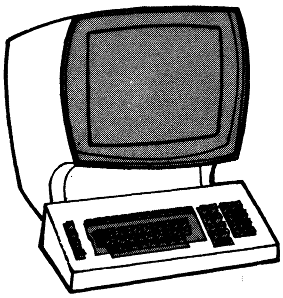


Figure 3. A visual display terminal

There may be one or several of these terminals in a department, depending on transaction volume and walking distance. One or more of the terminals will be equipped with a high-speed visual display (Figure 3) which is used by the foreman in making job assignments.

Work station terminal

Because the system has a complete "real-time" picture of the plant (order status, job and machine assignments, etc.), the operator need enter only a minimum of data. Therefore, the terminals can be simple and relatively inexpensive. This means that more terminals located close to the operator's work location can be included in a system.

The reduction in data entry requirements increases the probability of error-free reporting and reduces the reporting time.

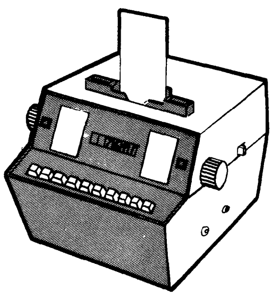


Figure 4. A work station terminal

An example of work station terminals is shown in Figure 4. It is used to report events such as end of setup, end of job, interruptions, etc. Requests for assistance such as maintenance and materials handling can also be made via this terminal. Such a terminal normally handles from one to ten or more operators in one area of a department.

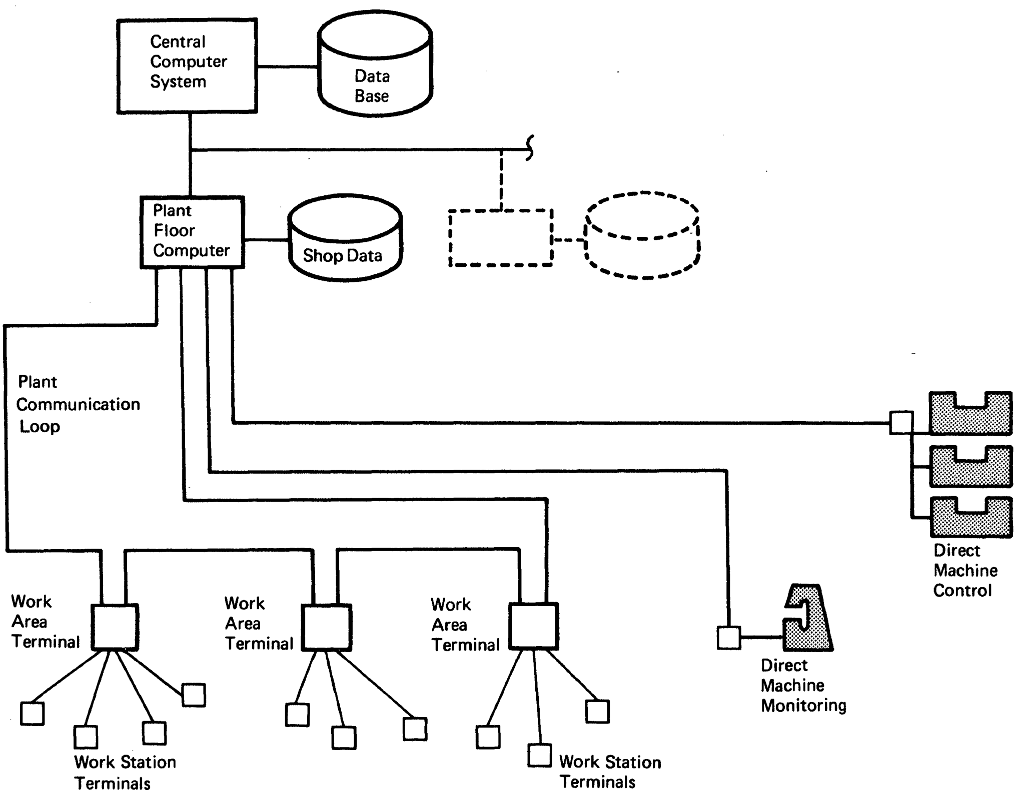


Figure 5. Schematic of a plant communication system

Work station terminals can also be in the form of a telephone handset with pushbutton dialing (Figure 6). Data is keyed in and transmitted to the computer. A voice response assembled from recorded words stored in the computer system acknowledges the entry and guides the operator in entering additional information.

audio response

For instance, when the operator enters the shop order number and transaction code representing end of job, the system responds: "Please enter the number of pieces completed." As the operator enters, say, 100 on the buttons, the system immediately verifies the quantity back to the operator with: "Thank you, you have reported 100 pieces completed." If the quantity entered is incorrect, the operator hears the wrong quantity and can enter the correct data immediately.

Figure 6. Audio-response terminals provide a spoken response to inquiries and transactions

Computer system

The data entered at terminals and from sensing devices attached to machines or processes is transmitted via communication lines to the computer. The computer then processes the data and sends back confirmation of correct data entry, error messages or answers to inquiries and alarms.

The computer system can consist of one large central system that processes and stores all data concerning manufacturing activity (Figure 7). As an alternative, a separate computer can be situated on the plant floor itself and then linked to the larger central processing unit (Figure 8). The use of such a computer is normal when directly controlling the manufacturing process, test equipment, or conveyor systems.

Plant floor computers store data reflecting the status of facilities and released shop orders for only a limited area of the floor. Each handles most of the transactions originating in the building or department it covers, leaving the large computer to handle problems of a broader scope (involving several departments) or problems requiring a large amount of calculation. Plant floor computers may be located in various areas (Figure 9).

The distributed (decentralized) computer facilities often result in lower equipment costs, provide backup capability in case part of the computer complex is temporarily out of operation, and allow dual usage both for data collection and for direct monitoring and control of manufacturing and testing operations.

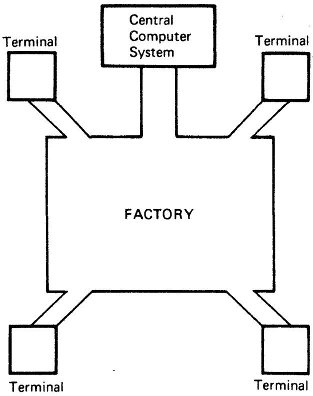


Figure 7. Terminals and devices can be linked directly into a central computer

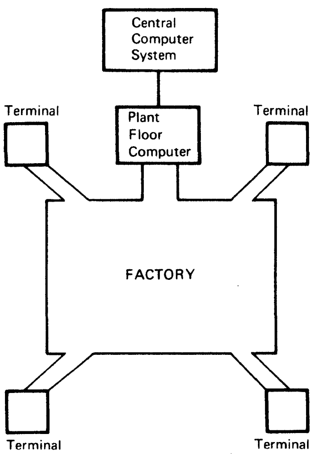


Figure 8. Activity can be monitored and controlled by a small computer linked to a larger computer system

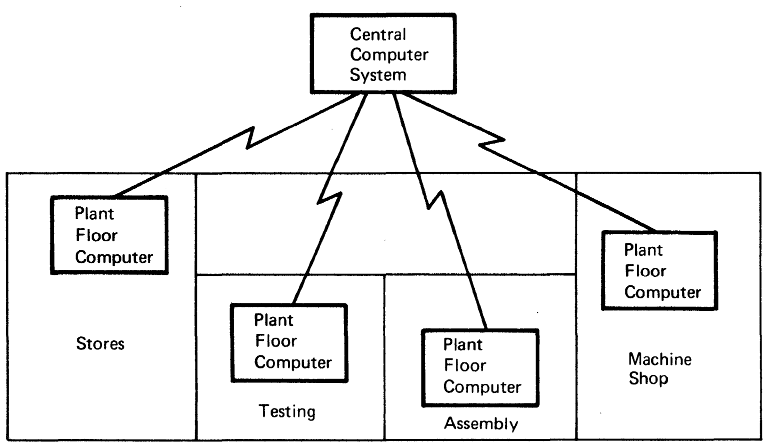


Figure 9. Computers may be located in various areas of the plant and linked to the central system

Functions of Plant Monitoring and Control

The basic functions of PLANT MONITORING AND CONTROL, discussed here, are summarized in Figure 10.

attendance reporting

Attendance is recorded through a terminal on the shop floor. At the start of the shift the system reports the planned and actual manpower for each department or critical work center.

shop order documentation control

Control of shop order documentation includes making alterations to the basic shop order records and authorizing the creation of new or revised paperwork. The need for floor changes to shop order documentation is reduced, however, because orders are released just before the first operation, not weeks or months in advance. Tool requests, material requisitions, material move orders, etc., are not issued until they are needed, thus allowing last minute changes to be incorporated without disrupting the shop. The net effect is a sharp reduction in the time spent by the foreman, Production Control, and direct production workers in implementing such changes.

material requisitioning

The requisitions for raw material and components needed on the first operations are generated by ORDER RELEASE. PLANT MONITORING AND CONTROL coordinates the delivery of material required at subsequent operations. This means that material required in later operations is not handled unnecessarily. It also means work-in-process inventory is reduced, minimizing congestion on the shop floor.

job assignment

The work sequence list, prepared in MANUFACTURING ACTIVITY PLANNING, takes into account the overall scheduling objectives of plant management. Displayed on a terminal, it suggests to the foreman the sequence in which jobs should be worked. As various production activities are performed, the work sequence list is updated to reflect the latest status. The foreman uses a terminal to assign jobs to machines or assembly facilities. He has complete freedom in making the assignment and is thus able to use his knowledge of individual worker skills, machine tolerances, etc. Significant deviations in the suggested sequence are automatically detected, recorded, and flashed to other affected production departments and coordinating support departments. If an employee is about to run out of work because of lack of assignment, an alarm message is generated.

A worker reporting completion of a job immediately receives the assignment of his next job while he is at the terminal. The system helps ensure that all required materials, tools, etc., have already been delivered to the machine or assembly area.

expediting and status reporting

Expediting an order is accomplished by a change in order priority, as described in *Chapter 6, Manufacturing Activity Planning.* Increasing the priority will move the job near the top of the work sequence list. Since the dispatching function of PLANT MONITORING AND CONTROL ensures that the job will be worked on as planned, the need for many expediters or stock chasers is eliminated. The system knows the exact status of all orders, machines, workers, tools, and materials. An increase in an order's priority rating ensures faster movement through its manufacturing cycle. The ratio of high-priority jobs in the system can be measured to help avoid expediting too many jobs.

The foreman knows of the existence of urgent orders well in advance, thus avoiding unnecessary teardowns to process them on short notice.

Customer service is improved because manufacturing management can quickly determine the up-to-the-minute progress of all orders.

manufacturing activity reporting

The employee uses a simple terminal located at or near his work area to report the completion of setup and any interruptions to normal production. The reporting of certain types of interruptions, such as "machine down", automatically triggers requests to the foreman and the responsible production support areas for assistance. Activity reporting ends with notification of the completed job.

quality control

Inspection and testing may be performed in a separate area or on the production floor immediately after an operation. If the inspection is carried out in the production area, the system notifies Quality Control, via an Action File, shortly before the job is expected to be finished.

Quality data can be fed directly to the computer for analysis, thus allowing off-standard production to be corrected while the operation is still under way. The system priority-sequences all pending inspection operations, thus ensuring that important orders are handled first.

Reject control procedures help to pinpoint trouble areas and to distribute costs accurately. Scrap analysis reports and other quality control data are obtained as a by-product.

materials handling control

On the basis of information from Manufacturing Activity Reporting, the system can estimate when an operation will be completed and schedule the movement of raw material, work-in-process, tools, etc., required for the next assigned job so they arrive at the work center just before they are needed. Production idle time caused by undelivered materials and tools is sharply curtailed. Time lost searching for misplaced material is reduced because the system maintains each order's physical location.

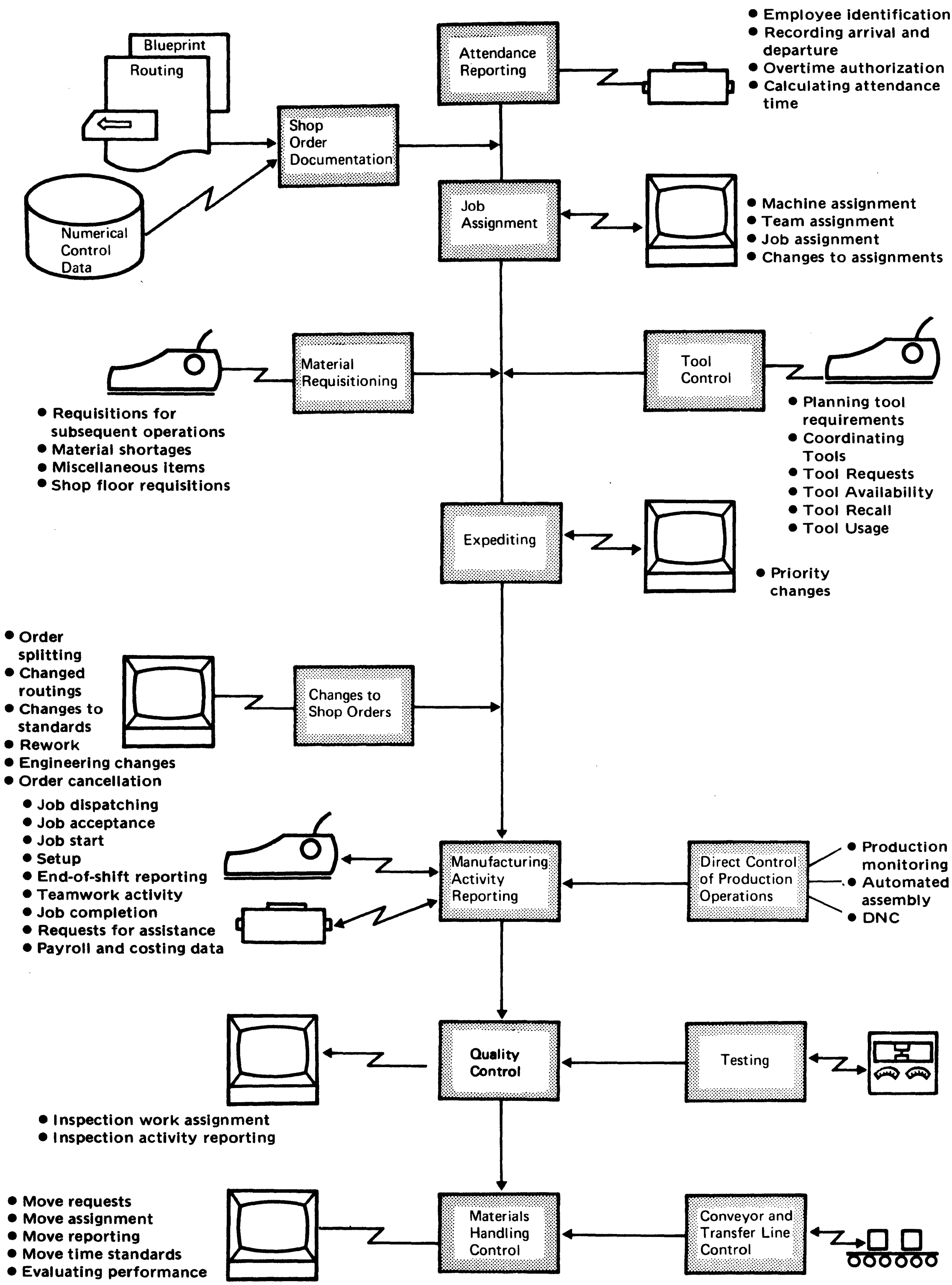


Figure 10. Functions of PLANT MONITORING AND CONTROL

Foremen and workers no longer have to locate and negotiate for materials handling facilities, because the system provides dispatching information to control the utilization of trucks, fork lifts, overhead cranes, etc., charged with moving material, tools, shop documentation, and so on. Materials handling equipment of all types is more fully utilized because empty-handed movement between work centers is reduced.

The materials handling operator is given his next assignment when he reports the completion of his present assignment. The system assigns the next job according to job priority and proximity of the operator to the location requiring the move. Material handlers' performance can be measured and evaluated against standard move times, thus encouraging improvement.

Direct computer control of automatic materials handling systems and coordination of subassembly feeder lines with main assembly lines are also part of materials handling control.

tool control

Dispatching of tools, jigs, gauges, and fixtures is handled similarly to dispatching of materials. The system can "look ahead" and schedule the picking of tools and their movement to the production area. Tool stores is notified of planned tool requirements before they are needed. The advance notice allows time for tool maintenance by considering toolroom load and expected time for repair. Delays due to tool shortages are thus reduced.

Tool recall procedures ensure the return of tools at the proper time for gauging, regrinding, etc., thus improving product quality, reducing scrap, and increasing the effective production life of tools. Tool history records serve as a basis for optimizing the use of tools. Inventory control procedures reduce tool shortages and at the same time keep tool inventory to a minimum.

direct machine monitoring and control

A computer connected directly to a production facility via instrumentation can significantly increase machine productivity and product quality. Examples of this type of computer use (Figure 11) include:

- Direct Numerical Control of Machine Tools (DNC), in which the computer is used to control a number of numerically controlled machines
- Monitoring the operation of machine tools, presses, etc., and reporting on piece count, downtime, limit checking, etc.
- Control of continuous process operations, such as steel rolling or plating
- Control of automated assembly operations

- Monitoring and control of testing operations for items such as electronic circuits, engine test stands, and so on
- Monitoring and control of transfer lines such as those used for automotive engine blocks
- Control of conveyor lines used for high-volume assembly, heat treatment, and so on
- Control of automatic storage and retrieval of parts in a warehouse

These activities are linked directly to a central computer, or one situated on the plant floor, by means of sensors (electrical contacts, switches, counters, etc.) attached to the factory equipment being monitored. The information is scanned by the computer continuously or at fixed cycles in order to *monitor* the process.

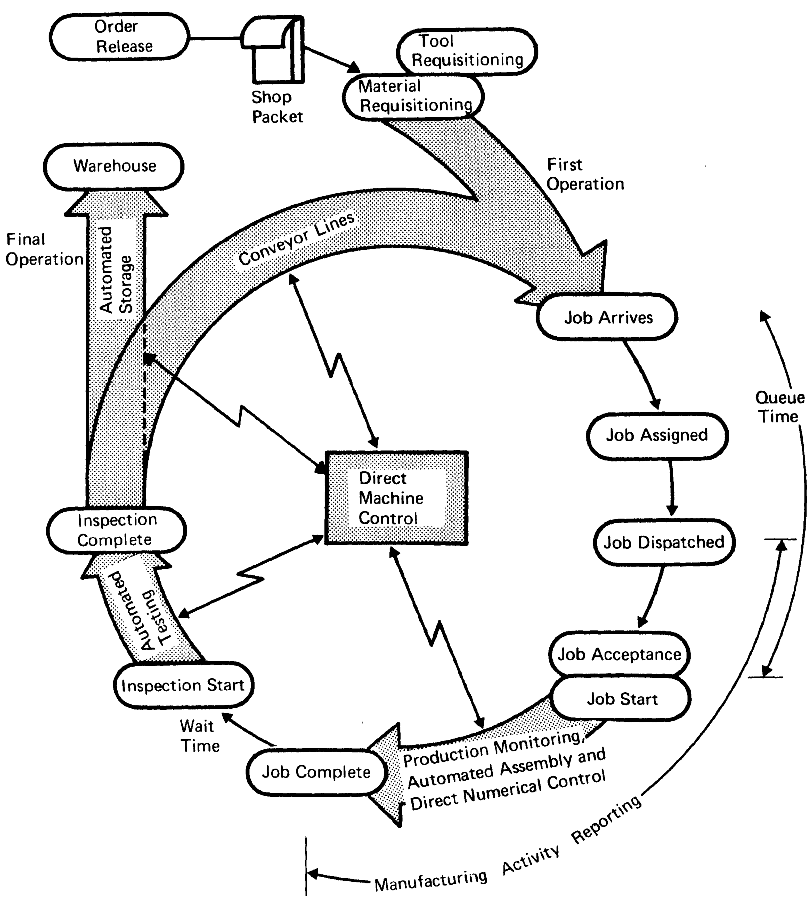


Figure 11. Relationship between direct machine control and other areas of PLANT MONITORING AND CONTROL

If the process is going out of specified limits – for example, if more parts are counted than the order calls for, or if a machining operation produces components that are near the limits of the allowed tolerance – an alarm is immediately triggered at the production area with a message calling for the necessary corrective action.

Where the computer is also controlling the process or machinery, the system gives signals directly – to adjust the speed of the cutter, open the valve, etc.

When computers are attached directly to the process, the system becomes event-responsive – that is, the computers continuously monitor the facility and signal when any activity needs outside corrective action such as maintenance. When notification of the various activities (job start, interruptions, etc.) is given by the operator, the system is not considered event-responsive. This means, for example, that controls needed, such as the ability to halt overproduction, are known only after the pieces have been produced.

Impact of Coordination on Shop Floor Activities

Traditionally, the time directly spent on fabrication or assembly of products has received most of management's attention. Yet in many manufacturing companies the cost of indirect production support services is equal to or greater than the cost of direct production labor. PLANT MONITORING AND CONTROL increases the effectiveness of these supporting activities through close coordination with production operations (Figure 12).

In addition, this coordination has a major impact on the activities of shop floor supervision:

- By automatically coordinating the activities of most production support activities, the system relieves the foreman of one of his most time-consuming duties.
- Less direct supervision is required. The system monitors most manufacturing activities and generates a specific alarm for the foreman when something is going out of control – for example, when a machine is about to run out of work, or a machining operation exceeds the normal allowed time, or an urgent order fails to arrive according to schedule.
- Less time is spent tracking and correcting production activity reporting errors. All transactions originating from the shop floor are edited at the time they are entered. Is the quantity completed

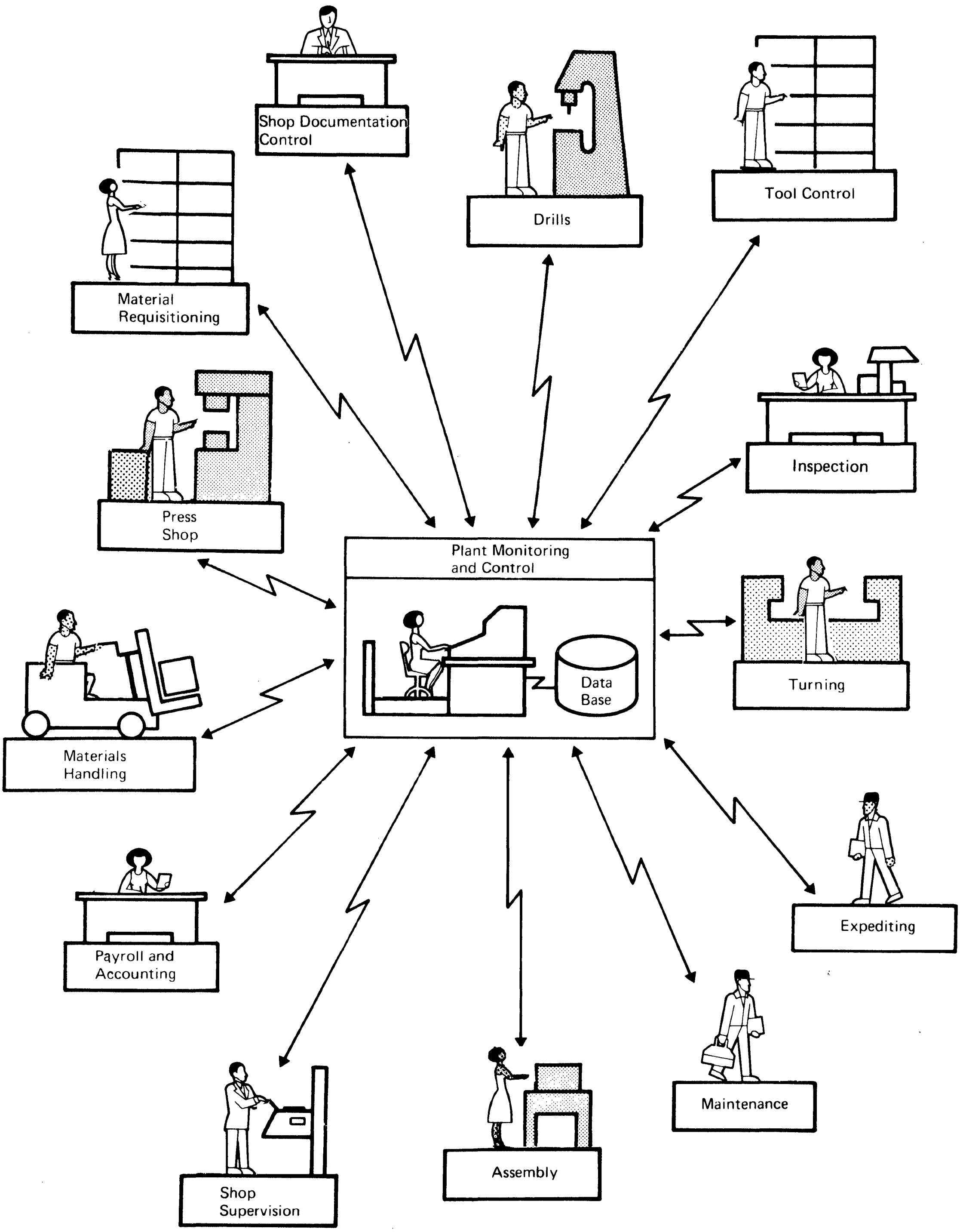


Figure 12. PLANT MONITORING AND CONTROL provides coordination of all functions related to the shop floor

consistent with that reported at the previous operation? Did the worker accept the correct job? Was all the necessary data entered? When an error is detected, the worker is notified while he is still at the terminal and can usually make the correction himself, although in special cases a Transaction Control Center will help him. In either case, the error is corrected while the event is still fresh in everyone's mind. Thus the foreman has the current information and fewer errors to track.

- The foreman's reporting and paperwork load is significantly reduced. Approval of payroll data is reduced to handling exceptions highlighted by the system. Production and efficiency reports are maintained automatically by the system.
- The foreman's work sequencing and job assignment functions are significantly assisted by the system. Constant negotiation with management, other foremen, and expediters over which job should be done first, is sharply curtailed.

The net result of close coordination, shop floor monitoring, and fast notification of out-of-line situations, is increased productivity. Idle time of supporting activities is reduced through the system's ability to direct attention to the most important orders, avoiding inefficient expediting to meet emergencies. The system's ability to measure performance and to control widely dispersed service facilities throughout the plant also helps increase productivity.

Relationship with Other Application Areas

As Figure 13 shows, PLANT MONITORING AND CONTROL is closely related to certain other application areas:

- INVENTORY MANAGEMENT determines the planned shop and purchase orders to be placed to meet the master production schedule. PLANT MONITORING AND CONTROL maintains the status and location of released shop orders and feeds this information back to INVENTORY MANAGEMENT.
- MANUFACTURING ACTIVITY PLANNING helps establish the capacity level required to meet the schedule and adjusts order release dates to meet the schedule. Either daily or for each shift, OPERATION SEQUENCING prepares a work sequence list for each work center. This serves as a basis for assigning and dispatching work. The work sequence list is a major input to PLANT MONITORING AND CONTROL. The shop order data and work sequence information are updated by feedback from PLANT MONITORING AND CONTROL.

- ORDER RELEASE prepares the shop documentation and notifies supporting departments to supply materials and components, blueprints, numerical control tapes, etc., in time to start the first operation. PLANT MONITORING AND CONTROL may request additional data required for subsequent operations. The timing of the request is based on start times established in OPERATION SEQUENCING.
- STORES CONTROL issues materials and components as requested by ORDER RELEASE and PLANT MONITORING AND CONTROL. Completed shop orders are dispatched to the warehouse, where inventory and shop order records are updated.

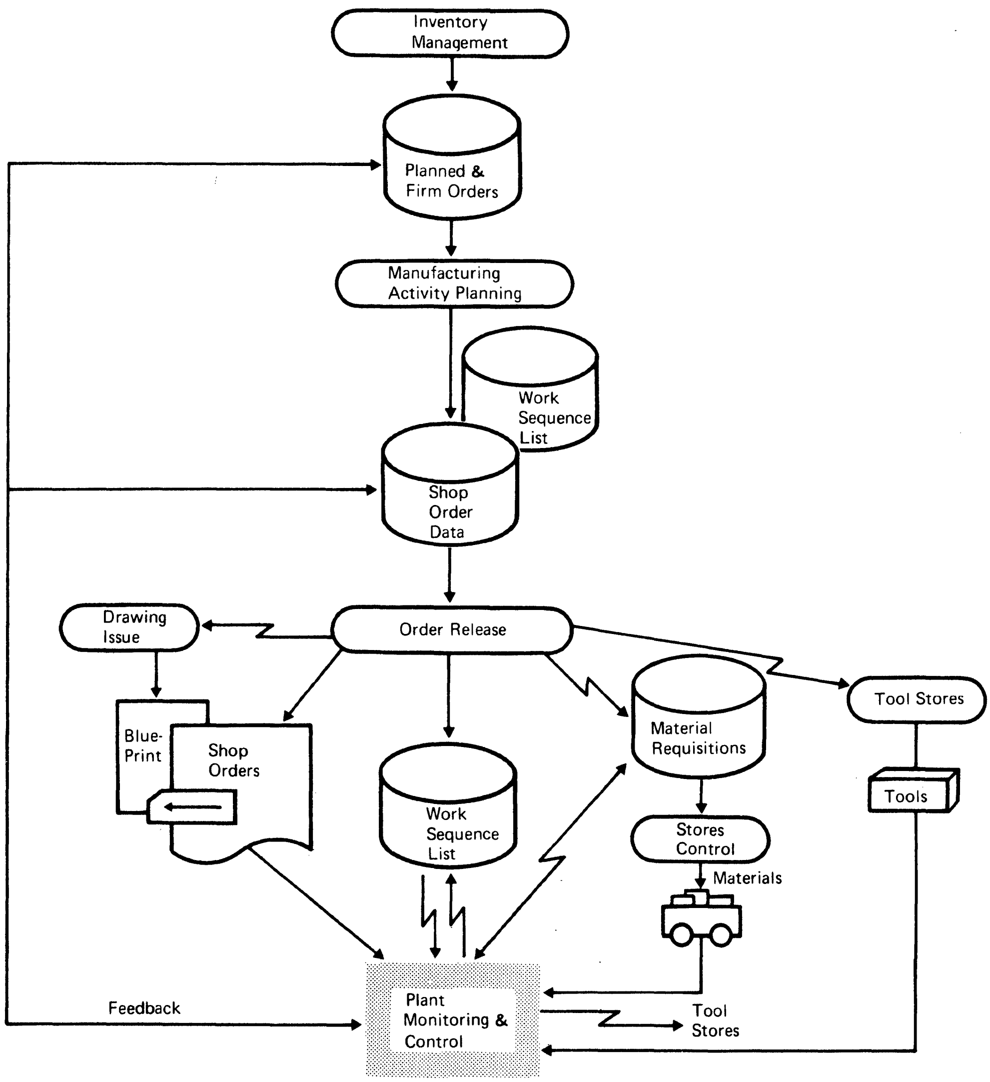


Figure 13. Relationship with other application areas

Attendance Reporting

Traditionally, attendance reporting has been used to establish the employees' elapsed attendance time, which is then reconciled with the time reported on the various jobs. This is still a major function of real-time attendance reporting. While it still serves this major function, attendance reporting in the real-time shop floor control environment takes on an increased significance by providing plant management with a quick assessment of missing personnel. Since demands on "manpower pools" are known earlier, personnel can be assigned or transferred to areas where they are needed to avoid costly bottlenecks. Figure 14 outlines the attendance reporting functions.

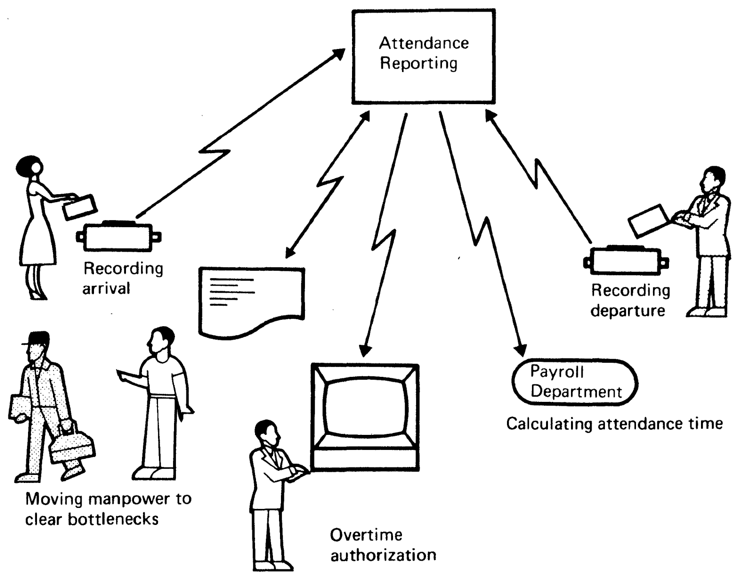


Figure 14. Attendance reporting functions

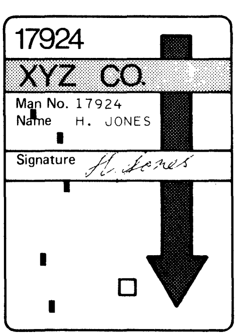


Figure 15. An employee badge

Employee identification

Each employee is identified with a plastic badge punched or otherwise permanently encoded with his number (Figure 15). Shop floor terminals read these badges and transmit the employee identification data to the computer. The badge thus acts as a "signature" for the plant communication system. Most transactions involve use of a badge identification.

The badges may be held in racks near the time cards, or they may be carried and used as authority to enter the plant.

Recording arrival

As the employee enters the plant or arrives at his work area, he normally inserts his badge into a terminal. As the transaction is entered, it is automatically associated with the time of day. This arrival time is posted to the employee's master record (see below).

In order to reduce the number of transactions at the peak period, attendance may be reported on an exception basis. If employees arrive before starting time, they move their badge from an "out" to an "in" rack. Immediately after start of shift, a clerk or foreman enters the badges still in the "out" rack into the terminal to signify absentees. Late arrivals enter their badge at time of starting.

Employee master record

The employee master record, a portion of which is illustrated in Figure 16, records all labor transactions submitted by the employee during the day. This record also contains the man's normal shift start and stop time. The system compares the actual arrival time with the expected arrival time. If the employee is late, a payroll adjustment may have to be made. The foreman is notified for later confirmation with the employee.

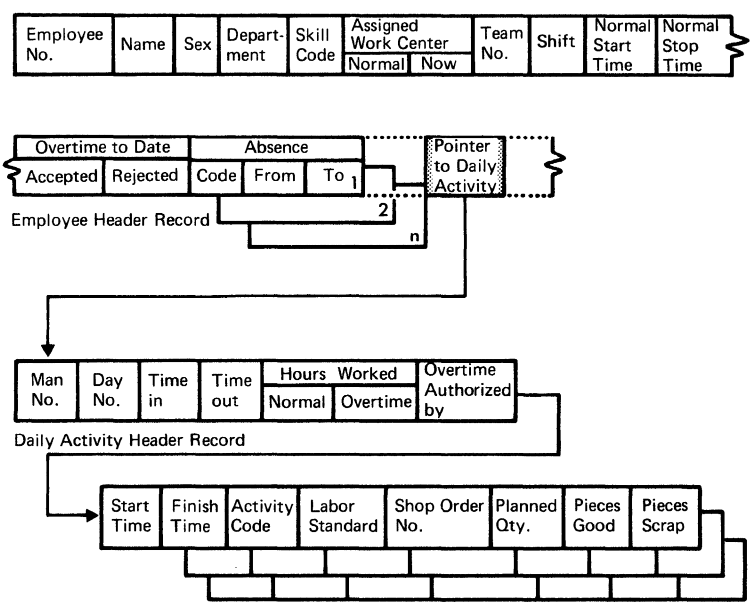


Figure 16. The employee master record contains payroll and performance data

Moving manpower between work centers

Immediately after the beginning of the shift, the system determines who is absent. The absent employees' master records are checked to determine whether the absence was expected – for example, because of vacation or a previously reported personal reason.

A manpower availability report (Figure 17) is prepared for each department. The foreman may retrieve this report upon request. It shows the difference between the planned manpower capacity, as established in MANUFACTURING ACTIVITY PLANNING, and the available capacity calculated from attendance transactions. The system also provides a measure of the present manpower available and the backlog of work in each department. Plant management can use the report to move manpower from areas with minor backlog problems to those that could become bottlenecks if allowed to run significantly below capacity.

When a man is transferred to another department, the employee's master record is updated to reflect the new assignment. A terminal is used to enter the employee number, the department to which he is now assigned, the department to which he is to report, and a code designating whether the assignment is in effect for today only or until the employee is again transferred. The work center file is updated to reflect the new assignment.

MANPOWER AVAILABILITY

WORK CENTER NUMBER	CAPACITY			BACKLOG					
				HOURS			NO. OF JOBS		
	PLANNED HOURS	AVAILABLE HOURS	DIFF. %	PLANNED	ACTUAL	DIFF.	PLANNED	ACTUAL	DIFF.
701	800	720	-10	180	240	+60	90	127	+37
702	800	880	+10	100	47	-53	25	21	-4

Figure 17. Summary of available manpower and work backlog

Recording departure

The procedure for recording departure at end of shift is identical to that for arrival. When leaving, the employee simply inserts his badge into a terminal. The system compares his checkout time with his normal end-of-shift time and updates the employee master record. Employees clocking out early without authorization can be highlighted for the foreman on an Action File.

Overtime authorization

The foreman authorizes overtime by using a terminal to enter a transaction code, the individual's employee number, the number of hours authorized, and his own identification badge. The foreman's employee number is checked against an authorization file to prevent unauthorized entry.

Where an entire department works overtime, a "blanket" overtime entry can be made. If some employees will not be working overtime, their numbers and a "no overtime" code are entered into the terminal.

Overtime offers

If it is desired that all operators in a department have an equal chance of working overtime, a record of "overtime offers" can be maintained. Whenever the foreman offers an operator the chance to work overtime, the number of hours is entered with the employee number at the terminal.

The system accumulates to-date figures on overtime offers and overtime acceptances. These figures can be displayed at the foreman's request (Figure 18) to help him achieve the desired distribution of overtime offers. Overtime rejections can be confirmed by a printed acknowledgment at the terminal.

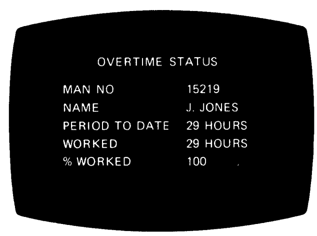


Figure 18. Overtime offers and acceptances can be displayed

Calculating attendance time

The system adjusts the actual arrival and departure time to agree with normal shift start/stop time. The foreman can be notified of employees who are arriving too early or leaving too late and who are not covered by an overtime authorization. Attendance time adjustments resulting from employees working overtime or leaving early are checked to agree with the foreman's authorization. Elapsed attendance time is then calculated, balanced with the detailed transactions accumulated in Manufacturing Activity Reporting, and posted to the employee's daily activity record.

Some companies operate with staggered working hours; that is, the employee works a constant number of hours per day but can, by arrangement, start at any time between, say, 0700 and 0900 hours. The system checks that the total number of hours worked is correct.

Shop Order Documentation Control

A shop packet is produced for all shop orders at time of order release. This packet contains the documents that accompany material as it moves through the shop, as well as the information needed by shop personnel to fabricate and assemble parts. Included in the shop packet could be:

- Drawings, microfilms, etc., of the item to be manufactured.
- A manufacturing routing showing, for each operation, the department, work center, operating instructions, and materials and tools required.
- A shop order identification card, prepunched with the shop order number, and also containing other printed order identification information. It is used when reporting transactions on a particular job. If the order is normally subject to operation overlapping or parallel running, or if multiple containers are required, multiple cards are produced.

Shop packets are sent to stores and placed with the material initially released. As the job travels around the shop, the packet is kept with the material.

When ORDER RELEASE releases an order, a material requisition record is created in the Action File for the stores location supplying material. This Action File is sequenced according to the priority assigned by MANUFACTURING ACTIVITY PLANNING to ensure that urgently required material is issued first.

The shop packet is sent with the material to the first work center (see *Chapter 7, Order Release* and *Chapter 11, Stores Control* for more detail). Figure 19 outlines the material requisitioning function.

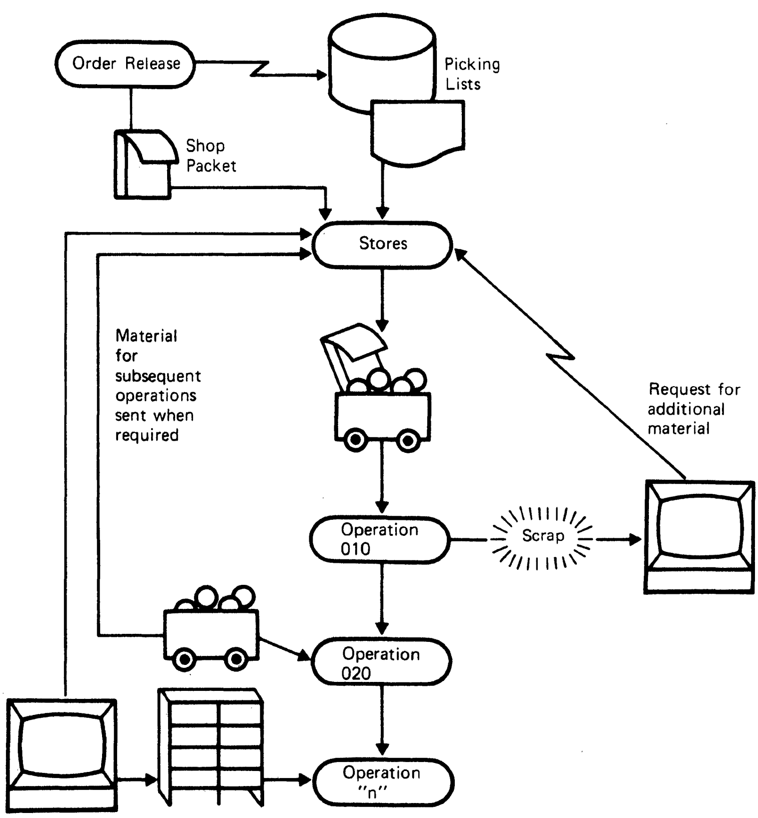


Figure 19. Release of shop order documents and material requisitions

Requisitions for subsequent operations

Material is often required on other than the first operation. In Figure 20 material is designated for delivery at operations 020 and 030. From OPERATION SEQUENCING the system knows the approximate starting time of operations 020 and 030 and can therefore automatically set up another request for material in the Material Requisition Action File. The request is generated far enough in advance to allow the material to be picked and moved to the required work center. Since the material is not released to the work center until needed, the amount of material on the plant floor is reduced. The total volume of material handled is also reduced, since the material does not have to accompany the shop order through the early operations.

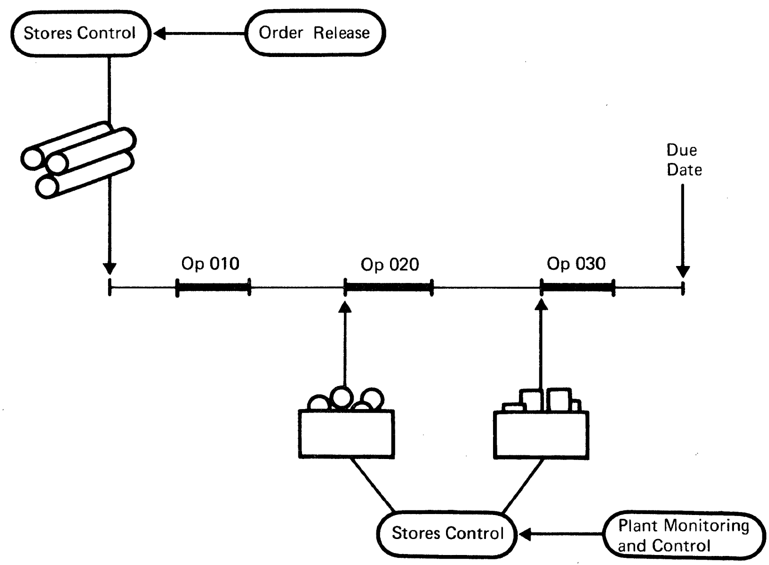


Figure 20. Material for intermediate operations is requested by PLANT MONITORING AND CONTROL

Material shortages

Shop orders may be released even when components are known to be short. The components may be expected to arrive in the next few days or they can be added during a later operation (see "Forced Release" in *Chapter 7, Order Release*).

ORDER RELEASE maintains a record of these shortages. When the required components are completed or received from the supplier, the system immediately notifies Receiving or the last work center to deliver the required quantity direct to the present location of the shop order. Materials Handling also receives a high-priority notice to move the material.

This procedure shortens the delay due to material shortages and ensures that the highest-priority shortages are filled first. It is described in more detail in *Chapter 10, Purchasing and Receiving.*

Requisitions created on the shop floor

A foreman or other authorized personnel may make a material request direct from the work area terminal on the shop floor – for instance, in the case of scrap or the issuance of incorrect material. Supplies and some maintenance items may also be directly requested.

A request is entered for a display of the material requirements for the assembly (Figure 21). If, for example, six more of the item indicated in line 4 (item 327401) were required, a requisition code (requesting additional material) would be entered along with the order number (014296) or shop order identification card. To request additional material, only the line number of the material (4) and the quantity required (6) need be entered. Material not indicated on the list can be requested by entering, in addition, the required item number.

The system immediately acknowledges the request. If the material is not available, the system estimates the date on which it is expected. Where an excessive quantity is requested, which could cause a shortage on other orders, the inventory administrator is notified via his Action File.

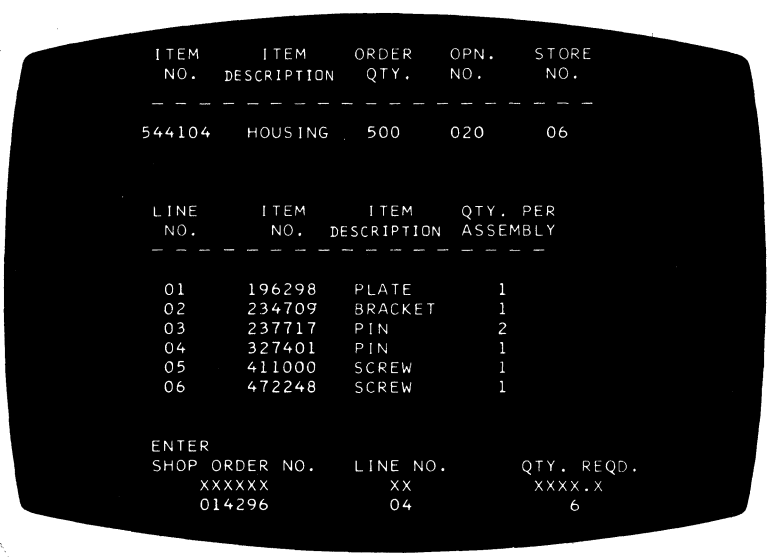


Figure 21. Additional material can be requested

Upon acknowledgment, a request to issue the item is immediately set up in the Stores Action File. Since the work center is waiting for this material, the request will automatically be placed on top of the picking priority list. When Stores acknowledges that the order has been filled, a material move request is automatically placed on top of the Materials Handling Dispatch File (see "Materials Handling Control"). As a result the material is on its way in minutes, and the worker or foreman does not leave his work area.

requisitioning miscellaneous items

Many small, high-volume bulk items, such as rivets, nuts and screws, are stored in bins located in the assembly area. As supplies are depleted, personnel responsible for keeping the bins "filled" with these items can request more by entering, via a terminal, the item number of the required item. An order number does not have to be entered. Confirmation is supplied by the system.

In the case of some supply and maintenance items, the item number may not be known. In this case the foreman or worker enters a requisition code, the item description (instead of the item number), and the quantity needed. The request is routed to stores. Personnel there must enter the correct material identification number. Normal procedures can then be followed.

Throughout the day, the foreman assigns jobs and workers (or teams of workers) to the machines and production facilities in his work center. Jobs are assigned in the sequence in which they are to be run. Figure 22 outlines the job assignment process.

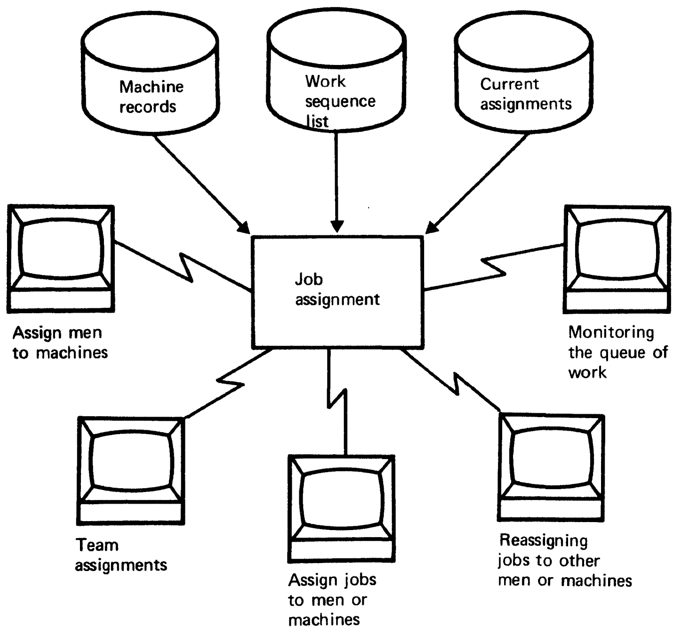


Figure 22. Job assignment

Since both the job and the employee are assigned to a particular machine or production facility, the job is indirectly assigned to the employee (Figure 23). This arrangement simplifies job assignment and manufacturing activity reporting.

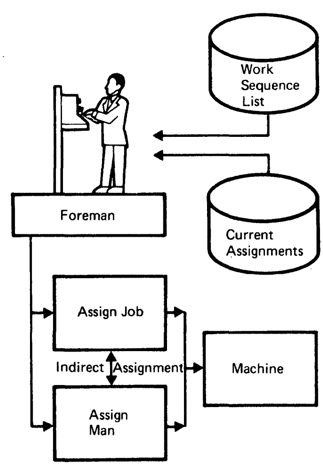


Figure 23. Assigning both a man and a job to a machine indirectly assigns the man to the job

Machine Assignment and Work Sequence Lists

The system creates and maintains two sources of information that help the foreman make job assignments: a machine assignment list and a work sequence list.

Machine assignment list

The machine assignment list indicates the jobs and men currently assigned to each machine or assembly station in the work center. Figure 24 illustrates a typical display. It shows all jobs assigned by the foreman in the work center.

The list can be displayed in machine number sequence or by employee name or number. The status code column indicates the present status of the machine – running, awaiting tools, down for repair, etc.

The list contains an estimate of when the current job will be completed. If the machine is down, the list indicates when the maintenance man should be available. Similarly, the estimated time for completion of maintenance can be shown on the basis of an estimate from the maintenance man or planner (see *Chapter 9, Plant Maintenance*).

The "hours assigned" column indicates the remaining load assigned to the machine. A quick scan by the foreman indicates the need for further assignments.

The foreman may request displays that are designed for fast review of special problems, for example:

- All machines reported down or having trouble
- All unassigned machines
- All machines not being used on direct production work

WORK CENTER 107 GRINDERS DAY NO. 231

MACH NO.	STATUS	MAN	CURRENT JOB	NEXT	HOURS ASSIGNED	COMPLETION CURR. JOB	DAY NO.
01	SETUP	PARKER P.	01142	05579	12.4	10.05	231
				02017			
				10024			
03	RUN	ADAMS K.	74201	12936	4.9	9.45	231
				12937			
07	DOWN	-	MAINT	62114		12.00	231

Figure 24. The machine assignment list shows all work currently assigned to each machine in the work center

Work sequence list

The work sequence list shows the jobs now at the work center or scheduled to arrive in the next few days. The system prepares a new work sequence list once a day or before each shift. This list is maintained in the sequence determined by OPERATION SEQUENCING (see *Chapter 6, Manufacturing Activity Planning*). This procedure takes into account overall management objectives as well as current conditions on the plant floor to establish the sequence in which jobs should be run.

OPERATION SEQUENCING considers *all* orders contending for production facilities, as well as current and planned availability of all production facilities (manpower, machines, and tools), before making sequence decisions.

If a plant is working multiple shifts, some production activity will have transpired between the time batch-oriented OPERATION SEQUENCING starts and the time the updated list is returned to the foreman. Therefore, the system updates the work sequence list with transactions that have taken place, so that a current list is always presented to the foreman.

Figure 25 illustrates a typical work sequence list. The jobs are listed in the sequence in which they should be assigned. The "status" column indicates the present status of the order, such as setup complete, awaiting transport, inspection, running, assigned, etc. An order may have more than one status code assigned, for example, both a tool and a material shortage.

All time estimates are based on standard times and historical performance adjustments. The estimates for tool shortages and other unspecified delays are provided by the departments controlling the delay. The estimates for resolving material shortage are obtained from Purchasing or, in the case of manufactured components, from the completion time estimator in MANUFACTURING ACTIVITY PLANNING.

The status is updated as the events are reported from the shop floor. At the time of the display request, the time estimates are automatically reduced on the basis of the original estimate and elapsed time since the estimate was made.

FROM WC	SHOP ORDER	ITEM NO.	DESCR.	OPN. NO.	QTY.	SET -UP	OPN. TIME	NEXT WC	PLANNED WC	STATUS
610	43201	003204	SCRAPER	020	1000	0.0	3.5	753		IN OP
752	50043	220121	GRIP	080	500	0.4	10.1	752		IN OP
610	42964	003204	SCRAPER	020	1000	0.0	3.5	753	756	ASSIGND
653	42978	003210	SUPPORT	060	400	0.2	7.8	753		WTG. TOOL
752	30214	220121	GRIP	080	100	0.4	2.0	752		AVAIL
753	50417	003210	SUPPORT	060	400	0.2	7.8	900		TRANSIT

Figure 25. Work sequence list

The foreman can review the exact status of all jobs at any work center by requesting the display on his terminal. The up-to-date status information supplied by the coordinating departments helps him make decisions regarding job assignment. The system also provides him with the capability to "look ahead" at jobs scheduled to arrive in the near future. This allows him to pull together jobs with similar setups and to assign the right job to the right machine (and man).

The foreman may make inquiries for additional information, such as:

- All unassigned orders
- All orders complete but not yet shipped to the next work center
- All orders with tool shortages identified

Such requests may be for a particular work center or for all work centers for which he has responsibility.

If the foreman wishes to have more detail concerning a job than is indicated on the sequence list, he can obtain it direct from the shop order data held in the system. Additional information may be required when the foreman is unfamiliar with the part or operation, or when the order status indicates that an engineering change has occurred since the shop packet was issued. Figure 26 illustrates the result of such an inquiry.

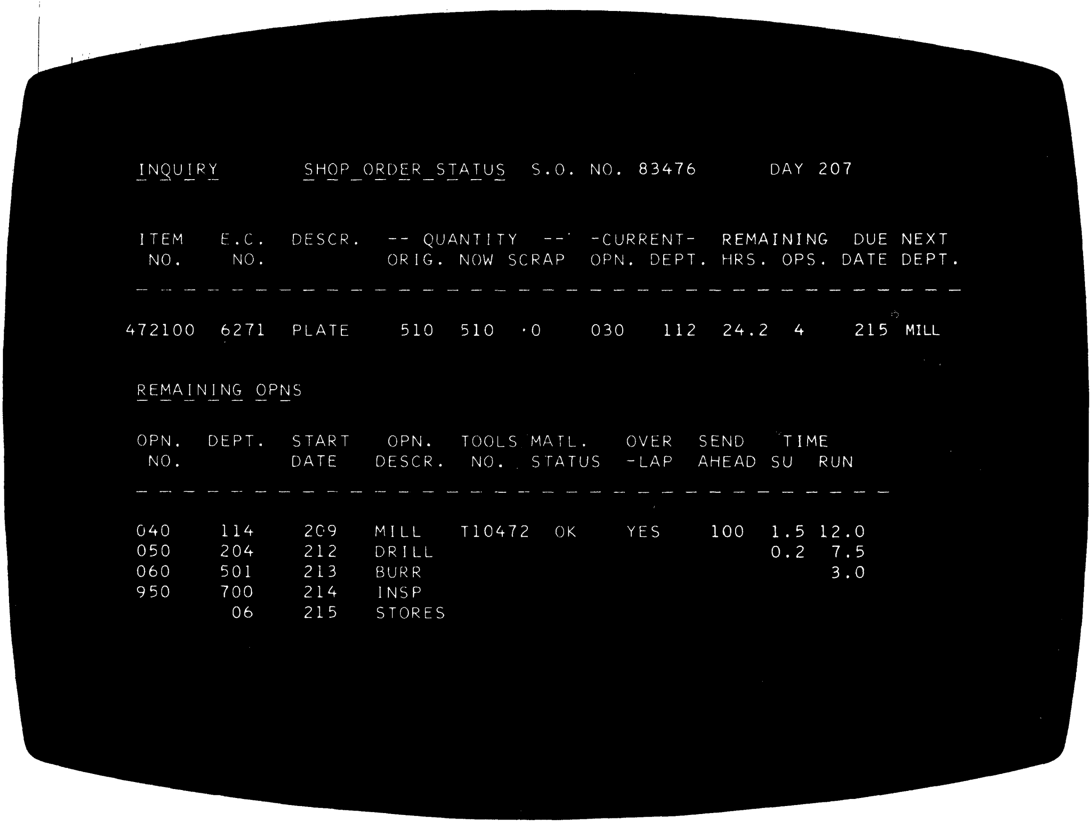


Figure 26. Example of a response to an inquiry on the status of shop order 83476

Assignment of Jobs to Machines

At the beginning of the shift, the foreman requests a simultaneous display of machine status and the planned work sequence (Figure 27). The foreman assigns a job to a machine by entering the line number of the job assigned in the first "entry" column. For example, to assign line 8, order number 21162, which has a similar setup to that of the job assigned to machine 10, the foreman simply enters "8" in column 1 of the first line.

ENTRY 1 XX	ENTRY 2 XX	MACH. NO.	STA	MAN NO.	CURR. JOBS ASSND	CUM. MACH. LOAD	LINE NO.	STA	SET UP CODE	SHOP ORDER NO.	ITEM NO.	OPN. NO.	PRIO-RITY	--TIME-- SET UP	--TIME-- RUN HRS	QTY
		10	R	4137	02	4.9	01	S		20431	404362	010	17	1.0	5.4	10
					04	9.8	02	R		40217	921714	010	17	1.0	3.9	15
							03	R		41356	921731	030	16	2.5	4.7	25
		11	R	4013	03	7.2	04	A	4	62179	687661	020	16	1.5	3.4	10
					05	13.7	05	A		20117	487046	010	17	2.0	4.5	1
							06	N		24321	292010	020	14	1.0	5.7	95
		12	S	4201	01	6.4	07	N		90632	243771	070	18	1.0	8.8	10
							08	D	4	21162	804132	020	13	1.5	0.8	3

STATUS R = RUNNING, S = SET-UP, A = ASSIGNED, N = NOT IN DEPT., D = AVAILABLE IN DEPT.

Figure 27. Job assignment

Immediately after this entry, the status of order 21162 is changed to "assigned". The machine status is updated to include the line number of the job assigned.

The foreman may assign ahead as many jobs as he desires; that is, he may assign only a few hours' work or an entire day's load. Care should be taken not to assign work much past the time when a new work sequence list will be issued, as sequence alterations may occur because of changing shop conditions or customer requirements.

One feature of the system is that the foreman can make assignments when the job is not yet physically available in the work center. This is important when considering common setups and when expediting is required.

Automatic assignment

OPERATION SEQUENCING uses a detailed simulation procedure to determine the sequence in which jobs should be assigned. This simulation may assign individual jobs to individual machines. The foreman can accept these assignments, for instance, when a large number of small jobs are to be assigned, or when all elapsed job times are very long, or when the work center is very specialized and there is not much freedom in assignment.

There are several conditions which the system cannot consider when making automatic assignments and which therefore require the foreman's experience and knowledge – for example:

- Operations requiring similar setups are sometimes not recognized and coded. The foreman uses his knowledge in sequencing jobs to minimize setup time.
- Many machines, although ostensibly similar, may not be able to hold the same tolerances because of differences in machine use or age. The foreman decides which of the high-tolerance jobs he will assign to the machines capable of producing the required accuracy.
- Employees vary in skill and experience. Their attitudes, which can also affect performance, may change from day to day. The foreman considers such factors when making an assignment.

For these or other reasons, the foreman may wish to assign many of the jobs directly. The choice as to which work centers are to be automatically assigned is entirely up to him.

Assignment of Men to Machines

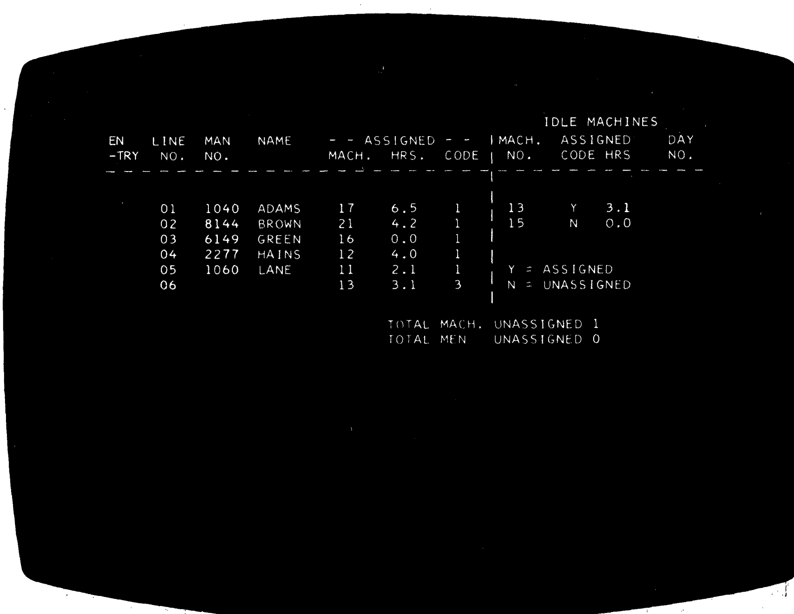
In many shops, employees have normal fixed assignments that are recorded in the system. In a machine shop, a man might be regularly assigned to a particular machine. Thus, assignment of a job to a machine or production facility automatically assigns the job to a specific worker.

If the foreman finds it necessary to reassign workers to other machines, he first reviews the current assignments by requesting a visual terminal display. To change an assignment, he enters the number of the new machine (Figure 28, top display) in the blank space before the name of the employee who is being assigned to it.

Current assignment of men to machines is displayed on request.

Man no. 1060, Lane, is assigned to machine no. 13 after completion of job on machine no. 11.

To assign man no. 6149, Green, who is currently on Indirect Work, to a machine, the machine no. (16) is entered on the left-hand side of the screen against his last assignment.



The new assignment list showing 6149, Green, now assigned to machine no. 16.

Machine no. 16 does not appear on the unassigned machine list.

Figure 28. Assignments of men and machines can be made easily and quickly on a display terminal

The foreman must also indicate whether the assignment is to take effect immediately, after the completion of a particular assignment, or on a specific day. If it is to go into effect immediately, the number of the machine to which the man was previously assigned will now appear as idle. The system removes the machine just assigned from the "idle machine" list.

If the change is to take effect upon completion of the currently assigned job, the machine assignment will be shown as "pending" (Figure 28, lower display, line 06). Here, machine 13 is pending assignment to employee 1060, Lane, who is expected to finish his present job on machine 11 in about two hours.

If the new assignment is to take place on a specific day, the day number is also entered.

Deletion of machines already assigned is accomplished by entering a "delete" code on the line of the assignment to be deleted.

The assignment of one man to more than one machine is accomplished by entering an additional line code in the "entry" column on the left of the screen in the same manner as in making an assignment alteration.

Start of Shift. At the start of shift, the operator normally carries on with the job left on his machine from the previous day or shift. If his machine assignment for today has in the meantime been changed, a warning light can be switched on at his work station to indicate that he should contact his foreman or go to the work area terminal station for his new assignment.

Team assignments

Figure 29 illustrates a group of men working as two teams. The currently assigned team members are listed together with their team numbers (10 and 14). With this arrangement, teams can be shifted from one production facility to another just like individual employees, simply by recording the team number.

Team assignments can be made by entering a code and the line number of the employee being assigned, at the line on which the team number is displayed. In Figure 29, employee 2321, Green, has been reassigned to team 10.

The system edits the foreman's entries for errors such as assigning one man to two teams, or assigning a team to a facility normally handled by one man. The edit exceptions are displayed on the terminal.

WORK CENTER 701 ELECTRICS

EN-TRY	LINE NO.	MAN NO.	NAME	- - -ASSIGNED- - - TEAM	HRS	CODE
08	01	TEAM		10		
	02	1020	BLACK	10	4.7	1
	03	2437	BROWN	10	3.1	2
	04	1212	JONES	10	4.7	2
	05	4711	SMITH	10	4.7	2
	06	TEAM		14		
	07	2214	GREY	14	10.2	1
	08	2321	GREEN	14	6.4	2
	09	2100	BALL	14	6.4	2

Current Team Assignment is displayed upon request.
Team Leaders are denoted by Code 1. (Black and Grey).

To transfer man no. 2321, Green, from Team 14 to Team 10 involves entering a transaction code for "change team assignment" and the line number (08) against the team no. (01).

WORK CENTER 701 ELECTRICS

EN-TRY	LINE NO.	MAN NO.	NAME	- - -ASSIGNED- - - TEAM	HRS	CODE
	01	TEAM		10		
	02	1020	BLACK	10	4.7	1
	03	2437	BROWN	10	3.1	2
	04	2321	GREEN	10	0.0	2
	05	1212	JONES	10	4.7	2
	06	4711	SMITH	10	4.7	2
	07	TEAM		14		
	08	2214	GREY	14	10.2	1
	09	2100	BALL	14	6.4	2

The new team assignment list shows Green, 2321, reassigned to team 10.

Figure 29. Team assignments are changed and controlled by using unique team numbers

Reassigning Jobs

A foreman may need to make changes in previous job assignments for a number of reasons:

- He is not satisfied with the automatic job assignment.
- Machines break down or men are sick, and previous job assignments must be redistributed to available men and machines.
- A rush order arrives, requiring a machine that is currently on a long assignment. (The system's expediting ability should ensure that such requirements are minimal.)
- Men are moved from another work center, and some high-priority jobs can be reassigned to them.

Immediate resequencing of all work released to the plant floor (for example, because a work center goes down for repair) is not economically feasible in most cases, because the resequencing planning procedure must be run in a batch environment and must look at large quantities of data (see *Chapter 6, Manufacturing Activity Planning*).

During the shift, however, the foreman can request the system to resequence the work for his work center only. This request would be most common when there was a large amount of "automatic assignment". A new suggested sequence can be provided with very little delay.

The system can also provide rapidly a picture of the status of alternate work centers, to determine whether jobs could be shifted to those work centers.

The effect of all resequencing decisions is immediately transmitted to other departments via an alteration of the estimated arrival time included in that department's work sequence list (Figure 30). If the job has already been assigned in the next work center, and the order has been delayed beyond the assignment time, an alarm message will be generated. Either a delay or an improvement in availability will also cause automatic changes in assignment priorities in supporting departments such as Materials Handling and Stores.

Care must be taken in altering the assignment specified by the operation sequencer. Significant delays at one work center could cause unplanned upsets in subsequent work centers and could result in major reshuffling in the production support departments. For this reason, orders that for no apparent reason experience excessive delays appear as an alarm in the plant manager's Action File.

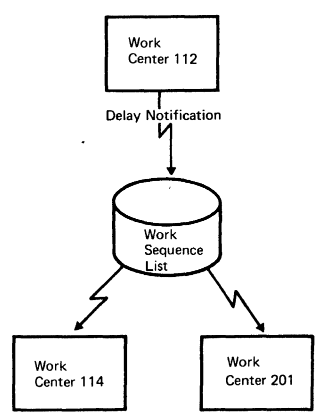


Figure 30. Delays at one work center are communicated to others

Making an Assignment Alteration. The second "entry" column on the job assignment display in Figure 27 is used to insert a job into the middle of previously assigned jobs. In the example, to assign the job on line 07 (order 90632) to machine 11 in front of the job represented by line 05 requires the entry of 07 in column 1 and 05 in column 2. The system then inserts the job in the list before line 05.

In the example in Figure 27, a job can be removed from the assigned machine by entering the job line number in column 1 and the letter D in column 2. The job will immediately reappear as "available" in the work sequence list and can then be assigned in the normal manner.

Monitoring the Queue of Work

The foreman is always concerned about the amount of work in the work center and the work assigned to each machine (and man). As already indicated, he may inquire into the system at any time to review the work sequence list. However, to relieve the foreman of the need for constant reviews, the system has two automatic "queue alarms":

- A warning to the foreman that an employee is about to run out of work. This alarm, and all others mentioned, are communicated via a foreman's Action File to his terminal. The system may also turn on a light or ring a bell by way of asking the foreman to review his Action File immediately.
- A warning for plant management that a planned queue calculated for a work center by MANUFACTURING ACTIVITY PLANNING exceeds the plan by a specified amount, or that the work center is running with a significantly lower queue than planned. The former case may call for a quick authorization of overtime, while the latter may require work to be pulled forward from other work centers in order to keep the particular work center from running out of work.

Queue statistics

Statistics are maintained for the average time a job is in queue at each work center. "Snapshots" are taken at periodic intervals, and the length of the queue (that is, the actual number of hours work available at the work center at that point in time) is measured. These figures are used to determine the planned queue time discussed under "Interoperation Time" in *Chapter 6, Manufacturing Activity Planning.*

Additional statistics are maintained on the length of time a job is in queue at each work center. These are classified by external priority or priority group and are used to plan how much time is required for jobs of each priority to get through the shop.

Input/output measurement

The system measures the number of jobs (and hours) going into, and completed at, each work center during each period. It can be produced as a regular report (Figure 31), say weekly, or be displayed upon request. It gives an indication to management of the performance of each work center, and a measure of the backlog of work in the queue in relation to previous periods, by showing cumulative variances.

WORK CENTER 4052-107 SINGLE SPINDLE AUTOS

WEEK ENDING	201	206	211	216	221	226
INPUT						
PLANNED HRS	400	400	400	400	500	500
ACTUAL HRS	390	370	410			
VARIANCE	- 10	- 40	- 30			
PLANNED JOBS	40	37	42	38	47	52
ACTUAL JOBS	40	35	42			
VARIANCE		- 2	- 2			
OUTPUT						
PLANNED HRS	420	420	420	420	500	500
ACTUAL HRS	437	415	390			
VARIANCE	+ 17	+ 12	- 18			
PLANNED JOBS	42	44	42	43	50	52
ACTUAL JOBS	41	40	37			
VARIANCE	- 1	- 5	- 10			

Figure 31. The input and output of work at the work center is continually measured

Summary of Job Assignment

The system helps the foreman assign the important jobs first. This allows him to meet overall scheduling and workload leveling objectives. The foreman may, at his discretion, accept the automatic job assignment made by the operation sequencer or make his own assignments. He makes his own assignment or reassignment through a simple entry on a terminal.

The foreman has complete flexibility in assigning and is able to take advantage of common setups, employee skills, and machine capability. All jobs presently in the work center and those arriving shortly can be reviewed in order to make the best assignment.

Expediting and Status Reporting

Expediting ensures that critically needed parts are completed in time to meet delivery commitments. In most plants this is done by personnel who physically follow or "chase" the order to make sure that it gets preferential treatment. In some plants everyone from the production manager down acts as an expediter or progress chaser at some time or other. This is costly and not very effective, because expediters, working on different orders, compete against each other. They take up much of the foreman's time with negotiations that have to do with getting their orders placed ahead of other orders that are also being expedited.

changes to priority

The system handles the expediting activity without requiring individual expediters or progress chasers. It initiates this activity by simply altering the "order priority" code maintained for all released orders. *Chapter 6, Manufacturing Activity Planning* describes the priority procedure in detail. When the priority rating is increased, the order moves toward the top of the work sequence list. Contention with other urgent orders is resolved not through negotiation, but on the basis of the overall priority system established by top management (Figure 32).

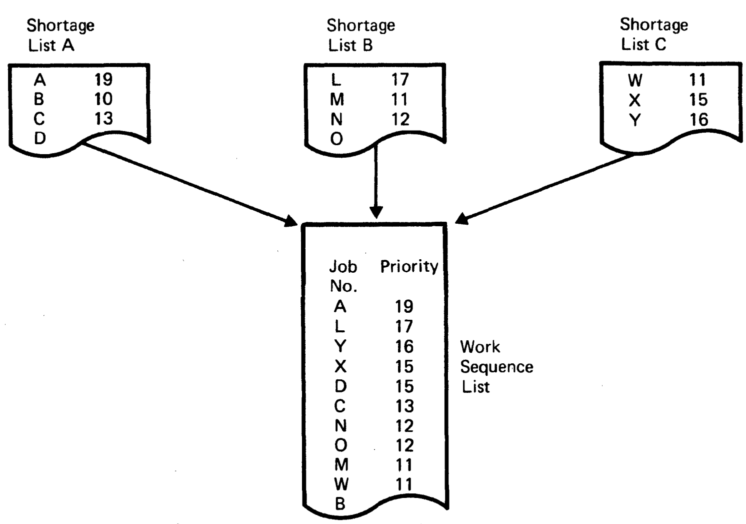


Figure 32. Expediting is based on the relative priority of each job, not on a number of independent shortage lists

The job assignment procedures in PLANT MONITORING AND CONTROL ensure that orders will be executed in, or almost in, the suggested sequence. To schedule supporting production activities, the system uses the same priority code established in the planning system. This means that once a work center has finished an operation on an urgent order, the system coordinates the move to the next work center by automatically placing it near the top of Materials Handling's priority list. Contention with other urgent orders for materials handling facilities is resolved in the same way as contention for production facilities. The priority dispatching of other support activities, such as inspection and material requisitioning, is also handled by PLANT MONITORING AND CONTROL in the same manner.

Manufacturing Activity Reporting

In order to control a job once it has been assigned, the system must have up-to-date information on its progress through the plant; it is no use trying to plan the next day's work on last week's data. A vital function of MANUFACTURING ACTIVITY REPORTING, therefore, is to feed back current information on the status and location of each order while it is in the shop. This information immediately updates the Shop Order Status Files used by MANUFACTURING ACTIVITY PLANNING and for online order status inquiries. As illustrated in Figure 33, MANUFACTURING ACTIVITY REPORTING involves the following transactions:

- Job dispatching
- Job acceptance/job start
- Interruptions
- Requests for assistance
- Teamwork activity
- Multiple machine assignments
- Job completion

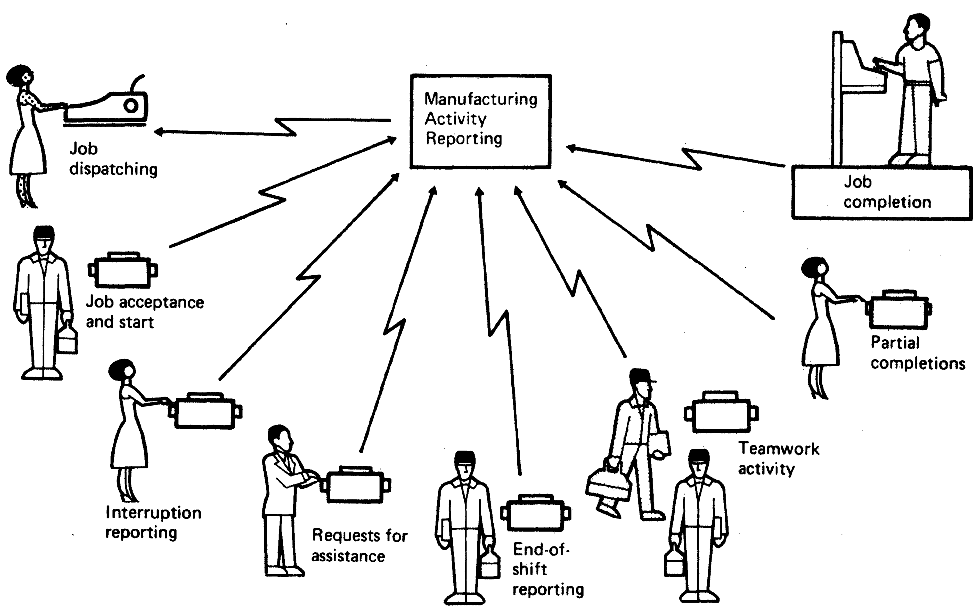


Figure 33. MANUFACTURING ACTIVITY REPORTING

The detailed transactions can be varied to suit the industry and conditions. Reporting on other activities, such as inspection, transport, and direct monitoring of the production process itself, is described later.

MANUFACTURING ACTIVITY REPORTING also includes:

Transaction editing and control

Interface with payroll and costing data

Preparation of shop management reports

Job Dispatching

The next job assigned to an employee is automatically "dispatched" to him when he reports completion of his current job. Job dispatching is done via the work area terminal so that a reminder of the assignment can be printed.

When it is critical that the employee remain at his machine, his next job may be dispatched to him by shop supervision or by some other authorized individual before he completes his current job. The operator may also request his next job assignment without reporting completion of his current job – for instance, after absence, interruptions, etc. In each instance the operator's badge or number is entered into the work area terminal with a "dispatch" code.

As shown in Figure 34, when dispatching a job, the system prints out:

- Shop order number
- Operation number
- Drawing number and engineering change level (in case of a change since the documentation was issued)
- Production quantity, that is, the number of pieces to be completed at this operation – usually the number reported at the previous operation
- Number of containers used to move the job
- Notification of components or tools that have not yet arrived at the work center. (If Stores has supplied an estimate of when these will be available, this estimate also appears. This eliminates time lost in searching for items that have not yet been delivered.)
- Overlap or parallel running code and the send-ahead quantity
- Notification that the previous setup should be retained

- In the case of an added or changed operation, the full operation description, standard times, tools, and required components
- Location of material and tools in the work center

Several jobs can be dispatched to the operator at the same time, depending on the length of job and normal shop practice. This reduces operator time spent picking up new assignments.

Shop Order No.	Op No.	Dwg. No.	Level	Qty.	Overlap Code	Parallel Run	Tool/Matl. Loc.	No. of Containers
12470	020	12470	E	45			A135	1
Op Description (New or added ops.)			Tools/Materials Required				Tools/Materials Missing	

Figure 34. Job dispatching

Job Acceptance/Job Start

In most cases, the operator can accept the next job and start it immediately. Tools and materials should already be available at his work location, as a result of the materials handling and tool control functions (see these sections later).

If all items are available, the employee enters his man number and the shop order identification card from the shop packet into the work station terminal, with a transaction code for "job start". The system checks the order number against the foreman's assignment and confirms that the assigned job has been reported. At this point, the system changes the job and machine status to either "being set up" or "running".

Occasionally, items are misplaced or the supporting department has not provided the materials or tools as they reported. The operator cannot accept the job because these items are not available, and he indicates this by entering an "interrupt" code and the shop order identification card into the work station terminal (see "Reporting Interruption"). An alarm message is sent to the foreman, who must then decide whether to wait for the missing items or begin the next job.

Reporting setup

If the routing specifies setup as a separate operation, setup is assumed to start when the employee starts the job. When setup is complete, the employee enters a "setup complete" code and his identification (by badge or card or through dialing) in the work station terminal. The setup is then recorded in the employee's daily activity history record and the order and machine status record are changed to "running". When setup is not done by the operator himself, it is reported separately by the setup man.

Reporting Interruption

A job may be interrupted for many reasons that the system cannot anticipate. The accompanying table lists some of the most common.

Reason for Interrupt	Code
Machine Breakdown	01
Tool Breakdown	02
Waiting Materials	03
Waiting Tools	04
Waiting Blueprint	05
Waiting Planning Change	06
Waiting Materials Handling	07
Waiting Foreman	08
Union Business	09
First Aid	10

Interruptions are reported by setting the dials on the terminal to the appropriate reason code (for example, code 01, "machine breakdown"). When the "machine breakdown" code is entered, a request for assistance is automatically sent to the Maintenance Action File (see *Chapter 9, Plant Maintenance*). The foreman is also notified via an alarm message, and the status in the facility record is updated.

A labor transaction is generated containing the time at which the interruption started. This goes to the employee's daily activity record. The operator is logged onto indirect labor until the next transaction is reported. Figure 35 summarizes these activities.

Requesting assistance

The employee may also use the local work station terminal to request additional help, such as a maintenance man, inspector, crane operator, or foreman. Dialing a code requesting the particular facility required causes a message to be set up in the Action File of the department or man responsible, and the request is printed or displayed at the appropriate work center. Figure 36 indicates how action messages will look to the foreman when he reviews his file.

In most cases, setup, inspection, and materials handling are automatically scheduled by the system. This "special request" capability is for extra handling, or events difficult to schedule, such as the inspection of the first or the hundredth piece.

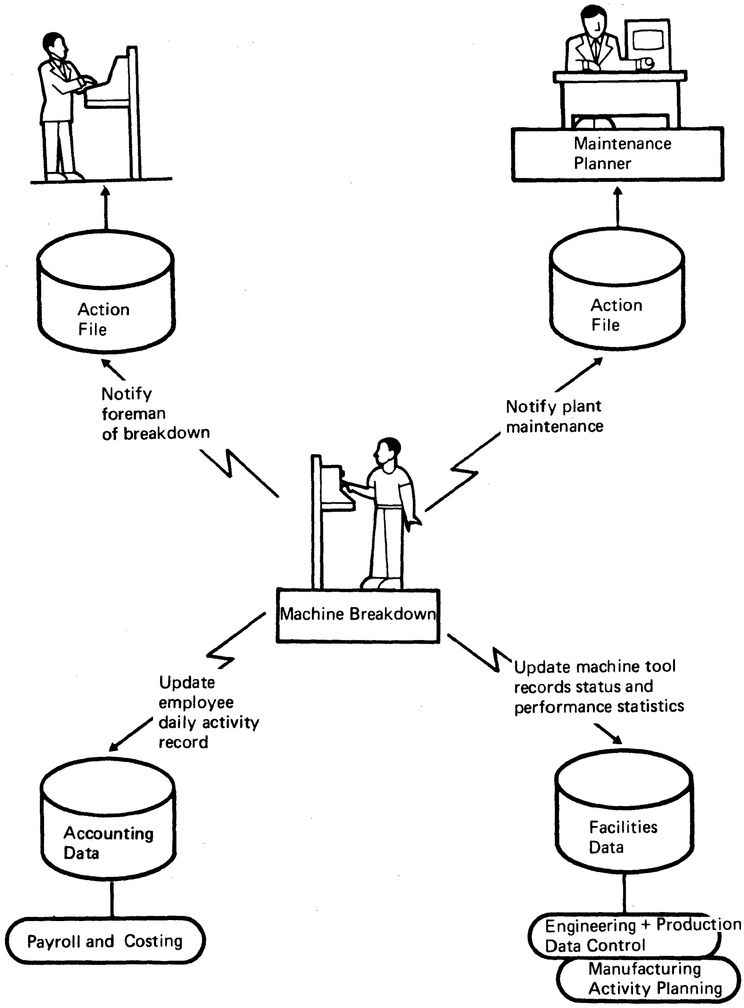


Figure 35. Notification of interruption (machine breakdown) sets a number of activities in motion

```
TIME 14.32 MACH. NO.37  MAN  SMITH  REQUEST  HELP
TIME 14.35 MACH. NO.32  MAN  JONES  REQUEST  NEW ASSIGNMENT
TIME 14.36 MACH. NO.17  MAN  BROWN  REQUEST  NEW ASSIGNMENT
```

Figure 36. An example of how requests for assistance are printed on the work area terminal via the foreman's Action File

Reporting Teamwork Activity

Production reporting of teamwork is almost identical to that of individuals. The major exceptions are:

- Only the team leader reports setup, production, and indirect labor and receives new assignments.
- Only one badge or team number is used to report transactions.
- If employees are paid on an incentive basis, the system must be notified of any change in the makeup of the team, along with the quantity produced up to the time of the change.

Reporting with Multiple Machine Assignments

Reporting production activity when multiple machines have been assigned to an employee is identical to normal reporting except that the machine number must also be entered, either manually or by card or badge.

Job Completion

When the operation has been completed, the operator reports by inserting his badge in the work area terminal and entering the completed quantity and a code for "job complete". He may also enter any quantity scrapped.

The system balances the reported quantity against the originally assigned quantity. If the calculated difference agrees with a previously established tolerance, the transaction is accepted. Production efficiency, direct labor costs, and payroll data can be immediately calculated at this point. The system also tests the transaction for reasonableness (see "Transaction Editing and Error Control"). Checking the validity of the piece count can be done by computing the efficiency rate and comparing it with the historical efficiency.

If the quantity scrapped occurs on one of the first operations and lies outside a previously established tolerance, it may be feasible to replenish the scrapped material immediately. The system can be instructed to notify the operator to retain the setup, pending delivery of additional material.

In some circumstances the operator can report completion at his local terminal without leaving his workplace. He does this when:

- He has been given more than one job to do.
- He has previously been dispatched a job by supervision or a shop clerk as described earlier.
- He is not going to start another job immediately – perhaps because of cleanup, union business, etc.

In any such case he enters his man number, "job completion" code, and possibly the quantity completed.

The next job assignment is dispatched as soon as the job completion transaction is entered at the work area terminal. This assignment is made automatically in the sequence prescribed by the foreman.

Activities initiated at job completion

All status files are immediately updated (see Figure 37) and the coordinating support departments are notified to take action:

- The completed job is removed from the "current job" column of the machine status record. The next assigned job is moved into the "current job" column. The "assigned backlog" hours column is reduced to reflect the completion of the job.
- The order status is changed from "running" to "complete" on the work sequence list of the completing work center.
- The employee's daily activity record is updated to reflect the completed operation.
- Materials Handling is informed to move the job to the next center (see "Materials Handling Control").
- If returnable tools have been involved in the operation, their status records are updated to reflect that they are "available" (see "Tool Control").
- If the tools are to be returned to the toolroom, Materials Handling is instructed to move them.
- The shop order record is updated to reflect that this operation has been completed. This information is one of the primary inputs to the system's planning section.

- If an inspection is required before the next operation is started, a message requesting an inspector can be generated (see "Manufacturing Quality Control"). *Note:* If the inspection operation involves a move to a special testing or inspection location, it is treated as a separate operation.
- If preventive maintenance has been scheduled to follow the completion of the job, a message is generated for the maintenance department indicating that the machine is now "available". (This notification is sent out a short time in advance so that maintenance can plan to have a man there very near to completion. See *Chapter 9, Plant Maintenance* for more detail.)

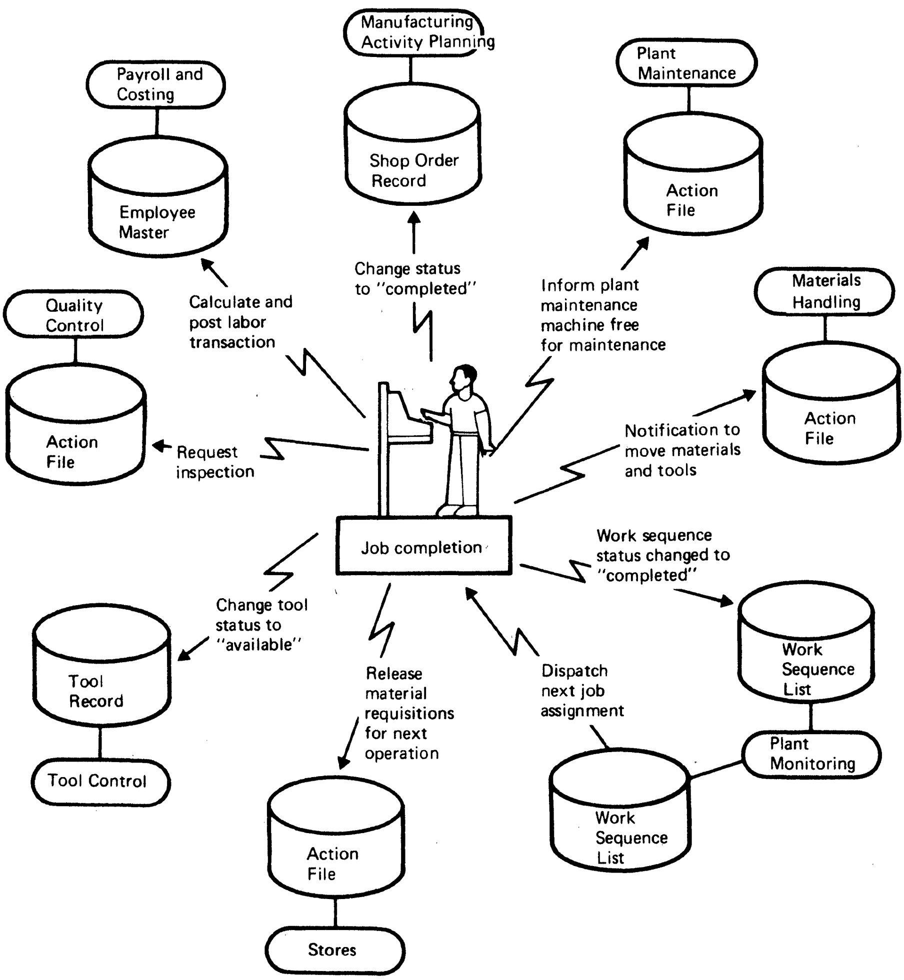


Figure 37. Activities occurring at the end of the job completion

Partial completion of order

Because of interruptions, arrival of a higher-priority order, insufficient material, end of shift, etc., a job may be only partially completed. This is reported at the work station terminal, by entering the man number, the partial quantity, and the "partial completion" code. Work is resumed as in "Job Acceptance/Job Start".

Reporting teardown

Some companies report "teardown" (or "setdown") separately – for example, dismantling of assembly jigs, cleaning of vats or machines, etc. Teardown should be executed after the operator receives his next job assignment. This avoids the destruction of a common setup. If the teardown allowance is indicated on the routing, he reports by inserting his man number and a "teardown complete" transaction code. Alternatively, start of the next job can be assumed to be end of teardown.

End-of-shift reporting

The peak load on the plant communication system normally occurs at end of shift when operators are reporting the number of pieces completed. One of the commonest ways of overcoming this peak load is to allow end-of-shift piece counts to be reported at any time during, say, the last 20 minutes before shift end. This reporting is done as described in "Partial Completion of Order". If a job is reported as complete at end of shift, no new assignment is made. The operator receives his new assignment the next day.

Summary of the Transactions

Figure 38 summarizes the different transactions. In all cases, a minimum amount of data must be entered by the employee. Employee terminal training is therefore simple, the chance of error is reduced, and time spent at the terminal is minimized. The use of a simple work station terminal also reduces walking distance and communication facilities costs.

Transaction Editing and Error Control

As transactions are made, they are checked for accuracy and reasonableness against status data maintained by the system. If a possible error is detected, the employee is asked to correct the erroneous data or to confirm the data in question by entering a code.

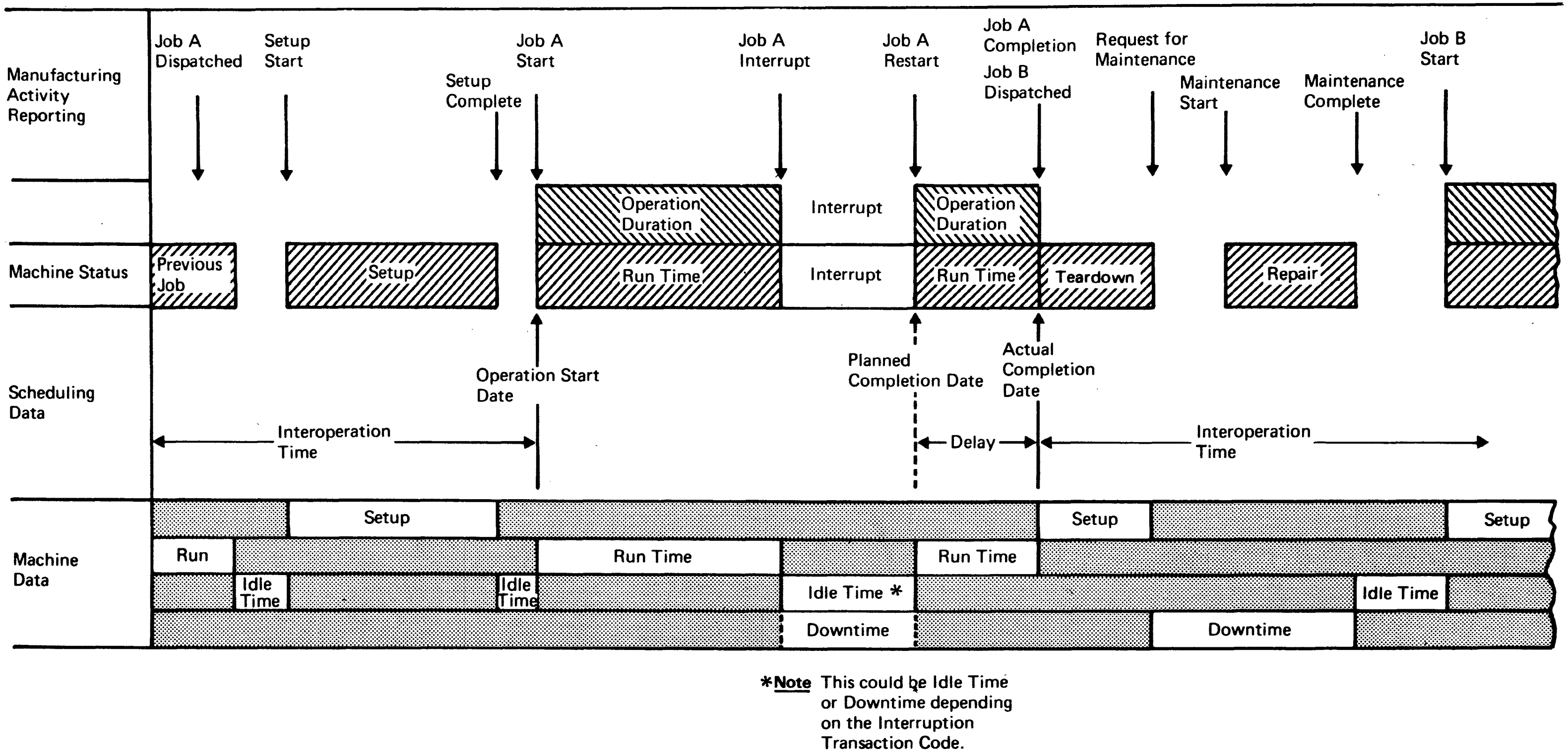


Figure 38. Summary of the transactions made to report manufacturing activity

If the operator reenters or confirms and the system still detects an error, the operator is instructed to contact his foreman or to proceed to his next assignment. The decision to proceed is based on the type of error. For example, if an excessive quantity has been reported, he may be allowed to proceed; if he has reported an insufficient quantity, he will not be allowed to proceed, because he may have missed some parts. In the case of repetitive errors, the Transaction Control Center is notified (Figure 39). In many cases the operator cannot himself correct the error; for instance, he may have been given the wrong shop order identification card, and the system does not accept it.

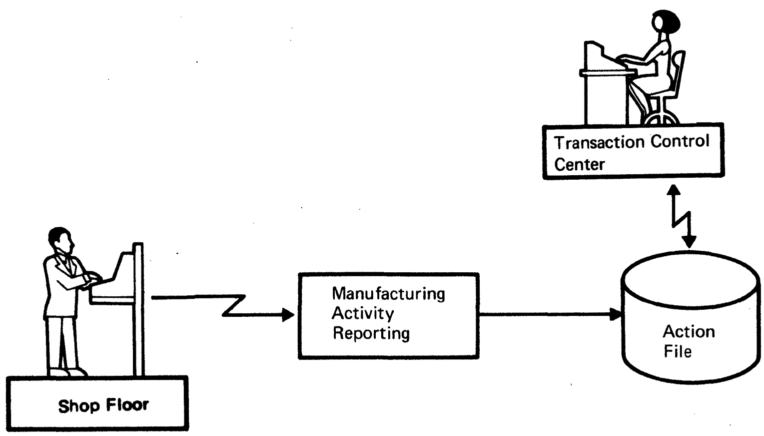


Figure 39. The Transaction Control Center is notified of errors not corrected by the operator

Notification to the Transaction Control Center is in the form of an Action File, which ensures that all errors are handled promptly and completely. The errors needing immediate correction – for example, those holding up a new assignment – are given priorities to ensure that they are handled quickly. A log of all errors is maintained for each employee. This indicates when retraining is necessary because of persistent errors.

The Transaction Control Center also handles errors detected at end of shift, thus allowing employees to leave at their normal time by ensuring that some attempt, even a temporary correction, will be made to correct important errors.

For most of the errors detected, correction involves the use of terminals (see "Implementing Changes to Shop Orders"). Examples of commonly detected errors are:

- The quantity reported as completed exceeds the previously reported or assigned quantity. This is an overrun or a recording error.
- The quantity reported falls short of that assigned or previously reported by more than a specified tolerance. This could indicate failure to report scrap, or it may be a "partial" completion. It could also indicate that some of the parts have been mislaid.

Canceling Incorrect Transactions

Whenever an incorrect transaction is detected, the operator can cancel it by transmitting a "cancel previous transaction" code and inserting his employee identification badge. The last transaction from that work station is then canceled and the operator can enter the correct data. All such "cancel" transactions are logged at the Transaction Control Center so that operators who repeatedly make errors can be retrained in the use of the system.

Interface with Payroll and Cost Data

The payroll system utilizes the data created by the production system. When the completion of an event is reported, the system automatically calculates the elapsed operation time. The record is stored in the Employee File, which is used by the payroll system to calculate the employee's earnings.

Preparation of Shop Management Reports

The system will, on demand, produce various briefing reports – for example:

- Daily and weekly efficiency for each man, work center, department, or plant (Figure 40)
- Machine utilization (Figure 41) showing actual utilization versus planned availability

EFFICIENCY REPORT BY EMPLOYEE

DEPT.	MAN NO.	JOB NO.	ITEM NO.	OPN. NO.	QTY	TIME TAKEN	STD. TIME	PERFORMANCE %	PREVIOUS PERFORM HIGH	LOW	AVE
304	530	280	INDIRECT CODE 14			1.0					
304	530	161062	40100	090	12.0	4.0	3.0	75	88	76	84
304	530	161062	40100	090	27.0	8.0	6.8	85	88	76	84
304	530	161062	40100	090	28.0	8.0	7.0	88	88	76	84
304	530	161062	40100	090	6.0	1.3	1.5	116	88	76	84
304	530	161062	40100	095	35.0	7.0	8.9	127	110	99	102
304	530	161062	40100	095	30.0	6.7	7.6	114	110	99	102
304	530	161062	40231	080	11.0	4.0	4.1	103	89	74	83
				GROSS HOURS		40.0					

Figure 40. Example of an efficiency report

WORK CENTER 114 WELDING — FOREMAN J. CRUMP

PERFORMANCE AND UTILIZATION REPORT — WEEK 201 - 205

INDIRECT HOURS

NON RATEABLE	3 NON CHARGEABLE		.0	
	4 INDIRECT		14.0	
	8 REWORK OTHER DEPTS		23.0	
		TOTAL	37.0	
RATEABLE	5 INDIRECT		.0	
	6 REWORK OWN DEPT		2.0	
	7 WAITING TIME		.0	
		TOTAL	2.0	
DIRECT HOURS		PLAN	ACT.	EFFY.
	CODE 01	59.7	83.0	71%
	CODE 02/04	55.8	73.0	76%
	TOTAL MEASURED	115.5	156.0	74%
	UNMEASURED		52.4	
	TOTAL DIRECT		208.4	
UTILIZATION	DIRECT / GROSS HOURS			84%
DEPT. RATING	DIRECT X EFFY. / GROSS HOURS - CODES 3, 4, 8			70%
PRODUCTIVITY	DIRECT X EFFY. / GROSS HOURS			62%

Figure 41. Example of a machine utilization display report

Implementing Changes to Shop Orders

Many changes occur between release of a shop order to the floor and its completion. The system allows these changes to be implemented quickly and accurately. It is concerned with their authorization and entry, as well as the communication of their impact to all affected departments.

As the shop order documentation itself does not carry any scheduling information such as operation start dates or order due dates, there is no need to withdraw or change shop orders because of a scheduling change. The changes that do affect information already released to the shop floor are:

- *Lot splitting*, or the permanent separation of one shop order into two or more orders. This "send ahead" is usually to help relieve a shortage, and the other portions follow later.
- *Changed routing*, which involves selecting alternate operations or changing the sequence of operations.
- *Changes to time standards*, which may be needed temporarily because of off-specification material, etc.
- *Rework*, usually involving the addition of one or a series of operations.
- *Engineering changes*, which are permanent changes to an existing operation, the addition of new, or the deletion of old operations.
- *Shop order cancellation*, which may result from excessive scrap or customer order cancellation.

Some of these changes may be made directly from the shop floor. Changes to time standards, and simple rework, for example, can be initiated at a work area terminal by authorized personnel, and confirmed by printout or display detailing the changes made.

Changes to documentation and records should be made from one central location. For example, the Transaction Control Center, in addition to helping correct reporting errors, could also control change transactions (Figure 42). Reasons for centralized control are as follows:

- The terminal entries required to make this type of change involve more data and therefore require more time and clerical skill than can normally be expected from the shop floor.
- The authorization for the change may involve getting approval from multiple sources and therefore can more effectively be carried out by a central authority.

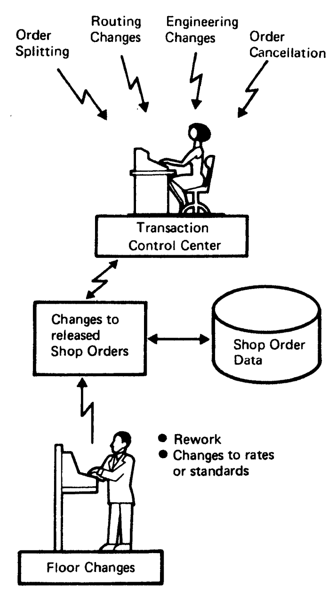


Figure 42. The Transaction Control Center can immediately transmit changes.

- Centralized control helps ensure that the change is implemented only once and disseminated to appropriate personnel who have the "need to know".

Lot Splitting

A shop order may be divided into two or more lots after an order has been released. This may be done to keep a work center running, but is more commonly done to expedite some critically needed pieces. The system's capability for expediting orders should keep the incidence of lot splitting to a minimum.

When splitting is required, it is accomplished via a terminal in the Transaction Control Center. A "split transaction" code, the number of the shop order that is to be split, and the split quantity (Figure 43) are entered via the terminal. The system replies with a description of the split order.

Upon entry of a split shop order into the system, the following events occur automatically:

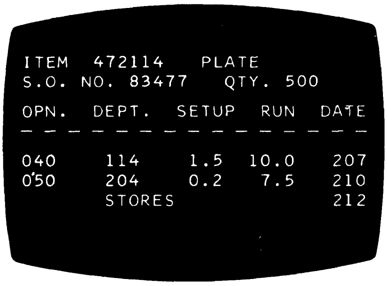
- An order number is assigned, consisting of the original order number plus a suffix.
- ORDER RELEASE is notified via an Action File to create new shop order documentation and to set up a separate shop order record for the split order.
- The original order record is updated to reflect the split, and the quantity remaining is reduced accordingly. The change is verified immediately by an alteration of the status display on the screen.

Changed Routings

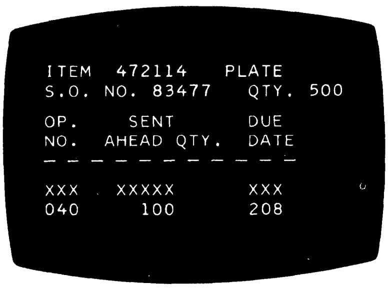
The use of alternate operations and routings is sometimes planned in MANUFACTURING ACTIVITY PLANNING. Actual shop floor conditions, however, may be such that these alternates cannot be used or that a different alternate work center would be better. In addition, orders not previously planned for an alternate work center may have to be rerouted because of a machine breakdown.

A terminal is used to select operation alternatives, change the normal sequence of operations, or call for unplanned overlapping of operations (Figure 44). The changes are immediately reflected in the shop order record and the work sequence list. The change is confirmed by displaying the revised routing on the screen. Any material or tools affected will automatically be routed to the revised work center.

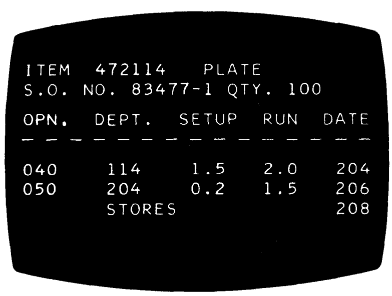
The current shop order status is displayed.



The details required to split the order are entered.



The system responds with the changed order status.



The changed record of the original order can be displayed

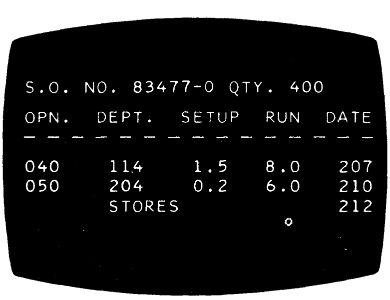
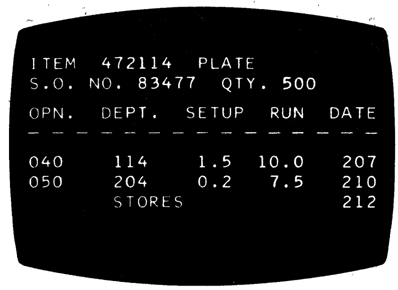
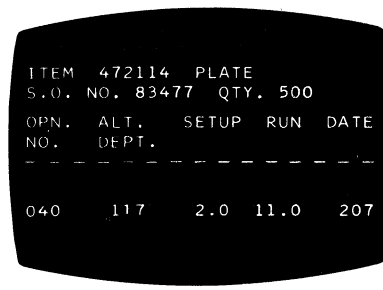


Figure 43. Splitting a released shop order

The current shop order status is displayed.



The details required to change the routing to an alternative work center are entered.



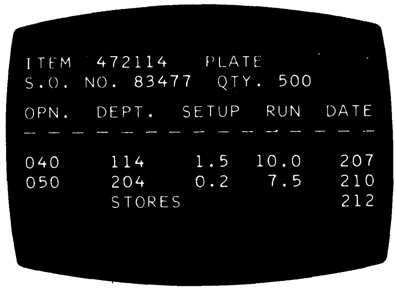
The system responds with the changed routing.

Figure 44. Routing changes, such as use of alternate work centers or changes to the normal sequence, can be made by terminal

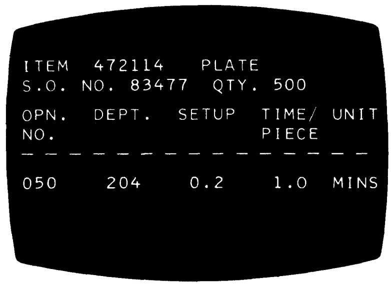
Changes to Time Standards

The use of different materials, alternate machines, etc., may require a new standard time for an operation. As soon as the new standard is available, the production engineer can enter the change on the shop floor via the work area terminal. He requests a display of the original operation on the order, and then keys in the changed times. A printout would be made confirming the change. This is illustrated in Figure 45.

The current shop order status is displayed



The engineer enters the changes to the routing.



Confirmation of the change is printed or displayed for the engineer.

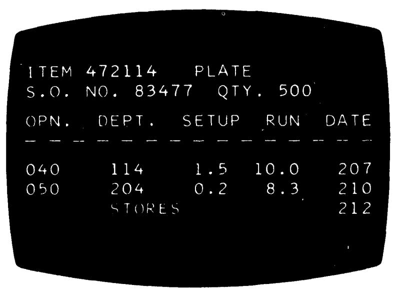


Figure 45. Changes to standard times can be made on the shop floor. A confirmation of the change is displayed or printed

Rework

If rework involves only a minor correction, the part may be recycled through the same operation. This is handled like a normal job start transaction, except that a special rework transaction code may be used.

In cases where rework is more involved, an added "rework" operation (or operations) may be needed. The engineer adds the new operation, as shown in Figure 46. The order status record is immediately updated to reflect the additional operation(s) and the work sequence lists are changed. The rework operation can now be handled by the system as if it were a normal operation.

In some cases there may be a standard rework routing already on the Manufacturing Routing File. This reduces data entry on frequently performed rework operations.

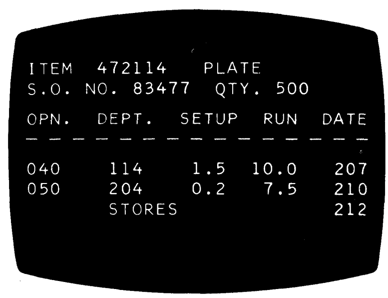
Engineering Changes

Engineering changes affecting the Manufacturing Routing will automatically generate entries to amend all outstanding shop orders. However, some engineering changes may apply only to specific orders. If these changes are implemented after order release, they must be entered at the Transaction Control Center. The engineering change may add, delete, or alter operations.

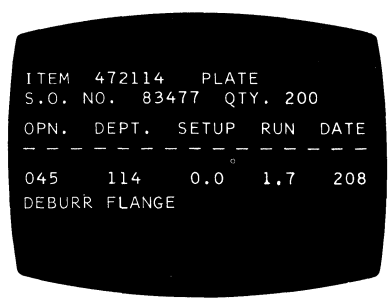
The entry is almost identical to that used for rework (Figure 46). A different transaction code is used for accounting purposes.

All changes are immediately reflected in the shop order record, and are displayed or printed for confirmation. Revised documentation is prepared as necessary.

The current shop order status is displayed.



The engineer enters the rework operation via the terminal.



The rework routing is printed for the operator.

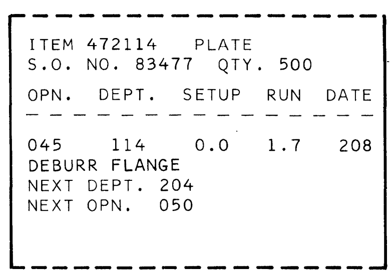


Figure 46. Additional rework operations can be entered on the shop floor

Canceling Orders

An order may be canceled before completion – for instance, when a large quantity is scrapped and the remaining quantity does not warrant further processing because of setup costs. It could also result from cancellation of a customer order.

Before the cancellation is made, its effect can be determined by the planning systems, and cancellation costs can be calculated immediately. An order can be canceled by entering a "cancel" transaction code and the number of the order to be canceled. The canceled order remains in the system's files until disposition of the work-in-process is determined.

Summary of Changes to Shop Orders

All changes to released orders must be controlled, whether they are entered on the shop floor or from a Transaction Control Center. The changes can be implemented by entering a small amount of terminal data – much less than would normally have to be written. Confirmation of the change is immediately displayed at the terminal. Coordination of activities such as preparation of new shop packets, creation of new shop order records, etc., is done automatically. The simplified procedure ensures that changes are implemented quickly and accurately.

Direct Monitoring and Control of Production Process and Operations

Direct computer monitoring or control of the production process and operations is an integral part of PLANT MONITORING AND CONTROL. The production operations – cutting the metal, forming the parts, assembling the components, etc. – are the primary events on the shop floor. *All other activities support these events.*

There are many applications for direct monitoring and control of the production machine, process or operation. Direct monitoring and control is used in two broad areas:

- *Monitoring* of the production process, machine tools, presses, automated assembly operations, etc.
- Direct control of the process or machinery
  - Machinery with built-in controls
  - Numerically controlled machines

Machine or Process Monitoring

The computer can directly monitor activities during production or assembly operations by its attachment to switches, counters, sensors, and other instrumentation throughout the plant floor. These devices sense such activities and conditions as:

Power on/off status

Machine or process status

Feed rates

Temperatures

Flow rates

Pieces produced

The information gathered from these machines and processes is transmitted direct to the computer system. That is, an operator does not have to read or record production rates, machine stoppage, etc.

The computer uses this current process data to generate messages and automatically transmits them to control points, for instance:

- Exception reports highlighting variations in production rates.
- Notification of machine stoppage and reason.
- Information regarding machine running conditions, such as hydraulic pressure being low, or maximum bearing temperature being exceeded. The operator is warned of such conditions as they develop. The computer can be instructed to stop the machine when the maximum temperature or minimum pressure is exceeded.

Continuous computer monitoring of production machines and processes relieves the foreman of much time normally spent checking. He can thus devote more of his time to supervision and increase his span of control, knowing an action message will tell him when attention is required.

As opposed to conventional methods which notify the foreman only after something has gone wrong, the system becomes "event-responsive" in that it notices when things begin going wrong.

Types of equipment monitored

Lathes, presses, multistation machine tools, transfer lines, moulding machines, etc., are all candidates for monitoring – also forming, drilling, welding, casting, grinding, and milling machines. The machine being monitored may be manually or numerically controlled.

Generally, with more complex equipment, higher equipment costs, and more interrelated production processes, the need for production monitoring increases. The objective of production monitoring is to keep the machine as fully utilized as possible and thus improve productivity.

Functions of machine or process monitoring

The following are the major functions addressed by machine or process monitoring systems.

production counting

Accurate piece counting means a reduction in the costs incurred by producing excess pieces, or the costs of additional setups due to production of less than the required quantity. Without direct monitoring the system is dependent on historical recording of production by an operator. With direct monitoring, overruns can be stopped immediately.

checking production rate	The time required to make an item is reduced because the machine is running at optimum speed. This means a lower cost per piece. The system can detect the change in the production rate if the operator runs the machine faster or more slowly than the optimum rate for the job. By preventing excessively high running rates, direct machine monitoring helps improve product quality and reduce wear on machines and tools.
monitoring machine status	Accurate statistics on downtime, idle time, machine utilization, etc., are obtained automatically by monitoring the machine status on a continual basis – for example: Is power on or off? Is the machine cutting or cycling? End-of-shift reports can be produced summarizing the machine status for the complete shift.
monitoring machine running conditions	The computer can directly measure running conditions such as feed rate, temperatures, flow rate, coolant conditions, oil pressure, etc. This helps ensure that machines operate at or near their optimum running conditions; downtime due to operator error or misuse is therefore reduced and throughput is increased. Early detection of changes in running conditions means also that the faults can usually be corrected *before pieces are scrapped.*
pinpointing faulty equipment	The system helps pinpoint internal machinery faults, such as malfunctioning switches, relays, etc. The maintenance man can thus be directed straight to the faulty mechanism. The result is minimum downtime and a reduction in maintenance costs.
automatic data collection	Automatic collecting of production and interrupt data means less reporting by the machine operator. The risk of operator error and the time spent in piece counting, walking, etc., are reduced.
scheduling tool changes	A tool change notification can be generated in advance of the required change. The system can monitor to make sure the machine is scheduled for the needed change. This helps ensure that the change is made at the right time, thereby decreasing scrap and increasing tool utilization. The time taken for the tool change is measured against the standard. This capability allows precise evaluation of tool performance because accurate count statistics can be compared against tool wear to help determine the best point at which to make a tool change.

Multiple tool changes can be coordinated to occur at one time, thus reducing idle time. With the knowledge of when future tool changes will be required, tool changes can be staggered to optimize the use of the setup man's time. Other service functions, such as preventive maintenance, can also be coordinated to occur at the same time as tool changes.

Direct Control

Direct Control is the application of computers to feed information direct to machines or processes to control their operation. There are many types of computer control applications, depending on the types of machinery and processes involved.

Process Control is not discussed in detail here. Basically, the computer takes process status data, compares it against the best performance, and then provides feedback control signals to bring the process to the best operating point.

Machinery Control falls within two broad categories: Machine Control (MC) and Direct Numerical Control (DNC). The MC application is the broader of the two and consists of machines that have built-in sequences of functions that a computer initiates by various types of signals. DNC is the application of computers to directly control the operation of machines. It is the online extension of controlling machinery that operates by reading numerical instructions from a computer-prepared tape. As shown in Figure 47, the computer can be used in a tape reader bypass system, or it can perform the functions of a conventional controller.

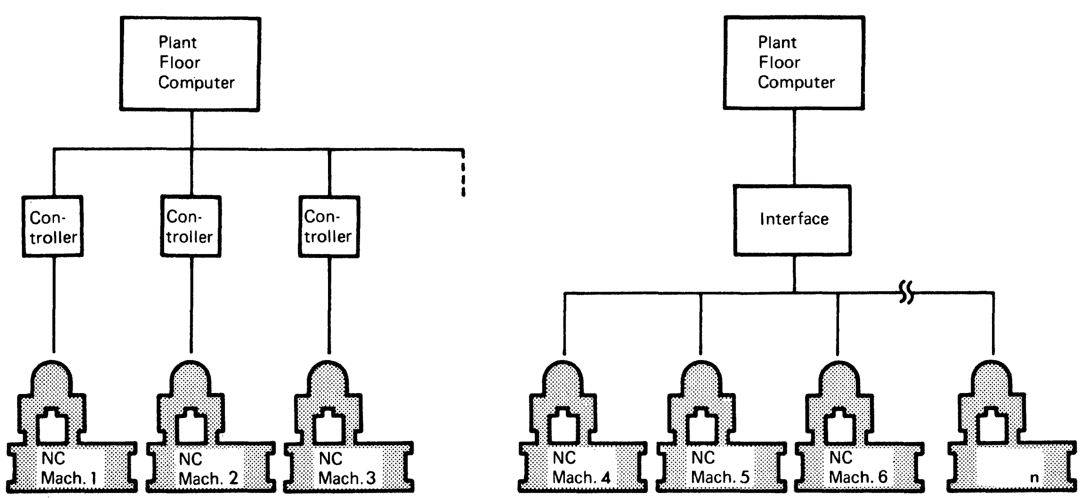


Figure 47. A local computer acts as a tape reader bypass system or replaces part of the conventional controller

In many instances a DNC user may decide not to eliminate the controllers and their tape readers on DNC machines because they represent a low-price backup in case of system malfunction. With or without the controllers and tape readers, however, DNC provides the advantage of eliminating the troubles caused by tape breakage and malfunction of tape input/output devices. It also reduces the waiting time for parts program editing, the possibility of using an out-of-date tape, and the physical handling and storing of an NC tape library.

The computer has made it possible to integrate individual NC machine tools into the overall manufacturing control system, thus closing the control loop and allowing information to flow both to and from the machine tool.

DNC has been applied in many areas of production – for instance, with machine tools, drawing machines, flame cutters, and welding machines.

Equipment functions

Figure 48 illustrates the different units utilized in a DNC system. They are part of the same plant communication system used for Manufacturing Activity Reporting.

central computer system

The same central computer system that oversees all other areas of manufacturing is used to run the high-level NC languages and to store the "parts programs" needed. It has the functions of maintaining and transferring to the plant floor computer all the DNC data that is to be used.

plant floor computer

The plant floor computer receives DNC data from the central computer, stores the data, and sends it to the attached DNC machines as required.

interface

The interface between the plant floor computer and the DNC machines may be either a controller or a simpler device. In either case, it receives control data from the computer and forwards it to the machine tool drives and other components for action.

visual display terminals

An online terminal situated close to the machine tool allows the final preparation and testing of parts programs "on-side". During an actual run, errors can be detected and corrections entered into the computer, allowing an immediate retry. The time for checkout and maintenance of parts programs is considerably reduced.

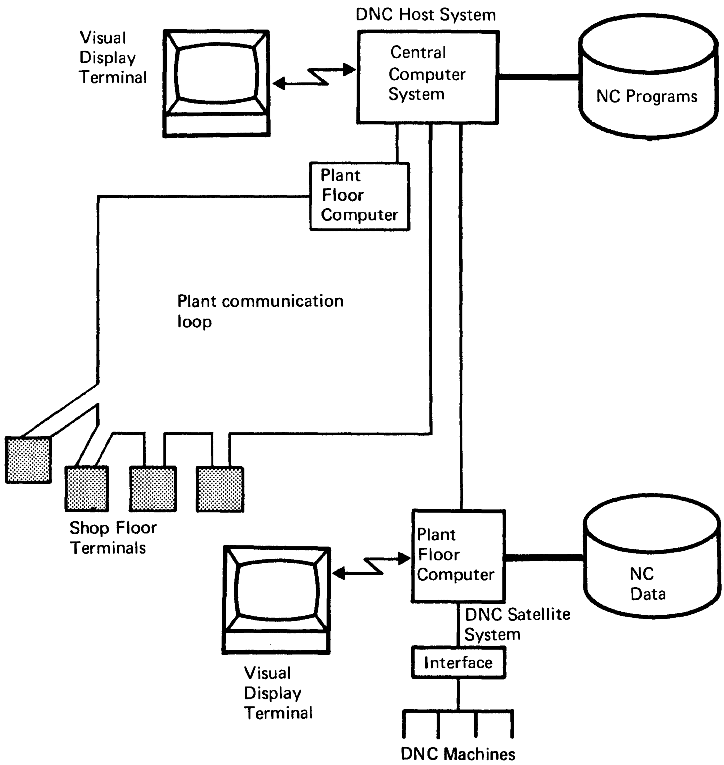


Figure 48. The DNC system is part of the plant communications system

The objectives and benefits of DNC include:

- Fast loading of the NC program required for a machine, with a consequent reduction in machine setup time.
- Ability to quickly check out new programs and change running programs, which means reduced turnaround in getting jobs running on the machine and more time spent in producing parts.
- A mode of operation between the parts programmer and the system, allowing the programs to be optimized during testing and thereby giving increased performance.
- Ability to incorporate adaptive control as an integral part of the system. Adaptive control means that feeds and speeds are optimized according to actual feedback measurement from the machine tool – for instance, because of material characteristics. This enables the *maximum throughput* or *maximum cost per piece* to be achieved within the limits of tolerances, tool life, and surface finish.
- A means to obtain increased utilization because of DNC's ability to provide online status information.
- Replacement of paper tape readers, which are a source of transmission errors and which require considerable maintenance.

Summary of Direct Monitoring and Control of Production Process and Operations

Attaching the computer direct to the production process provides the means to initiate corrections much faster when abnormal conditions occur. Realistic production rates can be established, thereby increasing productivity without overloading the operator. Monitoring produces data for shop supervision to help operators manage work stations with more optimal methods. Continuous monitoring by the computer can free much of the time the foreman spends determining online status and thus enable him to effectively supervise more men and equipment.

Experience indicates that because of reductions in setup time, better communications, improved program checkout, parts program optimization, and improved reliability, DNC machines can usually spend considerably more time cutting metal than standard NC machine tools. The addition of adaptive controls can provide automatic program optimization whereby the DNC machines will cut at faster rates.

Manufacturing Quality Control

The function of Manufacturing Quality Control is to establish and maintain specified quality levels for parts, components, assemblies, and final products.

This section does not cover all the functions of inspection quality control. Tool and gauge inspection is covered later in this chapter under "Tool Control", and purchased parts quality control and the establishment of inspection requirements, sampling data, etc., are presented under "Purchase Quality Control" in *Chapter 10, Purchasing and Receiving.*

Only those functions that affect the status of the shop order as it progresses through the plant are included (Figure 49) – that is, the actual inspection, reporting, and testing procedures. The following subjects are covered:

Specifying inspection operations

Location of the inspection function

Assigning inspection work

Inspection activity reporting

Assembly line inspection

Direct computer control of testing

Objectives of the System

The objectives of the system are:

- To detect off-standard production as soon as possible, thus preventing production of further faulty items. Fast determination of where and why a defect is being caused leads to *defect prevention,* instead of *historical* defect analysis.
- To coordinate the remote dispatching of inspection operations, thus making distributed (decentralized) plant floor inspection more practical. This reduces material handling expenses, shortens the total manufacturing lead time, and reduces the idle time that results when inspectors and machine operators have to wait for each other.
- To improve the accuracy and reduce the costs of testing by means of direct computer control of the testing process.

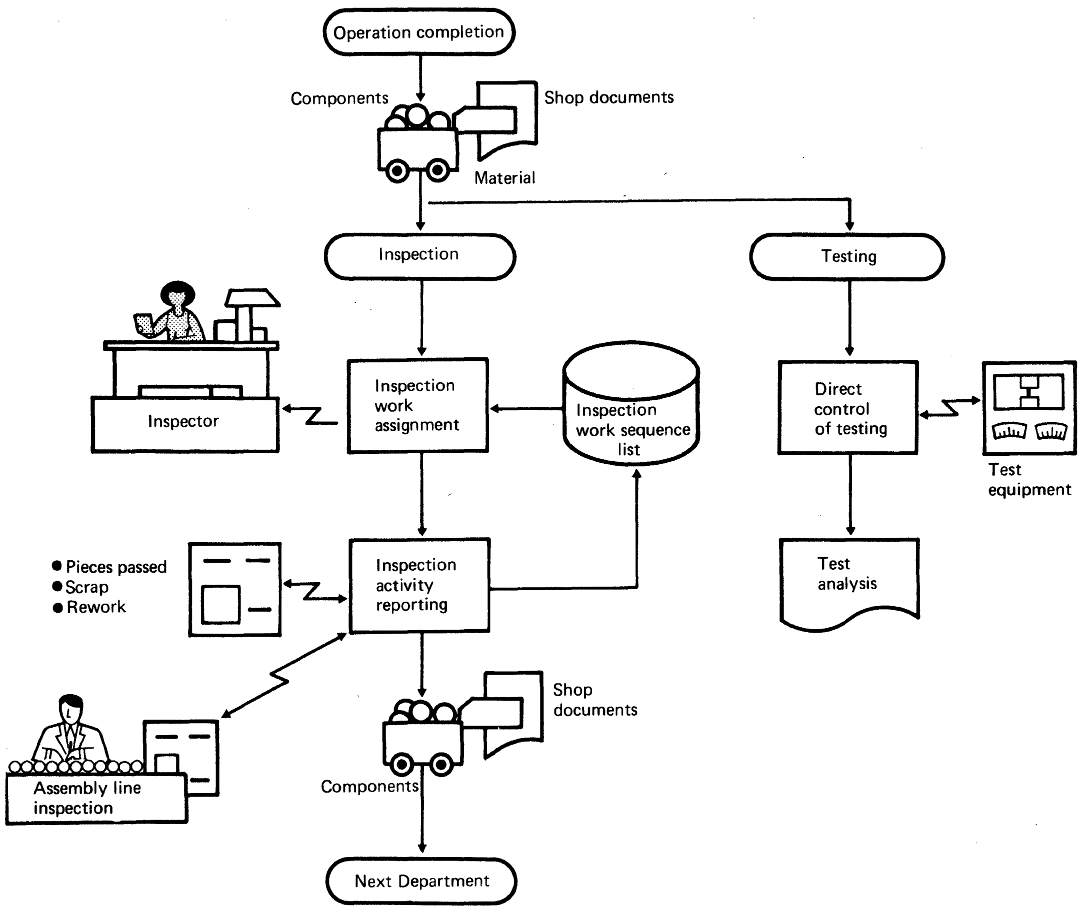


Figure 49. Manufacturing Quality Control functions

Specifying inspection operations

Separate Inspection Operations. Inspection operations may generally be treated as normal production operations; that is, they appear in the routing sheet as a sequenced operation. If 100% inspection is called for, a standard inspection time can be assigned or developed historically. If all items are not inspected, the system can develop an historical standard from inspection activity reporting. This standard is used in planning inspection activity.

The work center designated for the inspection operation should reflect the type of inspection needed. The inspection work center number indicates whether inspection is to be done at a specific location (in which case the order has to be moved) or at the department just completing the operation. Special test equipment or tools should also be listed on the Manufacturing Routing. If the inspection is overlapped with an operation, this is indicated via normal overlap coding (see "Special Techniques Affecting Lead Time" in *Chapter 6, Manufacturing Activity Planning*).

Recording of inspection operations allows statistics to be built up on inspection time, from which the workload on the inspection departments can be planned.

Inspection Not Separately Specified. In many companies, inspection is done primarily at the production work center, although this is not reflected on the Manufacturing Routing. As described under "Capacity Requirements Planning" in *Chapter 6, Manufacturing Activity Planning,* time for this type of inspection is allowed for in the interoperation time segment of manufacturing lead time. It is normally specified as a percentage of the operation time (for example, in work center 112, inspection time is allowed as 10% of the operation duration).

Location of inspection function

The nature of the manufacturing process, the product being produced, and the type of inspection required determine whether inspection is distributed or centralized. With computer-based inspection and quality control it is practical to have both centralized and distributed (decentralized) operations.

Assigning inspection work

When inspection is specified as a separate operation, MANUFACTURING ACTIVITY PLANNING treats it in the same way as a production work center.

The inspection work centers receive a work sequence list in the same format as a production work center foreman. Dispatching and reporting of inspection operations follows procedures identical to those for direct production operations. However, the inspection department's work sequence list is more unpredictable than that of a production department. For example, some inspection operations are performed shortly after the operation is started (say, after the first 10), or at stated intervals (after every 100 pieces). This type of inspection cannot be effectively scheduled in advance. Therefore, it is handled by a direct request from the machine area (see "Requesting Assistance"). The requests are assigned a priority by the system and are placed high on the inspection department's work sequence list. This ensures that they receive attention quickly.

The inspection foreman can utilize the system to dispatch work to a widely dispersed inspection force. Assignments are made at a central inspection terminal. Several jobs can be assigned at one time, and assignments can easily be altered to handle high-priority jobs (see ("Job Assignment").

Inspection activity reporting

The inspector reports the completion of his current assignment from any work area terminal on the plant floor. He reports by entering his badge, the shop order identification card, and the results of his inspection (quantity accepted, quantity rejected, and reason code). He immediately receives his next assignment on the work area terminal's printer (Figure 50). The assignment may be in the same department or in one nearby.

Required inspection materials listed on the routing, such as tools or gauges, should already have arrived. They are scheduled and moved on the same basis as tools and material for production operations.

After the inspector locates the job, he inserts the shop order identification card and a transaction code in the nearest terminal to indicate start of the assignment.

When he completes the assignment, he reports on the closest work area terminal and automatically receives his next assignment. Job interruptions are reported just as they would be for normal production work.

INSPECTION ASSIGNMENT

NAME D.JONES MAN NO. 4721

W/C NO.	MACH.	SHOP	ITEM NO.	ITEM DESCRIPTION	OP NO.	QTY.
301	27	47321	801426	VALVE	030	420

INSPECTION TASK	DWG. NO.	LEVEL	RATE
10% SAMPLE	801426	E	1.5 HRS

TOOL DESCRIPTION	TOOL NUMBER
3/4 IN. DIA. GO/NO GO + ·010	241023
GAUGE	192471

Figure 50. The inspection assignment

This procedure, almost identical to that used for normal production, offers several advantages:

- The inspection foreman can review all pending requests for inspection. This allows him to sequence assignments so as to reduce inspector transit time.
- High-priority jobs are dispatched first. Waiting time for both the inspector and the production worker is reduced. The worker, assured of fast response, doesn't request inspection until he is ready, and the inspector can move from job to job with a minimum of delay.
- Inspection costs can be directly related to the specific shop order for which they are performed.
- The system monitors total job time and the time spent between assignments, and thereby calculates inspector efficiency and compares it with historical averages.
- The inspector can use any work area terminal to report job completion and receive his next assignment. This eliminates the need for him to return to a central dispatching point, and it gives the inspection foreman complete freedom in assignment.

Assembly line inspection

In assembly line operations, inspectors are often posted right on the line and, as assemblies pass by, perform inspection and tests and report the results. These results can be entered at a terminal located at the inspector's station. The inspector enters:

- The serial number of the unit inspected. This is obtained from a punched card accompanying each unit.
- A defect code indicating the trouble – for example, 101, meaning "left panel loose".
- The man number of the employee performing the assembly operation. In operations where a series of small assembly lines are feeding a central inspection point, the man performing the assembly operation often identifies himself by stamping the operation number and his man number on a card that travels with the material.

The defect entries are accumulated and compared with predetermined quality limits. If these limits are exceeded, an alarm message is generated in the department performing the assembly operation (Figure 51), thus pinpointing the problem, its location, and even the man involved.

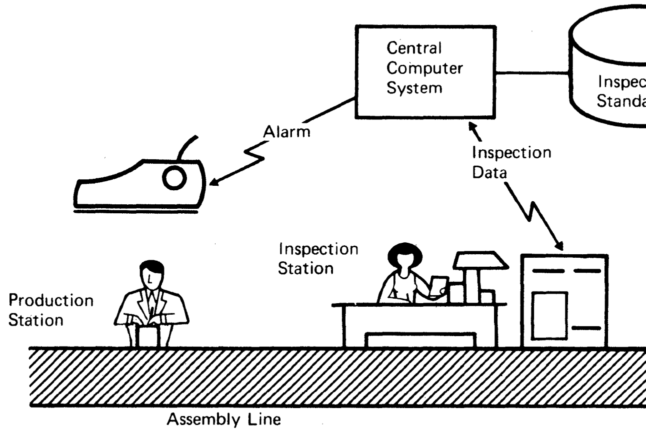


Figure 51. Inspection data is checked against standards

This procedure relieves Inspection of attempting to detect trends and allows concentration on the inspection function. More important, it can pinpoint troubles as they are happening, thus reducing the incidence of off-standard production.

The inspection data for each part, assembly, or product can be printed as a guide for rework.

In products where selective fits are required, such as pistons, the critical dimension can be measured and fed direct to the computer for classification. The on-hand inventory of the various size groups can be used to set the tolerance limits for the manufacture of the matching parts.

Direct Control of Testing

With the increased complexity of products and the greater volume of production, more attention is being focused on production testing.

The same type of plant floor computer used for control of production machines (see "Direct Monitoring and Control of Production Process and Operations") also fulfills the need for better measurement and testing procedures (Figure 52). The computer performs a wide variety of functions from simple "go/no go" decisions to total monitoring and control of complex test sequences, such as engine-testing.

Automating test equipment reduces setup, test time, and costs, and improves product quality. Computers, directly attached to the test equipment, can further improve the performance of this equipment by assuring that it is operating correctly and that the test sequence is performed as specified.

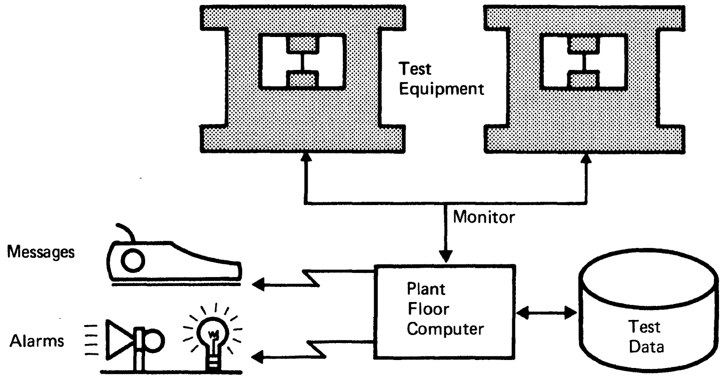


Figure 52. The plant floor computer is used to monitor and control test equipment

Types of equipment monitored

The following are four examples of computer monitoring and control of test equipment.

engine testing

Data obtained directly from attached instrumentation (such as oil temperatures, RPM, torque, oil pressure, manifold pressure, exhaust temperature, etc.) is compared with preset limits to perform "critical point" checking. Tests are controlled by the computer, which directly controls the throttle and therefore can take an engine through a prescribed test sequence.

precision products

Compensation for known ambient conditions, such as heat deflection, can be programmed into the computer to provide greater accuracy. The amount of roll, pitch, and yaw inherent in measuring devices can be determined by sensors and compensated for by computer calculations.

engine exhaust analysis

Exhaust gas components are analyzed for constituents such as carbon monoxide, carbon dioxide, hydrocarbons, oxides of nitrogen, etc. At the end of the test the concentration and/or volume of each monitored gaseous constituent is computed.

circuit testing and analysis

Continuity, impedance, test stimuli, circuit output, etc., can be measured in a prescribed manner for each item under a variety of conditions. Rejected circuits or lots are reported, along with the reason for rejection.

Features of online testing

Some of the important features in the direct computer monitoring and control of test equipment are as follows:

- Test results are automatically captured by the computer as they occur. The system continuously performs required analysis procedures. Very complex statistical analysis can be performed. When out-of-limit conditions occur, the system directly informs the responsible production department. The result is improved quality and higher yield.
- The computer can automatically control operations that have previously been handled manually – for example, controlling the movement of products into and out of the test stand, or moving the throttle. This ensures that the test proceeds at a uniform, maximum speed, thereby increasing throughput. It also ensures that all tests are administered as prescribed in a consistent manner.
- Instructions to vary the test sequence can be easily entered, thereby increasing the flexibility of the test equipment and speeding the setup for new components. This reduces the need to change or to obsolete test equipment.
- Instrument costs can be reduced because many of the specialized functions built into instruments can be carried out by the computer system.
- Automatic instrument calibration can be periodically performed to see that instruments perform to preset standards. If the test equipment fails to perform within the prescribed limits, the computer shuts down the test station and advises the operator of the problem location.
- The test sequence can be varied on the basis of early test results. For example, if the product is borderline, the test sequence can be made more exhaustive. This also means that good products can be tested in a shorter cycle.
- Any equipment malfunction which could cause serious damage is detected faster and the test equipment automatically shut down to protect the item or test equipment.
- The test results can be immediately printed and attached to the component or assembly.
- Critical events that occur at short intervals during testing can be detected and plotted for later analysis.
- Data collected by the computer during testing can be logged for later test result analysis.

Analyzing test results

Test data is usually collected at the many test locations throughout the plant. After it is analyzed, a report is produced for management review. Since analysis of the data may be complex and time-consuming, the elapsed time from the end of the test to final conclusion is usually quite long. During that time, the causes of rejects, off-standard products, or low yields remain unknown.

Attaching the computer directly to measurement and test equipment significantly reduces the time between the end of the test and the analysis and reporting of results (Figure 53). Consequently the costs of off-standard production are reduced.

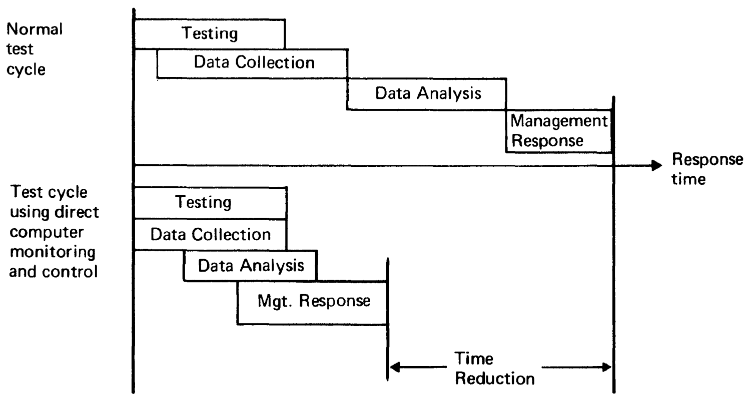


Figure 53. Computer collection and analysis of test results reduces the response time

Summary of Manufacturing Quality Control

Computer-based inspection and quality control provides improved testing facilities, consistent testing, reduced test time, immediate alarms in the event of off-standard work, and timely information on quality.

Inspection reporting via terminals involves less paperwork, produces on-time reports, and provides job status information at all times. Assigning and dispatching work as though it were a production operation improves control over inspection and reduces waiting time.

Materials Handling Control

A vital function of every shop floor operation is the handling and movement of work-in-process inventory. Estimates have been made that between 15% and 30% of a factory's manpower costs are for materials handling. These estimates include not only the time spent by personnel assigned directly to materials handling operations, such as truck drivers, fork lift operators, crane operators, etc., but also the time spent by machine operators and assemblers picking things up and setting them down, trying to locate items, or going to the storeroom for a missing tool or an extra part.

This section addresses scheduling and dispatching material movement, reporting the location and delivery of material, and direct computer control of automated materials handling equipment on the shop floor (Figure 54). Materials handling in the receiving area and stores is discussed in *Chapter 10, Purchasing and Receiving* and *Chapter 11, Stores Control.* Outside transport is discussed in *Chapter 2, Customer Order Servicing.*

The materials handling system applies not only to the movement of work-in-process between stores and work centers, but also to:

- Tool movement to and from the tool storage areas
- Movement of blueprints to and from the printroom or drawing library
- Miscellaneous materials and supplies requested from stores

Functions of Materials Handling Control

The functions outlined provide the following capabilities:

- A priority dispatching system that ensures the movement of important orders first and minimizes waiting time.
- Remote dispatching, which allows materials handlers to receive move assignments from any work area terminal. This reduces the handling of partial loads, makes better use of existing materials handling facilities, and enables rush orders to be picked up by the closest suitable materials handler.
- A move reporting system that pinpoints the location of all materials and materials handling facilities. This reduces search time spent by materials handlers and the incidence of lost material.

- The ability to handle requests such as delivering material to a specific machine rather than a general area. This reduces materials handling by direct workers, as well as the need to have material movers or laborers assigned exclusively to an area.
- Direct computer control of automated handling equipment such as conveyor lines.

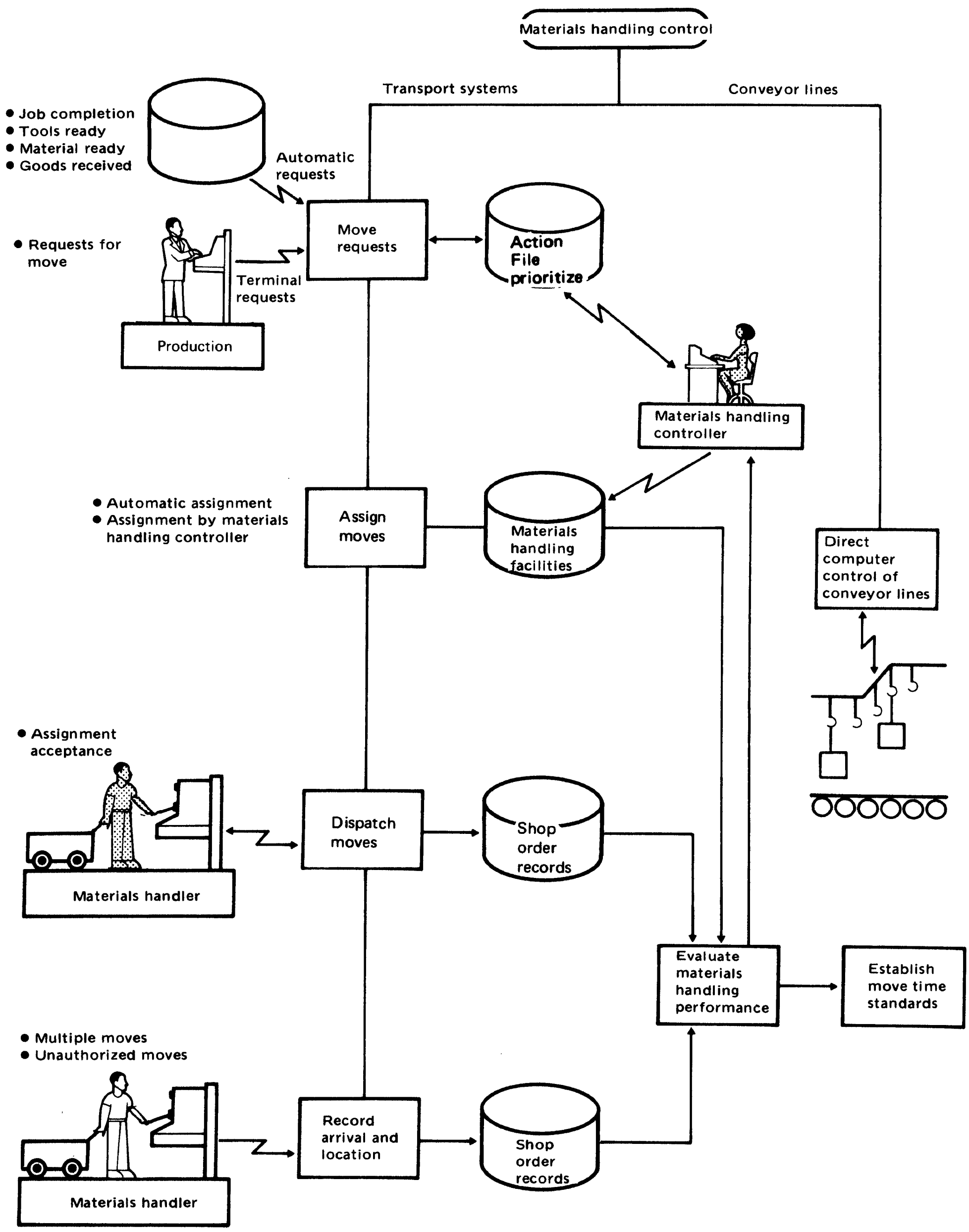


Figure 54. Functions of materials handling control

Material identification

Whenever possible, all material moved should be identified by a document that can be read by the plant communication terminals. (Failure to move the right item means that parts can be physically and "administratively" lost.) The materials handler is thus able to identify each move to the system, ensuring that the right item is moved. For example:

- Shop orders are identified by the shop order identification card in the shop packet.
- Tools are identified by tool identification cards or badges attached by tool stores.
- Material requisitions (for other than the first operation) are identified by the shop order identification card or by the item number entered at the terminal.
- Receipts are identified by a receipt identification card.

Materials Handling Facilities

In order to control the movement of materials, the location of the handling facilities (for example, fork lift trucks, vehicles, hand trucks and even individuals on foot) must be known at all times. Too often, time is lost because once a materials handler has moved, it cannot be located for a long period of time.

In order to achieve better control, the materials handling facilities must be individually identified and classified. The typical classification may include:

Trucks (interplant – large)

Trucks (interplant – small)

Fork lifts – large and small

Overhead cranes

Individual employees (with no special equipment other than scooters, carts, etc.)

This information is stored in a materials handling facilities record (Figure 55). Handling facilities are assigned to materials handlers in the same manner as machines are assigned to production workers (see "Job Assignment").

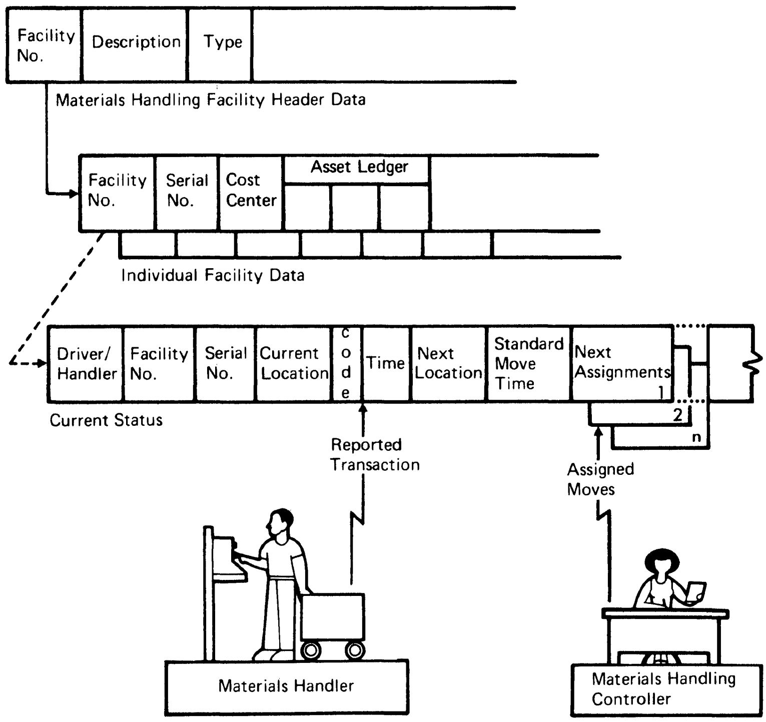


Figure 55. Example of data stored in the materials handling facilities record. The current status is updated from reported transactions

Approaches to Movement Routes

There are two basic approaches to scheduling movement: fixed route and variable (random) route.

fixed routes

Fixed route moves have been effectively used in flow or semiflow plants, where the material is normally moved in a predetermined sequence (Figure 56). Plant layout has a great deal of bearing on whether this type of movement can be implemented. Only when large quantities of work flow in the same path is fixed route movement economical. In environments such as job shops, it does not make best use of the facilities because:

- It is relatively inflexible when changes have to be made.
- It does not provide for movements in a priority sequence – this is usually left to expediters or progress chasers.
- Where more than one truckload is available for movement, some work has to wait until the next time around.

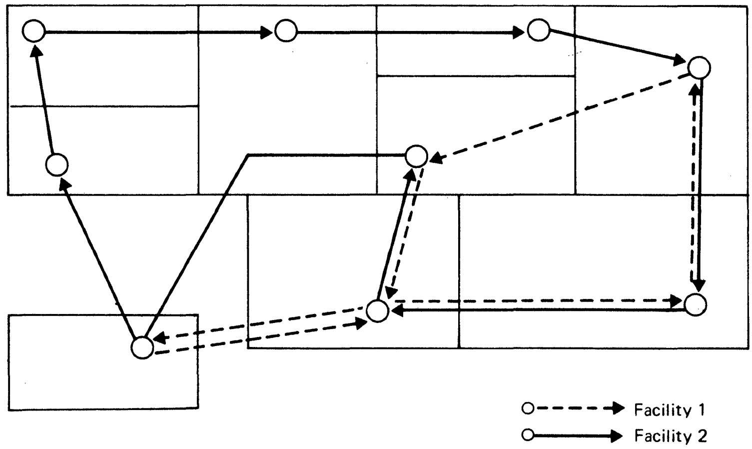


Figure 56. Fixed routes for materials handling

variable routes

Variable or random route moves are more common than fixed route, especially in a job shop environment where, theoretically, any material could go to any work center at any time (Figure 57). This requires more control than a fixed route system, and it has the greatest potential saving when run efficiently by a communications-oriented control system. This type of movement is flexible and easily adaptable to change. Move assignments can be based on a combination of job priority rules and a minimizing of the distance that a materials handling facility must travel empty.

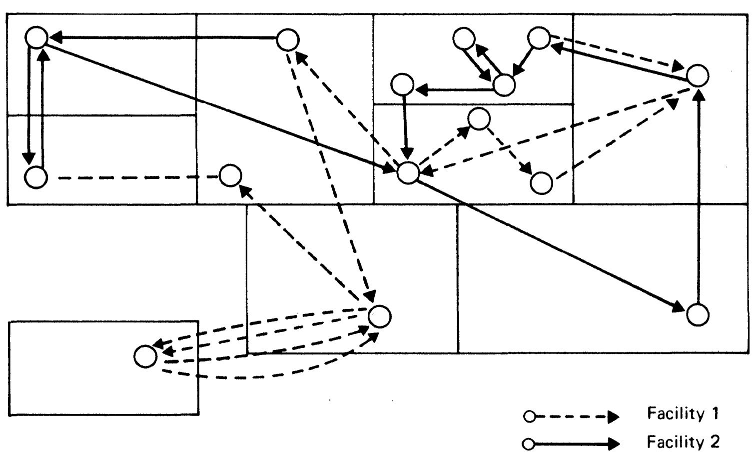


Figure 57. Variable route movement for materials handling

Move Requests

A move request contains:

- What to move – an identifying number that tells the handler what to look for in making the move. This would normally be a shop order number but could also be an employee or item number.
- Where to find it – the location (department, work center, bay number) of the material to be moved.
- Where to move it – the location (department, work center, or machine) to which the material is to be sent.
- How to get it there – the type of move facility required.

Most move requests are generated automatically by PLANT MONITORING's coordinating system. Special move requests, however, can easily be entered from any terminal on the plant floor by operators, shop foremen, or inspectors.

Giving priorities to move requests

All move requests are placed in a Materials Handling Action File (Figure 58). The system places them in sequence according to the existing priority number.

The priority system is based on when the job that requires the material is scheduled to be run. The schedule is a consolidation of each work center's work sequence list.

The priority system also handles requests for special moves, such as moving a job to a particular machine (and normally moving another job away), which is sometimes referred to as "spotting". Jobs with identical priority ratings are sequenced on the basis of the time the request was entered and the present location of, or the type of, move facility required.

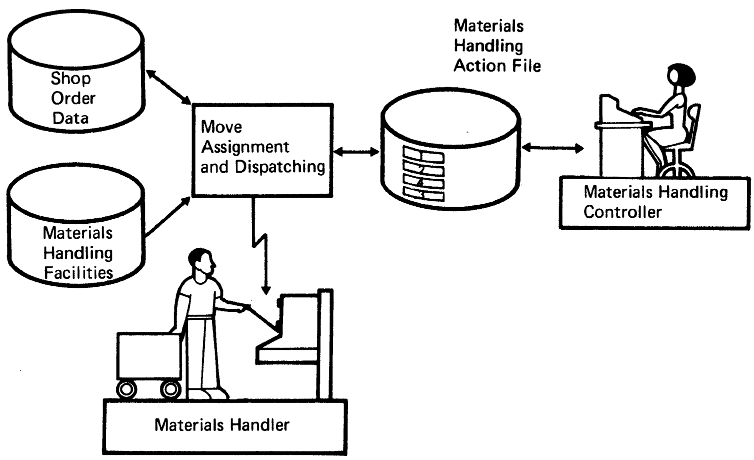


Figure 58. Move requests and assignments are accomplished via the Action File

Priority can be altered by the Materials Handling Control Center. If material is building up in one department, the controller can enter, via a terminal, a special request that raises the priority of all jobs waiting to be moved from that department.

The type of move facility required is obtained from the code in the routing, or is supplied by the requester.

The "from" and "to" locations are obtained from the work sequence list. These may not be the same as specified on the routing because of the use of alternate work centers. On special move requests, the "from" is inferred from the terminal location; the "to" location is often not needed, since most special requests are for placing material closer to the machine from a holding area in the department.

Generating move requests

Move requests are generated automatically at the following times:

- When a job assignment, including inspection, is completed (move orders for both the job and the return of tools are generated)
- When the toolroom reports that tools are ready for an order
- When the receiving area acknowledges receipt of purchase order
- When Stores acknowledges that a picking list or requisition has been filled

Move requests are manually entered at a terminal in the following instances:

- When placing ("spotting") material next to the machine or man
- When handling miscellaneous requests such as "clearing an area", moving production equipment, etc.

Assigning moves

Assignment of moves to men or facilities is done from a centralized Materials Handling Control Center. The technique is similar to that used when a production foreman assigns jobs.

Data regarding the job to be moved (from the Materials Handling Action File) and the available materials handling facilities (from the facilities record) is displayed on a terminal.

As in job operation dispatching, move jobs to be dispatched appear on one side of the screen, and facilities on the other. Jobs already assigned to a move facility are shown, and those unassigned are also indicated. The procedures for making move assignments are identical to those used for production assignment.

Dispatching moves

The materials handler receives his next assignment when he reports completion of the current one. When he completes an assignment, he enters:

- The job or tool identification card of the material just moved.
- The location where the item has been stored. The location number identifies the physical location of the order. It may consist of a department number and a rack, bin, or floor area number.
- A code indicating whether this is a temporary storage area. This may be used when the area designated on the assignment is full.

The system checks whether the location reported is the one originally designated. This check is bypassed if a "temporary" storage location has been indicated. The location code is placed in the shop order record or the tool master record. Upon verification, the next assignment(s) are printed on the terminal (Figure 59). The handler takes this document with him as a "reminder". He may discard it at the end of the assignment.

```
MAN NO.  4237   E.JONES

SHOP ORDER NO.  12470   QTY.  45   CONTAINERS 1

FROM  W/C  114  LOCN.  B12

TO    W/C  121  LOCN.  A135
```

Figure 59. The next assignment is printed on completion of the current move

Assignment acceptance

In most cases it is not necessary to verify that the assigned job has been located and is about to be moved. Where this is required, however, the handler can insert the shop order identification card and a "move" transaction code in the nearest terminal. The system checks this information against the assignment and signifies acceptance to the operator. The handler may also enter a code to indicate that the complete order cannot be handled on one trip.

unauthorized moves

In many cases the materials handler is asked to move material that has not been dispatched to him – say, when the move is small and the foreman or machine operator finds him in the area. Such requests should be discouraged, because honoring them may delay more urgent moves. If the handler does, however, make such a move, a normal "move completion" entry should be made so that the status records of the system can be updated with the new location.

automatic assignment

The dispatching procedure previously described can be performed by a materials handling controller or it may be delegated completely to the system. The system can make the assignment by matching the materials handling facility required against the facility records, and can assign the highest-priority jobs first.

In addition, the system can consider the distance between locations. If the distance is excessive, it may assign a slightly lower-priority job to avoid an empty move. There is always a possibility that a high-priority job will suffer some delay because it is in a remote location in the shop. To prevent this, the system monitors the time that elapses after the request is made. This is compared with an alarm limit (for example, 15 minutes). Any top-priority job remaining in a queue longer than the alarm limit will be assigned by the system despite any distance consideration.

multiple movements of a job

Many jobs may be too large to be moved in one trip. If one handler only is assigned to multiple trips, there is a lot of wasted movement (he delivers one load, returns empty to get another load, etc.). To avoid this, the shop order record and the assignment both carry the number of containers or lots in the order.

If the mover cannot handle all the material in one move, he enters, at the time of assignment acceptance, a code indicating that another move is required. The system retains the move request and subsequently directs a further handler (or handlers) to transport the remaining material to the correct location.

Establishing move time standards

A portion of manufacturing lead time is the time taken to move material and the time spent waiting for materials handling equipment. The move time is used throughout the manufacturing planning cycle – that is, throughout MATERIAL REQUIREMENTS PLANNING, CAPACITY REQUIREMENTS PLANNING, and ORDER RELEASE PLANNING.
To facilitate accurate planning, it is necessary to have realistic move-time and move-queue statistics. The information required is the time to move from one work center to another, and the average time a job waits to be moved.

The times at which the move request is issued, the authorization is printed, and the move is completed, are posted in the move record. This enables the system to calculate the "waiting to be moved" time and the time for the actual move.

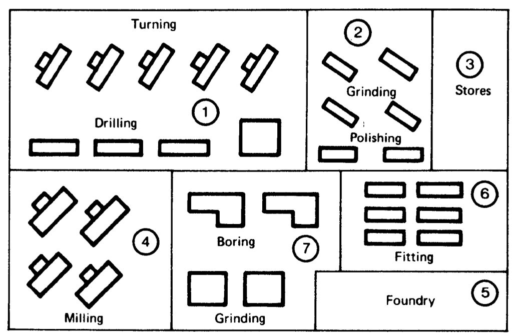
These times are used to develop statistical information for the calculation of manufacturing lead times (see "Capacity Requirements Planning" in *Chapter 6, Manufacturing Activity Planning*) and the establishment of standards for move operations.

They are described in the form of a "to" and "from" location matrix (see Figure 60).

If the move matrix will be used to rate the efficiency of materials handlers, a separate matrix should be developed for each type of move facility. The establishment of measurement standards for materials handlers can significantly improve their performance.

	TO LOCATION						
FROM LOCATION	1	2	3	4	5	6	7
1	1.0	2.0	4.0	1.5	-	10.0	3.0
2	2.0	-	50	6.0	-	4.0	1.0
3	5.0	4.0	-	8.0	4.0	4.0	4.0
4	1.0	6.0	8.0	-	-	6.0	2.0
5							
6	1.0	4.0	5.0	6.0	2.0	1.5	2.0
7	3.0	1.5	4.0	2.0	-	3.0	3.0

Category			
A	B	C	D
0.5	1.0	2.0	4.0



Transportation time depends on category of transport required

e.g. A Fork lift truck
B Hand electric truck
C Hand truck
D Overhead crane

Figure 60. A move time matrix is used to determine the standard move times between work centers

Evaluating materials handling performance

Figure 61 illustrates information that can be displayed when briefing is required. It shows the average response time to move requests by class of priority. Of particular interest is the response time to top-priority requests. A top-priority request usually implies that some production facility is waiting. The cost of this waiting time can be compared with the cost of the idle time of materials handlers waiting for requests (this idle time can also be measured by the system). The "move efficiency" is provided to determine whether poor response time is the result of inefficiency or of work overload.

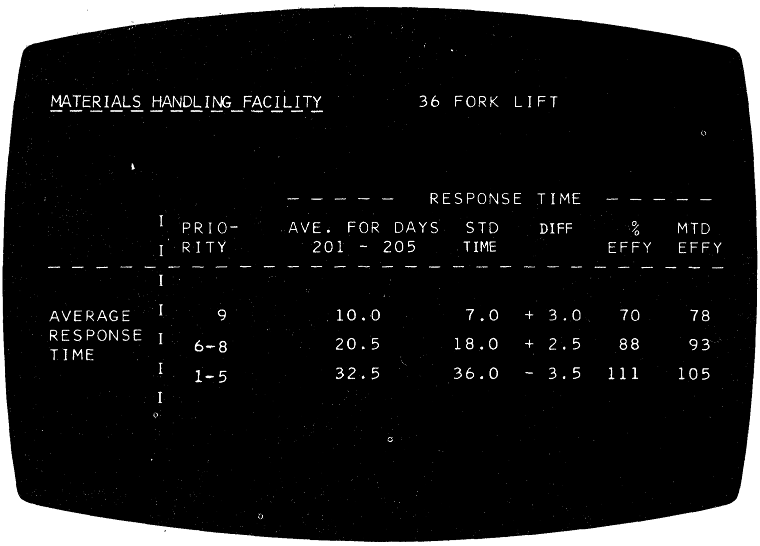


Figure 61. A display of the performance of the materials handling facilities compared to standard move times

Direct Control of Conveyor Lines

The control of material stored on automated conveyor lines creates unique problems that are difficult to solve by conventional materials handling means. For example:

- Is the required material on the conveyor?
- Where is the material located on the conveyor?
- How can a move be expedited?
- If a work station is overloaded, how can delivery of material be stopped?

Conventional conveyor systems (without computer control)

To route the right part to the right destination, the material, or its container, must have a control device to identify either the material or, more normally, its destination. At every branch and switching point within the conveyor system, there must be a sensing station to determine the path the material must follow. "Reading" this destination code causes the control mechanism of a conventional conveyor system to guide the material through the system. Problems that occur with these systems are as follows:

- Control is usually only at one point (sending point).
- A large, complex conveyor system requires many reading stations, which are expensive and difficult to maintain.
- The controlling logic is fixed, since all control decisions must be based on the setting at the sending station.
- The identity and status of material is "unavailable" once it enters the conveyor line. The material must go to the selected destination without changes to alter that destination.

Direct computer control of conveyor lines

A plant floor computer, of the type used to control production operations, can also be used for the direct control of an automated conveyor line:

- With control from computer terminal locations
- With flexibility to make in-transit changes
- With automatic retrieval of specific selected items, such as critical shortage parts
- With the ability to make inquiry of the location of any part in the line

Identification of material is maintained in computer memory rather than externally, provided the system knows the sequence and identification of material as it enters the system. The computer tracks every item as it moves along the conveyor system (Figure 62) and maintains continuously the status of the complete system by means of attached sensing equipment – for example, to count material as it passes.

In order to avoid errors in sequencing items, random synchronization points are established. For example, every 17th item could have a special device that could be sensed as a synchronization point. Out-of-phase conditions would automatically be printed and appropriate steps taken to correct the condition.

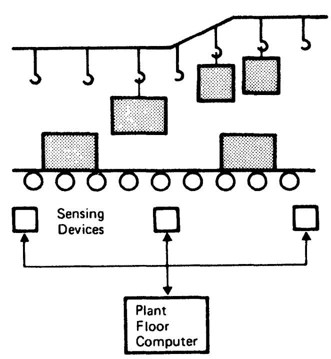


Figure 62. A plant floor computer controls conveyor lines

Since the movement of material is no longer tied to physical identification and hard-wired logic, the computer system can randomly select an item or series of items and move them in preference to other items that may have entered the system earlier. Destinations can easily be altered.

The system also is aware of such things as:

- Operation sequencing at a work center based on priority
- Available and unavailable machines or men
- Changes occurring on the shop floor

For this reason it is able to control the movement, storage, and batching of material on the conveyor line to meet current conditions.

Functions of Direct Computer Control. The typical functions performed are as follows:

- The operator loads the item onto the conveyor system manually and transmits the shop order identification and status via a terminal. The status may indicate rework required, operation complete, special action needed, etc.
- The computer assigns a route, based on item status and production schedules, and updates the shop order record.
- The computer instructs the conveyor system to deliver the item to the next production area or the next repair or rework section, as required.
- The computer monitors the conveyor system and merges items from the mainline conveyor with items in a recirculating inventory as they are needed. This is done to achieve proper batching of lots and balancing of item movement through the production processes. Batched lots are routed to the warehouse.
- The computer can monitor the conveyor equipment for the purpose of maintenance requirements.

Summary of Materials Handling Control

The entry of most material move requests is performed automatically by the system when operations are completed, or requisitions filled, etc. These requests are sequenced in priority to ensure that important requests are handled first and that production waiting time is reduced.

By a simple terminal transaction, materials handlers report the exact location to which the material has been moved. This reduces search time and the instances of lost material.

The handler automatically receives his next assignment when he reports completion of his current one. This allows last minute changes to handle "hot" requests and provides complete flexibility in making assignments.

The system considers the location of all move requests and makes assignments that will reduce the incidence of "moving empty".

Move standards can be established on the basis of historical performance. They are used to set up manufacturing lead times and to improve the performance of materials handlers.

Direct computer control of conveyor lines provides immediate access to inventory status and to the location of critical items stored on conveyor systems. It can control the routing of items on the conveyor line to meet current conditions.

Tool Control

The term "tools" is used here to cover all types of jigs, fixtures, disposable tools, etc., used in the manufacturing process. The toolroom is, in effect, a plant within a plant, its customers being the production departments. Therefore, the control techniques previously described for production material apply equally well to ordering and manufacturing tools (Figure 63) – for example:

- Forecasting the requirements for consumable tools
- Material requirements planning for new tools, jigs, and fixtures based on demand for components and assemblies

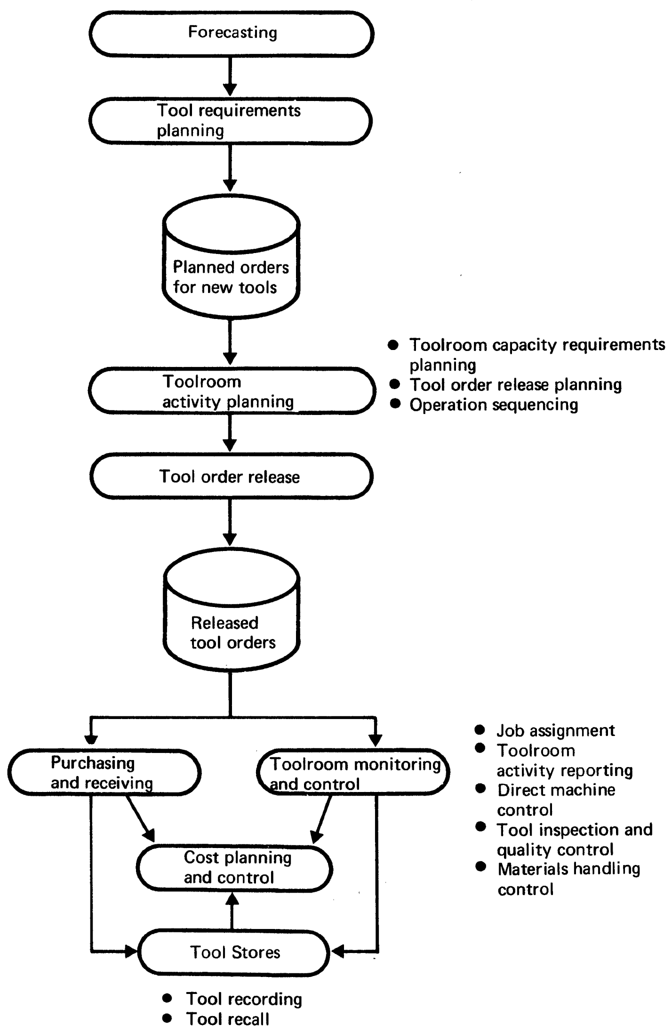


Figure 63. Planning and control techniques apply to the acquisition and control of tools

- Capacity requirements planning, order release planning, and operation sequencing in the toolroom
- Tool order release for both internally made and purchased tools
- Monitoring and control of the toolroom, using the same terminal-oriented techniques described earlier in this chapter
- Tool inspection and maintenance
- Purchasing of new and reconditioned tools
- Warehousing techniques for tool stores

Two factors, however, make planning and control of tools different from that of production items:

- *Tool reusability.* Tools are returned to stores in the same form in which they are issued.
- *Tool life.* Tools can be used for only a certain number of hours before needing repair, regrinding, etc.

These factors do not apply to all tools, but certainly to a high proportion of them.

Functions of tool control

Because the same techniques apply both to tools and items for production, this section concentrates on planning tool requirements and coordinating these with the production schedules, rather than discussing the actual manufacture and purchasing procedure for tools. As Figure 64 indicates, it covers:

- Tool stores
- Planning tool requirements
- Coordination of tool availability with shop orders
- Tool requests
- Tool usage history
- Tool recall and obsolescence

Need for tool control

Since an operation cannot be run until tools are available, tool information is needed in order to sequence orders in the shop. Traditionally, long lead times have been allowed for acquiring tools, and large quantities of them have been kept in stock to react to problems as they occur.

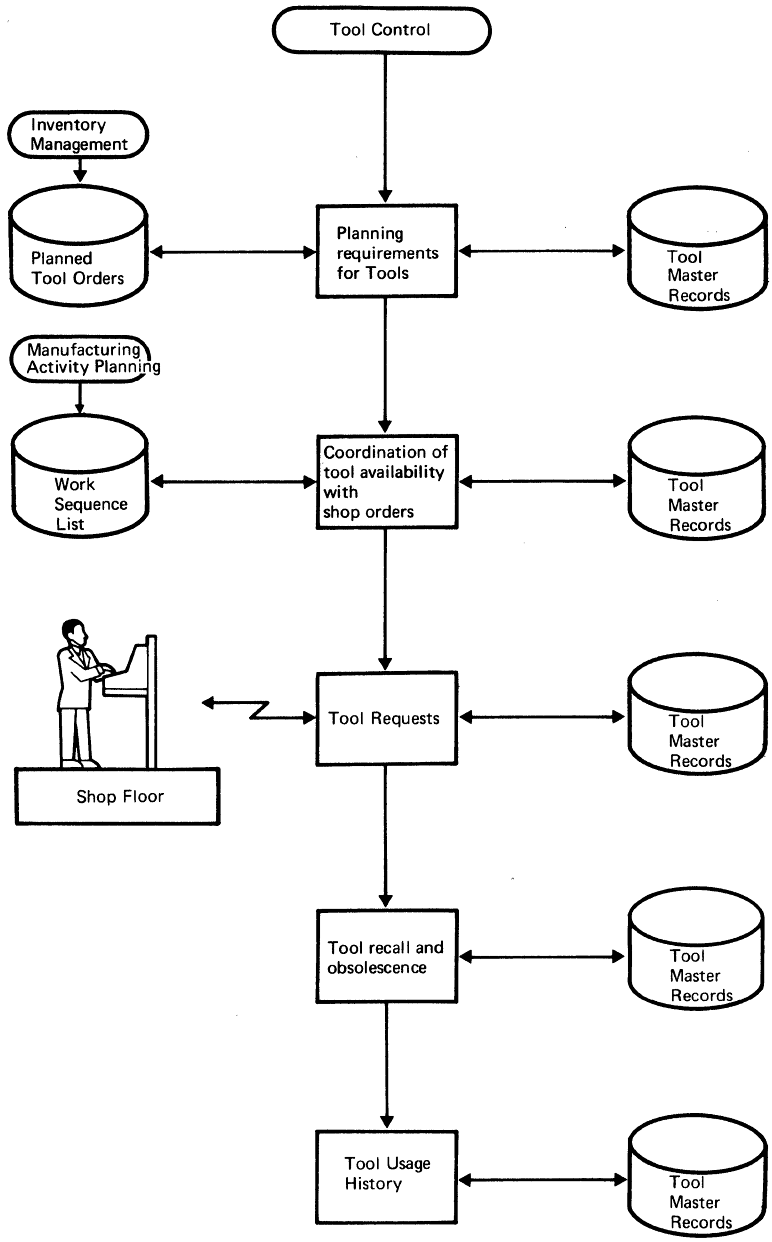


Figure 64. Functions of tool control

The procedures outlined here, however, will provide:

- A reduction in tool inventory and shortages through the application of specialized inventory control procedures
- A reduction in the number of order delays that result from unavailability of tools
- An increase in tool utilization through historical evaluation of performance

- A reduction in the amount of off-standard production that results from the use of a worn or inaccurate tool or gauge
- Reduced inspection and maintenance costs because tools and gauges are controlled according to actual usage
- Accurate estimates of tool inspection and repair load for planning purposes
- Priority lists of tool requirements so that urgent orders for new tools or repairs to tools are handled first.

Tool Stores

Tools and production items are normally kept in different stores, because:

- Tools should be close to the shop floor in order to minimize the walking distance for production workers and materials handlers.
- Tools are reusable and their location must be closely controlled – for instance, when a rush order requires a tool that is already out in the shop.
- Tool recording procedures vary; different types of records are used requiring additional information such as time out/time in, hours before recall, usage history, etc.
- Tools are "pilferable" items and it is therefore convenient to keep a small specialized area locked and secure.

The techniques described in this section apply equally well to separate tool stores and to combined production and tool stores. Use of the improved procedures offered in this system, however, reduces the need for separate tool stores. These procedures are as follows:

- Tool requirements are planned. Materials handlers dispatch them to the work center in time for the start of the operation, thereby reducing the walking and waiting time of the operator, as well as the need for individual materials handlers in the work center.
- For gateway operations, tools and materials are dispatched at the same time from the same location, thereby reducing materials handling costs.
- The system is at all times aware of tool location and status, and automatically maintains information such as time issued, time expected back in stores, actual tool usage history, number of hours before recall, etc. This means more accurate tool information on which to base planning.

- The procedures described in *Chapter 11, Stores Control* discuss why locked stores are needed for *all* items. By including tools in the same system, the number of storekeepers can be reduced, the same terminals can be used for all transactions, and improved service can be provided during second and third shifts when tool stores are often closed or are open for only a limited time.

Tool Identification

Each tool of a certain description is identified with a basic item number and is further identified with a serial number. To facilitate analysis of tool usage, these numbers should be attached to each tool. The system maintains a record identifying the characteristics of each tool, such as any drawing numbers, dimensions, description, etc. (see *Chapter 1, Engineering and Production Data Control*). To identify the movement of tools into and out of stores, each tool should have a prepunched card or badge containing its item and serial number.

Planning Requirements for Tools

Depending on the type of tool, one of three approaches to planning tool requirements can be used:

- Forecasting based on past demand, which is normally used for consumable tools and small tools such as grinding wheels, milling cutters, drills, and so on
- Requirements planning for permanent tools such as jigs and fixtures
- Tool life requirements planning for tools with limited life, such as large broaches, special milling cutters, etc.

Forecasting

Small and consumable tools, or hand tools such as air drills, hammers, and screwdrivers, are handled by the techniques described in *Chapter 3, Forecasting* and under discussions of independent demand in *Chapter 5, Inventory Management.* Use of these techniques can make possible a reduction in investment in these types of tools, with the same or better service to the production departments.

Requirements planning for permanent tools

Permanent tools, such as drilling jigs, milling fixtures, and assembly jigs, are normally designed to make one specific item or several items of a similar nature. These tools have a relatively high value and usually require a manufacturing lead time of several weeks or months.

Planning the requirements for such a tool can be done by regarding it as a further level on the product structure (Figure 65), just as raw material is another level for a fabricated part. The requirement is then treated exactly like the requirement for a component on an assembly. From the requirements planning report the requirements for new tools over the material planning horizon can be seen.

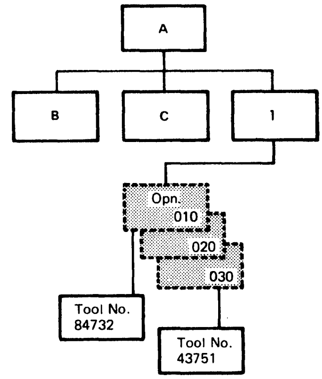


Figure 65. Tools can be included in the product structure

In determining net requirements, tool return after job completion must be accounted for. This is done by considering a "usage lead time" calculated by the system for each tool type. It is based on the operation duration plus an allowance for picking time, move time, and waiting time.

Where routing information can be obtained or estimated, the capacity required for new tool production in the toolroom can be determined using the techniques described in *Chapter 6, Manufacturing Activity Planning*. The result is:

- Better advance information regarding toolroom workload
- Work sequence lists in the toolroom based on priority of tool orders and due date
- Information that makes it possible to decide how many sets of tools to order, and whether additional sets are required for existing tools because of, say, a planned increase in production

Tool life requirements planning

The problem of planning tool requirements is more complicated for those items that have a limited tool life, such as special cutters, broaches, and press dies. It is not enough to know that a tool exists or when a tool is required; the remaining "life" of the tool must also be known in order to plan for replacements.

The requirements planning technique described in *Chapter 5, Inventory Management* can be used for tool life requirements planning. The tool life is the expected number of pieces that will be produced before the tool wears out. Tool life can also be stated in terms of number of hours use.

As the tool is used, production quantities are subtracted from the record of remaining tool life to indicate how many pieces can be produced from the tool on future orders.

Coordinating Tool Availability

OPERATION SEQUENCING is done daily or on a shift basis. The output is a work sequence list for each work center. This is kept up to date by

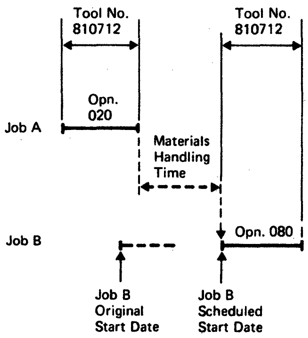


Figure 66. Contention for the same tool is resolved in OPERATION SEQUENCING

feedback as described earlier. The system therefore keeps track at all times of when each operation is expected to start. The issue of tools from the tool stores is tied to the start date (Figure 66).

The decision to issue tools to a particular work center cannot be made at the time of order release because of "tool contention". This results from the simultaneous need for a given tool by operators working on two or more separate shop orders (Figure 66). Because of changes in priority and upsets to the schedule, the decision as to which operation should use the tool first must be made as late as possible. It is planned therefore, in OPERATION SEQUENCING.

Tool Requests

As Figure 64 shows, a request to issue a tool can therefore be made:

- Automatically by the system on the basis of the schedule established by OPERATION SEQUENCING
- From the shop floor via a terminal transaction

A tool request (similar to a material requisition), as in Figure 67, is transmitted to the tool stores a specified interval before operation start time. The interval depends on how long it normally takes to pick the tools and move them to the required location. Tool requests may be transmitted on a daily basis, when all tools for the next day's operations are picked and sent to the respective work centers.

The materials handler is notified of tools that are located at another work center and that are to be picked up and taken where needed. If such tools are not needed at another location, the system generates an automatic request for their movement back to the storeroom.

TOOL REQUEST

SHOP ORDER	ITEM NO.	OP NO.	DEPT.	WORK CENTER	TOOL NO.	TOOL DESC.	BIN LOC.
43400	182974	030	20	114	83741	GAUGE	A127
43400	182974	030	20	114	82913	DRILL JIG	B 23
79123	004321	025	20	114	81471	GAUGE	A135

Figure 67. Tool request

Tools may be requested from the shop floor by entering a "tool request" code and the shop order identification card into a shop floor terminal. Knowing the operation and, therefore, the tools required, the system generates a detailed request to move the tools to the appropriate location.

Recording tool usage

Tool usage is recorded from the data provided by Manufacturing Activity Reporting and/or Machine Monitoring. The data recorded includes, by serial number, the actual hours the tool is in use. Tool life history is used to determine when a tool will start to produce excessive scrap.

Tool recall

Recall notices are automatically generated for tools as the number of pieces produced approaches the expected tool life. An order to gauge or replace the tool is created, the due date being based on the known or forecast requirement for the tool.

Tool obsolescence

Most companies have many tools that have not been used for years but are kept "in case they get a requirement for the part". The cost of storage often outweighs the cost of making the limited number of new parts from scratch.

The system can monitor tool usage and can highlight on a special report any tool neither used nor requested during a specified length of time.

If it is likely that there will be a limited demand for a particular item over the next few years, steps can be taken to forecast this demand so that a product-life supply can be made and the tool thrown away.

Tool History

Historical records of tool usage can help determine the expected life of a tool. As each individual tool is worn out, the number of pieces (or number of hours) produced by it is added to the tool master record and is exponentially smoothed (see *Chapter 3, Forecasting*) into the previous figures. Broken or obsolete tools are not included in the analysis. Management is notified of variances outside prescribed limits. Similarly, tools discarded before the end of their planned life are also brought to management's attention.

Summary

The functions of PLANT MONITORING AND CONTROL are to:

- Ensure that the production schedules established in MANUFACTURING ACTIVITY PLANNING are being communicated and implemented.
- Continuously update shop order status information as the order progresses through the plant.
- Highlight out-of-line situations immediately via Action Files for corrective measures.
- Provide coordination between production and supporting activities to implement the manufacturing plan. Effective coordination and integration reduces the amount of time that production men spend waiting or searching for material, tools, materials handling equipment, and inspection. Since interruptions caused by shortages are reduced, buffer stocks maintained to absorb fluctuations caused by delays can also be reduced. The result is lower work-in-process inventory and shorter manufacturing lead times.

  Coordination also results in better utilization of the support functions. Maintenance workers, materials handlers, and inspectors can be remotely dispatched from central locations. The procedure allows tight control over these widely dispersed employees and ensures that high-priority jobs are serviced first. This results in significantly lower production support costs and faster reaction to requests for expediting.
- Help the foreman make better use of his time. Job dispatching and acceptance assure him that jobs are being done in the assigned sequence; manufacturing activity reporting procedures relieve him of much of his paperwork; special alarms warn him when employees are running out of work or behind schedule. All this allows him to enlarge and tighten his span of control.
- Improve the efficiency and utilization of the production, testing, and materials handling equipment in the plant through direct machine monitoring and control. This makes existing automated production and handling systems more effective. It opens up new, more effective approaches in establishing standards and in detecting and preventing off-standard production.

PLANT MONITORING AND CONTROL makes the plan happen and provides up-to-the-minute status of all items on the shop floor: orders, machines, and manpower.

Chapter 9. Plant Maintenance

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Introduction

The maintenance area is receiving increased attention for the following reasons:

- As labor costs increase, manufacturing companies are investing more resources in sophisticated production equipment. Effective maintenance helps to extend the life of this increasing investment, thereby reducing production costs. As the degree of automation increases, however, maintenance effort also increases (Figure 1).

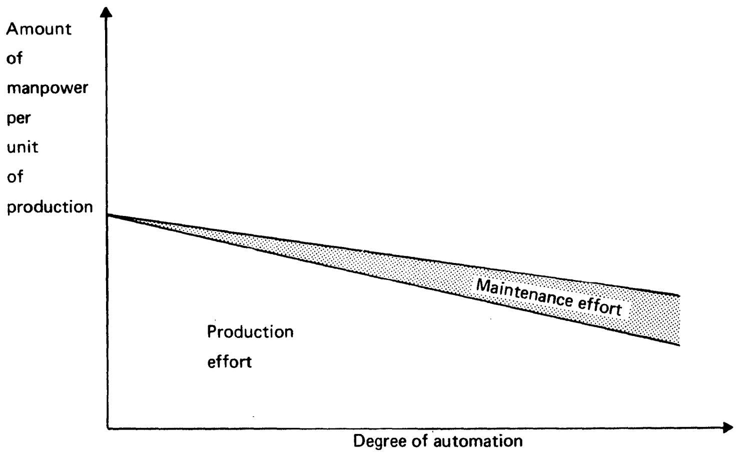


Figure 1. As automation increases, the cost of maintenance per unit of production also increases

- The demand for shorter lead times and the frequent changes in the production plan forced by competitive pressures require that the plant operate with as little work-in-process as possible. Modern production techniques require specialized and highly interdependent production machines and facilities. This combination of low work-in-process and machine interdependence means that the loss of a key piece of production equipment for an excessive amount of time can virtually shut down a plant. Well planned maintenance can keep such situations to a minimum.

- The trend to more complex, integrated equipment means that maintenance can no longer be left only to the man on the machine. As a result, an increasing number of highly trained, high-priced technicians are being assigned to the maintenance function. Maintenance personnel are thus accounting for a larger share of the total cost. In industries normally classified as "fabrication and assembly", for example, the average number of employees assigned to maintenance presently exceeds 6% of the total. In "process" type industries, such as chemical and paper, this average exceeds 20%. Because of these trends, the costs associated with maintenance are increasing at an annual rate near 4%.

A maintenance control system helps to assure efficient utilization of this manpower.

Types of maintenance

Maintenance can be divided into three major categories (Figure 2).

Type of maintenance	Characteristics	
Preventive maintenance	Repetitive	Planned
Breakdown (emergency)	Nonrepetitive	Not planned
Planned repair	Nonrepetitive	Planned

Figure 2. Maintenance jobs can be divided into major categories, based on whether they are repetitive, scheduled, and subject to advance planning

Repetitive scheduled maintenance, classified here as preventive maintenance (PM), represents the bulk of the maintenance work in most plants. It includes both minor operations, such as lubrication and inspection, and major jobs, such as the overhaul of a press.

Breakdown (emergency) maintenance comprises nonrepetitive jobs normally involving a facility that is already down or malfunctioning. It includes diagnosis to determine the trouble as well as any repair performed after the diagnosis. The incidence of each type of maintenance activity varies by type of company. In fabrication and assembly industries there is a large amount of breakdown maintenance. Process industries, such as chemical plants, have a larger number of planned repair orders.

Planned repair includes maintenance not likely to be repeated in the near future or, if repeated, not likely to be performed in the same manner. If it is a major job, such as installing new equipment, it will be subject to advance planning techniques.

The term "machine" is used primarily to designate the object of the maintenance effort. In process industries the term "equipment" or "facility" would be more applicable.

maintenance priority

Maintenance orders can also be classified according to their importance to the production activity:

- *Critical.* Failure to perform the job could result in the loss of a production facility. This would also include a machine already down.

- *Semicritical.* Failure to carry out maintenance could or does already impair operating efficiency.
- *Routine.* Failure to perform the job causes inconvenience and possible future failure, but no current production loss is involved.

This priority coding system is used in the maintenance work order scheduling system described later. It is combined with other priority ratings, such as the number of days behind schedule. An example of how various jobs may be classified and assigned priorities is presented in Figure 3.

Work order type	Classification	Priority
Replace furnace lining	PM	Critical
Replace cutting oil	PM	Semicritical
Paint traffic lines on floor	PM	Routine
Press not working	Breakdown	Critical
Reject Gate sticks occasionally	Breakdown	Semicritical
Door not closing	Breakdown	Routine
Replace cracked lathe bed	Planned repair	Critical
Install engineering change	Planned repair	Semicritical
Repair leaking roof	Planned repair	Routine

Figure 3. Example of work order classification and assignment of priorities

Approaches to maintenance

fire fighting method

There is nothing preventive about the fire fighting approach; equipment is repaired only after breakdown or when scrap is excessive. Maintenance personnel wait for breakdowns with the excuse that "as long as everything is running we are earning money for the company". The costs of this approach – idle production men, excess scrap, lower production efficiency, faster wear rate, increased investment in equipment, higher work-in-process inventory, etc. – make the exclusive use of this method uneconomical.

Fire fighting can also result in situations where a large number of machines break down at one time and there is consequently insufficient manpower to handle the load. The effect on production can be disastrous.

For these reasons the other two approaches must be considered.

preventive maintenance (pm)

The preventive maintenance approach assumes that preventing downtime is less costly than making emergency repairs. PM operations are established by:

1. Identifying points that are subject to wear.
2. Establishing procedures to detect pending failure and restore proper operating conditions.
3. Estimating the rate of deterioration and setting an interval so that PM is performed shortly before expected failure.

direct machine monitoring

With Direct Machine Monitoring, instruments are attached directly to production equipment and a computer is used to constantly survey points of possible deterioration. Impulses representing readings from these instruments can be sensed by the computer, which then calculates a rate of deterioration and automatically signals when PM should be performed. For example, a reduced airflow rate will indicate the need for filter replacement.

A summary of the characteristics of these approaches is presented in Figure 4.

Approach to maintenance	Interval set by	Cost of downtime	Cost of maintenance
Fire fighting	No interval	Very high	High
Preventive maintenance	Analysis of history data	Low (planned rate)	Low (balanced with downtime)
Direct machine monitoring	Calculating current rate of deterioration	Lowest	Minimum (performed only when needed, but before breakdown)

Figure 4. Interval and cost characteristics of three approaches to maintenance

Controlling maintenance

Even though maintenance costs are increasing, the area has not been subject to the same degree of management planning and control found in the direct manufacturing areas.

The difficulty in establishing tight control stems from three major factors:

- The absence of precise labor standards for maintenance work makes it difficult to use the same control techniques as those used for production.
- A widely dispersed maintenance labor force makes direct supervision difficult.
- A high incidence of emergency repair work makes advance planning difficult.

justification for tight control

Computer-assisted maintenance planning and control reduces manufacturing costs by reducing machine breakdown and maintenance costs, while improving machine efficiency.

The basic premise of maintenance is, "It is better to prevent than to repair." Increasing the frequency of preventive maintenance, however, does not necessarily reduce total maintenance costs (Figure 5). If PM is performed too frequently, it wastes material, manpower, and production capacity and may even increase the incidence of machine breakdown; if it is performed too infrequently, it causes excessive downtime and leads to production inefficiency. PLANT MAINTENANCE helps determine the optimum PM interval.

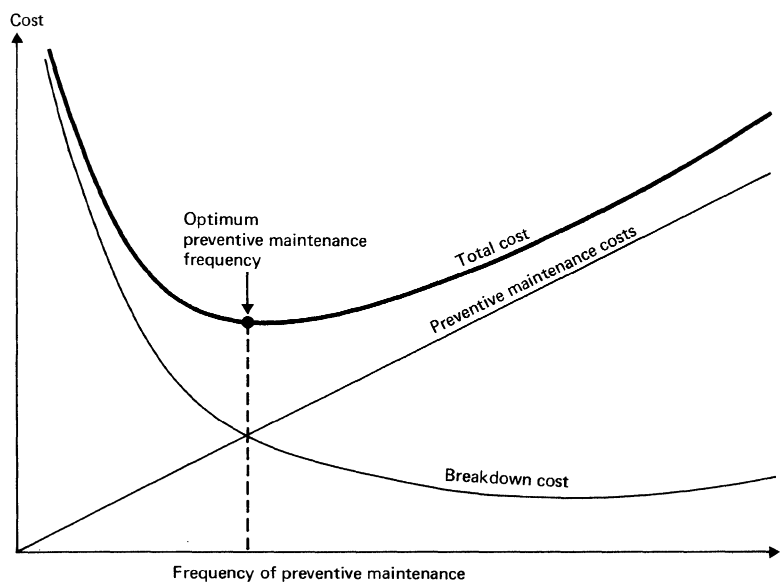


Figure 5. The cost of preventive maintenance must be balanced with the cost of machine breakdown to determine the optimum preventive maintenance frequency

The effects of downtime on production costs are extensive:

- It causes delays to orders, resulting in dissatisfied customers and increased expediting costs (overtime, stock chasers).
- While the machine is being repaired, production workers are idle, or time is lost in reassignment and duplicated machine setups.
- Additional production capacity may have to be acquired. For example, if production objectives can be met with four machines operating at 100% availability, it takes six machines, or 50% more investment, at 75% availability (Figure 6).

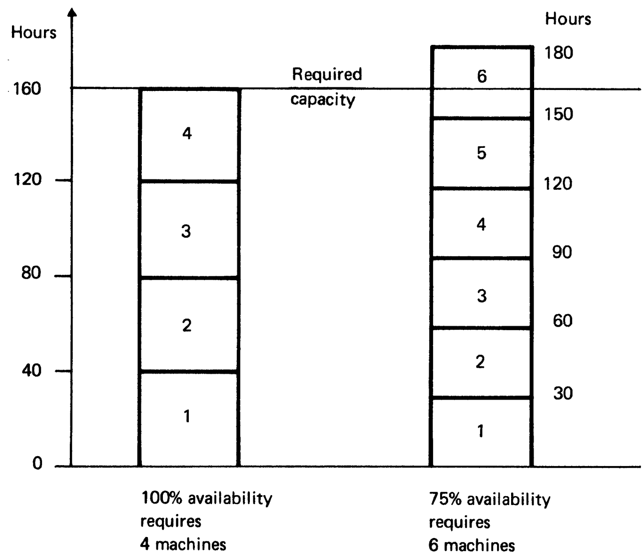


Figure 6. A reduction in machine availability can significantly increase investment in equipment

- If machines are interrelated to the extent that the output of one directly feeds another (Figure 7), machine availability is especially important. If no work is stored between units, an average availability of 90% on each of four machines means (according to statistical probability) that all four will be available together only 66% of the time. A 5% increase in machine availability to 95% results in an increase of 24% in overall availability of the four machines (from 66% to over 80%).

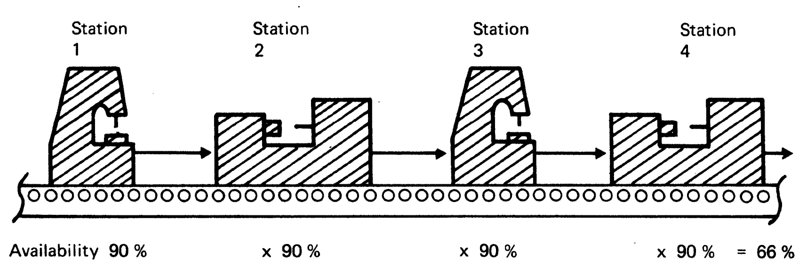


Figure 7. Interdependency of machines reduces the availability of the total system despite high availability of individual machine stations

- The queue of work at machine centers must be increased to allow for downtime at previous centers. This increase in work-in-process inventory increases production lead time, requires more floor space, and results in higher material handling costs.

Not all economies are associated with preventing machine breakdown. For example, inadequate PM causes production equipment to run less efficiently and also contributes to shorter equipment life. This results in operation of machines below the rated speed and increases the amount of time that workers spend on non-rated operations. Lower efficiency can also cause more demand on service facilities, such as steam, air, and water, thereby increasing indirect unit production costs. Machine inefficiency also leads to lower quality and increased scrap.

Because the consequences of the breakdown and inefficiency of machines are severe, it would seem logical to plan for preventive maintenance so that machines never break down. In fact, some managers consider low incidence of repair work an indication they are doing an effective job, when, actually, excessive PM and standby labor may be wasting the company's resources.

In many companies, once PM intervals are set they are never altered unless excessive downtime occurs. This implies that most PM is performed too frequently. The computer helps reduce such waste.

Maintenance costs can be further reduced by establishing labor standards. The measuring of actual job time against responsible time estimates has significantly reduced maintenance labor costs.

Functions of plant maintenance

With the aid of computers, maintenance costs can be effectively controlled. The techniques applied are similar to, and can be integrated with, normal manufacturing control systems.

Following are some of the functions addressed by PLANT MAINTENANCE (see Figure 8 for their relationship):

- Assistance in establishing labor requirements and standards
- Assistance in determining the scheduled maintenance interval, the objective here being to reduce facility downtime and/or excessive maintenance costs
- Direct entry of emergency work orders from the plant floor
- Help in detecting new areas where preventive maintenance may be economically initiated

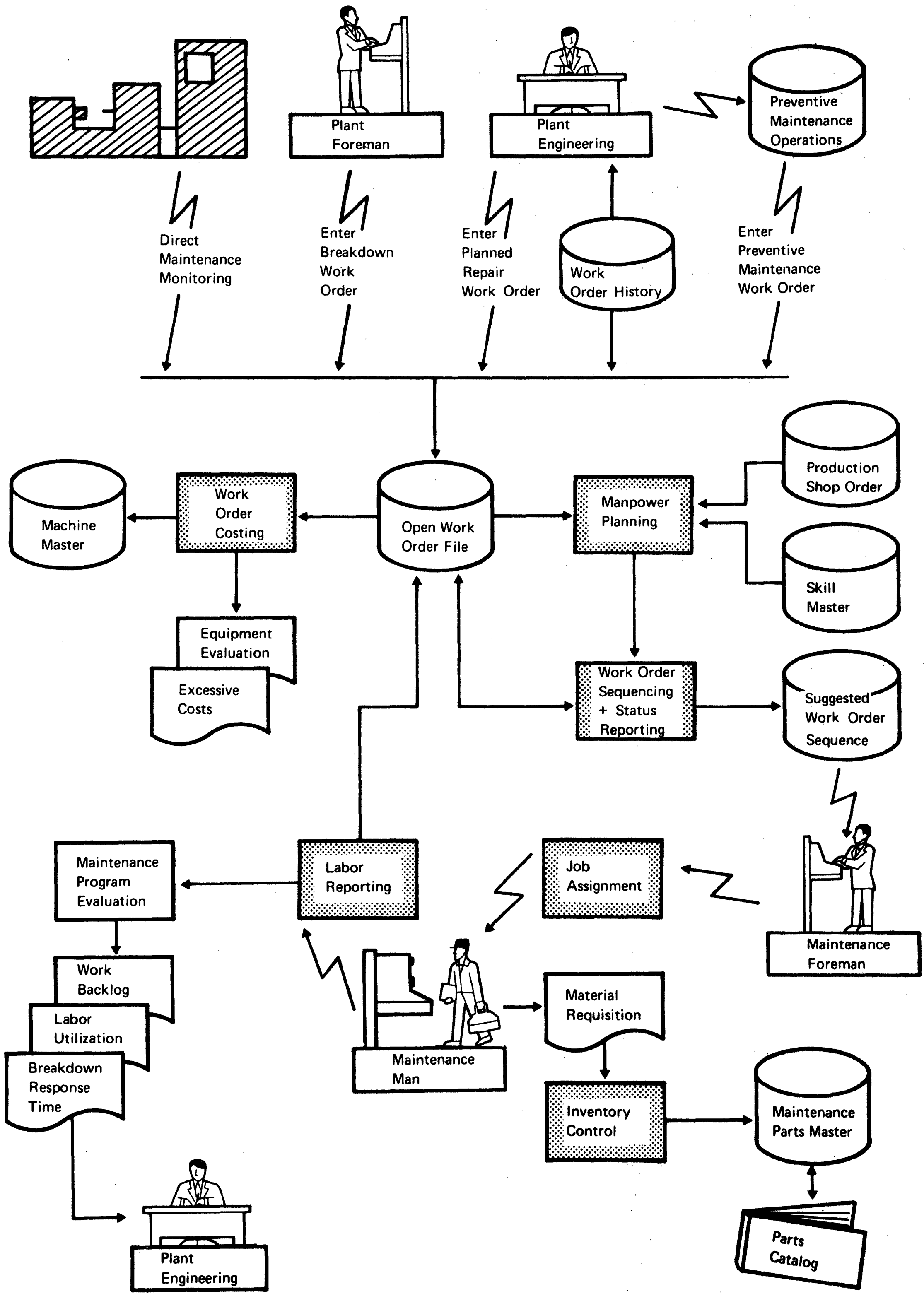


Figure 8. Summary of basic functions addressed by the maintenance system

- Direct machine monitoring, whereby an instrument is attached directly to a machine. This allows downtime and preventive maintenance costs to be reduced to the lowest possible level.
- Use of inventory control techniques that reduce maintenance parts inventory and decrease the number of stockouts
- Status reporting, via a terminal, on all open work orders, with automatic notification of overdue orders
- Use of workload leveling techniques that reduce overtime and increase the number of jobs completed on schedule
- Integration and coordination of production shop order and maintenance work order scheduling, which assures minimum machine downtime due to maintenance
- Flexible, terminal-oriented job assignment, which improves reaction time for emergency situations and increases maintenance manpower utilization
- Labor reporting, which pinpoints the exact location of each maintenance man, thus allowing rapid action to meet emergency situations and reducing transit time between jobs
- Work order costing, which detects out-of-line maintenance or downtime costs and helps evaluate purchases of equipment

Relationship with other application areas

In most companies, maintenance procedures can be incorporated into systems already installed for production control. Separate systems for handling maintenance purchasing, inventory control, labor reporting, etc., are costly, and usually unnecessary. This does not mean that production systems apply to maintenance without modification. There are special problems in maintenance that force system modification, and these are highlighted in the sections to follow.

The competition between production jobs and maintenance work orders for machine time requires that machine scheduling be done with simultaneous consideration of both needs. The system allows for the integration of production and maintenance requirements and encourages cooperation.

Figure 9 illustrates how PLANT MAINTENANCE interfaces with other sections of the system.

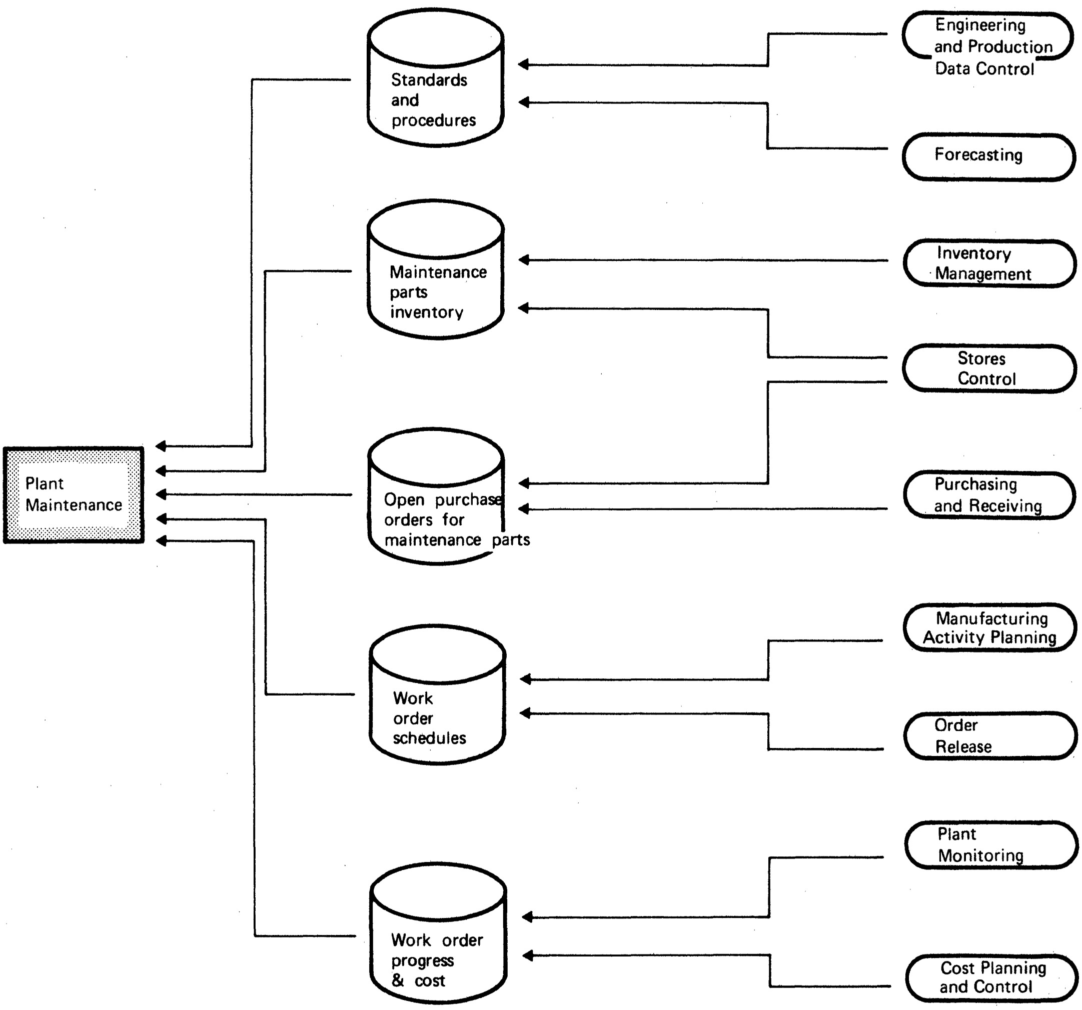


Figure 9. Plant maintenance utilizes slightly modified production systems and integrates with them

Preventive maintenance (PM) requires (1) a procedural description of the particular maintenance operation and (2) determination of a fixed interval between performances of that operation. Adding this interval to the date of the most recent PM operation yields the date for the next performance of the operation.

last date performed + interval = new schedule date

Most maintenance crews establish some kind of operational procedure and intervals for the critical equipment. Often, however, they do not establish these factors, because:

- The PM operation is considered insignificant and not worth the cost of establishing and maintaining a procedure.
- The large amount of breakdown maintenance and high-priority planned repair maintenance makes it impossible to perform the job consistently at the specified interval.
- The amount of maintenance history retained is insufficient for determining a realistic interval.

With computer-assisted maintenance control systems, intervals are easier to establish, and the cost of keeping records is low. This allows a more extensive application of PM techniques.

Identifying Points Requiring Preventive Maintenance

Initial points requiring preventive maintenance (PM) are usually identified by the equipment supplier. He will specify an interval, a procedure, and material standards. However, unless the equipment is used extensively within the supplier's own plant, or he maintains an extensive field installation analysis system, the information is incomplete. For this reason, Plant Engineering usually adds and deletes PM procedures on the basis of actual experience.

The computer can help detect candidates for PM. To do this a "maintenance code" is established (Figure 10) and assigned to every PM operation performed. The coding scheme, which varies with the type of company, basically describes the portion of the machine being serviced, and the activity performed. Maintenance men filling out "downtime reports" also use this code.

Machine component

782	A.C. line regulator	402	Motor
783	Adapter	935	Ohmmeter
785	Ammeter	652	Oscillator
539	Cables	263	Oven
802	Commercial test equipment	264	Pallet
228	Condensers	964	Performance box
572	Connectors	954	Power supply
867	Current generator	142	Probe
324	Ductwork	819	Relay
535	Fan	288	Scope
259	Filter	709	Socket, air
642	Frequency meter	722	Switches, selector
612	Generator	130	Temperature controller
279	Gas system	876	Test box
920	Lamps	982	Test box contacts
614	Generator	997	Voltmeter

Activity Code

01	Adjust, electrical	05	Replace, electrical
02	Adjust, mechanical	06	Replace, mechanical
03	Other	07	Test
04.	Overhaul	08	Calibrate

Figure 10. A generalized maintenance code consists of a number describing the failing machine component and a number representing the maintenance activity performed

Those maintenance codes that the system cannot match to an established PM operation can be summarized in a Downtime Analysis Report (Figure 11). The frequent appearance of a maintenance code indicates the need for a preventive maintenance procedure. When the frequency exceeds a management standard, the detail is shown on a report.

DOWNTIME ANALYSIS REPORT

MACHINE TYPE	MACHINE NUMBER	NAME	MAINTENANCE CODE	WORK ORDER DATE	MAINT. HRS.
02	104161	CONVEYOR	RELAY-ADJUST	2/10	0.50
			RELAY-ADJUST	2/12	0.75
			RELAY-ADJUST	3/11	0.50
14	912216	MILL	MOTOR-REPLACE	1/11	2.60
			MOTOR-REPLACE	4/11	3.25

Figure 11. The system's analysis of the maintenance codes on downtime reports can help detect candidates for new or revised PM procedures

Establishing Preventive Maintenance Procedures

Once a PM point is identified, a procedure must be established for actually performing the maintenance. This procedure is described in a similar way to procedures for production parts (see "Manufacturing Routings" in *Chapter 1, Engineering and Production Data Control*). The PM procedure record also contains information particular to maintenance (see *System Data Base* for more detail).

PM Interval Unit of Measure

Intervals are normally stated in Gregorian calendar days, for example, once a month or once a week; or shop calendar days, for example, every 20 days of shop operation. Gregorian calendar intervals do not allow for holidays or vacations. Neither approach allows for overtime usage. Therefore, since most PM points are a function of actual machine use, both approaches should be avoided. PLANT MONITORING AND CONTROL supplies information regarding actual machine running hours, or unit production. Intervals should be specified in the same units of measure. For example, if usage is expressed in hours, the interval should be expressed in hours. This method of interval expression will significantly increase accuracy.

Establishing the Preventive Maintenance Interval

One of the major problems with intervals established and maintained by manual methods is that they are revised only when excessive failures are attributed to them; then they are shortened. As a result, in most systems PM is performed too frequently. Maintenance managers, however, aware that intervals are too short, allow the established interval to be consistently exceeded. If PM intervals are exceeded by too much, machine malfunction occurs and the objective of the interval is lost. The problem is to determine the optimum interval and make sure that the PM schedule is maintained. The system can assist in both areas.

Statistical method

In some noncritical maintenance areas, a machine can be run until it fails. The interval can then be established by backing off a set number of days. For example, if failure occurs after 45 days, the interval may be established at 40 days. Basing the interval on only one incidence of failure is probably not realistic. Where there are many similar machines, multiple failures can be observed. In this case, the system can develop statistics that can assist in establishing the optimum interval. Figure 12 indicates a normal distribution of failure intervals.

Figure 12 indicates that the average number of days until failure is 45. Other incidences of failure are normally distributed around this average. Using statistical methods, statements such as "95% of all failures will occur between 39 and 51 days" can be made. Therefore, if the PM interval were established at 39 days, the equipment would go down only 2.5% of the time it was exposed to this particular failure. The system can develop and maintain such statistics. In this way management can balance the cost of preventive maintenance with the cost of machine downtime (see Figure 5).

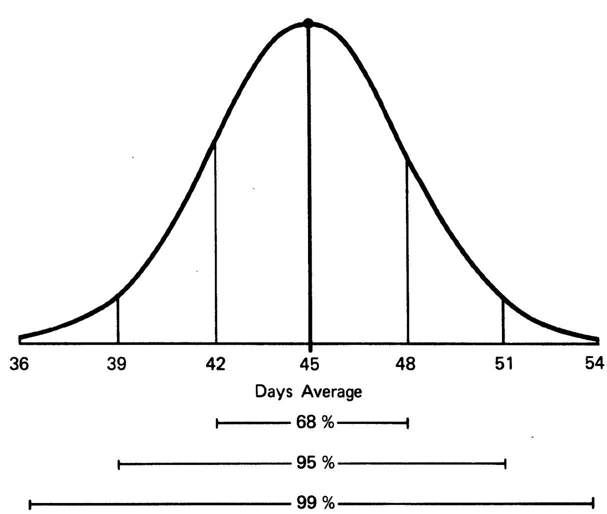


Figure 12. The interval between failures can normally be distributed around an average

Stepwise method

In most cases, however, the number of observed failures is not sufficient to use statistical methods. If failure can be tolerated, a stepwise approach can be initiated by the system.

The initial estimate of the interval is established by Plant Engineering. The interval is adjusted if no failures occur after a certain number of exposures to failure. In the example, the initial value of the interval was set at 20 days. Preventive maintenance was performed ten times and no failure occurred. The system can be instructed to increase the interval automatically if no failure occurs. The amount of the increase can be based on such things as the class of maintenance and the importance of the machine. In the example shown in Figure 13 the increase for this PM point is 25%. This increases the interval from 20 to 25 days. After ten more PM activities the interval is again automatically increased. The fourth increase (from 30 to 37.5) finally results in a failure. The system then decreases the interval back to its last point.

The interval can be fixed at this point or increased in smaller increments (in the example, 5%) until another failure occurs. Once an interval has been fixed, unusual failures can be rejected by the interval control system, on the basis of history retained in the Maintenance History File and a percentage statement of how many failures can be tolerated.

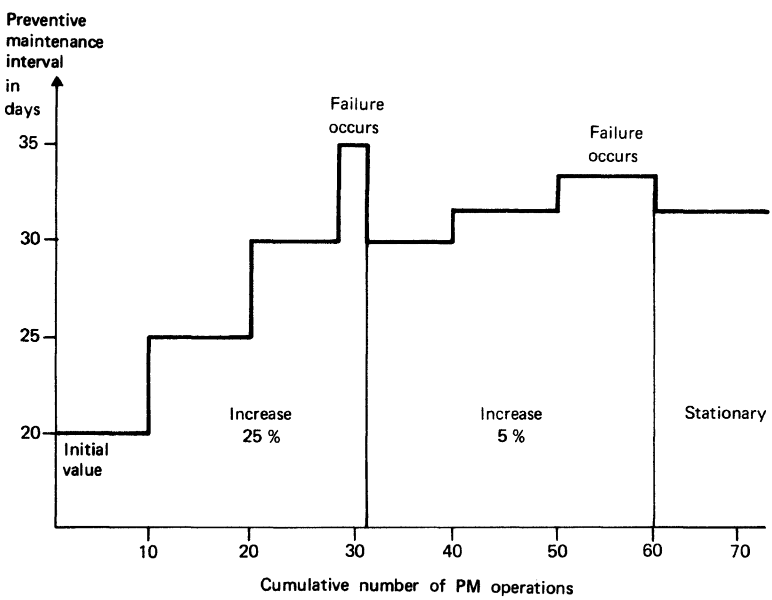


Figure 13. PM intervals can be automatically increased by the system until a satisfactory level is achieved

This procedure increases the PM interval, thus reducing maintenance costs, until just before downtime starts to appear. It is a self-monitoring system that demands little attention once the initial estimate has been set.

Overriding the Normal PM Interval

PLANT MONITORING AND CONTROL maintains individual machine measurements that may indicate the need for a preventive maintenance inspection before the normal PM interval is complete.

The following signals may indicate the need for PM:

- An increase in the machine's scrap rate over a period of time
- A reduction in the performance efficiency (average production rate per hour)
- An increase in setup time (adjusting machine tolerances)
- An increase in the amount of nonincentive work performed because of machine trouble
- Wide deviations from inspection tolerances

These signals are passed via a computer-maintained Action File to the responsible maintenance planner. The planner, before initiating an inspection, contacts the foremen to determine whether other factors may be contributing to the deviation from historical rates.

Figure 14 summarizes the creation and maintenance of PM standards.

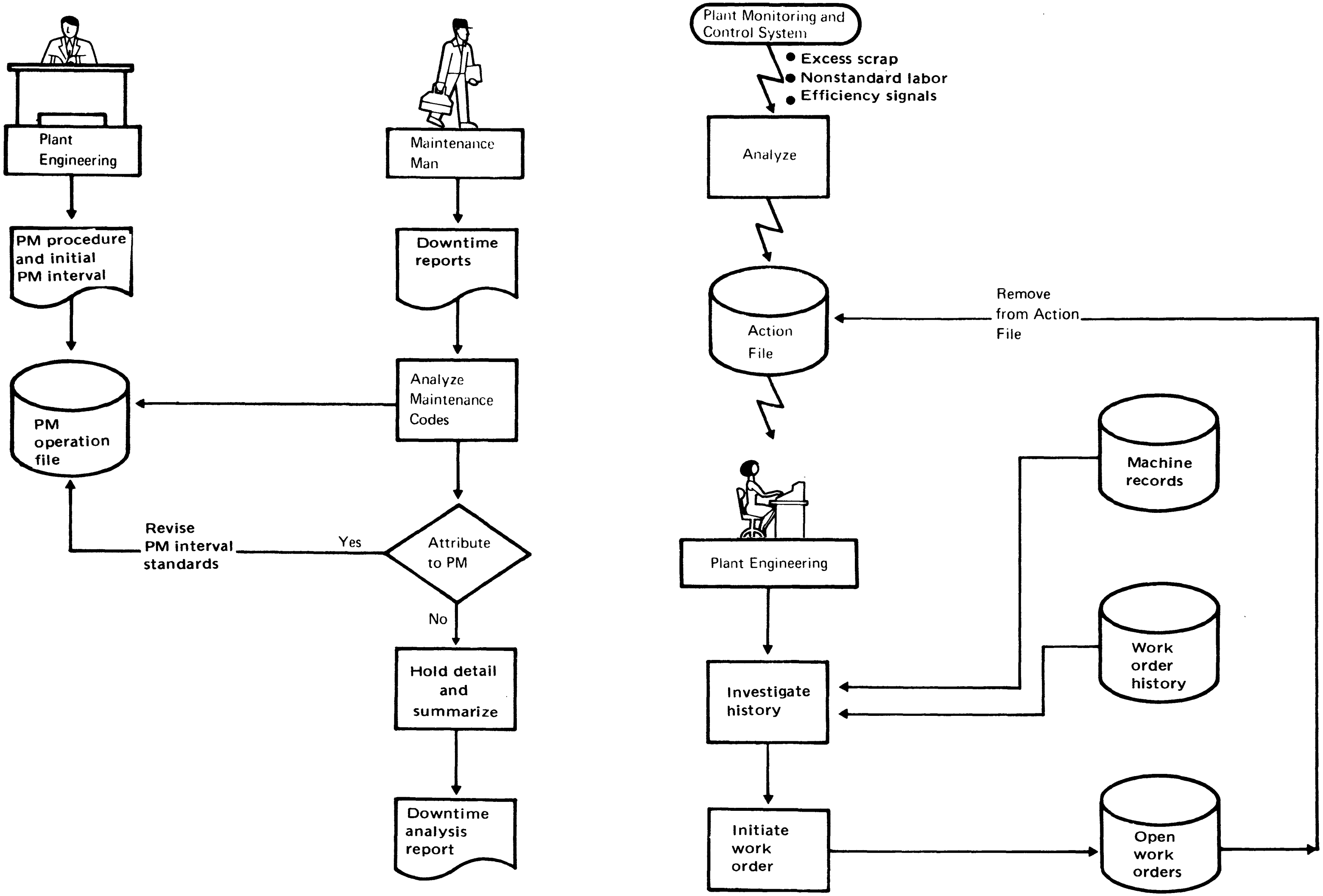


Figure 14. Basic steps in the creation and maintenance of PM standards

Preparation of Maintenance Work Orders

The term "work order" is reserved for the authorization of maintenance work. This is to differentiate it from authorizations for direct production work, which are called "shop orders".

Preparation refers to the creation of a computer record, which is used to trace the activity of a work order from the time the job requirement is recognized, to the time the work is complete.

Some nonrepetitive maintenance activities are so short in duration that the effort to create a control record cannot be economically justified. Maintenance labor and material costs associated with such minor activity can still be charged to the machine and department incurring the charge (see "Labor Reporting" in this chapter).

Preventive Maintenance Work Orders

The PM work order is entered into the system only once. This is at the time the PM point is established and the initial estimate of the interval is made. The data is held as part of a file called the PM Job File. The basic data entered by Plant Engineering is presented in Figure 15.

The ability to indicate multiple labor and material requirements is provided.

Preventive maintenance job record	Machine serial number	Operation number	Sequence number	Description	Maintenance code	Maintenance instruction book and page number

Priority code	Interruption code	Interval standard	Interval unit of time	Interval increment code	Labor standard	Labor skill(s) required

Material required	Part number	Quantity	Associated PM operation number	Preventive maintenance job record

Figure 15. Some of the basic information entered for each PM job. More detail is presented in *System Data Base*

On the basis of labor reports, the system keeps track of the last time PM was performed. Using the number of elapsed calendar days or the amount of machine usage, it calculates when the next operation is to be done and automatically enters the order in the Open Work Order File a few days before the work is to be performed (Figure 16).

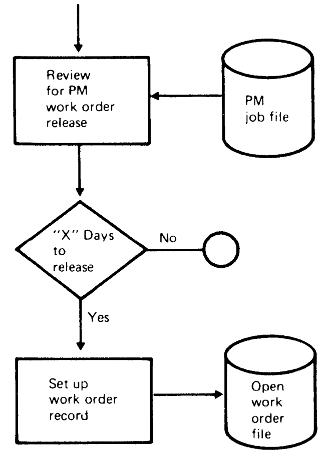


Figure 16. The system automatically generates records requesting maintenance activity

Several fields in the PM job record need definition:

Interruption code. This code indicates whether the facility must be shut down during the operation.

Skill required. A code designates what type of labor skill is required for the operation. It may reflect labor union association.

Machine serial number. This is a permanent number assigned to a capital goods item such as a machine tool. The number is placed in a visible spot on the item and is used for cost accumulation, verification of job assignment, etc. The number may carry a suffix designating an area on a larger unit, such as a transfer line or an assembly line. Very large units (buildings, grounds, tanks, etc.) may be identified by facilities coding – for example, a number identifying a building, and a suffix designating a unit within the building (heating system, electrical system, etc.).

The decision regarding what to number is based on judgment. The additional costs of computer file space and time for review are negligible compared with the confusion caused by a work order lacking a machine number. Lack of numbers can also distort distribution and other monitoring and analysis systems. For these reasons, it is an advantage to assign a machine number to everything that is visually separable. The more extensive the numbering system, the better management can exercise control.

Labor standard. Because many PM operations are not repeated frequently, when compared with direct production operations, and because a large proportion of work performed by maintenance personnel will never be repeated, there is a reluctance to assign maintenance labor standards.

The lack of a labor standard is the most serious deficiency in establishing control techniques in the maintenance area. A point to remember is: "Any kind of labor standard is better than none." Maintenance standards are not generally used for incentive labor payments; they are used primarily for planning purposes and for measuring performance. The presence of reasonable standards will significantly improve maintenance labor efficiency.

PM operations with high repeatability are subject to the same kind of work measurement techniques applied to production operations. Standards for PM operations with low repeatability or short duration times can be automatically developed using statistical techniques. In summary, this technique calculates an average time for the operation based on actual labor reports. It establishes standards for all PM operations in a short amount of time and at a low cost. Similar PM operations can be periodically grouped together to see if one operation is out of line. Labor activity reporting that exceeds the average by more than a specified amount is referred to an Action File. The foreman then indicates whether they should be included in the new average.

Another type of labor standard applying specifically to maintenance work is a "transit time allowance standard". This is the time allotted to maintenance workers to move between any two machine centers in the plant (Figure 17).

The transit time allowance standard is set up in a matrix form similar to that used in MANUFACTURING ACTIVITY PLANNING. This standard is assigned to the man at the time the work order is dispatched and becomes part of his performance measurement.

Department from \ Department to	101	104	107	110	112	113
101	X	.10	.10	.15	.18	.20
104	.10	X	.10	.15	.10	.10
107	.10	.10	X	.20	.15	.05
110	.15	.15	.20	X	.22	
112	.18	.10	.15	.22	X	
113	.20					

Figure 17. A transit time matrix in hours is used to measure performance in moving between two consecutive jobs

Breakdown (Emergency) Work Orders

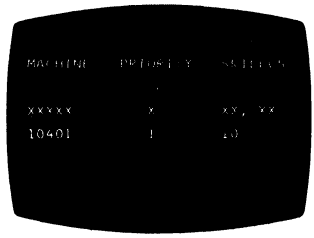


Figure 18. Work orders can be entered directly from the shop floor

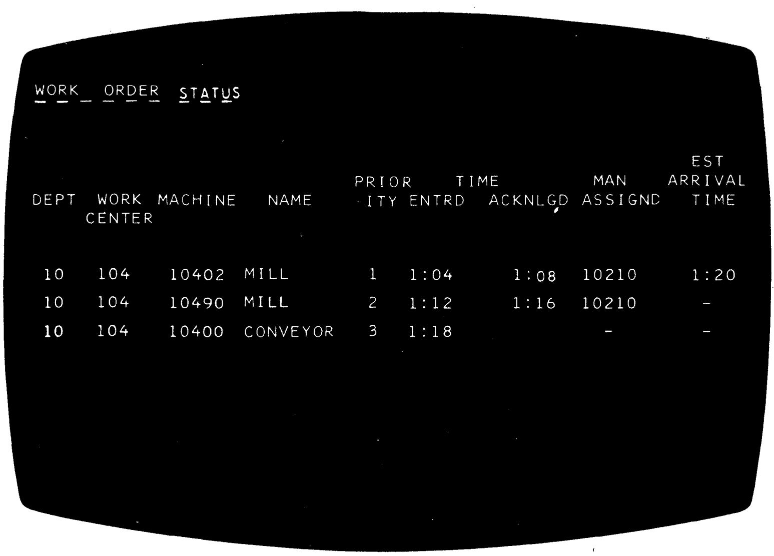
Work orders are entered by the foreman or the worker via a terminal located at the work center. Figure 18 shows the small amount of information entered.

Upon entry, the system automatically sends an alarm message and a request for maintenance to a Central Maintenance Dispatching area via an Action File and it sets up a control record in the Open Maintenance Work Order File. The computer maintains the requests in sequence by priority and time entered.

Central Maintenance Dispatching for all labor skills is done by foreman-level dispatchers. They have access, via terminals, to the data necessary to dispatch and coordinate maintenance resources.

Using a technique described in this manual under "Dispatching", Central Maintenance Dispatching acknowledges the order by entering an approval code and a man number.

On demand, the foreman can retrieve the status of all his requests to determine whether the order has been acknowledged, a man assigned, and, if so, the approximate time of his arrival. Figure 19 illustrates the displayed information.



WORK ORDER STATUS

DEPT	WORK CENTER	MACHINE	NAME	PRIORITY	TIME ENTRD	ACKNLGD	MAN ASSIGND	EST ARRIVAL TIME
10	104	10402	MILL	1	1:04	1:08	10210	1:20
10	104	10490	MILL	2	1:12	1:16	10210	-
10	104	10400	CONVEYOR	3	1:18		-	-

Figure 19. The foreman can display the status of pending maintenance requests for his department upon demand

Using his employee identity card, the maintenance man indicates his arrival at the work center via the same terminals used for production labor reporting. The system then allows him a specified time to examine the problem and report his estimate of the amount of time needed to complete the job. He makes this estimate also via a terminal by inserting his identity card and entering the expected time to completion.

If the maintenance man cannot make an estimate because of failure to locate the trouble, or if his estimate exceeds a specified amount of time, he is instructed to call a maintenance planner. The planner uses a terminal to key in a brief description of the trouble and to establish, verify, or alter the man's job estimate. Either the maintenance man or the planner may alter the job estimate via a terminal any time he discovers that the original estimate is substantially incorrect.

Figure 20 summarizes this entry procedure.

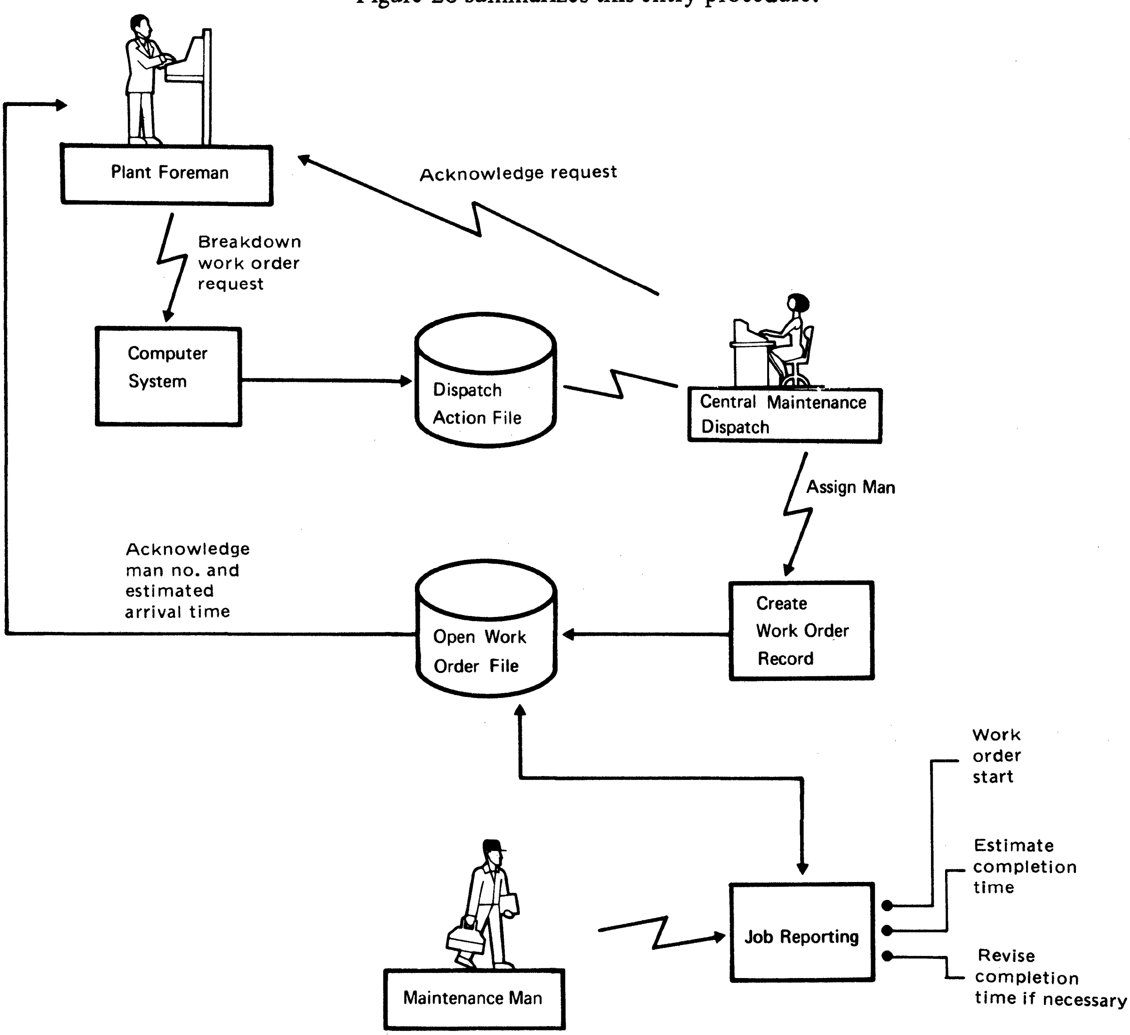


Figure 20. Summary of basic steps to enter breakdown work order from the shop floor

Planned Repair Work Orders

This type of work order is planned in advance if:

- A production facility has to be shut down for an extended period.
- The assistance of an outside contractor is necessary.
- The repair procedure is complex and must be established.
- Non-stocked parts or equipment must be obtained.
- The workload on the available labor crafts must be considered.

The entry procedure is similar to that of a breakdown work order. When the need for major repair is recognized, additional information is entered via a terminal (Figure 21).

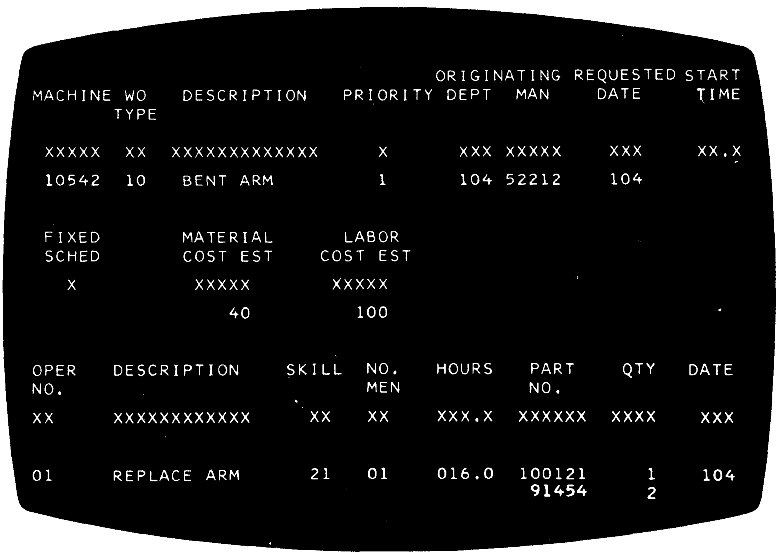


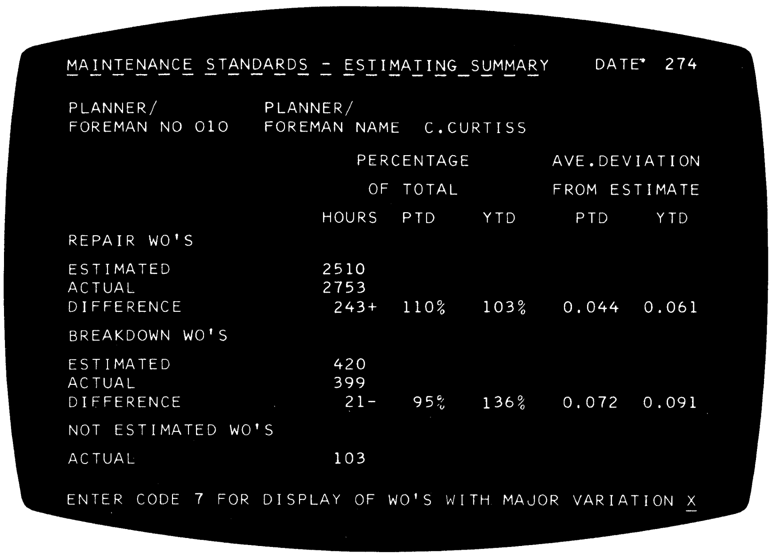
Figure 21. Data for planned repair work orders can be entered via terminal as it becomes available

Not all data need be entered at one time, because the data for complex orders is created over an extended period of time. For example, long lead time material requirements may be added well in advance of procedures or labor standards.

Setting planned repair work order labor standards

The problem of assigning labor standards to nonrepetitive jobs is largely a matter of intelligent guessing. However, estimating procedures (see *Chapter 1, Engineering and Production Data Control*) can significantly help to remove some of the uncertainty.

A history of work orders is retained on the basis of equipment type. A "maintenance code" is used to classify this work order history. When estimating a new order, the planner can use a terminal to search for similar or identical maintenance codes and machine types. Actual labor hours used on similar work orders then serve as a basis for future estimates. Periodic reports can be prepared that help planners evaluate their estimating techniques (Figure 22). An attempt should be made to estimate a labor standard for every job; the presence of a reasonable standard will significantly improve labor efficiency. Accuracy is not as important as in production operations, since maintenance personnel are usually not paid on the basis of these estimates.



MAINTENANCE STANDARDS - ESTIMATING SUMMARY DATE' 274

PLANNER/ FOREMAN NO 010 PLANNER/ FOREMAN NAME C.CURTISS

		PERCENTAGE OF TOTAL		AVE.DEVIATION FROM ESTIMATE	
	HOURS	PTD	YTD	PTD	YTD
REPAIR WO'S					
ESTIMATED	2510				
ACTUAL	2753				
DIFFERENCE	243+	110%	103%	0.044	0.061
BREAKDOWN WO'S					
ESTIMATED	420				
ACTUAL	399				
DIFFERENCE	21-	95%	136%	0.072	0.091
NOT ESTIMATED WO'S					
ACTUAL	103				

ENTER CODE 7 FOR DISPLAY OF WO'S WITH MAJOR VARIATION X

Figure 22. This report helps planners measure the effectiveness of their maintenance standards estimates. The same report can be prepared by the system in foreman sequence to help them evaluate their efforts to stay within estimates

Material requirements for planned repair work orders

Much of the material required is supplied from stock. The entry of a material requirement via a terminal results in an immediate verification of its availability. If the work order is critical, the planner has the option to reserve available stock immediately.

Much of the required material, however, may be special and therefore carry no part number. In this case, the work order's material requirements record is assigned a sequential item number, which is then associated with the computer-assigned work order number to form a pseudo part number. This number is used for purchasing, receiving, and stores operations. The entry of non-stocked items in the work order record automatically sets up a temporary record in the Item File. This allows standard purchasing and receiving procedures to be utilized.

A summary of the planned repair order entry procedure is shown in Figure 23.

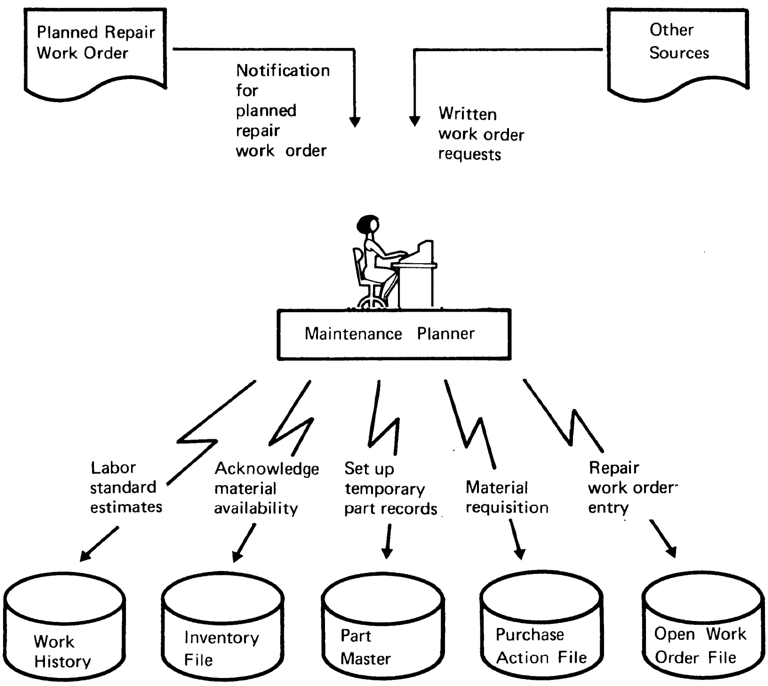


Figure 23. A summary of the basic functions performed in the entry of a planned repair work order

Direct Machine Monitoring

Whenever computers are being used to directly control and monitor machines (piece count, temperature regulation, pressures, etc. – see "Direct Monitoring and Control of Production Process and Operations" in *Chapter 8, Plant Monitoring and Control*), they can also be made to monitor deterioration in the condition of the machine. With this approach the determination of when to perform preventive maintenance is very accurate. If PM costs are high, or machine availability is extremely important (as in the case of a transfer line), computer usage may be justified exclusively for maintenance monitoring.

This type of control reduces maintenance costs to the lowest possible point. One reason for this is that the actual rate of deterioration can be measured. For example, a decreasing rate of air flow could indicate when a filter needed replacement; a measure of oil level, oil acidity, or bearing temperature may indicate the need for lubrication; a pressure drop may indicate a leaking seal. The calculation of a deterioration rate makes possible a prediction of the point when the facility will become inefficient or inoperable. A PM operation can then be scheduled just prior to this point. The effect is no loss due to lower efficiency or downtime, and no wasted effort caused by performing PM too early.

While not all PM can be scheduled on the basis of a deteriorating machine condition, this approach, where it is possible, can significantly reduce costs.

Maintenance monitoring is not limited to measuring points of deterioration; it can also help the troubleshooter diagnose the problem and thus return the machine to production much faster. For example, in a highly complex materials handling system, a line stoppage may be caused by the failure of any one of a large number of switches, gates, etc., to operate correctly. The computer can narrow the trouble area, and possibly even pinpoint the exact trouble spot, by simply checking the status of switch contacts at time of failure. A message directing the man to the location of the fault can be typed on a terminal next to the machine.

Maintenance Parts Inventory Control

The effective inventory control of maintenance parts is important to the success of a maintenance control system. A high incidence of breakdown and repair can be met with overtime or subcontracting; if parts are short, however, weeks can be added to the downtime of a machine.

Generally, the same inventory control techniques used for production can be used for maintenance parts. Normal purchasing and receiving procedures also apply to maintenance parts. In many companies, the major obstacle to overcome before these techniques can be used is the assignment of internal part numbers to stocked maintenance parts and material.

Parts Catalog

An essential component of maintenance inventory control is the parts catalog, which contains a record for each item stocked or ordered frequently (Figure 24). The system maintains this information in the Item File.

Some of the information maintained on this record is:

Part number – an internal identification number used in reporting all inventory transactions, etc.

Vendor part number – used for purchasing only.

Category code – used to group similar items together – for example, gaskets, motors, pumps, valves, resistors.

Standardized description – an indication of physical features in a sequence and manner that are fixed for each inventory class, with important features always appearing first. This description, together with the category code, serves as the basis for locating part substitutions in an emergency situation. This coding structure makes possible such inquiries as "Display all motors on hand that have an HP rating 10 or above" (see Figure 25).

In addition, when all items are listed in sequence by inventory class and standard description, a large number of identical parts are usually discovered. This leads to a sharp reduction in the number of parts stocked.

Machine used-on Sequence

P A R T S   C A T A L O G

EQUIP. NO.	EQUIPMENT DESCRIPTION	SUPPLIERS EQUIP.NO.	PART NOS. STOCKED FOR THIS EQUIPMENT (✱ INDICATES STOCKED ONLY FOR THIS EQUIP.)			
00173	BRADSHAW 2A CHUCKING LATHE	B1000/2A	42324	42326(✱)	42371	42373
			48721	48714	48743	48759
			49210	49371(✱)	49744(✱)	49800(✱)
			49811	49876	49880(✱)	49891
			49900(✱)	49923	50011	50012(✱)
			51179(✱)			
			17401	17402	17410(✱)	17797
			18171	44321(✱)	44380(✱)	44397(✱)

Part Type Sequence

P A R T S   C A T A L O G

INVENTORY NO.	PART DESCRIPTION	SUPPLIERS PART NO.	INTERCHANGEABLE WITH PART NO.	ALSO USED ON EQUIPMENT NO.			
MATERIAL GASKETS							
13570	12 X 0.125 ASBESTOS FILLED SS GASKET	12125AMI		09067			
26124	0.250 ASBESTOS-NEOPRENE SHEET GASKETING MATERIAL	6571	13576	06071	07010	07011	07811
				07321	07340	07924	08110
				11010	11321	11333	11797
				12121	12273	17924	19745
				22431	25017		
				10101	11321	11333	11797

Part No. Sequence

P A R T S   C A T A L O G

PART NO.	PART DESCRIPTION	SUPPLIERS PART NO.	INTERCHANGEABLE WITH PART NO.	ALSO USED ON EQUIPMENT NO.			
12273	120 GPM 500 PSI STAINLESS STEEL CENTRIFUGAL PUMP	1635900X		05070	06322		
12374	5HP MOTOR COUPLING	L759	14739	06322	07197	08010	08012
			15362	08013	12431		
12375	200 GPM 500 PSI STAINLESS STEEL CENTRIFUGAL PUMP	1637110X	1637115X	00271	00272	04004	
12490	WATKIN RADIAL DRUM						

Figure 24. The parts catalog helps classify and organize data concerning maintenance parts

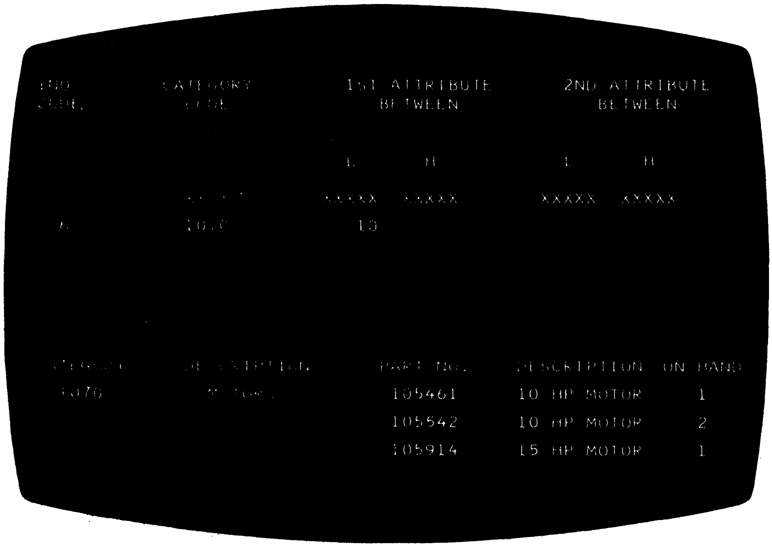


Figure 25. Standardized description of maintenance parts makes it possible to locate substitute parts through terminal inquiry

Equipment used on – a listing of the facility number(s), if parts are stocked to service a particular facility. Replacement part lists for a facility are then easily obtainable via inquiry.

Interchangeable part numbers – an indication of predetermined substitute parts for certain critical items.

Inventory Control Techniques

The inventory control techniques described in *Chapter 5, Inventory Management* also apply to maintenance parts. Their application usually results in fewer shortages or reduced inventory, or both. Depending on the situation, there are three methods that apply to spares inventory control:

- Requirements planning for *dependent* demand items
- Requirements planning for *independent* demand items
- Carry Level

Controlling dependent demand items

If the material requirement is a result of a scheduled work order, the requirement can be generated when the order is planned and need not be forecast.

Figure 26 illustrates the effect of summarizing scheduled requirements from several sources. Machine A is scheduled for maintenance every two periods. It uses one of part number 12346 at the time the job is performed. Machine B uses two of the same part when maintenance is performed every four periods. Planned work order number 89424, scheduled for period 5, will use six of the same part. These requirements are added together to develop a requirements schedule. The requirements planning technique can then plan deliveries to coincide with this schedule. In the example of Figure 26, the on-hand balance of four would cover requirements in periods 2 and 4. A planned order for ten would be placed to cover periods 4 to 8, and at some later point an order for four would be placed to cover periods 10 to 12.

Period	1	2	3	4	5	6	7	8	9	10	11	12
PM schedule Machine 'A'		1		1		1		1		1		1
+												
PM schedule Machine 'B'		2				2				2		
+												
Planned repair work order 89424					6							
=												
Requirements schedule Part 12346 On Hand = 4	0	3	0	1	6	3	0	1	0	3	0	1
Planned order schedule				10					4			

Figure 26. Requirements planning for dependent demand maintenance items can be used for many items in PM and planned repair work orders

The system automatically generates the material requirements of PM work orders when the PM schedule is set up or revised. Planned repair material requirements are entered as part of normal order creation procedures. If the schedule date is moved, the system automatically adjusts the planned order schedule. This type of materials management system plans for 100% availability of maintenance parts. It minimizes inventory investment while balancing the cost of carrying inventory with that of acquiring inventory. The technique is described in more detail in *Chapter 5, Inventory Management.*

Controlling independent demand items

Parts usage generated from breakdown work orders, or low-cost maintenance parts used in PM and planned repair work orders can be analyzed to establish safety stock by using the techniques outlined in *Chapter 5, Inventory Management* under "Calculating Safety Stock". The system then forecasts future demand on the basis of recent history of usage. Orders are then automatically planned to cover the forecast, while still maintaining a safety stock level to absorb the fluctuations in parts usage. This technique applies only if there is sufficient usage to make statistical forecasting techniques valid.

Carry Level control

Most spare parts used in breakdown work orders do not have sufficient usage to justify statistical approaches. They are stocked only for critical production units and should be controlled via the Carry Level technique. This technique uses a fixed quantity as a level to be maintained at all times. Carry Levels are normally in the range of 0 to 5. A Carry Level of zero would mean "order only when a requirement is specified".

Figure 27 summarizes the applicability of the techniques.

Inventory Transaction Processing

When maintenance part records become part of the Item Master File, it is no longer necessary to maintain separate transaction processing systems for maintenance. Not only do the inventory control techniques apply, but also those used in purchasing, receiving, inspection, and warehousing.

Type of demand	Inventory control technique	
Preventive maintenance work order	Requirements planning for dependent demand	
Planned repair work order	Requirements planning for dependent demand	
Breakdown work order	High volume usage	Requirements planning for independent demand
	Low volume usage	Carry level

Figure 27. The inventory control technique selected depends upon the type of demand and the volume of usage

Manpower Planning

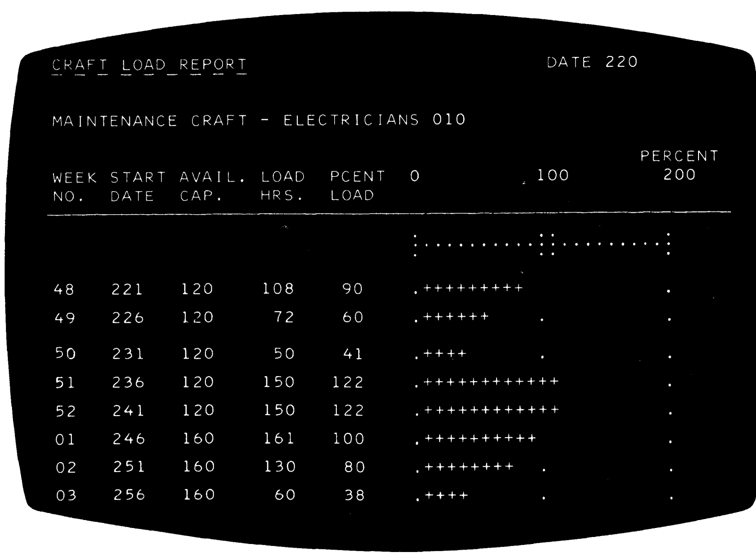
The maintenance work order and production shop order can be considered equivalent because they contain essentially the same information. For the same reason, the work center concept used in production can be considered equivalent to a skill center in maintenance.

A skill center is defined as a group of maintenance men with similar capabilities. The grouping may be based on craft and subdivided by master, apprentice, etc.

Because the basic data describing work centers is the same as that for skill centers, essentially the same capacity planning and load leveling techniques used to control direct production systems can be used for maintenance control

Determining PM work order load

A file representing planned preventive maintenance load is periodically generated. This is done by making a long-term projection as to when PM will be needed. Using a technique described in more detail under "Resource Requirements Planning" in *Chapter 4, Master Production Schedule Planning,* a PM load profile (Figure 28) can be generated for each skill.



```
CRAFT LOAD REPORT                                          DATE 220

MAINTENANCE CRAFT - ELECTRICIANS 010
                                                                  PERCENT
WEEK START AVAIL. LOAD  PCENT  0                100               200
NO.  DATE  CAP.   HRS.  LOAD
-----------------------------------------------------------------------
                               :...........::...........:

48   221   120    108    90    .+++++++++                 .
49   226   120     72    60    .++++++        .           .
50   231   120     50    41    .++++          .           .
51   236   120    150   122    .++++++++++++              .
52   241   120    150   122    .++++++++++++              .
01   246   160    161   100    .++++++++++                .
02   251   160    130    80    .++++++++      .           .
03   256   160     60    38    .++++          .           .
```

Figure 28. A PM load profile can be prepared for each required labor skill. Alterations to the PM interval can be made to level this load

The PM load profile indicates the periods in which each skill center is overloaded and those PM jobs contributing most to this overload. Using a terminal, a planner can level the load by altering the date on which PM is scheduled to be performed. The PM record is marked to make sure the adjustment doesn't affect the PM interval calculation. As soon as the date is altered, the system generates a new load profile for the skill center. Overloads generated from PM can thus be significantly reduced (see Figure 29).

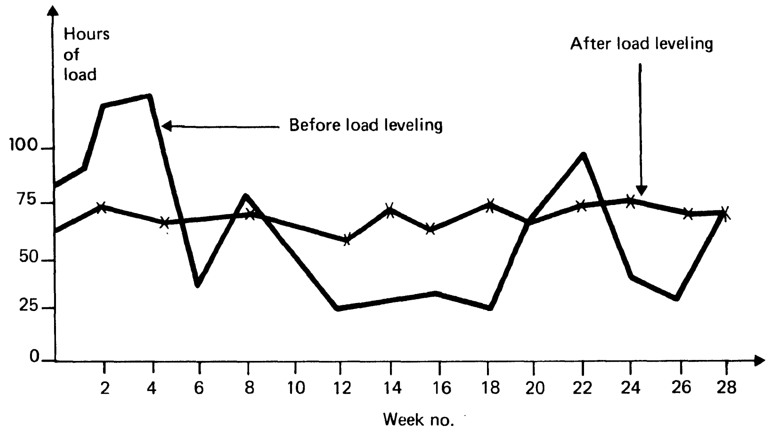


Figure 29. The planned workload generated by PM work orders is periodically adjusted to achieve a level load

Determining breakdown work order load

The skill center file is updated on a periodic basis with data from completed breakdown work orders. This updating technique assumes a normal distribution of breakdown labor demand. Using statistical methods similar to those used in *Chapter 3, Forecasting*, it calculates a mathematical representation of this normal distribution (Figure 30).

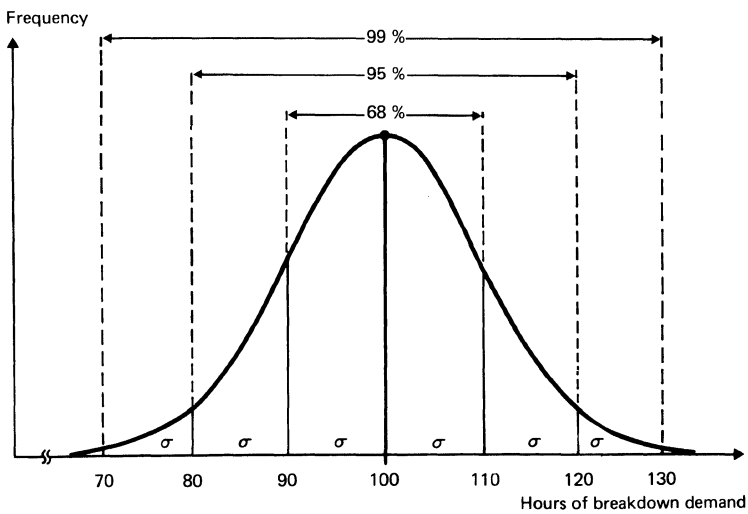


Figure 30. One example of a frequency distribution of daily demand for breakdown repair

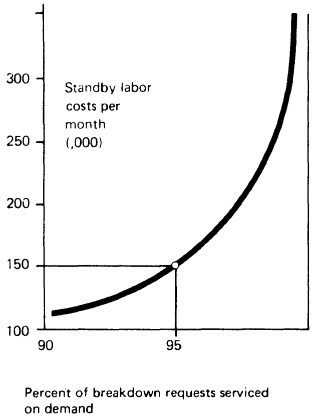


Figure 31. An exchange curve is used to determine the cost of standby maintenance labor

Maintenance management selects how much of the breakdown labor requirement it wishes to handle on demand. If, as shown in the example, management wants to be able to service an average of 95% on demand, the system calculates that this will take 140 hours a day. After allowance for such indirect labor demands as cleanup time, etc., this figure can be converted into the number of "standby" personnel needed for handling breakdown work orders. A curve representing the amount of standby labor required for each level of service can then be calculated. In the example shown in Figure 31, a 95% service level costs 150,000 in standby labor.

Since the cost of standby labor increases dramatically as the service level approaches 100%, maintenance management wants to know in advance the cost consequences of alternative service levels. The exchange curve technique makes it possible to examine the alternatives.

Determining repair work order load

The load represented by open repair work orders can be generated from the Open Work Order File. This file contains the total number of hours remaining for each operation and the estimated operation start date.

Load leveling

Using techniques described under "Order Release Planning" in *Chapter 6, Manufacturing Activity Planning*, the system can help solve load problems by shifting the start dates of planned and PM work orders. The objective is to plan a level PM and repair workload to allow the proper level of standby labor (see Figure 32).

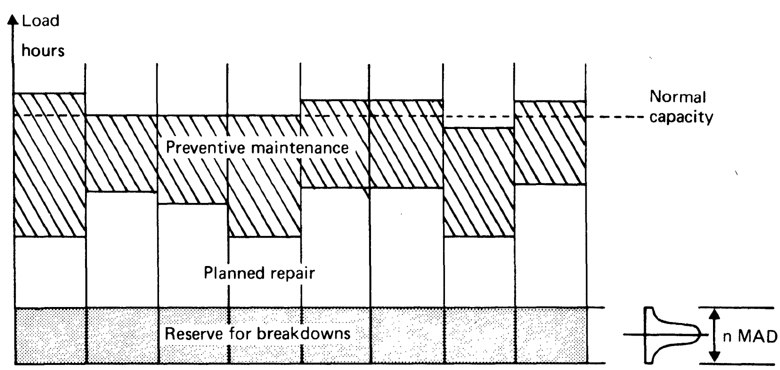


Figure 32. Load profile for a skill group

The actual amount of breakdown determines what portion of planned repair and PM work orders will actually be finished. If the breakdown load is small, PM originally scheduled for the following period may be moved up; if it is large, work has to be deferred. The sequencing of planned and breakdown work orders – that is, deciding what to move up and what to defer – is addressed in "Maintenance Work Order Sequencing".

When an order release date is planned, the system automatically looks ahead for other planned maintenance work that can be done at the same time. If it is economical to perform that work early, the release date on the work order is altered to coincide with the earlier work order. This technique reduces the incidence of shutting the machine down for maintenance.

Figure 33 summarizes the maintenance manpower planning procedure.

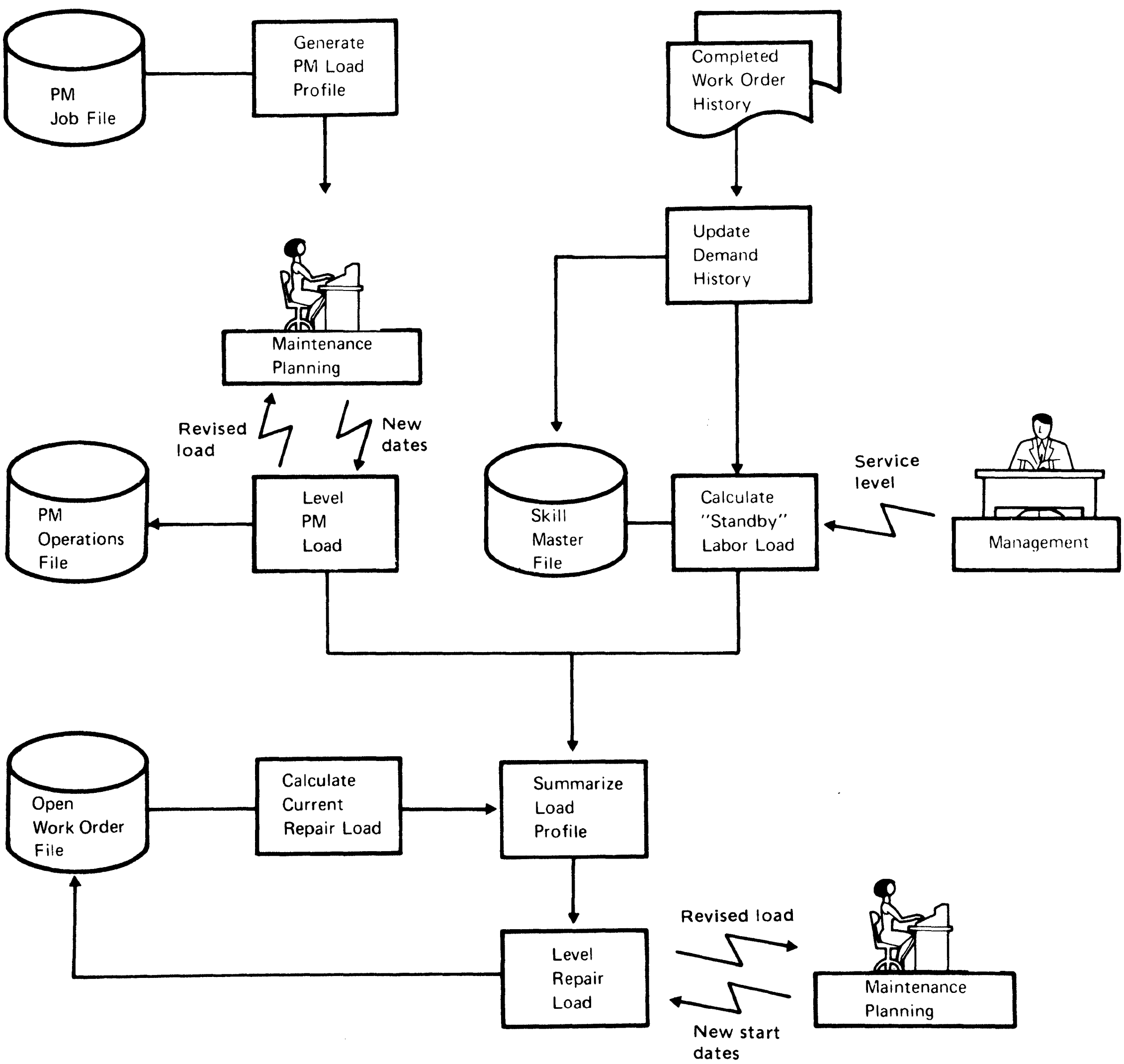


Figure 33. A summary of the basic steps in developing a planned level load on each manpower skill center

Maintenance Work Order Sequencing

The objective of maintenance work order sequencing is to suggest to maintenance foremen the sequence in which to start open work orders.

Establishing Order Priority

The work order entry procedure establishes a priority based on the importance of the operation to production. The system automatically modifies this priority rating on the basis of current conditions in the shop. For example, critical breakdown work orders for an overloaded work center will carry a higher priority than those for an underloaded center. The system automatically supplies other priority factors, such as number of days behind schedule, on a daily basis. The resultant dynamic priority number must be consistent with the priority rating system used for shop orders, because it will be used in the shop order sequencing procedure.

Material Availability

Before the order is released for sequencing, the system makes sure the required material is available. If items are short, the order is not "released" for scheduling. Override of this availability check is possible.

Sequencing

The system that sequences production shop orders will extract those maintenance work orders requiring production equipment to be shut down. These orders are sequenced on the same basis as normal production orders (see "Operation Sequencing" in *Chapter 6, Manufacturing Activity Planning*). The start date and estimated start time calculated by the system are passed back to the work order sequencing system.

This system, using the same logic as for scheduling production operations, then sequences the remaining work orders (those that did not require taking a machine out of production). These orders are scheduled around those that have had schedules fixed by the production sequencing system. The system schedules the highest-priority jobs first and attempts to level the load on the skill centers. The daily capacity of the skill center is scheduled after an allowance has been made for handling breakdown work orders.

Where multiple skills are involved on one work order, the system assigns a controlling skill center, and this is scheduled first. The associated skill requirements are handled on a high-priority basis, thus assuring their concurrent scheduling.

Work orders with short duration times, such as lubrication, are grouped together by job location and skill code. A work order group number is assigned which assures they are scheduled as an entity. This grouping also facilitates labor reporting by reducing the amount of data the maintenance man must enter.

The result of the scheduling system, the work sequence list, is placed in an Action File, which will be used by the foreman or dispatcher during job assignment. Figure 34 shows a terminal inquiry into this file.

MAINTENANCE WORK SEQUENCE LIST

LINE NO.	WORK ORDER NO.	PRIORITY NO.	CC	MACH NO.	AREA LOC	WORK ORDER DESCRIPTION	LABOR SKILL CODE	EST. STD. HRS.	IC	SCHED START TIME	MAN NO.	ESTD. COMP. TIME	STATUS CODE
1	50230	9	04	45927	01	BREAKDOWN	02	2.5	*	08:00	43210	10:30	RUN
2	53179	7		37172	01	REPAIR	04	1.3		08:00	51027	09:18	RUN
3	52421	7		20001	03	REPAIR	04	1.5	*	11:50	43210	02:30	RUN
4	50061	4		43972	72	GREASE	04	0.1		09:05	39110	09:11	WF
5	49317	2		20101	24	GREASE	04	0.1		09:15	39110	09:21	RUN

TITLE: CC CONTROL CODE; IC INTERRUPT CODE

STATUS CODE: RUN RUNNING; NA NOT ASSIGNED; WF WAITING FACILITY; WL WAITING LABOR; WM WAITING MATERIAL

Figure 34. The work sequence list recommends a sequence of work based on priority

Adherence to this schedule assures that management's overall objectives are met, including those of the production departments.

Figure 35 summarizes this scheduling procedure.

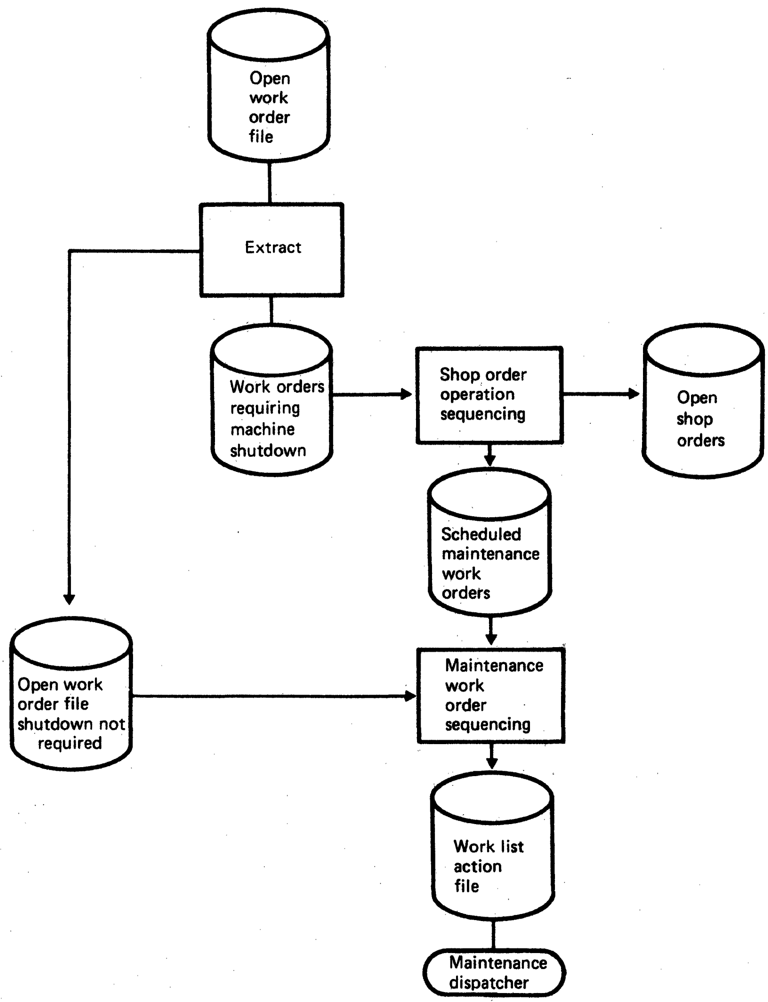


Figure 35. A summary of the basic steps performed during work order scheduling

The role of plant floor terminals in maintenance job dispatching is significant for two major reasons:

- Maintenance men are widely dispersed, making direct supervision difficult.
- The high incidence of breakdown work orders makes planning and dispatching a "real-time" application. That is, men are constantly being moved to meet high-priority downtime situations. This is in contrast to production, where, since men are normally assigned to one machine for the entire day, a whole day's work can be assigned in advance.

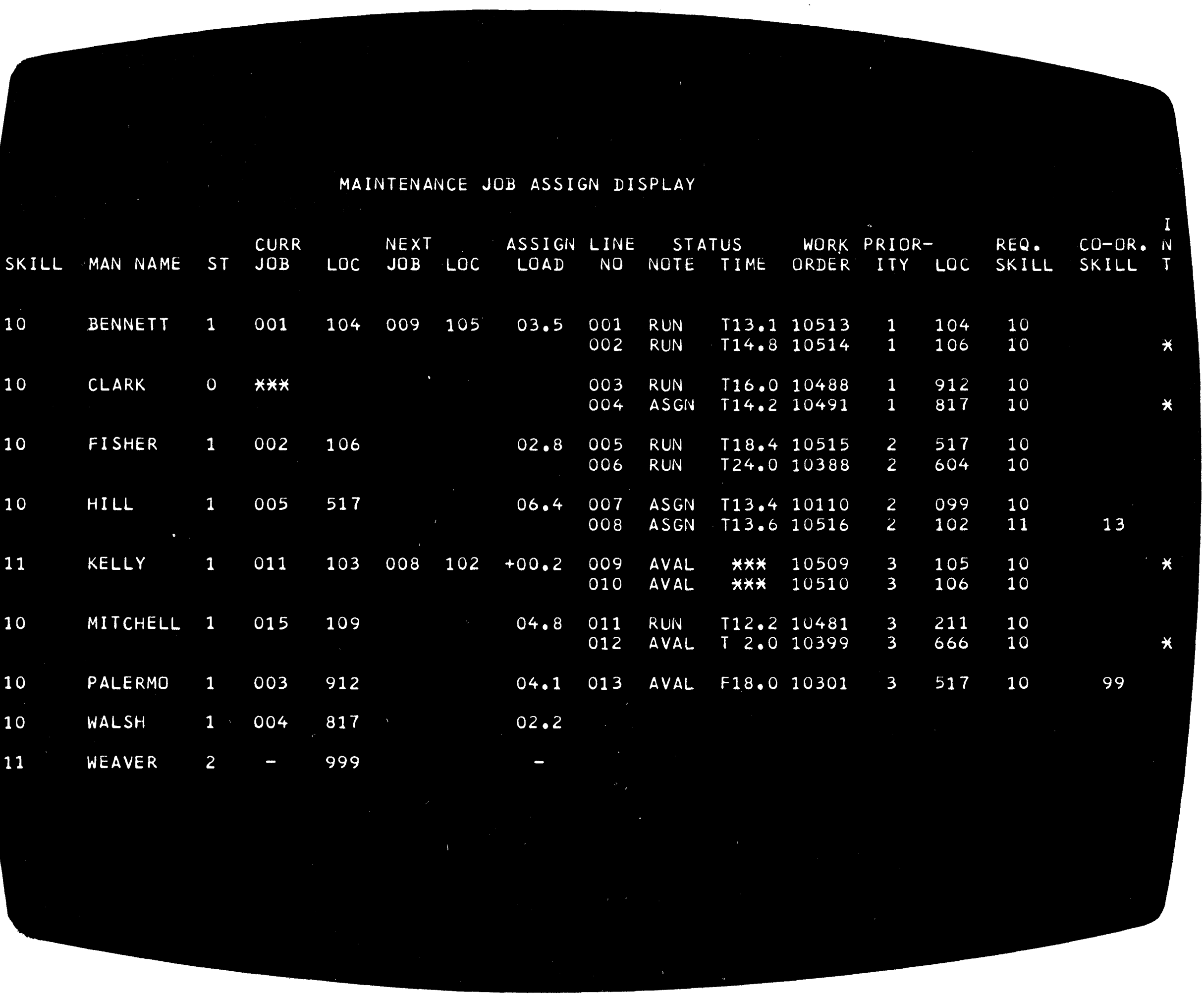
The procedures described in this section allow remotely located maintenance men to be assigned jobs without returning to some central point. As new high-priority breakdown orders are entered by the production foreman or worker, they are placed on the work sequence list according to priority.

Job Assignment by the Planner

The work list for each skill center is accessible to the maintenance planner (foreman or dispatcher) via an Action File generated by the work order sequencing system. This Action File is updated as the maintenance workers and production foremen enter breakdown and maintenance labor reports. For job assignment purposes, a portion of this file is displayed in priority sequence on one side of a screen (Figure 36).

The planner can request additional work order information from the Open Maintenance Work Order File if more detail is needed. The system also maintains an Assigned Work File, which keeps track of the jobs assigned to each man. It is concurrently displayed on a terminal (Figure 36). The planner assigns the work order by keying in the line number of the work order to be assigned in the space allocated next to the man's name. This procedure is very similar to that described under "Job Assignment" in *Chapter 8, Plant Monitoring and Control*, which should be reviewed for more detail. With the entry of the line number, the system:

- Updates the Work List Action File to indicate that the job has been assigned.
- Calculates the estimated work order start time on the basis of the estimates of jobs previously assigned to the man.



MAINTENANCE JOB ASSIGN DISPLAY

SKILL	MAN NAME	ST	CURR JOB	LOC	NEXT JOB	LOC	ASSIGN LOAD	LINE NO	STATUS NOTE	STATUS TIME	WORK ORDER	PRIOR-ITY	LOC	REQ. SKILL	CO-OR. SKILL	INT
10	BENNETT	1	001	104	009	105	03.5	001	RUN	T13.1	10513	1	104	10		
								002	RUN	T14.8	10514	1	106	10		*
10	CLARK	0	***					003	RUN	T16.0	10488	1	912	10		
								004	ASGN	T14.2	10491	1	817	10		*
10	FISHER	1	002	106			02.8	005	RUN	T18.4	10515	2	517	10		
								006	RUN	T24.0	10388	2	604	10		
10	HILL	1	005	517			06.4	007	ASGN	T13.4	10110	2	099	10		
								008	ASGN	T13.6	10516	2	102	11	13	
11	KELLY	1	011	103	008	102	+00.2	009	AVAL	***	10509	3	105	10		*
								010	AVAL	***	10510	3	106	10		
10	MITCHELL	1	015	109			04.8	011	RUN	T12.2	10481	3	211	10		
								012	AVAL	T 2.0	10399	3	666	10		*
10	PALERMO	1	003	912			04.1	013	AVAL	F18.0	10301	3	517	10	99	
10	WALSH	1	004	817			02.2									
11	WEAVER	2	-	999			-									

Figure 36. The maintenance planner uses this job assignment display in assigning work orders to maintenance men

- Updates the man's Assigned Work File to indicate that the extra work has been added.
- Edits to make sure that the proper skill code is assigned.

Many work orders call for a production facility to be shut down. This requires coordination with production work centers. PLANT MONITORING AND CONTROL maintains the current status of every production machine, including the estimated completion time for the production job that the work order is to follow. If the downtime is significant, the planner calls the production foreman to verify that the assigned sequence can still be maintained. If the plant monitoring system significantly alters its estimate of a job completion time, the planner is notified via an Action File. This interaction reduces maintenance men's waiting time while minimizing machine downtime (the man and the machine need not wait for each other).

If multiple skills are involved, the system assigns a "controlling" planner based on the highest labor hours estimate and the size of the work backlog of the required skills. For example, if two hours of skill code 10 are required and four hours of skill code 25 are also needed, the planner responsible for skill 25 is given control. The assignment of a maintenance man by the controlling planner creates a coincident demand on each of the coordinating skills. When the planner for skill code 25 assigns the work order, a concurrent demand is placed on the planner for skill code 10. This coincident demand is handled by automatically assigning it a high priority, which has the effect of moving it to the top of the work queue file. When the job is assigned, a fixed schedule is designated. This coordination of multiple skills reduces the idle time of maintenance personnel as well as facility downtime.

Assignment Acceptance

The maintenance man picks up his next assignment as a result of reporting the completion of his previous job. The terminal prints his next job assignment (see Figure 37). This eliminates the need for the man to return to a central point for assignment. It also avoids the need to assign several jobs at once and it preserves the flexibility needed to reassign men to meet emergency situations.

```
P. M. W O R K   O R D E R                       DATE  302
-------------------------                       TIME  14:29

W O NO: 43217   MACH: 00171  WARTON GRINDER    LOCN: 104
MAINT. CODE 0419   CO-ORD. CODE: 00
DESCRIPTION REF.NO. 194 REPLACE FILTER
STD. HOURS: 0.25
MATERIAL:    617002                          ALLOC. QTY. 1
DESCRIPTION 1.5 X 2.5 X 0.25 FILTER          ACTUAL QTY. 0
```

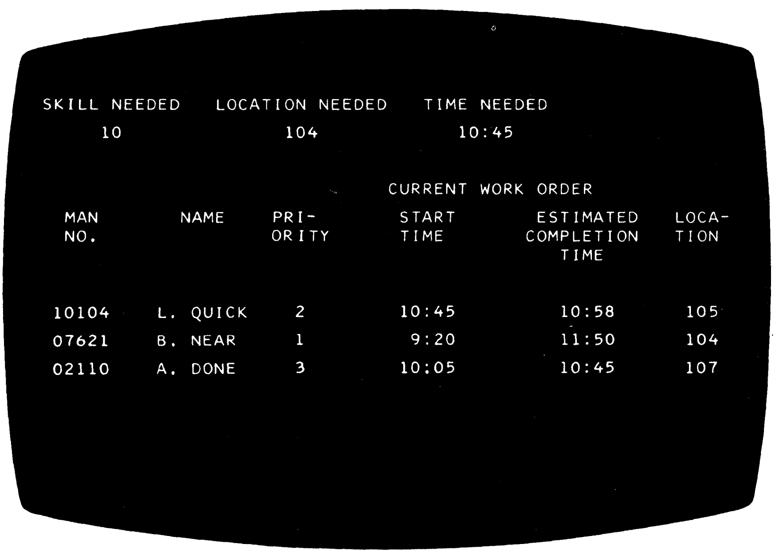
Figure 37. The next assignment is printed when the maintenance man reports completion of his previous job

When a machine goes down unexpectedly, the system can "look ahead" and release other pending work orders for the same machine. These additional work orders can be printed out at the same time. This lookahead capability saves transit time, reduces facility downtime, and reduces the production coordination that would be needed if the pending jobs were performed later.

The maintenance man uses the printed requisition as authority to withdraw any required material. Insertion of his identity badge and entry of the work order number at the stores area is sufficient to signify that the material has been withdrawn from stock. The Inventory File and the Open Work Order File are immediately updated to reflect the requisition.

Altering the Job Assignment

Because of the high incidence of breakdown work orders it may be necessary to alter the sequence of previously assigned work orders. The labor reporting system provides the planner with the exact location of all men at all times (see *Chapter 8, Plant Monitoring and Control*). Therefore, when a high-priority work order appears in the Work List Action File, the planner can request a display of the qualified men nearest the machine. In response, the system indicates the estimated completion time of the men's current assignments (Figure 38).



SKILL NEEDED	LOCATION NEEDED	TIME NEEDED
10	104	10:45

MAN NO.	NAME	PRI- ORITY	CURRENT WORK ORDER START TIME	ESTIMATED COMPLETION TIME	LOCA- TION
10104	L. QUICK	2	10:45	10:58	105
07621	B. NEAR	1	9:20	11:50	104
02110	A. DONE	3	10:05	10:45	107

Figure 38. Display showing the location of men and the status of jobs they are working on

This procedure reduces transit time and improves service by assuring the assignment of the next-available qualified man. The reassignment is accomplished as described under "Assignment of Men to Machines" in *Chapter 8, Plant Monitoring and Control.* The deferred job reappears in the Work List Action File.

Labor Reporting

Maintenance labor reporting is done via the system used by production workers. The procedure is essentially the same. The man reports both the completion of the present work order and the start of the next job. The difference between the two reports is the time it takes him to travel from the old to his new assignment. If he exceeds the transit standard by a significant amount, the system alerts the planner.

The major differences from production reporting procedures are:

- Within a specified time, the man must provide a time estimate for breakdown orders.
- A work order identification card does not exist and the maintenance man must key in the work order number when transmitting order activity.

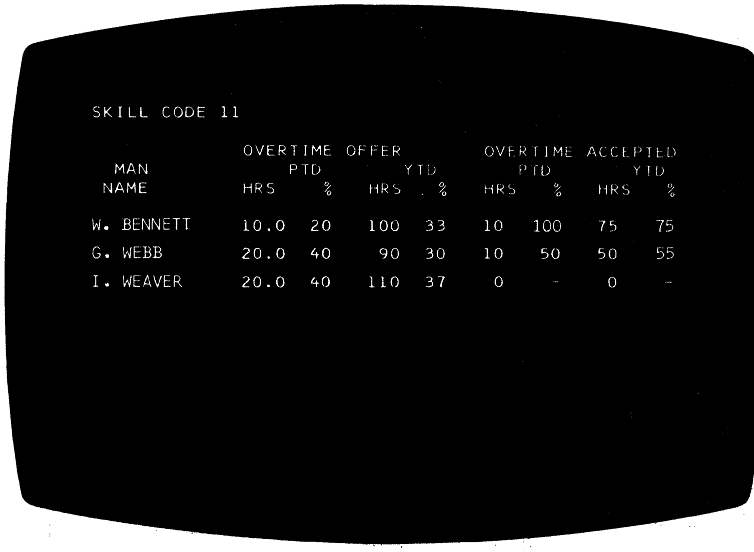
When the man reports completion of the work order, it is removed from the Work List Action File, the Open Work Order File and man's work queue. A summary of the work order is placed on the Work Order History File.

Overtime Offers and Acceptance

The planner can place offers for overtime in the man's Assigned Work File. An overtime offer consists of a requested work date and a start/stop time.

The offer appears the next time the man reports on the system. If the man is on an all-day assignment, he must be orally instructed to review his assignment. He responds to the request when it first appears. If not, the system notifies the planner. The man acknowledges the offer by inserting his identity badge and keying a code for acceptance or rejection. If he accepts, his assigned work record is immediately updated to reflect the fact that more work can be assigned. In either case, the man's record is updated to reflect how much overtime he has been offered and how much he has accepted. This information, being available to the planners, helps them make consistent overtime offers to personnel (Figure 39).

Figure 40 summarizes the job assignment and dispatching function. The procedure described is similar to that given further detail in *Chapter 8, Plant Monitoring and Control.*



SKILL CODE 11

MAN NAME	OVERTIME OFFER PTD HRS	%	YTD HRS	%	OVERTIME ACCEPTED PTD HRS	%	YTD HRS	%
W. BENNETT	10.0	20	100	33	10	100	75	75
G. WEBB	20.0	40	90	30	10	50	50	55
I. WEAVER	20.0	40	110	37	0	-	0	-

Figure 39. A history of overtime offers and acceptances is maintained to help planners make consistent offers

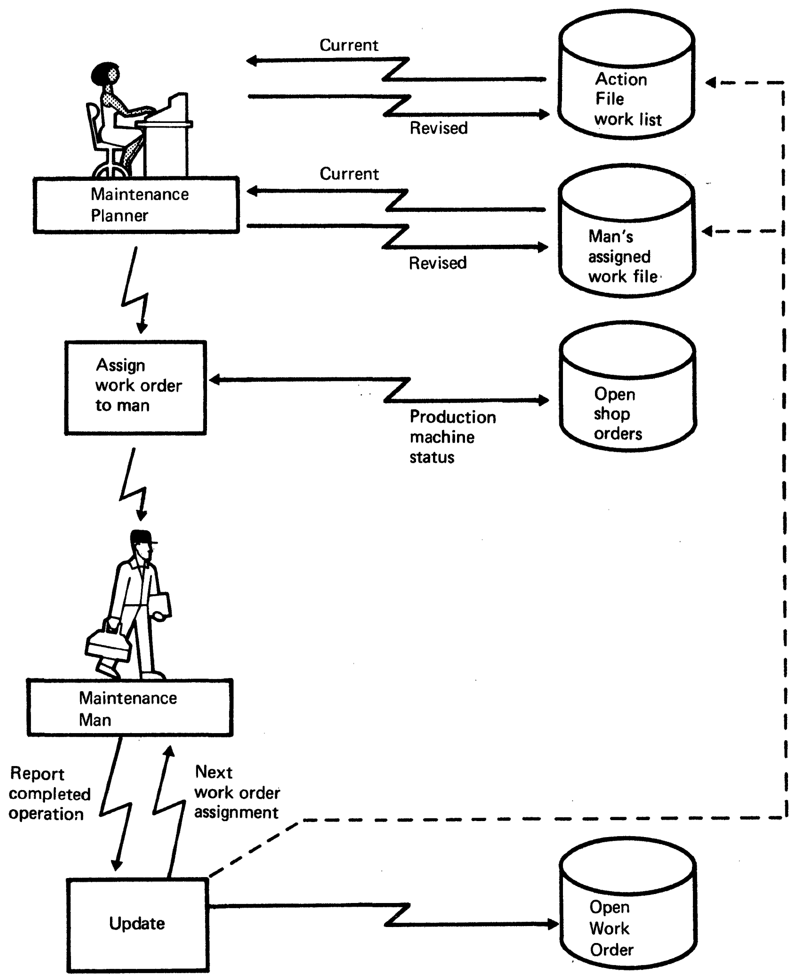


Figure 40. The basic steps for work order dispatching

As material requisition and maintenance labor reports are transmitted from the plant floor, the Open Work Order File is updated. The editing, error correction, audit trail techniques, etc., are very similar to those used for reporting direct production data. When the maintenance man, foreman, or planner indicates that the work order is complete, the system removes it from the Open Work Order File and transfers the data to the history file.

If the work order cost is to be capitalized (perhaps for a major facility modification), a separate "capitalized work order history" record is created. The accounting system uses this record to calculate depreciation, estimate salvage gain or loss, etc.

If the work order is not capitalized, it is summarized into the maintenance history file, which maintains an historically comparative cost record (life, last three years, year to date, month to date) for each facility. The system also calculates the average cost per unit of production, or hour of running time, for each machine.

Identical and/or similar facility records are linked together via a facility-type record. This record contains historical averages and trends of maintenance costs by similar types of facilities. Comparisons of machine running costs based on vendor (Figure 41) can be generated. This information can be useful when contemplating additional machine purchases.

SUPPLIER EQUIPMENT EVALUATION DATE 270

GROUP NO. 00110 GROUP NAME 42 IN HORIZONTAL MILLS

SUPPLIER NO.	NAME	MACH NO.	MONTHLY USAGE (HRS)	AVE. DOWN-TIME/MO.(HRS)	DIFFERENCE FROM AVE.	COST/ HOUR
43171	MILLING CORPN.	00017	120	24.0	+ 13.8	7.30
42010	MILLERS LIMITED	00302	157	2.5	- 8.7	11.51
37917	MACHINES INC.	00417	242	7.1	- 4.1	10.62
GROUP AVERAGE			173	11.2		9.61

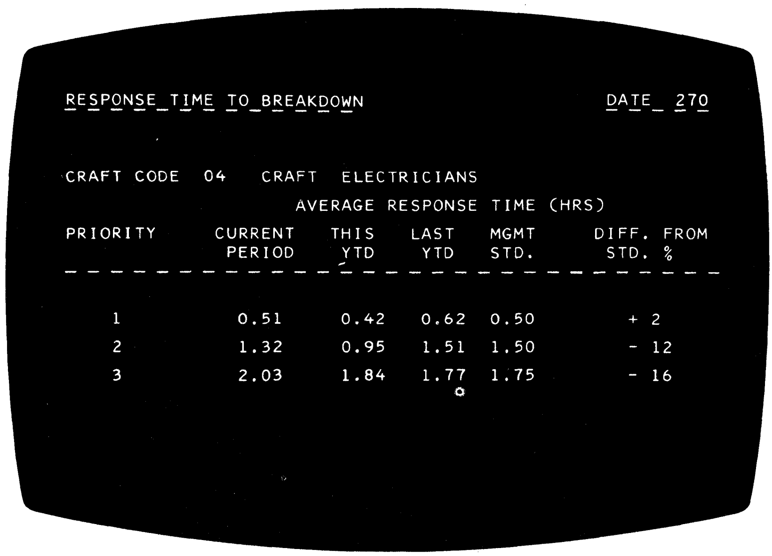
Figure 41. The work order costing system allows the maintenance costs of similar machines to be compared

Evaluating the Maintenance Program

The data established and maintained by the system allows the maintenance program to be evaluated by a wide variety of factors – for example:

- How well are the skill centers responding to calls for breakdown work orders?

  Figure 42 indicates the response time of skill centers. These reports encourage maintenance foremen to achieve quick response time. Historical comparisons, indicating unfavorable trends, can be highlighted in an Action File.



RESPONSE TIME TO BREAKDOWN DATE 270

CRAFT CODE 04 CRAFT ELECTRICIANS

	AVERAGE RESPONSE TIME (HRS)				
PRIORITY	CURRENT PERIOD	THIS YTD	LAST YTD	MGMT STD.	DIFF. FROM STD. %
1	0.51	0.42	0.62	0.50	+ 2
2	1.32	0.95	1.51	1.50	- 12
3	2.03	1.84	1.77	1.75	- 16

Figure 42. Response time to breakdown work orders

- How well are the foremen utilizing their resources?

  Action messages (Figure 43) can be generated when the percentage of nonproductive labor exceeds the historical average or a management standard.

LABOR UTILIZATION

CRAFT MILLWRIGHTS NO.OF MEN 8 TOTAL AVAILABLE HOURS/WEEK 280

TYPE	PERIOD AVE %	YTD AVE %	+ PCENT - CHANGE	MGMT STD.	+ PCENT - CHANGE	EXCEP -TION
PM	16.0	20.0	- 20	23.0	- 3	
REPAIR	24.5	22.0	+ 11	20.0	+ 4.5	
BREAKDOWN	7.0	14.5	- 52	12.0	- 5	
TRANSIT	17.0	13.5	+ 26	15.0	+ 2	
EDUCATION	8.5	12.0	- 29	10.0	- 1.5	
OTHER	6.0	12.5	- 52	15.0	- 9.0	*
IDLE	21.0	5.5	+ 282	5.0	+ 16	*
	100.0	100.0		100.0		

Figure 43. Labor utilization by skill center

- Is increased preventive maintenance effort lowering costs?

  Where is preventive maintenance most effective?

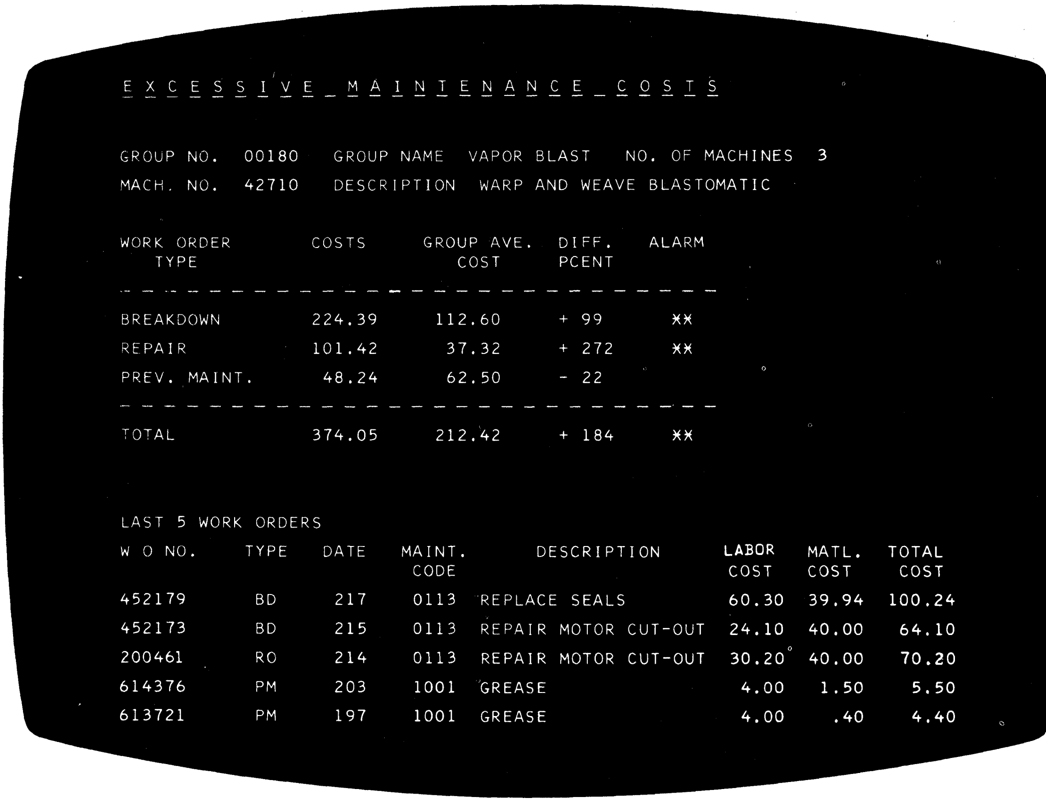
  An increase in total maintenance costs after a period of gradual reduction may indicate that recent maintenance changes were ineffective. Figure 44 shows an action message generated by excessive maintenance costs. If preventive maintenance costs are up, and breakdown and repair costs have not gone down enough to cover the increase, preventive maintenance should perhaps be cut back; if preventive maintenance is down and breakdown has increased, PM should perhaps be restored to its previous level.

  In the areas of maintenance costs, the system will indicate not only negative but also significant and positive trends. For example, if maintenance costs have decreased sharply in the face of increasing PM, the same PM procedures recently initiated for this facility should also be applied to facilities with similar functions.

- Are the work order schedules being met?

  An unusually high incidence of breakdown and planned repair may result in a sudden increase in the number of late PM work orders. If this demand is not met by overtime, outside assistance, etc., the failure to meet PM intervals will cause the incidence of machine breakdown to increase and the situation will rapidly deteriorate.

  The system, therefore, constantly monitors work order progress and issues exception reports when the late backlog increases beyond an established standard. Figure 45 illustrates such a report.



EXCESSIVE MAINTENANCE COSTS

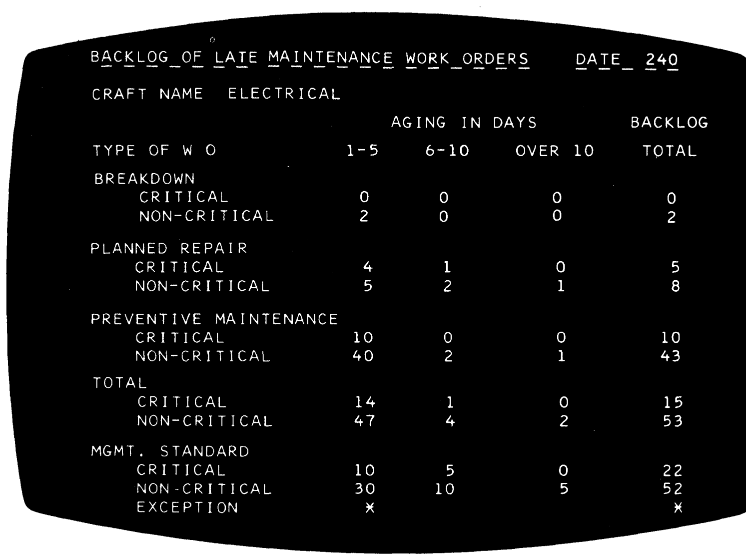
GROUP NO. 00180 GROUP NAME VAPOR BLAST NO. OF MACHINES 3
MACH. NO. 42710 DESCRIPTION WARP AND WEAVE BLASTOMATIC

WORK ORDER TYPE	COSTS	GROUP AVE. COST	DIFF. PCENT	ALARM
BREAKDOWN	224.39	112.60	+ 99	**
REPAIR	101.42	37.32	+ 272	**
PREV. MAINT.	48.24	62.50	- 22	
TOTAL	374.05	212.42	+ 184	**

LAST 5 WORK ORDERS

W O NO.	TYPE	DATE	MAINT. CODE	DESCRIPTION	LABOR COST	MATL. COST	TOTAL COST
452179	BD	217	0113	REPLACE SEALS	60.30	39.94	100.24
452173	BD	215	0113	REPAIR MOTOR CUT-OUT	24.10	40.00	64.10
200461	RO	214	0113	REPAIR MOTOR CUT-OUT	30.20	40.00	70.20
614376	PM	203	1001	GREASE	4.00	1.50	5.50
613721	PM	197	1001	GREASE	4.00	.40	4.40

Figure 44. Significant changes in maintenance cost



BACKLOG OF LATE MAINTENANCE WORK ORDERS DATE 240

CRAFT NAME ELECTRICAL

TYPE OF W O	AGING IN DAYS 1-5	6-10	OVER 10	BACKLOG TOTAL
BREAKDOWN				
CRITICAL	0	0	0	0
NON-CRITICAL	2	0	0	2
PLANNED REPAIR				
CRITICAL	4	1	0	5
NON-CRITICAL	5	2	1	8
PREVENTIVE MAINTENANCE				
CRITICAL	10	0	0	10
NON-CRITICAL	40	2	1	43
TOTAL				
CRITICAL	14	1	0	15
NON-CRITICAL	47	4	2	53
MGMT. STANDARD				
CRITICAL	10	5	0	22
NON-CRITICAL	30	10	5	52
EXCEPTION	*			*

Figure 45. Late work order backlog

- When should equipment be overhauled or replaced?

  Data generated by PLANT MONITORING AND CONTROL can be used to detect possible maintenance problems that would not appear as increased maintenance cost. For example, the following may signal the existence of unreported malfunction:

  Lower production efficiency on one machine when compared with others in its group

  Lower capacity utilization on one machine, possibly since the production foreman is avoiding it because of trouble

  An increase in the amount of non-rated labor

  Wide deviations in efficiency, utilization, etc., are highlighted via an Action File.

- Is PM being performed as directed and is it being performed correctly?

  Since most PM is performed without the direct surveillance of the maintenance foreman, it is hard to tell whether it is being done at all, let alone correctly.

  The system therefore keeps track of the man last performing a PM operation. If the equipment fails despite PM, the responsible man's record can be automatically updated to reflect the failure. If the man's failure rate exceeds the average for his skill classification, he may need retraining or closer supervision.

Summary

PLANT MAINTENANCE as discussed utilizes techniques similar to those used for direct production systems in order to bring a high level of planning and control into an area long considered too unique for "normal" systems approaches. It places heavy emphasis on the use of remote terminals to control a widely dispersed labor force and assure quick reaction to emergency downtime situations.

The system improves facility availability, thus reducing production interruptions while holding maintenance labor and material costs to a minimum. It establishes a base for evaluating preventive maintenance policy and machine replacement.

It helps establish a realistic preventive maintenance interval, thereby reducing PM costs.

The establishment of a parts catalog allows normal inventory control procedures to be applied. This reduces material shortages and/or investment in maintenance parts inventory.

The total effect is an increase in machine availability with lower overall maintenance costs.

Notes

Notes

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