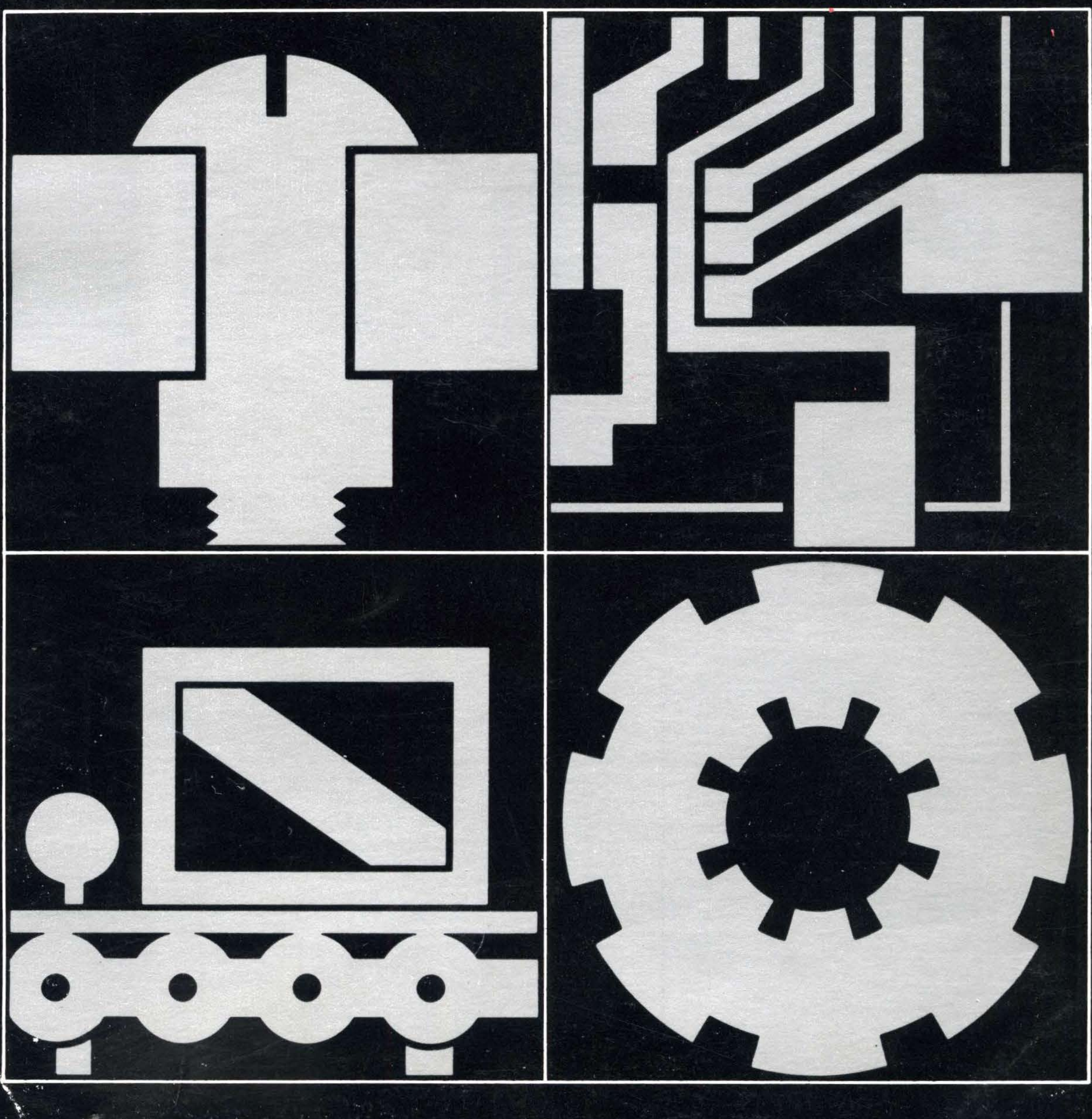
Communications Oriented Production Information and Control System

Volume II

Chapter 1 Engineering and Production Data Control
Chapter 2 Customer Order Servicing



IBM

Communications Oriented Production Information and Control System

Volume II

Chapter 1 Engineering and Production Data Control
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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 1. Engineering and Production Data Control

Contents

Introduction

ENGINEERING AND PRODUCTION DATA CONTROL addresses the creation, organization, maintenance, and communication of the basic engineering records within a company:

- *Bills of material* or "parts lists" describing what goes into a product or assembly
- *Engineering drawings* illustrating the shape, size, and relationship of the items in a product
- *Manufacturing routings* or "process sheets" describing the sequence of operations to be performed on fabricated items and assemblies
- *Manufacturing facility* records describing the machines, work centers, and tooling used in the manufacture of each item

For companies manufacturing products requiring complex engineering, such as aircraft, records of all changes must also be maintained from the point of initial design through manufacture and, if necessary, through the end of the product life. These records include:

- *Engineering changes* describing current and planned changes to products
- *Engineering change history* showing previous changes to products
- *Drawing change history* listing previous changes to drawings
- *Product history* detailing what went into completed products

Effects of engineering changes

Engineering data is subject to a large volume of changes. The designing and planning of a product is complicated and passes through a number of cycles before it is finalized.

In addition, companies are constantly changing product design and manufacturing methods to improve their products and reduce costs. New products are added and old products are discontinued all the time. Engineering departments are responsible for the creation and maintenance of the records that implement these changes and for the communication of this change information to other departments accurately, rapidly, and clearly. Accounting, for example, requires this data for costing and pricing; Production Control needs it to produce the items; Materials Control needs it to plan the acquisition of components and raw materials; and so on.

When the information is needed, it must be promptly supplied in different formats and sequences to satisfy each department's specific requirements. As a result, many companies have been forced into the costly practice of maintaining this essential information in several locations and several formats.

Because of the large volume of paperwork generated, the various locations where the data is maintained do not always make the changes in the same way at the same time. The result in many companies is that the bill of material in the accounting department is frequently not the same as the bill maintained in the engineering or production departments.

Consequently, different areas of the business may be making decisions that could affect the price, profitability, serviceability, and performance of the product on the basis of records that do not agree and may even be inaccurate.

A communication system is needed to disseminate these changes rapidly and accurately.

Advantage of one set of engineering records

The objective of ENGINEERING AND PRODUCTION DATA CONTROL is to organize and maintain engineering records in one central location for use by all areas of the business. This "one set of books", called a "data base", eliminates costly duplication of records and ensures that all departments are making decisions based on the same data.

The advantages of one data source for engineering records are:

- All reports throughout the company are in agreement, ensuring that the product is produced the way it was designed and costed the way it was produced.
- Notification of engineering changes is accomplished more quickly, reducing the risk of making or buying obsoleted parts.
- Fewer changes need be processed, reducing departmental costs. For example, Costing and Production do not need to update separate files as a result of a change to the bill of material.
- The organization of the data base is designed to facilitate change and rapidly determine the effect of a change. For example, new bills of material for product variants can be specified by just entering the differences from the original engineering bill of material.

Use of data processing terminals in the system

Terminals situated in the design and production engineering departments provide the ability to:

- Evaluate engineering changes before their approval, by simulating their effect.
- Enter changes directly, using inline editing techniques to help ensure that all data is entered accurately. Security techniques can be incorporated to prevent unauthorized personnel from entering changes to the engineering records.
- Rapidly communicate urgent changes via Action Files to other departments, thereby minimizing the risk of ordering or manufacturing obsoleted parts.
- Inquire into the data base – for example, to check whether similar items exist before designing new parts, thereby preventing wasted design and production effort.
- Report the movement of drawings and documentation through the engineering departments, thereby reducing time lost in searching for a drawing that is being modified.

Configuration control

A major use of engineering and production data is to ensure that the configuration of the product shipped is the configuration that was designed – in other words, that the correct features, customer options, and engineering changes have been incorporated. In addition, it may be necessary in the future to supply spare parts for a given model/configuration, and this may be impossible if details of the configuration are not known. The application that helps provide a solution to these problems is configuration control, sometimes called configuration management.

Although its use thus far has been in industries where there are complex engineered products, where there is a long manufacturing lead time, and where changes are constantly being made from initial design through delivery of the product, the requirement for good configuration control appears in varying degrees within many industries. The system assists configuration control by helping to ensure that:

- The engineering bill of material (how the product is designed) and the production bill of material (how it is made) are in agreement and produce the desired product.
- Customer-requested options, variants, and changes are feasible and currently incorporated into the product.

- Items are manufactured to the correct engineering change level and all necessary engineering changes are incorporated.
- Component items (usually designed first) are incorporated into a bill of material and all components referenced by the bill are fully described – that is, there are no "loose ends".
- Engineering change information can be maintained after delivery to the customer. This enables the correct service parts and product modifications to be fitted.

From design through production and field product support, the engineering data base and communication facilities provide the data, the data editing procedures, and the rapid communication necessary to maintain configuration control of a changing product (Figure 1).

Outline of the system

Figure 2 outlines ENGINEERING AND PRODUCTION DATA CONTROL and shows the major types of data used:

- *Item data* – the creation and organization of the information relating to each item used in current production or stocked as spares. An item could be a product, assembly, component, or raw material. Maintenance parts, supplies, disposable tools, etc., are also held, but normally without a bill of material.
- *Bills of material* – the structuring and organization of the data describing what the product is made from (raw materials used in each component, components used in each assembly, and the assemblies used in each end product) and how bills can be structured to handle variants and options.
- *Engineering drawing control* – the relationship of drawings to bills of material, drawing change history, and the control of new drawings and those being currently revised. A record of each drawing used to make a product is maintained. Thus all drawings used on a product, or, conversely, all products affected by a drawing, can be quickly determined. For each previous issue level of a drawing, a record related to the corresponding engineering change level is held in the drawing change data.
- *Engineering change control* – the entry of current and pending engineering changes into the system, together with the simulation of the effect of the change.
- *Product support* – the maintenance of the engineering change level for products delivered to customers (product history data). It can also include changes made to the product after delivery. The use of the system to develop parts catalogs and service manuals is also discussed.

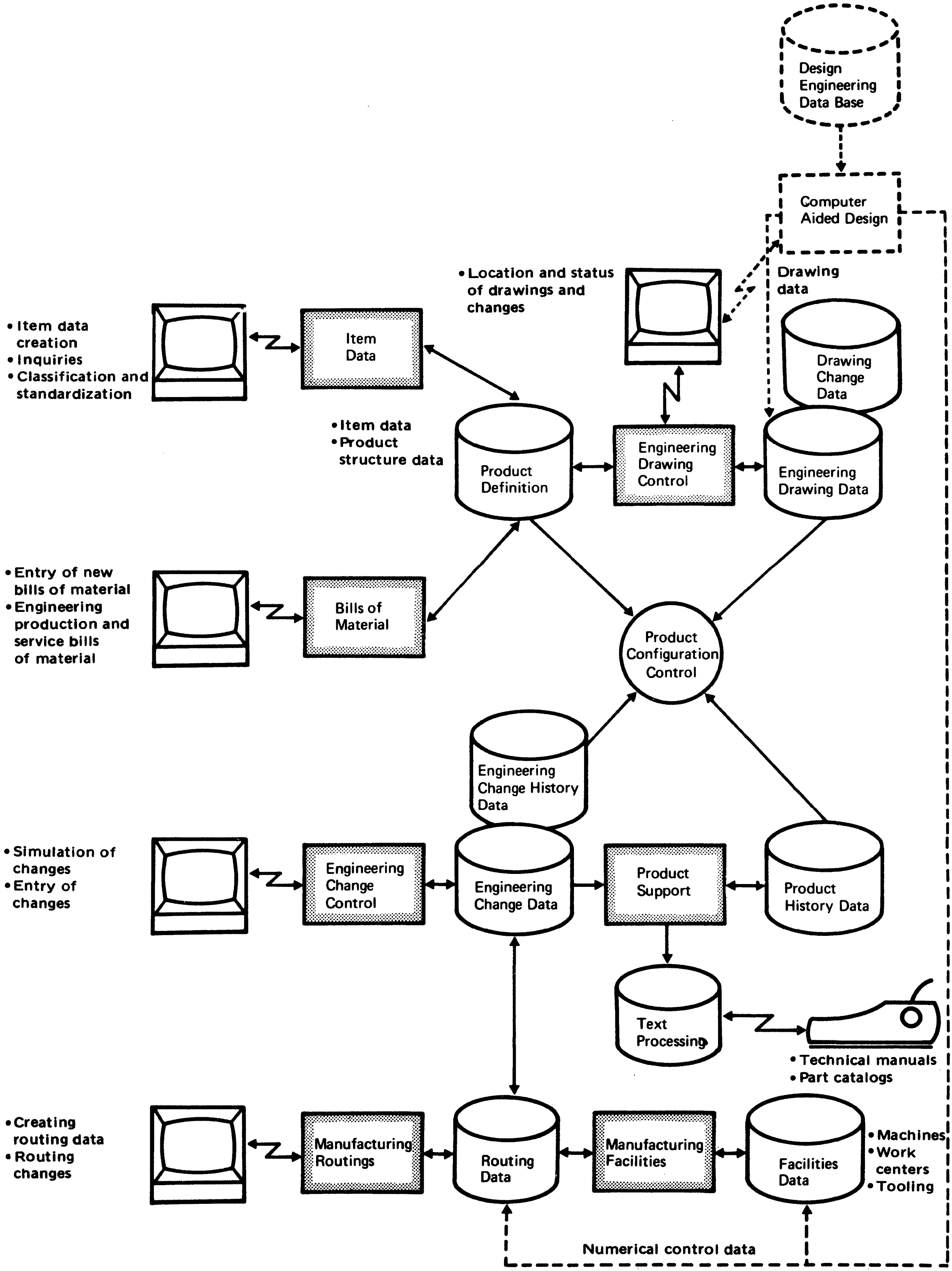


Figure 1. Configuration control helps ensure that the item is manufactured as designed

- *Manufacturing routings* – the creation and organization of routing and alternate routing data, describing the operations, tools, and machines used in the manufacture of each item. Each operation in the routing is associated with the record of the appropriate manufacturing facility.
- *Facilities data* – the creation and organization of data describing machines, machine groups, work centers, cost centers, and tools.

Relationship with other application areas

ENGINEERING AND PRODUCTION DATA CONTROL creates and manages much of the basic data used by other application areas. For example:

- INVENTORY MANAGEMENT uses engineering change records for planning and ordering item requirements.
- MANUFACTURING ACTIVITY PLANNING depends upon manufacturing routing and facility records for the planning of capacity requirements.
- PLANT MONITORING AND CONTROL uses facility records for machine and work center information, tool control, and so forth.
- PLANT MAINTENANCE requires production data from the facility records for planning preventive maintenance work and combining machine repairs with planned maintenance.
- COST PLANNING AND CONTROL uses bill of material and routing data to compute standard and actual costs, determine variances, and facilitate management controls.

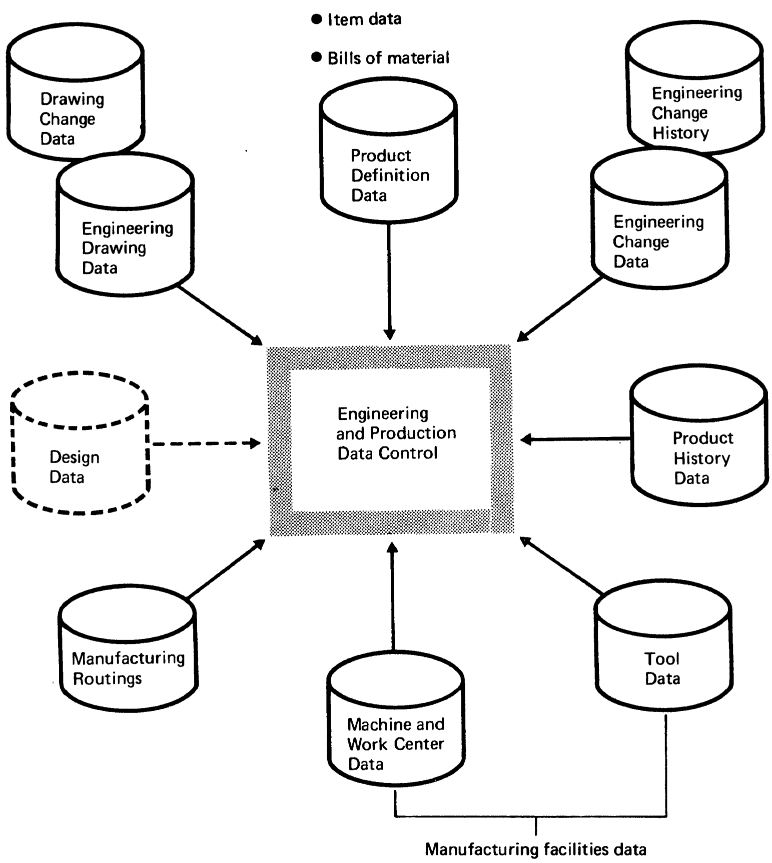


Figure 2. Major types of data controlled by ENGINEERING AND PRODUCTION DATA CONTROL

Item Data

Organization of Item Data

The product definition data base contains data describing products, the component parts and raw materials from which they are made, the bill of material, and the routing indicating the manufacturing process.

The foundation of this data base is the "master" information relating to each of these items. An "item" is any unique manufactured or purchased part, that is, end product, assembly, subassembly, component, or raw material. The information includes such data as item number, description, unit cost, lead time to manufacture or purchase, and other relatively fixed descriptive information. It also contains information subject to frequent changes, for example, on-hand inventory, future requirements, and planned orders.

This information originates in all departments in a company – Sales, Design Engineering, Production Control, Purchasing, etc. Each of these areas must communicate changes to the others, and in many companies each area maintains its own set of "master" records. In these cases clerical record maintenance and filing costs are excessive, and clerical error, lost paperwork, and time lost transmitting data virtually ensure that each master file will be different.

An objective of this system is to reduce redundant data by providing for the needs of all areas of the company through a single record for each item. The costly and difficult problem of maintaining separate records is avoided, and the risk of using different versions of the basic product data is reduced.

The item record

Each item record is identified by a unique part number, or "item number". Examples of the engineering and production data contained in each item record are shown in Figure 3. A more complete description of this data is given in *System Data Base.*

Classification of item data

Item records are held in item number sequence in the product definition data base because this is the most common method of presenting information in all departments. The requirements of different departments, however, call for the data to be referenced in many alternative sequences. The engineering department, for example, when designing new items, should determine whether existing similar items can be used. Sales classifies items to analyze orders by product group. Production Control classifies items into assemblies, components, etc.

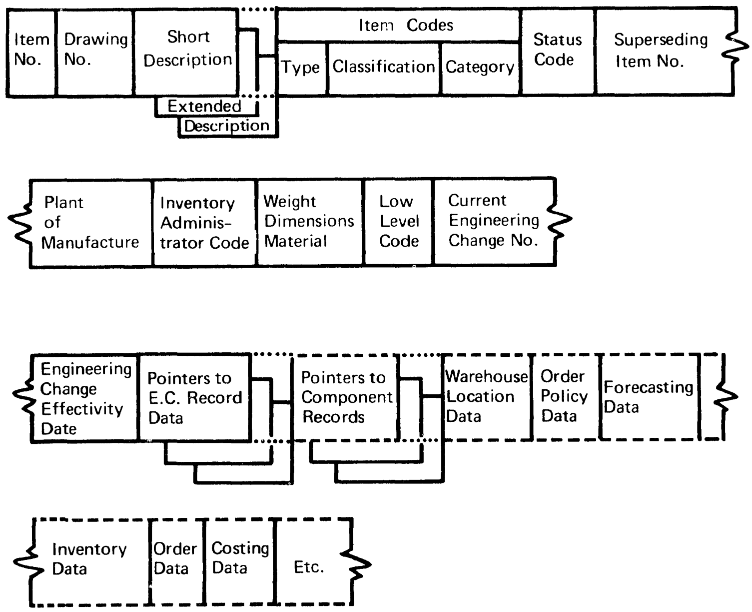


Figure 3. Example of data held in the item record

In order to meet these various requirements, each item is given a "classification code". This code should not be carried as part of the item number, since classification schemes tend to change.

In the design of new products, or variations of existing products, costs can be reduced if the engineer can use existing components and assemblies. However, because of the volume of parts involved, it is often faster for the engineer to specify a new item than to find a suitable existing part. As a result there is a steady growth in the number of items purchased, manufactured, and stocked, and yet many are distinguished only by small differences. It is common for an identical item to be designed many times with an identical specification, but with a different item number. Each time the item is designed, a new routing is needed and duplication may be created in the bills of material. This growth in the number of items causes:

- Increased purchasing costs because of the increased number of purchase orders, and higher prices resulting from smaller volume.
- Increased number of storage locations and higher inventory costs.
- Increased number of shop orders and special purpose tools.
- Duplicate routings and possibly even different standards on identical items.

The classification code enables the most suitable existing items to be found and specified.

product classification

Products are related by functional similarity, whereas components are usually classified according to size, shape, and material. Product classification is achieved by specifying a product group as, in effect, a higher level of the bill of material. The normal end item becomes a "component" of one or a number of classification groupings (Figure 4). The data base provides the ability to add a new group at any time.

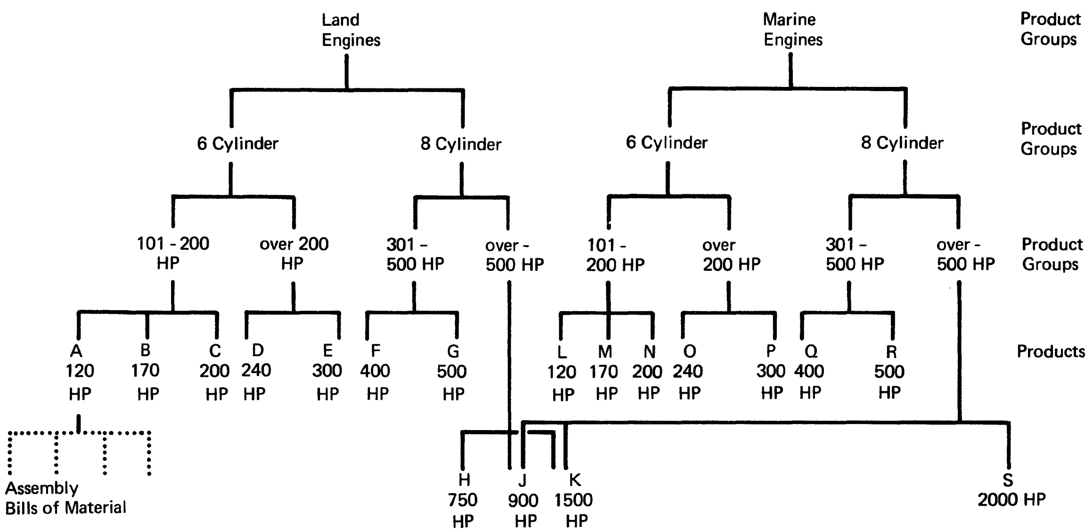


Figure 4. To classify products, they are connected to end-item groups in a manner similar to that of a component in a bill of material

Product classification allows the engineer to obtain information from two points of view – for example:

- Which fuel pumps are used on eight-cylinder engines?
- Which eight-cylinder engines use this fuel pump?

In many instances, a sequence of inquiries, beginning with a generalized question, will enable the engineer at a terminal to narrow the area of his search until he has a unique item or a restricted list from which to choose.

item classification

In order to be able to identify an item on inquiry, the system must be capable of finding items by type as well as by item number. Item classification provides two separate capabilities:

- Rapid identification of all items having common characteristics, when required for a specific design purpose
- A basis for classifying similar items in order to reduce the number of parts and develop standard parts to be used, if possible, in future design work

Classification codes can be of any length and format desired, provided they are not combined with the item number. To be useful, they often need to be relatively long. If classification codes are combined with the item number, it is usually impossible to accommodate the range of numbers required. Within a short period of time the range reserved for one of the characteristics is usually exceeded.

The classification code is held as a separate part of the item record (Figure 5). There may be separate codes for each department that needs to classify items. Thus the benefits of classification can be obtained without disturbing the existing item numbering system.

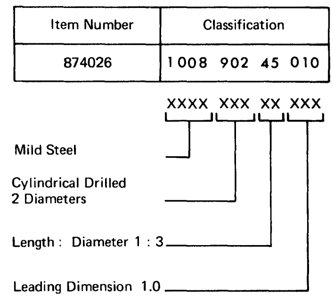


Figure 5. Item number and classification code in item record

If classifications are carried as part of the item number, small changes can have a heavy impact on the system. For example, a change from metal to plastic in a family of parts would require a large volume of changes to item numbers and bills of material.

With separate classification codes, the item number can usually be limited to a unique number of no more than six digits.

Characteristics that can be used for classification include material (copper, brass, stainless steel, plastic, etc.), form of material (bar, sheet, powder, etc.), shape (square, round, hexagonal, rectangular, etc.), standard description (pin, screw, angle), length/diameter ratio, leading dimensions, etc. Each type of item can contain its own classification format. That is, paint will carry a different scheme than screws. The system can handle as many schemes as required. Standardization need not be attempted for all items, but only for those which are used in large variety and which will provide the maximum return.

When implemented, the system can quickly search the item records for specific items or for specific classification codes. Figure 6 illustrates the steps in obtaining the standard item that comes closest to the engineer's requirement.

Creation of Item Data

Item data is supplied by many departments, for instance:

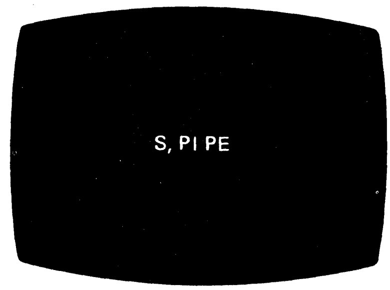
Design Engineering

Item number
Description
Item classification codes
Bill of material data

Production Engineering

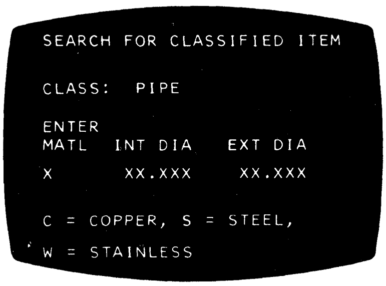
Plant of manufacture
Raw material quantity specification
Routing data

Engineer requests search for a classified item by entering code S (for search) and PIPE

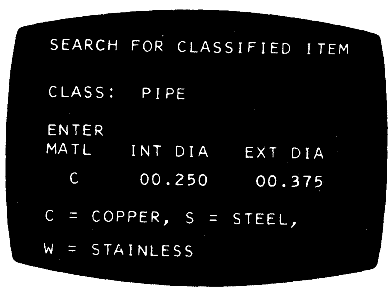


System responds by asking engineer to define his requirements

MATL. = Type of Material
INT. DIA = Internal Diameter
EXT. DIA = External Diameter

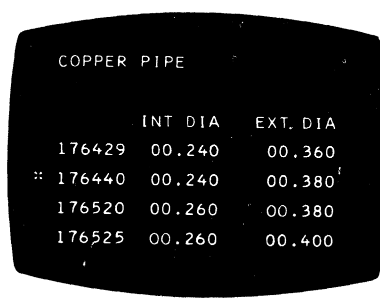


Engineer keys in the requested information in the fields provided



System displays item number and details of pipes approximating the request

Engineer selects Item No. 176440 as suitable and requests engineering specifications



System displays engineering specifications of pipe

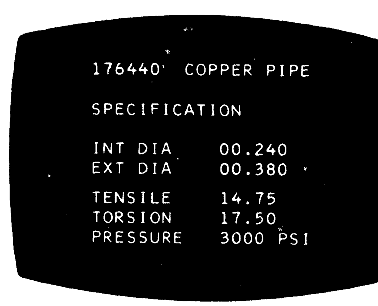


Figure 6. An example of how a system could lead the engineer through a search for a standard item to fit his design specifications

Unit of measure
Shrinkage factor
Bill of material data

Inventory Control

Source codes
Storage location
Order policy code

Sales

Selling price
Discount structure

Finance

Standard costs
Actual costs

Purchasing

Supplier
Purchase lead time

The system concept coordinates the gathering of item data requirements from different departments. The initial record created contains only the item number and an "incomplete record" indicator. This type of record may automatically be set up as a result of loading a new bill of material into the data base.

The complete item record is then gradually built up as each department is able to supply its own portion. Until the incomplete record indicator is removed, the record is monitored regularly for missing data. Action File reports are automatically issued to the responsible departments (Figure 7). Action Files are discussed in detail in *System Requirements.* When requests become overdue, they are reported via another Action File to the appropriate management level.

action file

Information is added to the item record from terminals situated in the responsible departments. When the item number is entered, the standard format of the required information is displayed (see Figure 8). The information supplier must meet the format requirements and must provide "reasonable" figures or the system will immediately reject the entry.

The advantage of computer monitoring of item data creation is that information requirements are communicated quickly. Errors are reduced because the system immediately rejects incomplete or unreasonable data. This means that the planning systems have more lead time to obtain material and/or to reserve capacity for the new item.

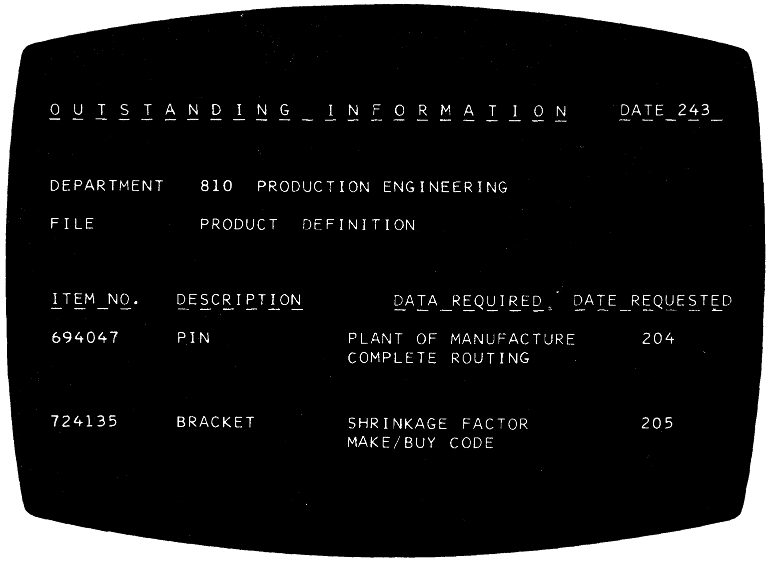


Figure 7. An example of an Action File report calling for completion of product definition information

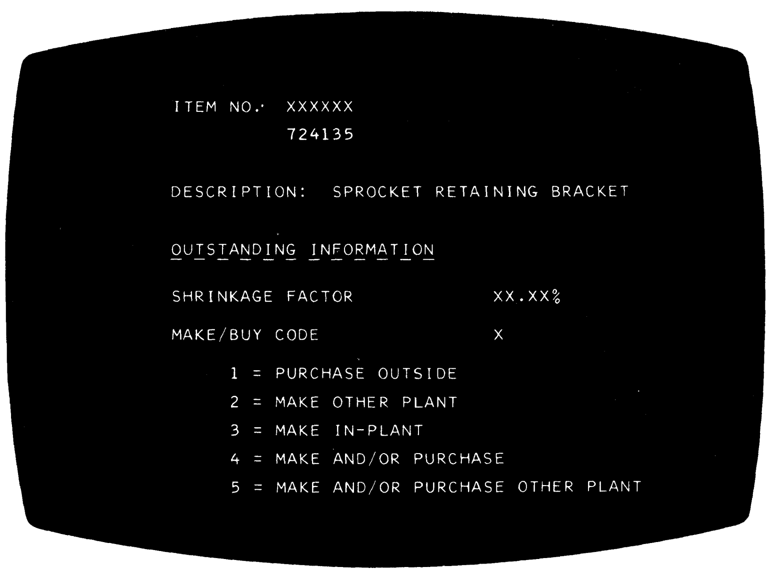
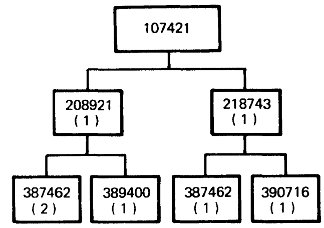


Figure 8. Entry of required item data is accomplished via a terminal located in the responsible department

How the basic parts lists or bills of material are specified, or "structured", can have a considerable effect on the administrative load, not only in engineering but in all departments throughout a company. Bills of material are usually structured for the convenience of a particular department, but this can cause problems in other areas.

For instance, a "summarized" bill of material (Figure 9), in which the total usage of each item is collected into a single list for the product, is convenient to MASTER PRODUCTION SCHEDULE PLANNING, since total requirements for each part can be determined quickly from a known product demand. However, with this approach, common assemblies are duplicated in each product. This means that each product bill using an assembly must be changed when the assembly changes. In addition, components are ordered earlier than necessary because the lead time requirements of intermediate assemblies cannot be seen.



Part No.	Qty.
107421	
208921	1
218743	1
387462	3
389400	1
390716	1

Figure 9. Summarized bill of material

An "indented" bill of material (Figure 10) shows the detailed makeup of the end product, including assemblies, and can be used by the assembly department and for order progress. Its major disadvantage is that there is a large volume of duplicated data, since all components of an assembly are repeated each time the assembly is used. This raises maintenance and data storage costs.

Assembly/Part No.	Qty.
107421	
208921	1
387462	2
389400	1
218743	1
387462	1
390716	1

Figure 10. Indented bill of material

A "single-level" bill of material (Figure 11) avoids duplication of data by holding each assembly only once. It identifies only those components used at one level. The components for a required subassembly are found in a separate bill for the subassembly. Engineering changes are made in only one place.

Assembly/Part No.	Qty.
218743	
387462	1
390716	1

Assembly/Part No.	Qty.
208921	
387462	2
389400	1

Assembly/Part No.	Qty.
107421	
208921	1
218743	1

Figure 11. Single-level bill of material

These types of file structures do not by themselves provide where-used information; that is, they do not answer the question "Where on all assemblies and products is this item used?" Usage information can be contained in separate data files, but this presents maintenance problems: when a change is made to a bill of material, the where-used information must also be brought up to date. A change in file structuring can produce where-used information with little duplicated data.

The bills of material held in the system's product definition data base are structured so that assembly data is included once only, thus simplifying maintenance (additions, deletions, and changes to the structure). This structure allows information retrieval in any desired format – summarized, indented, single-level and where-used.

Many items are used throughout all levels of the product line. To speed processing, a *low-level code* is maintained for each item. The code is a number indicating the lowest level at which a particular item is found in any bill of material. When an assembly component is added to the file via an engineering change, the system checks the level and lowers it if necessary. The low-level code is used to reduce processing time during the explosion for regeneration or the batch "net change" procedure by eliminating the repeated explosion and order planning of a multiple-usage subassembly or component (see *Chapter 5, Inventory Management*).

Structuring Bills of Material

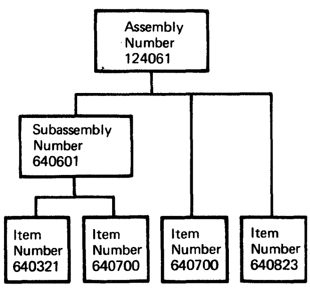


Figure 12. "Tree structure" describes a bill of material

In Figure 12, the bill of material is shown diagrammatically by using a tree structure. This example describes an assembly consisting of a subassembly and two component items. The subassembly in turn contains two component items, one of which is also used in the final assembly. To describe this assembly fully, the data base requires:

- *Item data* – a single item record for the assembly, the subassembly, and each of the three items used (see "Item Data").
- *Product structure data* – describing the way in which the assembly and subassembly are made up or "structured". This involves the relationship between the assembly and such component information as "quantity used on this assembly".

Product structure data

Figure 13 illustrates the organization of the data base records needed to represent this assembly. The item records for the assembly and subassembly are connected to the records of their component items. Product structure data cannot be stored conveniently in the item record since the data depends on its usage in the assembly. This information is therefore stored in a record that connects the assembly to its components (product structure connections). An example of the data stored in these records is shown in Figure 13. A more detailed description of this data is given in *System Data Base*.

where-used data

Item records that are common to different assemblies are logically associated by the system. In Figure 13 the broken line that joins the product structure records identifying item 640700 represents this connection. The assemblies and subassemblies in which item 640700 is used become part of a *where-used chain* beginning at the record of item 640700.

unspecified assemblies

Data is usually issued for component items first, since components have to be manufactured before assembly. As these items are added to the data base, the where-used information will not be known until the bill of material for the assembly on which it is used is specified.

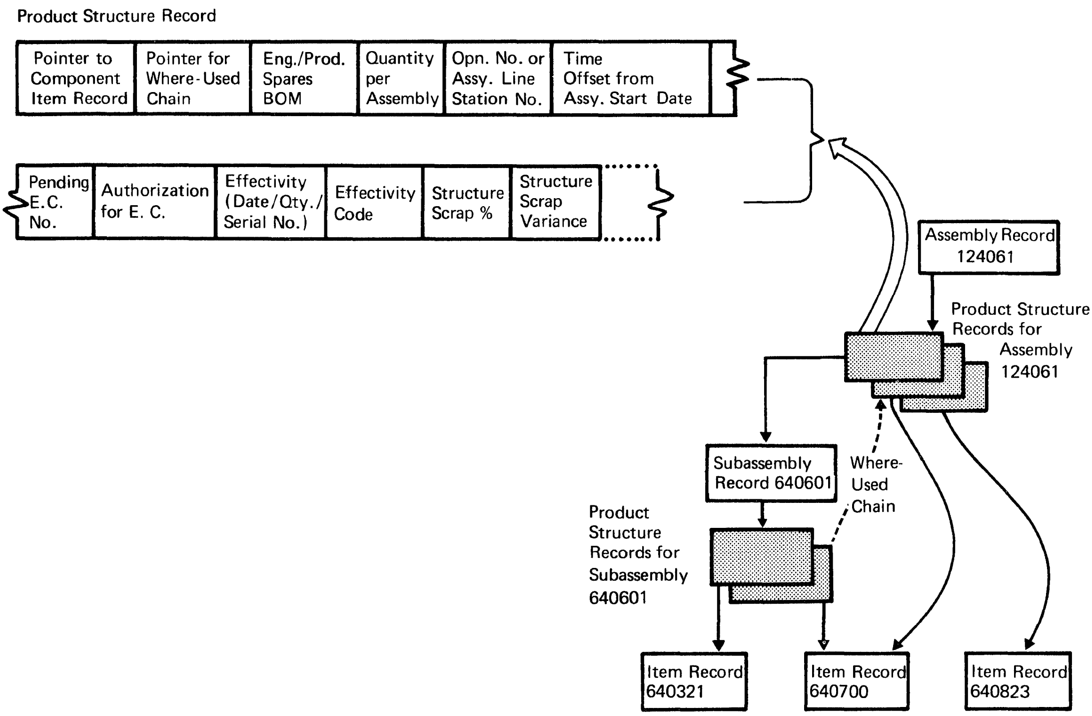


Figure 13. Product structure records provide bill of material information

The system keeps track of all items without where-used pointers and highlights these via an Action File if no assembly number is given within a specified period.

Using the Bill of Material

The generation of a parts list is accomplished by "exploding" the bills of material, that is, by progressively expanding each assembly level into its component parts. The bill of material can be presented as:

Summarized

Indented

Single-level

A similar technique is applied to the where-used retrievals. The result is an indented, summarized, or single-level where-used listing. The indented where-used retrieval traces each usage through every assembly level to the individual end item, whereas the summarized where-used listing shows all usages of the item collected together. Single-level where-used retrieval identifies only the assemblies into which the item goes directly.

Some uses of each of the above types of retrieval are:

- *Summarized explosion*

  Master production schedule planning
  Determining total part usage in a product
  Product costing

- *Indented explosion*

  Service parts cataloging
  Product assembly planning
  Product cost breakdown

- *Single-level explosion*

  Assembly requisition listing
  Requirements planning explosion
  Entering engineering changes
  Determining assembly costs

- *Summarized where-used*

  Determining end product usage of components affected by an engineering change

  Determining the effect of component cost changes on all end products

  Determining impact of a material shortage on all end products

- *Indented where-used*

  Identifying usage of components affected by an engineering change

- *Single-level where-used*

  Evaluating the effect of an engineering change

Organizing Bills of Material

The engineering bill of material produced by the design department does not always meet the requirements for production departments. An alternative method of specifying the data is often necessary because:

- The actual method of assembly may differ from the way an assembly is designed.
- Service (or spares) assemblies are sold in a different form than the original production assembly. For example, they may include parts for attaching the assembly.
- Engineering change modifications are supplied for an installed product.
- Groups of parts issued to an assembly department may include portions of several different engineering bills of material.

The organization of these slightly different bills of material into separate data files can result in a large volume of duplicate data. The maintenance of separate bills is costly and time-consuming. Errors in data maintenance would result in inconsistent bills of material. This would lead to the manufacture of obsolete items and products, and an inability to determine the engineering change level that was effective at any given time.

Combined bills of material

When two bills of material contain assemblies, some of them unique to one bill or the other, it is possible to incorporate both bills into a single structure. For example, by coding assembly records to distinguish between engineering assemblies and production assemblies, one bill can be integrated with the other.

Figure 14 illustrates an engineering bill of material containing three assemblies. However, because of space restrictions, the gearbox must be fitted to the drive shaft assembly before the motor is added, and so the production bill of material has to be different.

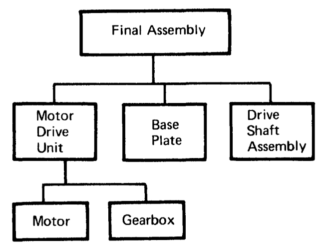


Figure 14. An engineering bill of material

The combined engineering and production bill of material (Figure 15) is developed through the creation of two production assemblies. The first "removes" the gearbox from the motor drive unit, and the second "adds" it to the drive shaft and base plate assemblies. The assembly item records are coded to distinguish between engineering, production, and combined (that is, effective in both engineering and production). The original production or engineering bills can be retrieved as required. Service (that is, spares) assemblies, etc., can be handled in a similar manner.

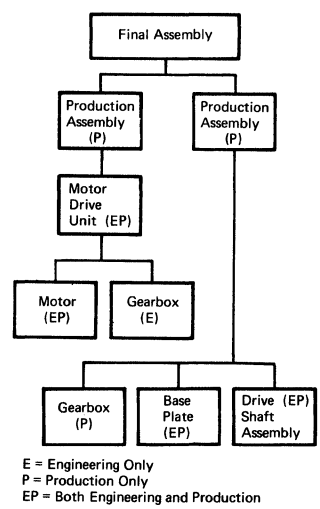


Figure 15. A combined bill of material

The creation of different assembly types allows the requirements for multiple bills of material to be stored within a single product definition data base. Since much of the data is shared, this avoids the maintenance and control problems of separate bills.

The total quantity required for each item in a product should be the same, whichever bill of material is exploded. The system checks to make sure this balance is maintained.

Production bills of material

The production bill of material is needed because the designer's view of how the product is made differs from the actual method of manufacture. The designer's bill may tie together a group of assemblies which, although they make up a functional part of the product, are not collected or assembled to each other but are added to the product separately at different stages of production. The complete fuel system of an engine is an example of a design assembly that is never manufactured.

Design Engineering cannot always go back and alter their drawings to suit production requirements; some of these drawings may have been produced months beforehand. It is common, therefore, for Production Engineering to put production parts lists on the routing or operation sheet. The effect is that:

- The engineering specification is defined by a single engineering bill of material.
- The production specification is defined by both the engineering bill of material and the production routing. This increases file maintenance and the probability of error.

Specifying a production bill of material as a variation of the design bill, however, provides a complete picture of the way in which the product is manufactured, with reduced maintenance problems and probability of error.

Some of the factors affecting the structure of the production bill are:

- Which assemblies are stocked before incorporation into a higher-level assembly.
- Which parts are issued together for assembly.

A key criterion is the stocking of partly assembled end products and assemblies. This policy is usually adopted to reduce the lead time from receipt of a customer order to shipping. The partially finished products or assemblies are usually stored at a level that provides the greatest commonality, that is, the level from which the widest range of end items can be produced. For example, if a pump may be stocked without feed and delivery connections, a bill of material must exist for this nonfunctional assembly. This allows common requirements from a wide range of end items to be summarized before production batches of the semifinished assembly are planned. Any item "created" by production and held semifinished should have its own unique item number and structure records.

The item numbers of assemblies that exist only for production reasons are identified as "production-only" assemblies in the combined bill of material.

Bills of material for product variants and options

A product *variant* is that part of the product which, while it must be present, may be specified to the customer's choice. For example, every automobile must have a transmission but the choice of manual or automatic is open to the purchaser. On the other hand, the purchaser may or may not choose the *option* of a factory-fitted radio.

Options and variants will be considered together, since the system's logic is identical for both of them.

Manufacturers who offer product variants and options often number the possible combinations in the millions. For each unique product made, a bill of material is required. However, there are certain drawbacks:

- It is often impractical to hold bills for every possible combination, as many of the possibilities will never be reauired.
- If complete bills for only the common variants are retained in the system, the product definition data base becomes uneconomically large and contains many nearly identical end items.
- If a special complete bill is specified and then discarded after use, the process of specifying the bill must be repeated whenever that unique product is required again.

Yet it is difficult to plan component part requirements, if end item bills of material cannot be expressed exactly.

A solution to this problem is to structure the bills of material so that the unique bill of material containing the variants or options can be specified easily and rapidly. This separate unique bill is added to the product definition data only while the product is being manufactured. Then, assuming it is no longer needed, it can be discarded.

The methods developed to solve this problem involve automatic conversion of an end item specification directly into a unique bill of material. While many methods are possible, two common ones are discussed here:

- Coding of variants in the structure record into a compound bill of material
- Organizing bills of material by variants

coding of variants in the structure record

Where the number of choices is limited, alternative component items can be stored within a single product structure record. The end item specification is compared with each optional structure record as it is exploded, and the specified structure record is automatically included in the exploded bill.

Figure 16 illustrates the product specification and the compound bills of material for part of an end item in which there are three variants: panel color, left- or right-hand door, and voltage. When the panel section of the bill is exploded, the specified color, blue, is compared with the coded color in the structure record, and item number 146292 is selected. This process is repeated for each variant. The generated bill of material is illustrated. For material requirements planning purposes, the usage quantities are expressed as a percentage of usage on the end product, that is, 110V = 43%, 220V = 57%.

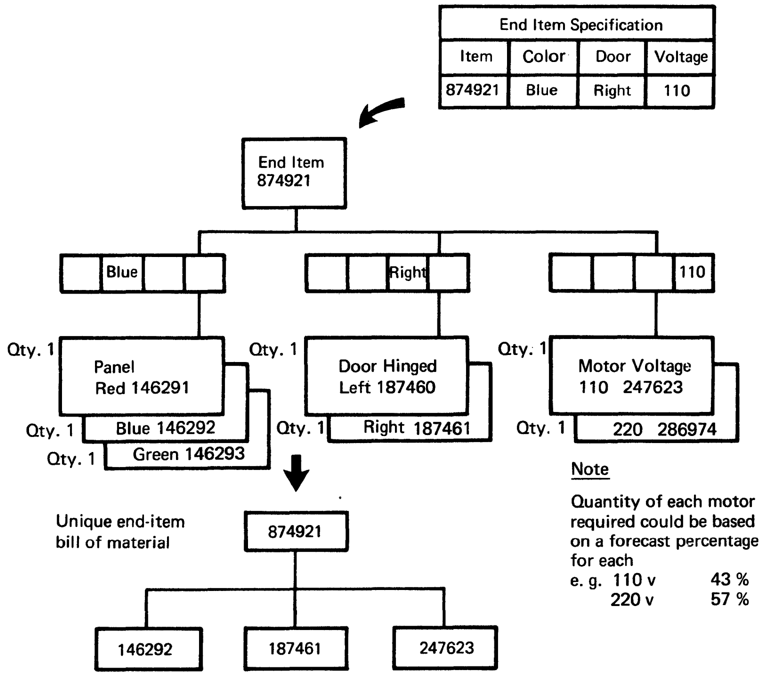


Figure 16. Compound bill of material develops a bill for unique end-item specification through codes held in the structure records

This is a simplified example, but the techniques can be expanded to include larger sets of choices – for example, requirements for control switches or instruction brochures in alternative languages.

The variants often occur at a low level in the bill of material and may depend on other variants; for example, a label may describe the specified motor voltage and be printed in a specified language. The huge number of possible end items can be generated from a single bill of material for each major end item.

organizing bills of material by variants

When the number of available choices is large, a better solution is to organize the bills of material by variants. End item bills of material are specified without any variants (Figure 17). That is:

- Items common to all end items are collected into a main bill of material
- Items that change with a specific variant are collected into a separate bill.

Using this type of modular bill of material significantly reduces the total number of bills needed to cover a wide range of variants. For example, Table 1 shows an end item with only five variants, such as capacity, power, etc., and a varying number of possible choices within each variant. With this combination, over 4,600 end item possibilities exist; yet only 33 bills are required in the data base.

Table 1

Variant	Variant Possibilities	Variant Possibilities
Main Bill	1	1
Capacity	12	20
Power	4	20
Material 1	2	2
Material 2	6	6
Switchgear	8	8
Total of Bills	33	57
End Item Possibilities	4,608	38,400

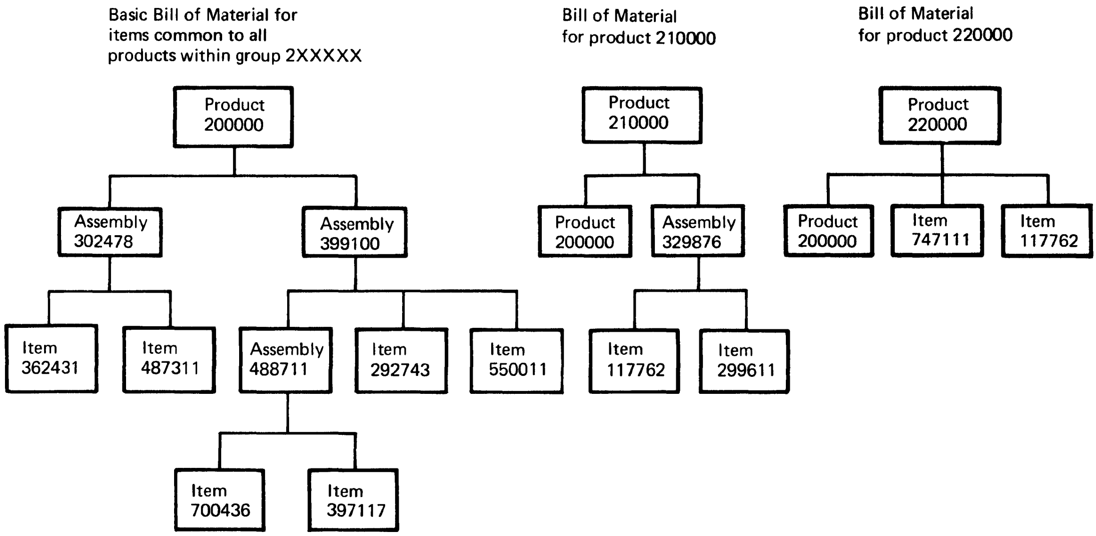


Figure 17. A large range of product variants can be represented by a small number of modular bills of material

If the first two variants in this example each contained 20 possibilities, the total number of end item possibilities would rise to more than 38,000, represented by only 57 bills of material.

The specific bill of material for an end item is generated for each product specification. If the total number of variants is low, this can be done manually. However, it is easy for the computer to develop the bill and so avoid the manual copying of item numbers with the attendant risk of error and loss of time (see "Automated Design Engineering").

Bills of material for service assemblies

Service assemblies usually fail to correspond with any of the existing bills of material. For example, a part may require an oilproof joint when fitted. This, in turn, may require a gasket or sealing material that is normally part of the next higher level assembly in the production bill. When the item is sold, it must be identified as a service assembly containing the part and the gasket. Items sold together as a service assembly are combined under a spares assembly item number in a manner identical to that used for production assemblies (see Figure 15).

Special types of bills of material

In many industries there are particular requirements which are normally specified outside the bill of material but ought to be included in it, since they are really part of the product definitions. Examples include:

- *Field installation items.* Some items – for example, electrical connections, piping, etc. – can be fitted only after the product has been installed in the customer location. These should be shown as part of the end item bill of material.

- *Packaging.* "Super" levels of assembly, such as finished goods packaging, can extend the number of stocked assembly levels considerably. For example, pharmaceutical products may be stocked in tablet form, in various-size boxes, in boxes within cartons, and in special seasonal packs. These can readily be held and maintained in the product definition data base.
- *Chemical formula.* Some products (paints, dyes, chemicals, pharmaceuticals, plastics, etc.) are specified by a formula which can readily be held as a bill of material. The system can handle special considerations like specifying the same item more than once – for example, where only small quantities of toxic materials can be used at a time in the same formula.
- *Select components on the basis of a test.* In many electrical or electronic assemblies, the particular resistor used depends on test results. The possible resistors are held as variants in the product structure records. The quantity required is specified as a probability based on historical results – for example, .40 Resistor A and .60 Resistor B. INVENTORY MANAGEMENT will order the appropriate quantities of each resistor based on these percentages. Requirements resulting from product reconditioning can be handled in the same manner.

Creating Bills of Material

As with item data, the product structure data is obtained from a number of different sources – for example:

Design Engineering

Design product structure

Manufacturing Engineering

Production structure

Customer Service

Service (spares) assembly structure

Production Control

Structure scrap percentage

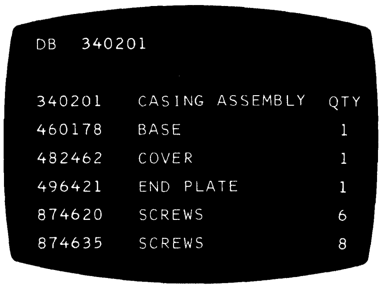
As described in "Item Data", Action Files can be used to request this information from the relevant departments.

Developing a new bill of material

Terminals can speed and simplify the creation of bills of material, particularly when new bills are derived from existing bills. Figure 18 shows the steps required to add a new bill of material that is a modification of an existing bill. The engineer first displays the existing bill. Identification of this bill may have been achieved through a sequence of inquiries and displays, based, for example, on either of the following:

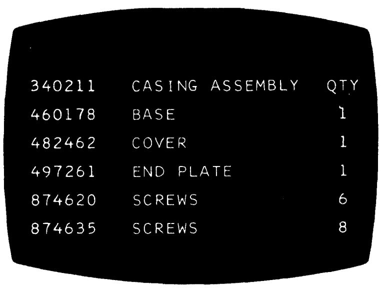
- A where-used search on the end plate which is to be altered, that is, a search for all assemblies using item 496421
- A search for the assembly based on an item classification code

Engineer calls up an existing bill of material (item no. 340201)
DB = Display bill of material



A similar assembly, containing an alternative end plate 497261, is to be created under item no. 340211

Engineer writes new assembly No. (340211) and end plate item No. (497261) over the existing numbers, and loads new assembly.



System displays the loaded bill of material and identifies the new item record created.

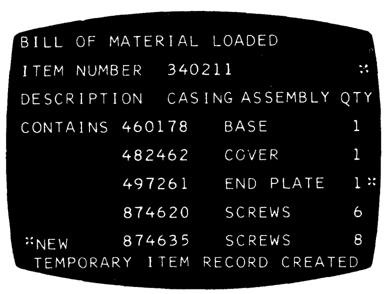


Figure 18. Development of a new bill of material from an existing bill

In this example, the engineer provides the new item numbers and the system automatically loads the new assembly and sets up the beginning of an item record.

The system displays details of the data base change. The new bill of material is displayed and items for which new records have been created are identified. To protect the data base, the new bill of material is coded as inactive until the assembly's item record status is altered to active. Bills of material required for only a single, or custom, order can be created using this same technique of "add and delete". The advantages of this method of creating new bills of material are:

- Only the changed items need be entered.
- The possibility of making errors when copying and entering the remainder of the existing bill is avoided.
- The time needed to create the new bill of material is significantly reduced. This includes the time needed to identify the existing bill that is to be altered.

Automated Design Engineering

Single-order bills can be generated by simply filling in a specification form displayed on a terminal. This is possible when the bills of material are structured as a basic product bill, with separate variation bills. The specifications entered through the terminal are analyzed by the system to produce the bill. This analysis is sometimes called Automated Design Engineering.

In many cases, much of the repetitive design work to produce bills of material for variations of a standard product can be reduced to a series of logical design steps.

Examples of products that can be specified using Automated Design Engineering include elevators, pumps, boilers, and industrial buildings and cranes.

Automated Design Engineering can be used wherever a basically standard product is adapted to specific customer requirements, provided:

- The design logic is well defined. It must be possible to derive from the product specification the necessary changes in dimensions and items required.
- The volume of orders or requests for price quotation is sufficiently large.

Design engineers identify the design steps and the logic governing the choice of components and materials. The design information is then built into a series of tables that are used in a predetermined sequence representing the sequence of the design steps.

Figure 19 illustrates a series of tables for the design of an armature assembly.

SPECIFICATION

Name	Value
• Service	DC
• Application	Speed
• Rating units	Millivolts
• Rating value	100
• Number of phases	1
• Scale size	8 inches

Table No. 1	Rule 1	Rule 2	Rule 3	Rule 4
Service	DC	DC	AC	AC
Application	Temper-ature	Speed		
Rating Units	MV	MV		
Number of Phases	1	1		
Type of Armature	Moving Coil	Moving Coil		
Number of Windings	1	2		
Part No.	012526	012526A		
Assembly Drawing No.	A26	A26A		
Next table	2	2		

Table No. 2 NEXT Table No. 3	Rule 1	Rule 2	Rule 3
Type of Armature	Moving Coil	Moving Coil	Electrodynamic
Rating Units	MV	MV	
Rating Value	10-75	76-200	
MW Number of Turns	52	13	
MW Wire Material	Aluminum	Aluminum	
MW Wire Diameter	16	16	
MW Number of Layers	4	1	
Drawing No.	012526-1	012526-1A	

Table No. 3	Rule 1	Rule 2	Rule 3
Scale Size	4	4	8
Rating Units	MV	MV	MV
Rating Value	10-75	76-200	10-200
Number of Windings	2	2	2
DW Number of Turns	24	45	Half the number of turns in the main winding
DW Wire Material	Copper	Copper	Aluminum
DW Wire Diameter	16	8	12
Drawing No.	012526-1A	012526-1A	012526-1A

Armature	
Type	Moving Coil
Item Number	012526 A
Number of Windings	2
Main Winding	
Drawing Number	012526-1 A
Number of Turns	13
Material	Aluminum
Wire Diameter	16
Number of Layers	1
Damper Winding	
Drawing Number	12526-1 A
Number of Turns	7
Materials	Aluminum
Wire Diameter	12

Figure 19. Automated Design Engineering uses a series of decision tables to develop bills of material for variations of a standard product

The output of the Automated Design Engineering process includes:

- The assembly and component numbers necessary to build the product (bill of material).
- Components with specific dimensions.
- Operation descriptions for the production of variable items, such as the number of windings on an electrical coil.
- Cost estimates for the developed bill.

The advantages of Automated Design Engineering are as follows:

- The time required to specify a new item is reduced from weeks or months to minutes or hours.
- The engineering effort involved in specifying a new item is greatly reduced. Quotations can be economically developed for more inquiries.
- The design logic can be established using the best engineering skills available. It is then automatically "built in" to every product specified.
- "Overengineering", or incorrect design, caused by hurried design and specification, or inexperienced engineers, is avoided.

Engineering Drawing Control

An engineer defines a product by:

- *A drawing* – showing relationships, shapes, sizes, etc.
- *A bill of material* – containing the list of parts.

Modifications to bills can be entered into the data base and made available immediately, without waiting for the drawing to be altered and reissued. Therefore, the engineering change level or "issue number" of the drawing need not be the same as that of the bill of material. For example, a change of material for one item on the bill may not affect the drawing, but would normally mean issuing a revised bill of material.

The system can help control the creation and revision of drawings.

Location of Drawings

In large design offices, determining the location of a new drawing, or of a drawing that has been withdrawn for modifications, can be a problem. This is because it may take days or weeks to modify a drawing, check it, microfilm it, reproduce it, and distribute copies. The time may even be extended to several weeks if the design has to go through stress calculation or weight control, as with aircraft products. To help solve the problem, location control, similar to the control of shop order movement through the plant, can be applied (see *Chapter 8, Plant Monitoring and Control*).

In a location control system, terminals are located at key points in the design office.

An identification card is created and attached to every original drawing. This card accompanies the drawing throughout its life. As the drawing moves toward completion, the card, together with the responsible man's identification badge, is entered into the system. The points at which a location report is made could include:

Withdrawal of the drawing to be revised
Start of new drawing or modification
Interruption of drawing activity
Completion of drawing or modification
Start of drawing approval or checking

Completion of checking
Delivery to microfilming department
Completion of microfilming
Delivery to reproduction department
Reproduction and issuance of copies
Filing of original drawing

From this data, which is held in the engineering drawing record, the current status and location of all drawings can be obtained at any time. The system monitors the progress of the drawing against established standards. The supervisor is notified of exceptions via an Action File. For example, if the drawing is in microfilming for more than three days, a notice is generated.

Statistics can be developed for design office workload planning using average man-hours and lead time by size of drawing or type of modification.

Engineering Drawing Data

If the drawing itself is specified as part of the bill of material, it is subject to the same degree of control as any other item. For example, the system can check for drawings not yet issued, follow up overdue drawings, etc.

Data regarding the drawing is held in an engineering drawing record (Figure 20), which the system cross-references to the item record.

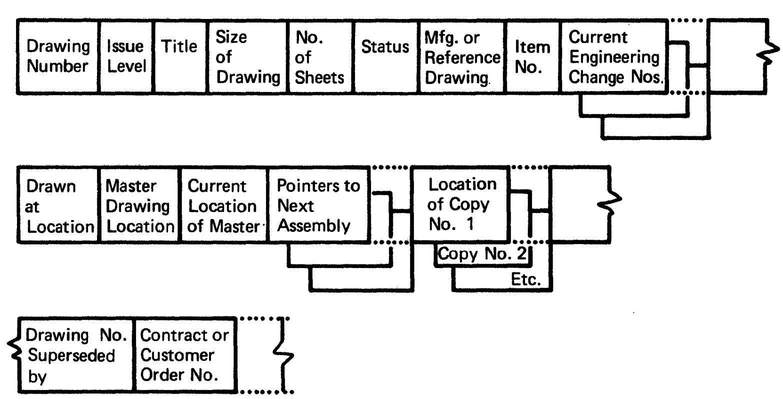


Figure 20. Example of data held in the engineering drawing record. A detailed description is given in *System Data Base*

Figure 21 shows a set of drawing records connected by pointers. The general assembly drawing record is connected to the record of each of the assembly drawings involved in the general assembly. Similarly, the assembly drawing records point to their component drawings. The product definition data base record contains the appropriate drawing number.

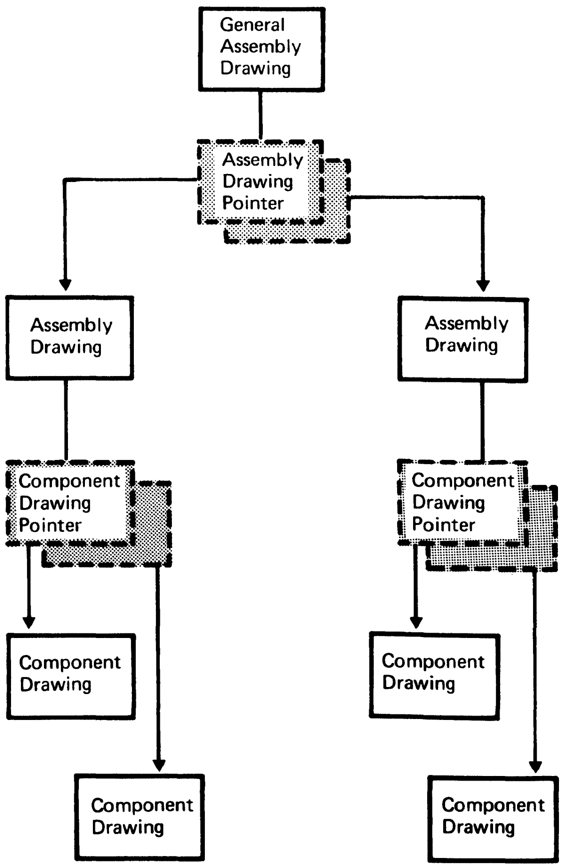


Figure 21. Relationship of engineering drawing records

Drawing information can be obtained from such terminal inquiries as: "What is the drawing number for this assembly?", or from more complex inquiries such as: "What is the issue level of each drawing on which this part appears, and which are effective for end-unit number 12572?"

Distribution of drawings

Held in the engineering drawing record is a note of all locations having copies of the drawing. After a reissue, copies of the new drawings are sent out to all such locations, which include:

- In-plant departments (Production Engineering, Costing, etc.)
- Other plants
- Customers
- Service engineers
- Subcontractors

In-plant locations acknowledge the receipt of the drawing via their terminals, thus ensuring that they work to the current version. Each location specifies the number of copies needed and a "stop" date indicating when new issues should no longer be sent – for example, when a subcontractor will have completed his work on the item.

Drawing change history data

Engineering Change No.	Drawing No.	Drawing Issue Level	Date of Change	...

Figure 22. Drawing change history data

Information concerning the drawing issue level corresponding to an engineering change can be held in the Drawing Change History File (Figure 22). The primary use of this file is in retrieving information about:

- *Service parts* – determining which issue of a drawing should be used for products delivered to customers.
- *Inspection* – checking that the correct drawing was worked to during manufacture.

Engineering Change Control

Almost every item has a change made to it at some time during its life.

Most products pass through a development period when the data is very volatile. In advanced technological industries such as electronics or aerospace, this volatile situation exists throughout the product life. Additions to the product range are made from time to time, using both existing and new parts, while other products are deleted. Modifications range from a small change affecting a single item, to a design change involving a number of assemblies. The changes affect not only the item data and product definition, but also tools or inspection gauges.

Failure to reflect these changes promptly and accurately in the product definition data base creates problems:

- The end product may not correspond to the product specified. This leads to customer dissatisfaction and the possible loss of future sales.
- The product may be incorrectly costed and thus sold at a loss.
- Obsolete parts may be made, resulting in scrap or rework.
- Subsequent engineering changes may be designed using obsolete information. Correction of this situation often requires yet another engineering change.
- Purchase commitments for discontinued parts are placed, resulting in cancellation costs.
- Orders for the new parts are placed late, resulting in expediting costs or material shortages.

The objectives of engineering change control are (1) to determine the cost effect of changes in advance (simulation on a terminal allows evaluations of proposed changes to be made before they are committed) and (2) to enter and communicate change information quickly to other departments and to avoid the manufacture or purchase of items no longer needed, as well as the loss of production through late arrival of new parts.

The stages involved in planning and implementing engineering changes are:

- *Making the engineering change decision.* The engineer, using a terminal, can search the product definition data base for each usage of an affected item and obtain existing item costs and stock levels.

This data provides an accurate basis for approval of the change. It answers such questions as:

Which end items are affected?

What is the effect on end item costs?

What material losses would be caused by the change?

What orders already in the shop are affected?

- *Introducing the engineering change.* After approval the change is entered into the data base by terminal and monitored by the system until it is implemented. Inline editing of the change information helps ensure correct entry.
- *Communicating the change information.* Problems arising from late or incorrect communication of change information are reduced or eliminated. For example, Purchasing can be informed by means of the Action File that an item is about to be made obsolete. Orders about to be placed can then be withheld. Production on orders already placed can be halted, minimizing cancellation charges. At the same time, production on released shop orders can be halted.
- *Implementing the change.* During the implementation period, the system monitors alterations to production plans, and it estimates the impact on the basis of engineering change effectivity dates. The system coordinates the discontinuance of the use of the old method or material with the start of the use of the new material.

  In a terminal-based system, the total time to implement an engineering change is significantly reduced (Figure 23). The terminal-based system can reduce the overall time to approve, plan, and implement an engineering change, through online processing and net change techniques.

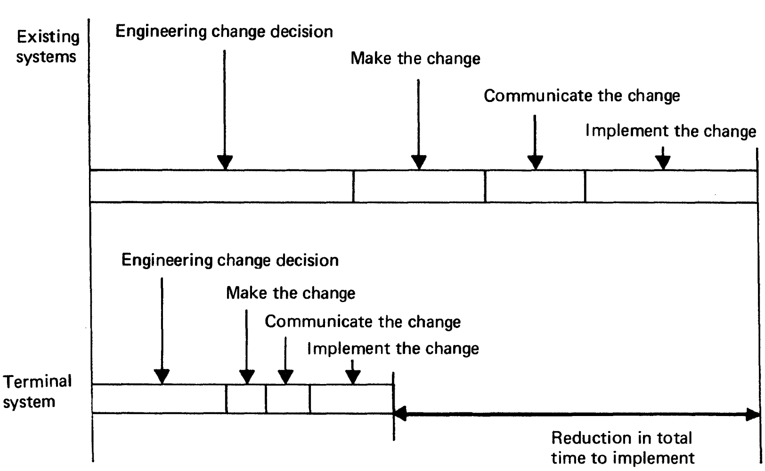


Figure 23. A terminal-based system reduces the total time needed to implement an engineering change

Making the Engineering Change Decision

The major reasons for making an engineering change are:

- *Correction of errors.* When large numbers of drawings and bills of material are issued, it is unlikely that they will be completely free of errors. After discovery of errors the product information in the data base has to be brought into line with the updated design information.
- *Product improvements.* Normal product development and reports from service engineers cause changes affecting the bills of material. This often requires a check on existing stock and orders before decisions can be made.
- *Safety considerations.* Changes made for reasons of safety are usually mandatory and must be implemented immediately. If they also apply to products already in service with customers, the engineering change level and location of these products must be known.
- *Cost change.* Changes to routings may affect item costs, lead times, tools, and work center loadings.

The person responsible for making the change can obtain all the information he needs directly from the system.

Previously, the collection of this data may have taken days or weeks. During this time, information on inventory and outstanding purchase orders has changed; the decision is therefore based on an inaccurate projection of the effect of the change. Now, however, the effect of the change can be simulated on accurate and up-to-date information.

Simulating the effect of an engineering change

Using a terminal, the engineer can examine the effect not only of a single, proposed change, but also of many alternative changes. For example, alternative materials can be introduced for an item, or a class of items, to obtain comparative cost effects. The time at which a proposed change will be implemented can be varied to discover the time which produces the lowest total cost, based on existing stocks or orders.

These answers are obtained by simulating changes to information taken from the data base. For example, to simulate an item substitution, an engineer keys in item number of affected assembly, old component item number, new component item number, and period in which the new item will be available. The change may apply to a single assembly, a number of assemblies, or to all assemblies containing the replaced item.

Using the requirements in the current master production schedule, the system considers the effect of introducing the change as early as possible, depending on the availability of the new item. Stocks and committed orders for the replaced item are reviewed, and the value of surplus quantities is calculated. If existing stocks of the item to be replaced will be exhausted before the new item is available, an uneconomical order may be needed to balance stocks of the item to be replaced. The excess cost of this order is attributed to the engineering change.

Only avoidable costs are considered. On this basis, exhausting stocks of the replaced item is usually the lowest-cost alternative, since no additional costs will be incurred. The projected date on which the change will be effected if stocks are exhausted is calculated. Figure 24 shows the information that is displayed.

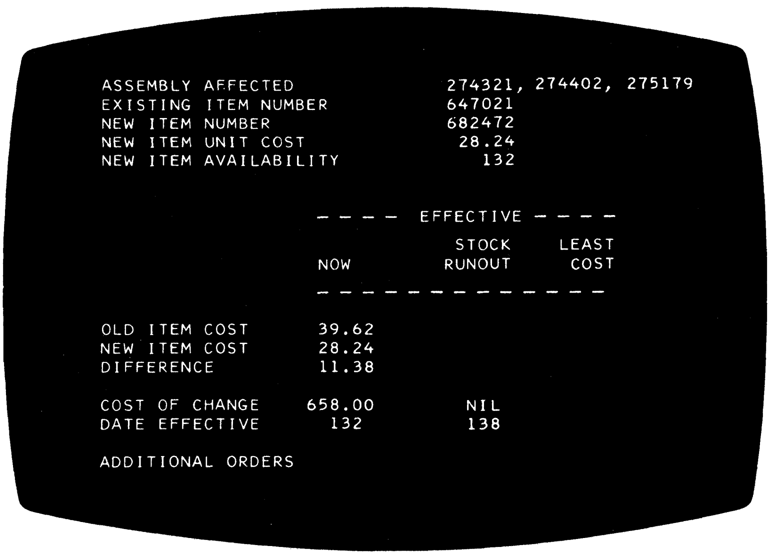


Figure 24. An item substitution is simulated

In this example, since no new costs are involved when existing stocks are exhausted, the change can be made on day 138. The earliest date on which the change can be made is day 132, when the new item becomes available. However, making the change on this date results in surplus replaced items to the value of 658.00.

Obviously, when there are other usages of the replaced item which are not affected by the change, there will be no additional costs through obsolescence, and the timing of the change can be determined solely by availability of the new item.

However, when a number of items in an assembly are to be replaced simultaneously, the existing stocks of the replaced items usually cover inventory requirements for different periods of time. A large number of alternative possibilities may exist for balancing orders for one or more of the items. In this case the system evaluates the cost of making the change in each period between the earliest possible date, when the replacement items are all available, and the latest date, when all stock is exhausted. The system then develops the date that will produce the least additional cost, together with the cost of making the change at that time. The comparable costs for earliest and latest implementation are also displayed.

A change aimed at product improvement may result in increased sales, which will affect the timing, and consequently the cost, of making the change. The engineer can repeat the simulation of the change after inserting new sales requirements for the affected end item. The sales change is entered into the temporary files used by the system during simulation and creates a modified master production schedule as a basis for the new simulation.

Introducing the Engineering Change

When the engineering change is entered, the time at which it will become effective must be established, and then monitored and controlled. The designer himself is usually no longer interested in the change once the drawing and bill of material has been changed. Therefore, the follow-up is done by an engineering change coordinator with the help of the system.

The timing or effectivity of engineering changes can be based on four criteria:

- *Immediate change.* Often, for reasons of product safety, the change is implemented without considering stocks or work-in-process, as when an electrical connection is found to be faulty. The change may also involve products already shipped to customers.
- *Stock runout.* The urgency is not so great, and stocks of replaced items can be exhausted before the change becomes effective. This can affect a single part, or there may be simultaneous changes affecting other parts whose stock must also be exhausted.
- *Availability of a replacement part, material or tool.* The change cannot be implemented until the new item is available. This may apply in addition to runout of stocks of old items.
- *End product serial (order) number.* This is used when a change must be identified with a particular customer's order or when change history information must be maintained by serial number.

Engineering change effectivity

Engineering changes can be divided into three categories: those affecting item data only, those affecting bill of material (that is, product structure) data only, and those affecting both. For example, a dimension change for a better fit affects the specification and routing of the item, without affecting the bill of material in which the item is used. On the other hand, a change in the item quantity required per assembly affects only the bill of material or structure records.

Changes to product structure records may be fewer than item changes, but their control is more complex, and the effect of inadequate control correspondingly more damaging.

Each of the four bases for timing the implementation of a change is reduced by the system to a single number. This number may be a quantity to be produced before available stock is exhausted or before a specific serial number is reached, or a date on which materials or a tool should be available for production. The system can automatically estimate the implementation of the change by using these quantities or dates and by counting off actual quantities produced or shop calendar days.

A typical change, involving many items, may involve many hundreds of item usages and replacements, all of which must be coordinated. *Chapter 5, Inventory Management* describes the use of engineering change records during the planning of item requirements.

The actual changeover quantities and dates may vary from the plan. For example, an engineering change scheduled at the runout of the obsoleted part will be incorrect if stock losses of the old part are discovered only when the last piece is issued.

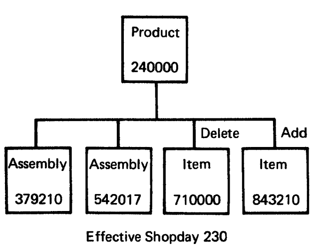


Figure 25. Bill of material containing a planned item change

Consequently, the method used for controlling changes must provide a current picture of the change situation throughout the planning period. This is achieved by carrying change data as a structure record. In this way, a picture of the old and the new assembly is always available (Figure 25).

Each time the bill of material record is handled, the status of a pending engineering change is reviewed and the proper product structure record is selected on the basis of how it is to be used. For example, when an order is released to the shop, the current structure record is used; when material requirements are being planned, the current structure record is used until the planned quantity or date for the change is reached and then the change to the new structure is made.

The structure record contains the current status of all pending engineering changes at all times. Figure 26 shows a single-level bill of material in which item 710000 will be replaced by item 843210 after an additional 200 units of assembly 240000 have been manufactured. The quantities in the structure records will be reduced as orders for assembly 240000 are processed until they both reach zero. The structure record for item 843210 will then become effective.

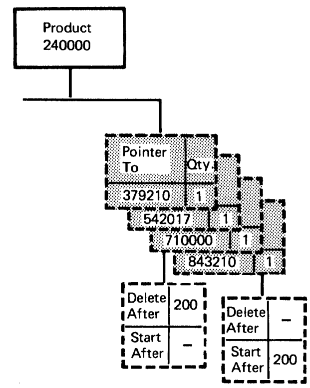


Figure 26. Changing a component after stock consumption

On some products, particularly those incorporating customer-specified variants, it may be necessary to change only certain models during manufacture. Figure 27, for example, shows how to designate the replacement of item 710000 by item 843210 on product serial numbers 201-250 only.

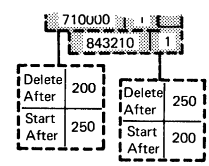


Figure 27. "On-off" engineering change in a structure record

After 200 products have been manufactured, item 843210 replaces item 710000. After 50 more are manufactured, the substitution is reversed. When an engineering change is to be incorporated specifically for one customer, it must not be inadvertently applied to other uses of that item. A where-used check can be displayed after any change to ensure that the change was made as intended.

Two or more successive changes for the same assembly may be planned and stored in the data base at the same time. Figure 28 uses the same example as Figure 27. After the manufacture of an initial 200 products, item 843210 replaces item 710000. When 50 more have been manufactured, item 843210 is itself replaced by item 920010.

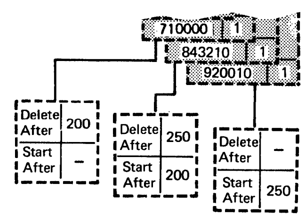


Figure 28. Successive "on-off" engineering changes

Complex engineering change combinations can be controlled by this same technique. Related changes, where a change on one assembly cannot be made unless another change is made at the same time, call for tying together change records. A large series of "on-off" changes involving the same component parts can be specified by multiple records to hold the start and delete figures.

Each of the multiple records can use a different factor for implementation of the change. For example, a change which becomes effective when stocks of the obsoleted part are exhausted may also depend on receipt of the new material (Figure 29). Separate start/delete records hold the runout quantity and the planned availability date for the raw material. The system then tracks the movement of one controlling factor relative to the other.

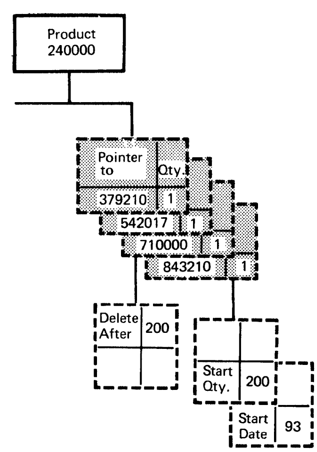


Figure 29. Change becomes effective when old stock is consumed and new item is available

Related changes are tied together by a change group number. Each individual change contains a sequence number describing the sequence of dependency. Simultaneous changes would carry the same sequence number.

Changing the item number

Where an engineering change modifies the "form, fit, or function" of an item, that is, when the new design is not interchangeable with the original, it is advisable to change the item number in order to avoid confusion.

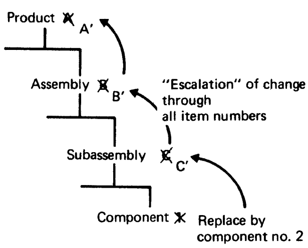


Figure 30. Change of a component may force several higher-level changes

While this is a fairly straightforward procedure, a question arises: How far up the product structure tree should item numbers be changed (Figure 30)? For instance, if component 1 is replaced by component 2, does the next-higher assembly number also change, and so on up to the end item?

A balance has to be established between providing a unique identity for planning and control purposes and putting the burden on engineering to change all the affected bills of material and drawings. As a general rule:

- If an engineering change affects the interchangeability of an item either physically or functionally, the item number is changed.
- If an engineering change does not directly affect the interchangeability of an item, only the issue number of the drawing and bill of material is changed.

Prototype and production items

Figure 31 illustrates the design cycle of a typical engineering product from initial design through production. The method of engineering change introduction is different at the various stages of the project. For instance:

- During the initial design phase, a decision to make an engineering change can be made by Design Engineering without affecting other departments. As manufacturing has not yet started, it is a waste of time changing item numbers even if interchangeability is affected, especially since the greatest number of changes normally occur during this period.
- During the prototype build phase, engineering changes affect the production, inspection, and sales departments for certain items common to other products.
- Once into production, all changes affect other departments. It is during this phase that most simulations of "trial fit" will be done.

Entering engineering changes into the data base

Engineering changes are entered directly into the system by means of a terminal. The use of a terminal allows data to be immediately edited for correct entry. Immediate notification normally means immediate correction. Examples of the types of errors detected are shown in Table 2.

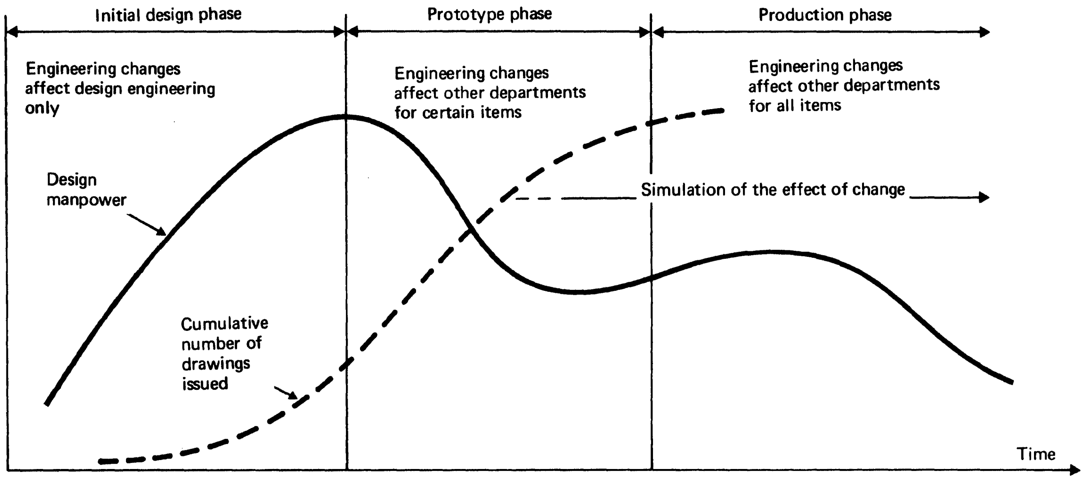


Figure 31. Introducing engineering changes throughout the product life

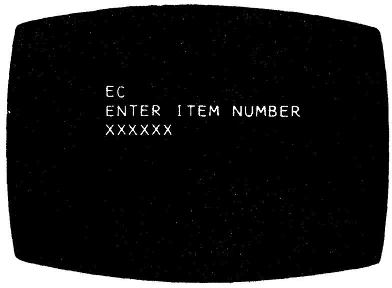
Table 2

Transaction	Possible errors
Add a new part	• Part already exists in the data base.
Delete a part	• Part is not in the data base. • Part is an assembly with components attached. • Part is a component of an existing assembly.
Add an assembly	• Assembly is already in the data base. • Assembly or component items are not in the data base.
Change an assembly-delete item A and add item B	• Assembly is not in the data base. • Assembly does not include item A. • Assembly already includes item B.

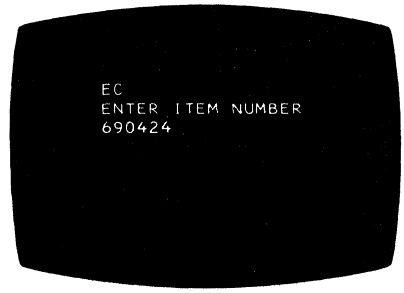
Graphic terminals, capable of rapidly displaying large volumes of data, provide particular advantages to the engineer concerned with making engineering changes – for example, the ability to examine the pending changes before making a further change.

The example shown in Figure 32 describes the steps involved in a simple component substitution. However, the terminal method of entry facilitates the handling of more complex changes. In this case, the entry of the change consists of a number of individual terminal steps. Inline editing by the system ensures satisfactory completion of each step before the next is begun.

Engineer enters code for engineering change. System requests item number



Engineer enters the item no. 690424



If this Item were not on the data base the error would be reported back immediately

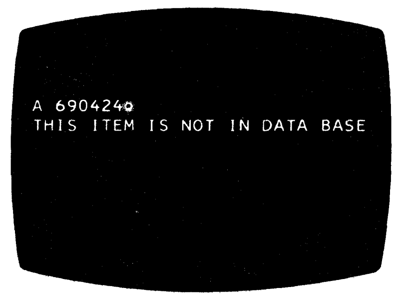


Figure 32. An example of how engineering changes can be entered at terminals. The data is edited as it is entered (Sheet 1 of 2)

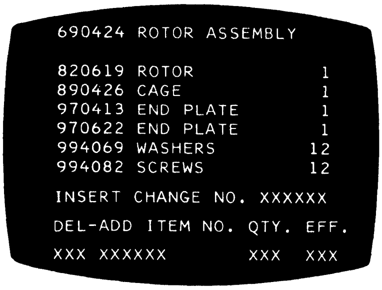
A restriction is put into the system to ensure that only authorized personnel can alter particular sections of the data base (see *System Requirements*). For example, engineering changes affecting the production bill of material are normally made only by a production engineer.

Engineering change data

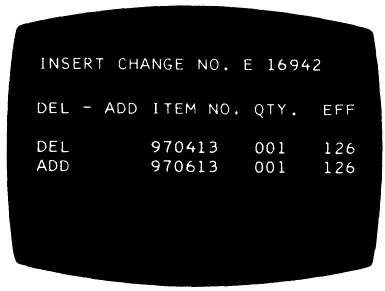
All current and pending engineering changes are held in an engineering change portion of the data base (Figure 33). This file communicates information concerning all changes. It contains, for example:

- The status of all changes (pending, current, superseded, etc.).
- The effectivity of the change (quantity, date, serial numbers).
- The interrelationship within a group of changes – for example, "E.C. No. 3479 can be fitted only if E.C. No. 2436 is already installed", or (to show how a modification is implemented in stages) "E.C. No. 3247 deletes item A, and E.C. No. 3833 replaces it with item X".

On successful entry the assembly and its components and quantities are displayed along with the format for entering change data.



Engineer enters data in the positions marked "XXXX"
Engineering change no. E16942
DEL. Item no. 970413
ADD. Item no. 970613
QTY. Quantity 1
EFF. Effectivity date 126



Proposed new assembly is displayed with all structure records, effectivity date and E.C. no. Engineer reviews, agrees and enters a code resulting in a new engineering change record and a changed bill of material

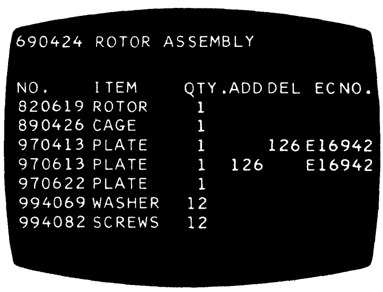


Figure 32. An example of how engineering changes can be entered at terminals. The data is edited as it is entered (Sheet 2 of 2)

- The difference between similar changes when there is more than one version. For example, different items are needed when the change is applied to products in the field rather than to those in production.

From the relationship of the engineering change data to the product definition data, the complete modification history of a product during its manufacturing cycle can be determined; this history is a key means of maintaining configuration control.

Engineering change information is later posted to a Product History File to establish the engineering change status at time of delivery. Additional changes made while the product is in service are also used to update the Product History File (see "Product Support" later in this chapter).

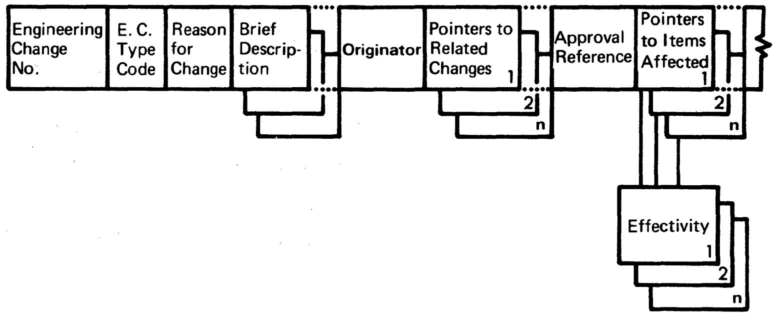


Figure 33. Example of the engineering change record. A detailed description can be found in *System Data Base*

Communicating the Change Information

The creation of temporary or "incomplete" item records has been described under "Item Data". The addition of a temporary item record creates automatic requests via Action Files for the remaining parts of the item record supplied by other departments. Engineering change control uses the same facility.

Adding a new item or bill of material via an engineering change will provide only the basic engineering information required. A large volume of additional information may be required before the change can be implemented. Some of this information, such as purchase specifications or routing data, may be required at an early stage for planning purposes. Action File requests for information, and automatic follow-up if the information is not provided, are a key part of engineering change control.

Examples of the information automatically requested or disbursed include:

- Routings and tooling requirements from Production Engineering
- New end item prices and class codes from Sales
- Estimated standards for planning purposes from industrial engineers
- Prices from Purchasing
- Notification to Purchasing and Production that a deleted part is now obsolete
- Notification to the production print room of canceled drawings
- Notification to the responsible production analyzer of an impending effectivity date

The engineering change coordinator

Overall control of engineering changes is complicated by the number of different departments involved in planning and implementing each change and by the wide range of different changes processed. While much of the routine work involved in checking and implementing changes can be controlled by the computer, lack of coordinated control in the departments concerned can result in inaccurate data being held in the system.

A commonly adopted approach to the problem is to place the responsibility for control in the hands of an engineering change coordinator, who is often located in the engineering department.

Implementing the Change

The effective date is automatically recalculated while the engineering change is pending. The exact time of implementation is determined by INVENTORY MANAGEMENT.

At the point when the change is about to be implemented, the engineering change coordinator resolves any questions that might require manual intervention. For example, if different assemblies are contending for the last available stock of changed components, the coordinator must resolve this contention.

When the exact changeover point has been reached, the system informs the affected departments automatically by placing a message in their Action File. The engineering change record must be updated with the actual effectivity if a Product History File is maintained.

Product Support

Configuration control does not necessarily end when a product is shipped to the customer. The need to retain product history data is increasing. Product history keeps track of what parts have actually gone into a particular end item. This information is used to:

- Recall affected products for modification when a fault in design is detected.
- Fill orders for spare parts on obsolete models.

The problem is complicated by the fact that some industries, such as aerospace, rarely make two identical versions of the same product.

Customer service requirements call for the ability to review the product history and to search for information on a number of different bases.

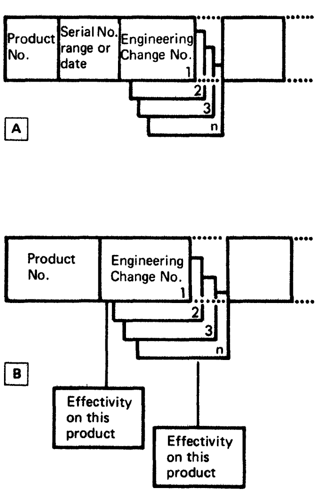


Figure 34. Two basic ways to maintain engineering change history

Product history data

At the time of engineering change, when the old structure or item data is removed from the data base, it is automatically added to the appropriate Product History File.

- When the product is large and unique, the data is added as a complete product bill of material or a list of applied engineering changes on each individual unit (Figure 34A)
- Otherwise, the data is added as a list of engineering changes from which the product configuration can be recreated in conjunction with the current product definition data (Figure 34B)

Data disposition is as follows:

Item data is left in the data base in the form of a skeleton or minimal record that indicates the number of the superseding item. The superseding item, in turn, carries an indication of the item it supersedes. Therefore, when a demand for an obsoleted item is received, the current item can be traced.

Product structure data is removed from the data base.

Engineering change data is retained. The old record in the engineering change data base is removed, and the record is recreated in the engineering change history file. The contents are similar to the engineering change records except that the actual item numbers of affected parts are used rather than pointers. Simultaneously a record is created in the product history data.

The engineering change history record contains not only the change information but also the identification of the end products affected by the change. Through use of this record, a range of products at a particular engineering change level, or the changes on specific serial numbers, can be rapidly identified.

Technical manual preparation

Many engineering departments publish service manuals, parts catalogs, and highly documented quotations. A problem exists in maintaining the text of these documents. The updating of these documents is often delayed because of the large amount of typing involved. Small alterations have a high impact on the final document. As an example, additions can cause lines of text to overflow to a following page, changing the format and numbering of pages. Consequently, small changes often require the document to be completely reprinted.

Text processing on a computer offers a solution to these problems. Text processing allows revision with reduced typing effort (Figure 35). The text is easy to update. The current text level can be printed at high speed whenever it is required. A clean, up-to-date master copy of a document can always be made available. This is achieved without any repetitive typing of old text; only the net changes need be handled.

Parts catalogs can be produced directly from the system's production definition data. The system can easily arrange the parts catalog by product or item type, as well as by item number. This allows customers and sales organizations to locate items more quickly.

Original data as input. Desired changes are indicated.

```
TECHNICAL MANUAL PREPARATION                                                      420
                                                                                  421
Many engineering departments publish service manuals, parts catalogs, and highly  422
documented quotations. A problem exists in maintaining the text of these documents. 423
The updating of these documents is often delayed because of the large amount of   424
typing work involved. Text processing allows revision with reduced typing effort. 425
The text is easy to update. Small alterations have a high impact on the final documents.426
As an example, additions can cause lines of text to overflow to a following page, 427
changing the format and numbering of pages. Consequently, small changes often require 428
the document to be completely reprinted.                                          429
                                                                                  430
Parts Catalogs can be produced directly from the system's product definition data 431
(Figure 37. 36)                                                                   432
Text processing on a computer offers a solution to these problems
```

Computer printout of original data.

```
TECHNICAL MANUAL PREPARATION                                  420
                                                              421
Many engineering departments publish service manuals,         422
parts catalogs, and highly documented quotations. A           423
problem exists in maintaining the text of these documents.
The updating of these documents is often delayed because      424
of the large amount of typing work involved. Text             425
processing allows revision with reduced typing effort.
The text is easy to update. Small alterations have a high     426
impact on the final documents. As an example, additions       427
can cause lines of text to overflow to a following page,
changing the format and numbering of pages. Consequently,     428
small changes often require the document  to be completely    429
reprinted.
                                                              430
Parts Catalogs can be produced directly from the system's     431
product definition data (Figure 37).                          432
```

Typed input needed to make above changes to original data.

```
erase 432
              (Figure 36).                                                        787
move 431;787

              Text processing on a computer offers a solution to these problems.  788
              Text processing allows revision with reduced typing effort. The     789
              text is easy to update.                                             790
move 430;788,789,790

erase 425,426
              typing work involved. Small alterations have a high impact on the final  791
              documents.                                                          792
move 424;791,792
```

Computer printout of revised text.

```
TECHNICAL MANUAL PREPARATION                                  420
                                                              421
Many engineering departments publish service manuals,         422
parts catalogs, and highly documented quotations. A           423
problem exists in maintaining the text of these documents.
The updating of these documents is often delayed because      424
of the large amount of typing work involved. Small            425
alterations have a high impact on the final documents.        426
As an example, additions can cause lines of text to           427
overflow to a following page, changing the format and         428
numbering of pages. Consequently, small changes often
require the document to be completely reprinted.              429
                                                              430
Text processing on a computer offers a solution to these      431
problems. Text processing allows revision with reduced        432
typing effort. The text is easy to update. Parts catalogs     433
can be produced directly from the system's product            434
definition data (Figure 36).                                  435
```

Figure 35. Example of text processing output

Manufacturing routings, the information that describes how a product is made, fulfill two distinct purposes:

Manufacturing instructions – describing to the shop how the operation is to be performed, the type of machine, the tools to be used.

Production planning – specifying the sequence of operations and the information needed to calculate work center loads and manufacturing lead time.

The names commonly used to describe this data are routing, route sheet, planning sheet, and process layout. In this discussion, the name routing is used. Routings are usually printed as separate documents, but in some industries are combined with the drawings.

The Routing Record

The routing record is illustrated in Figure 36. Item data specific to the whole routing, such as engineering change level, is held in a heading record. Other data required when printing the routing, such as item description and material requirements, is taken from the product definition data base.

Information relating to each operation is held in a series of operation records, which contain:

Operation data – needed for scheduling and payment purposes, such as operation run time, setup time, etc.

Descriptive data – specifying how the operation is to be performed. This is completely variable in length.

Tool or container data – reference to the jigs, fixtures, tools, or containers needed for this operation.

Material required for an operation is designated in the product structure record for each item.

Inspection operations

Inspection operations, containing rules for sampling, skill grade required, inspection location, applicable tolerances, required gauges, and time per part, can be held as separate operations in the routing. These operations use inspection locations and skill grades as "work centers". Each inspection facility, therefore, can contain capacity and load figures as if it were a work center.

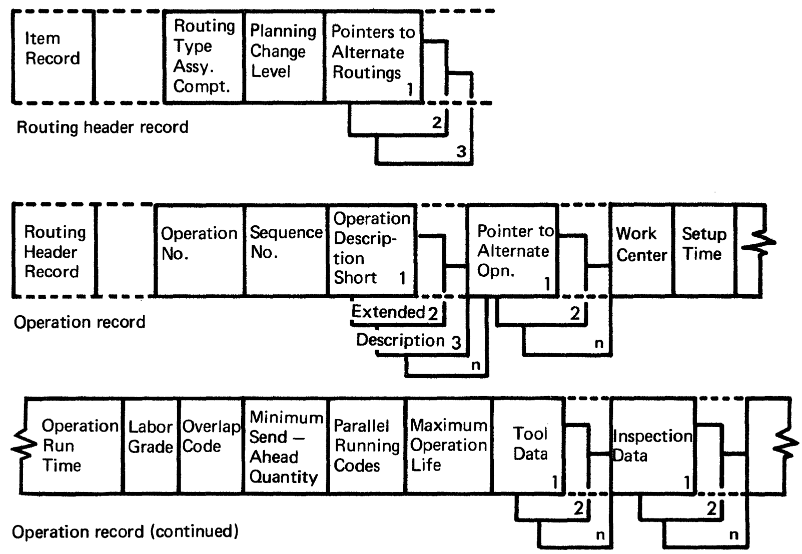


Figure 36. Example of a routing record in a product definition data base. A more detailed description of these records is given in *System Data Base*

However, in most cases where inspection is performed at the work center itself, inspection can be included as a factor in the interoperation time (see "Interoperation Time" in *Chapter 6, Manufacturing Activity Planning*).

Move operations

Where special move instructions are necessary, such as for special moving equipment, a separate move operation can be included in the routing. However, in most cases, transport time is included as part of the interoperation time (see "Interoperation Time" in *Chapter 6, Manufacturing Activity Planning*).

Setup operations

Setup can be specified as a separate operation. The interoperation time between the setup operation and the operation itself would then be set to zero or any desired figure.

Common Operations and Setup

Items with similar or identical shapes and dimensions may have some identical operations in their routings, or, more usually, the setup for some operations will be the same.

If such information is coded into the routing, ORDER RELEASE PLANNING and OPERATION SEQUENCING can identify the records in the data base, so that orders for such items can be released together, with consequent savings in setup cost. The coding scheme is outlined in *Chapter 6, Manufacturing Activity Planning*.

Alternate Routings and Operations

Alternatives may be necessary, either for complete routings or for individual operations. A small batch may be machined on a turret lathe instead of an automatic screw machine, or conventional machines may have to be used in place of a numerically controlled machine.

Alternate routings

Figure 37 illustrates the organization of alternate routings in the data base. The alternate is stored as a second routing, and can be entirely different from the normal routing.

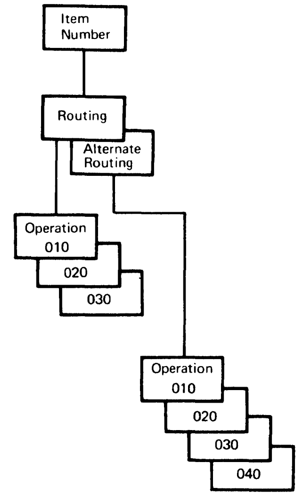


Figure 37. Alternate routing record

Alternate operations

An operation may be replaced by another operation, or by two or three operations that together perform the same function. Figure 38 shows how an alternate operations pointer is included in the operation record. The use of alternate routing and alternate operation data is described in *Chapter 6, Manufacturing Activity Planning.*

Other types of routing

In addition to the standard manufacturing routing and alternate routings, additional forms of routing information may be retained for use in particular situations, such as:

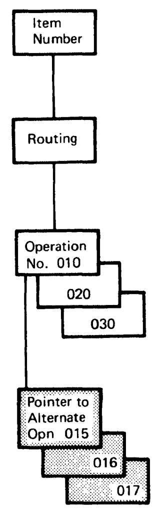


Figure 38. Operations 15, 16, and 17 together are an alternate for operation 010

- *"Blanket" routing.* This is written for a "family" of similar items that use the same set of operations. Often the operation descriptions are common and only the times vary with size of item. Specific setup and operation times can be generated at the time of generating the shop order by the techniques described later in this chapter under "Automated Manufacturing Planning".
- *"Composite" routing.* This is similar to a blanket routing, except that not all the operations are used to produce every item. In this case a selection of operations is made depending on the characteristics of the particular item. Examples of items having these types of routings are:
  1. Items produced on a process line.
  2. Items assembled as standard variants of bills of material. The operations to build the basic item are associated with all necessary additional operations to build each type of variant. This type of routing is customized for use as each order is released.
- *Temporary routing.* This may be a routing to make a preproduction item while the prime routing is being planned or before tooling is available. An engineer would normally have to give authorization before the routing may be used to fabricate a part.

- *Rework routing.* Normally this type of routing would not be permanent, as it is generated for rework to a specific order. In some cases, however, because of a high rate of rejection during a particular process, for example, the routing is held permanently in the routing data. The routing can be used to plan and schedule expected rework.
- *Specific routing.* This is a version of the standard routing held at a specific engineering level often for a specific customer or product.
- *Purchased item or raw material routing.* These routings do not carry any information to manufacture the item, but may contain specific instructions for receiving, inspection, stocking, etc. They can be used to track the order for the item, as described in *Chapter 10, Purchasing and Receiving.*
- *Numerical control/direct numerical control data.* NC/DNC data – that is, the instructions fed directly into a machine tool controller to control the cutting tool – can be held as part of the routing data or as separate instructions. These can be produced in machine-readable form (magnetic tape, paper tape, magnetic disk, etc.) when the shop order for the item is being produced.

  Other control data, such as for process operations, wiring, or cabling, can similarly be maintained as part of the routing or referenced in a similar manner to tools or gauges.

Creating Routing Data

Developing new routings involves Production Engineering in two major tasks: (1) technical specifications – developing and evaluating alternative methods and sequence of manufacture, and (2) documentation – creation and maintenance of the routing document. The computer system can significantly help Production Engineering in both these tasks.

The following aspects of the creation and maintenance of routing data are presented in this section.

- *Automated manufacturing planning* – complete automation of the routing document for families of items.
- *Operation time standards* – generation of time standards for operations.
- *Staged creation of routing data* – building up the routing as each part of the data becomes available – for example, the routing is planned before operation times are added. The control of information during the buildup period is described.
- *Changes to routing data* – controlling the maintenance of the routing once it has been created.

Automated manufacturing planning

Many companies have succeeded in automating part of their manufacturing planning process. They have reached this point through the realization that similarities between parts allow for the standardizing of routing data. Examples of items that can be successfully planned by means of this technique are turned parts, piston rings, valves, springs, cams. An automated manufacturing planning system produces routings directly from a design specification (Figure 39). The manufacturing instructions are generated through the logic developed by the production engineer, whose starting point is design data (shape, dimensions, and material). The system is based on the classification of parts into groups having the same manufacturing characteristics.

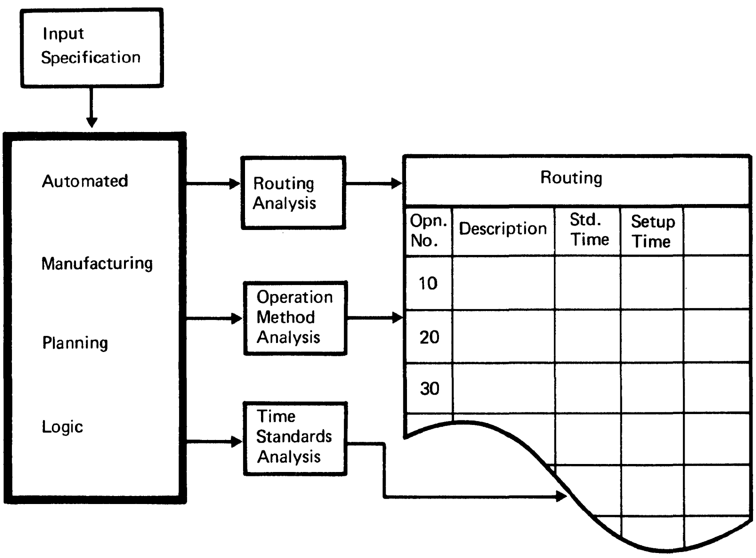


Figure 39. Automated manufacturing planning

These characteristics may be recognized from similarities in the overall shape and size of parts. For example, an item described as a pivot pin may be exactly the same as another described as a drive shaft, and the operations required to produce them may be identical except for the machining time required. When the data for all similar parts is collected, it is often found that machining time is so closely related to size that both the operations and standard times can be tabulated. The tables will produce accurate manufacturing instructions and times for any new parts falling within the size range of the parts for which the original data was collected.

Another way to spot similar characteristics is to compare parts that pass through common manufacturing processes or machines, such as automatic screw machines or small presses.

The product range should be examined for family groupings to identify those groups that offer the greatest advantage from automating the planning process. A group containing a reasonably large number of parts, or a large volume of modification activity, will repay most quickly the effort involved in data analysis.

The volume of data analysis can be reduced by the use of item classification codes described in "Creation of Item Data". The elements of the classification codes indicating characteristics such as complexity of shape, length/diameter ratio, and size can be used to isolate all parts having an individual characteristic. Successive selection of parts and combination into groups can be carried out automatically; only final selection is performed manually.

Operation time standards

Operation time standards are used by MANUFACTURING ACTIVITY PLANNING to calculate operation run times, and by Cost Planning and Control for payroll and costing purposes.

These standards are developed in different ways, determined by the average length of operations and by industry conditions:

- *Rate fixing or estimating* is used when operation times are long, usually on custom-engineered items and maintenance work.
- *Work measurement and synthetic standards*, both based on detailed analysis of work content, are normally used on short, highly repetitive operations.
- *A combination of the above methods*, by reducing the amount of estimating, can lead to improved estimates for nonrepetitive work such as maintenance or repair jobs. The system can gather historical data for recognizable elements of work, and tabulate it to provide standards for the repetitive parts of such jobs. The remaining parts of each job are estimated. The tabulated standard data can be stored in a computer, and the partial standards calculated as required.
- *Computer-calculation* allows standards to be developed from comprehensive tables of stored engineering data. Provided with coded operation specifications, the computer develops and prints a detailed standard in the form of a routing, with a description and standard time for each element.
- *Learning curves* are often used in repetitive manufacturing to modify standard operation times for order planning and payment purposes. They are usually employed when new products or operators are introduced. The learning curve can be expressed as a factor of the operation standard time for each period during the life of the curve, and can be applied automatically by the computer to planning and payment calculations.

Staged creation of routing data

When an item is added to the data base, requests for data needed to complete the item record are made by Action Files. The entry of this data to the item record has been described in "Creation of Item Data". If the item is coded as a manufactured item, a request for routing data is also automatically generated. Entry of the data from a terminal is through the use of a technique similar to that used for item data.

The information can be entered with the help of a display organized the same way as a routing. The data does not need to be entered completely at one time, but can be stored in the data base as it is developed. For example, as each operation is planned, it can be entered immediately.

Changes to routing data

The maintenance of routings usually involves a large volume of minor changes to the routing file. The technique of conversational data entry described in "Creation of Item Data" is used for the entry of changes to routings.

The engineer, through a terminal, displays the existing routing in a standardized form. He can then make changes to the routing, add an effectivity date, and store the changed data as an alternate operation until the effectivity date is reached. The ease and speed with which changes can be made will result in a higher percentage of up-to-date routing records, leading to fewer unplanned operations on the shop floor.

numerical control data

It is essential to keep track of the engineering change level for all Numerical Control (NC) and Direct Numerical Control (DNC) data. This can be done by maintaining the current engineering change number in the routing record and also in the heading record for the NC/DNC data. A segment in the routing record is linked to the correct level of NC/DNC data to be used, and the engineering change levels are checked to see that they correspond.

Manufacturing Facilities Data

All information regarding the manufacturing facilities available within a company is recorded in the facility records – for example, machines, tools, labor skills, etc. The major facilities described are:

Machine tools. The basic data regarding each machine is held in the facility record. This is used for accumulating machine load, recording maintenance activity, developing cost rates, etc. This can also include test equipment.

Groups of machines or men. Those having similar capabilities – for example, horizontal milling machines above a certain size – may be grouped together for planning purposes. Labor skill groups may be specified in a similar manner – for example, welders, skilled fitters, master craftsmen, etc.

Work centers. A larger group of men, machines, or areas of the plant where a particular type of work is performed which can be considered as a unit for overall loading – for example, turning, painting, subassembly, toolroom, etc. This will embrace a series of individual machines or groups of machines or men.

Tools. Jigs, fixtures, gauges, or any other critical tools are also treated as facilities.

Additional groupings of facility data – for example, by cost center code – can also be achieved.

The Facility Record

Machines and work centers

The type of information to be held in a facility record is shown in Figure 40. While this information is used primarily in MANUFACTURING ACTIVITY PLANNING and PLANT MONITORING AND CONTROL, it is also used by PLANT MAINTENANCE and COST PLANNING AND CONTROL.

Plant maintenance. The closer integration of maintenance and production planning described in *Chapter 9, Plant Maintenance* highlights the need for maintenance data to be available to MANUFACTURING ACTIVITY PLANNING. Part of the facility record relates to maintenance data. This data is used for planning preventive maintenance work and combining machine repairs with planned maintenance. The availability of planned maintenance and production load data through a single facility record enables work to be scheduled with the minimum interruption to production and with less waiting time for maintenance men. (See *Chapter 9, Plant Maintenance* for more detail.)

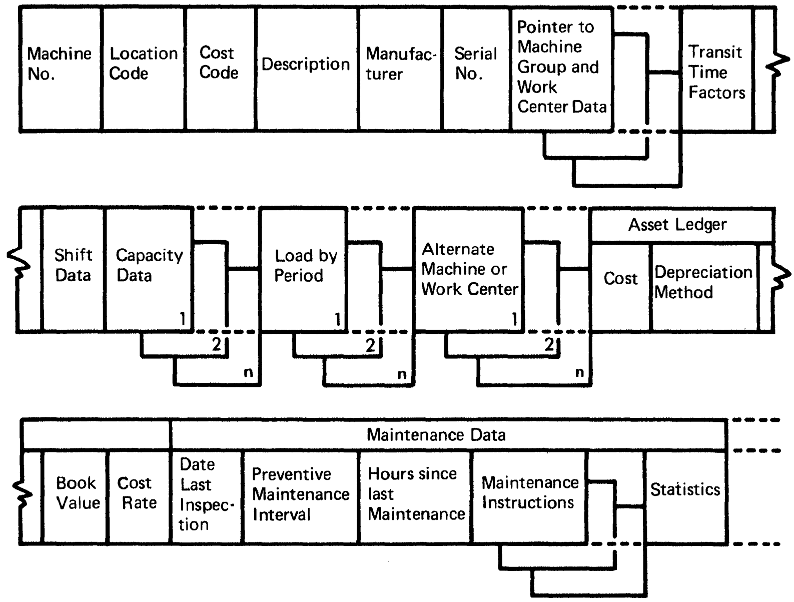


Figure 40. Example of a facility (machine) record. A more detailed description is presented in *System Data Base*

Asset ledger. The plant or asset ledger data maintained by Accounting is included as part of the facility record. It includes such information as asset number, original cost of the machine tool, depreciation method, depreciation period, book value, capitalized revenue (modifications and extensions), and machine hour rate (cost rate).

Tooling

MANUFACTURING ACTIVITY PLANNING helps ensure the availability of the tools and gauges needed for production. By including jigs, fixtures, and gauges in the facilities data base, the system can:

- Ensure that two orders requiring the same tools are not planned simultaneously (see "Operation Sequencing" in *Chapter 6, Manufacturing Activity Planning*).
- Ensure that multiple sets of tools required for an operation are all available when the operation is scheduled to begin.

The tool record is illustrated in Figure 41 and is similar to the standard machine tool record.

Tool records also contain maintenance data. This includes data for periodic inspection of the tool on the basis of usage (see "Tool Control" in *Chapter 8, Plant Monitoring and Control*).

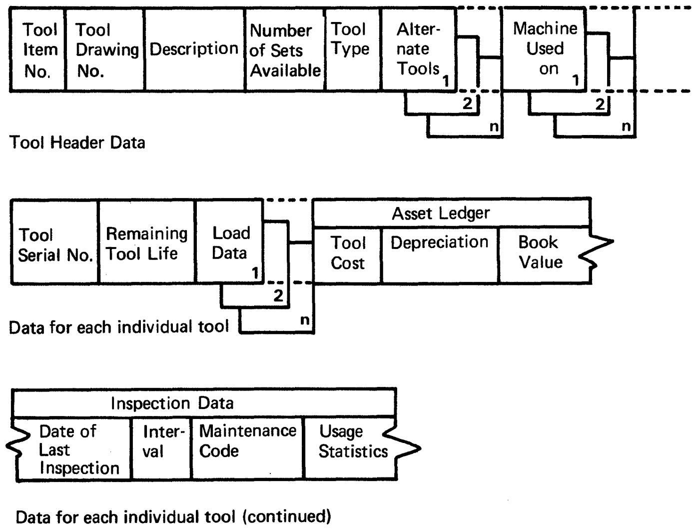


Figure 41. The tool record in the facilities data is similar to the standard machine record

Organizing Facilities Data

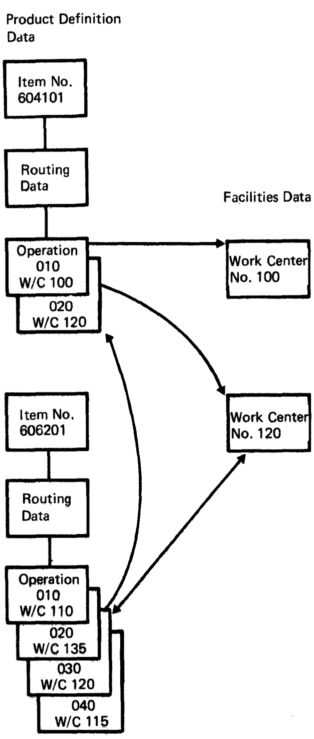


Figure 42. Work center used-on and where-used information is provided by connecting item operation records to facility records

Facility records are connected to the records of operations that require the facility. In Figure 42 operation 010 on item number 604101 is performed by work center 100. This connection makes it possible to quickly accumulate planned loads for each work center and to develop detailed capacity requirements (see "Capacity Requirements Planning" in *Chapter 6, Manufacturing Activity Planning*).

Where-used work center information is obtained by joining together all operations performed on an individual work center. In Figure 42 operation 020 on item 604101 and operation 030 on item 606201 are both performed on work center 120. Connecting these two operation records creates a where-used chain for work center 120. When all operations performed on a work center are identified in this way, the effect of a cost change in the work center, or the acquisition of a new machine tool can be easily simulated.

If, for example, an operation is eliminated:

- The system calculates the change in the direct cost of the operation.
- A where-used search identifies each end item involved, and the system calculates the effect on end item cost from the operation direct cost.
- The system reviews the load profile for the work center where the operation was eliminated. If it was an overloaded work center, offloaded work may be brought back from alternate work centers.

Work center organization

Work centers often contain a mixture of machines acquired over many years. Consequently, their capabilities, within these groupings, vary widely. The ability to carry out certain categories of work only on selected machines or on a group of machines within a work center, requires a facility record to be maintained for each work center, machine group, and individual machine tool.

Figure 43 illustrates how the facility records are organized. Each machine record contains the machine identification, capacity, etc., shown earlier. Each of the machines within a group is connected to a facility record that holds the summarized information for the group of similar machines. The machine group records are in turn connected to the work center record. This is analogous to the bill of material structure, where machines are equivalent to component items, machine groups to assemblies, and work centers to products. In some cases, an individual machine (for example, a specialized boring machine) may also be a work center. In a similar fashion, either a work center or group record can be used to identify a labor grade or skill for a number of men.

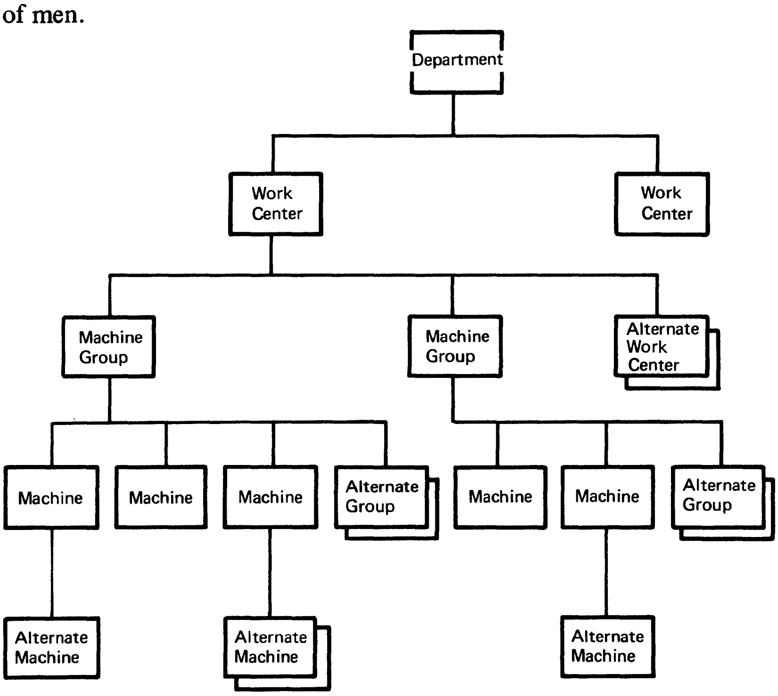


Figure 43. The facilities data is organized into groups of similar machines and work centers

Chapter 6, Manufacturing Activity Planning describes in detail the planning of capacity requirements and the organization of facilities for planning and scheduling. Briefly, this facility record organization allows work to be scheduled onto the individual machine or skill by shift over the next few days, and by week at group or work center level for months ahead.

Physical organization of work centers

The normal organization of facilities data is based on groups of similar machines, physically located together, and having a range of slightly varying capabilities. However, other bases may be used that group machines according to special capabilities or usage – for example:

- *Organizing machines by cost.* Traditional work center organization inevitably leads to the uneconomical use of some machines from time to time. For example, small jobs are sometimes run on machines with high setup costs. An alternative method of organization attempts to avoid this situation by grouping machines by cost characteristics. Each such group, called a machining cell, contains only machines with similar cost characteristics.
- *Grouping dissimilar machines by product.* Conventional machines can be grouped to resemble a flowline. They are normally set up to manufacture an individual part or a range of parts with similar machining characteristics.
- *Production flowlines.* Where flowline production is involved, as in the case of assembly lines or machine transfer lines, the line can be considered as a single unit or machine having a single capacity. However, it is usually necessary to identify specific stations or key points within the line. On assembly lines it is necessary to identify the stations to which materials must be supplied. On transfer lines the impact of a breakdown at a single station demands extensive preventive maintenance. Maintenance data is therefore gathered and controlled for each individual station on the transfer line (see *Chapter 9, Plant Maintenance*). These requirements can be met by the structured work center record shown in Figure 44.

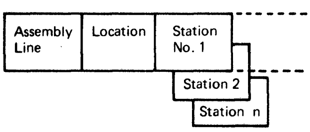


Figure 44. Structured work center record

Tool record organization

When a tool or gauge is specifically designed for the production of a particular item(s), it should be considered as if it were a machine tool. The operation record identifies the tool, and the tool record carries capacity and load data. When a tool is used for a group of similar items, contention between orders is resolved by scheduling the tool as if it were a machine (see "Operation Sequencing" in *Chapter 6, Manufacturing Activity Planning*). In this case the tool record in the facilities data (Figure 41) is connected to the records of all the operations on which it is used.

However, a tool is sometimes machine-dependent – for example, a dividing head used on more than one universal milling machine. In this case the tool record is associated with each of the related machine records. When an order requires a milling machine and dividing head together, the free capacity of each is examined before the order is scheduled.

Summary

ENGINEERING AND PRODUCTION DATA CONTROL addresses the organization, creation, and maintenance of the product definition, process, and facilities data bases. These data bases contain all the basic engineering and manufacturing data.

Changes to products and processes increase the complexity of most production planning and control functions. Consequently, heavy emphasis is placed on controlling engineering changes. Accurate and rapid communication of changes to all departments significantly reduces the number of problems in manufacturing. Techniques are discussed which allow fast simulation and evaluation of proposed changes, using computer terminals.

Bill of material organization for product variants and options provides advantages for manufacturers of nonstandard products. These same techniques, together with aids for engineering information retrieval, also reduce the cost of much routine design work.

Complete control over the configuration of the product can be maintained, from initial design, through production, and after delivery to the customer. These capabilities become possible through the use of advanced data base facilities, which allow the complex relationships existing in engineering and production data to be represented in the data base. The cost of creating and maintaining the data is minimized, and automatic monitoring of data creation ensures faster development of new product data.

Chapter 2. Customer Order Servicing

Contents

Introduction

Companies judge their suppliers not only on quality, performance, and price, but on how well their orders are handled. CUSTOMER ORDER SERVICING provides the means to handle customer orders, inquiries, and quotations rapidly and accurately.

Relationship with a sales information system

The system encompasses the servicing of customer orders from the initial order or request for quotation to shipping of the finished product. It is not a complete sales information system; it does not, for example, cover sales analysis or accounts receivable.

Rather, CUSTOMER ORDER SERVICING is the link between the manufacturing system and a sales information system. Manufacturing systems provide CUSTOMER ORDER SERVICING with the necessary information concerning item availability. A sales information system, in turn, obtains its information from CUSTOMER ORDER SERVICING. As orders are accepted and shipped, the system stores information on orders, customers, products, etc., for use by sales.

Reports generated by a sales information system from this data are illustrated in Figure 1.

While this chapter does not discuss the area of generating and maintaining sales information, it does present the interface between sales and manufacturing.

Controlling customer orders

CUSTOMER ORDER SERVICING helps solve many of the problems commonly experienced in controlling customer orders. Some of these problems – and their solutions – are as follows:

- Delaying orders during order entry because of missing customer data or incomplete item information results in mislaying orders and possible late delivery.

  CUSTOMER ORDER SERVICING provides central control of customer orders at every stage of processing, thus minimizing mislaid and delayed orders.

ORDERS RECEIVED

KEY CUSTOMER SALES

SALES BY REGION AND BRANCH

SALES BY PRODUCT GROUP

PRODUCT GROUP	YEAR TO DATE (,000'S)	---SALES--- THIS PERIOD	LAST PERIOD	LAST YEAR TO DATE (,000'S)	PERCENT INCREASE DECREASE
01 COMPRESSORS	340.2	30,246	28,200	298.6	+14.0
05 COMPRESSORS	482.6	51,923	38,333	401.2	+20.1
17 PUMPS	190.2	14,712	16,924	202.1	- 6.0
25 PUMPS LAND	301.6	25,600	31,422	280.7	+ 7.4
26 PUMPS MARINE	341.2	30,812	24,702	260.1	+31.0
27 PUMPS SUBM.	165.3	18,800	16,000	181.0	- 8.9

Figure 1. Sales analysis reports are generated from information gathered during CUSTOMER ORDER SERVICING

- Orders may be held up for special items while detailed specifications are located or created.

  CUSTOMER ORDER SERVICING provides fast development of specifications by using Product Definition Data and Automated Design Engineering techniques, which enable orders to be processed with less delay.

- Inadequate information about item availability and production plans increases order processing difficulties. For example, two order clerks may simultaneously allocate the same stock to different orders.

  CUSTOMER ORDER SERVICING provides terminal entry of orders to a central order file. This prevents simultaneous contention and provides current information for order entry personnel.

- It is often impossible to confirm an order delivery date with accuracy.

  CUSTOMER ORDER SERVICING allocates against the master production schedule and can confirm delivery dates as orders are entered at terminals. The impact of individual customer orders on capacity can be determined before the order is accepted.

- Customer inquiries as to order status cannot be answered quickly and accurately.

  CUSTOMER ORDER SERVICING can retrieve centralized order status information and update it constantly as shop floor conditions change; answers to inquiries can thus be handled effectively.

- Detecting out-of-control situations in order processing is difficult.

  CUSTOMER ORDER SERVICING monitors order backlog situations and notifies management if order servicing queues or individual orders spend too much time at one stage of processing.

Objectives

CUSTOMER ORDER SERVICING helps ensure rapid, accurate entry of orders into a control system, which in turn ensures on-time delivery and improved response to customer information requirements.

Faster order entry results from the use of terminals to enter order information. Online entry reduces the amount of data that must be entered and eliminates most of the time normally lost correcting the entry errors. CUSTOMER ORDER SERVICING processes orders in one step, eliminating paper handling for pricing, inventory allocation,

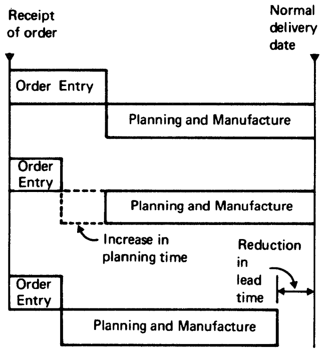


Figure 2. Reducing order entry time provides two major options

order typing, and shipping document preparation. Reduced order processing time results in a reduction in the lead time quoted to customers. This reduction in lead time usually provides a competitive advantage and can help increase sales. Alternatively, the lead time reduction can be used to provide a longer planning period, which in turn can be used to level the load on production facilities (Figure 2).

Accurate order entry results from a formalized and guided method for entering orders. The correction of entry errors is expensive; it leads to more errors, delays the order, and causes customer dissatisfaction. Order entry time is the best time to avoid entering inconsistent and inaccurate data. The interactive development of the order between the order clerk and the system "talks" an inexperienced clerk through order entry, and so ensures that no part of the process is forgotten. Errors and omissions are immediately detected and error statistics point out the need for retraining.

The greater part of the data in the order record is supplied by the system rather than by the order clerk. Only order quantities, requested delivery dates, and variations from order standards (such as special shipping instructions) are entered directly. Order records, because of reduced data entry, contain fewer errors. The system also reduces the work involved in locating information, through reducing the physical searching of customer lists and sales catalogs.

Accurate costed and priced quotations can be achieved through the use of Automated Design Engineering to specify products. The technique provides optimum design and greater cost precision, thereby offering a better probability of profit. Because of faster response to the customer's inquiry, a higher yield should result from the quotations handled.

Increased control throughout the life of an order is obtained when the order is recorded in a central Customer Order File and updated via terminal to reflect each change in its status. A basis is thus provided for answering:

- Such customer inquiries as

  What is the current status of my order?

  Can order delivery be improved?

- Such management inquiries as

  How many of this item are back-ordered?

  How many orders are held up in Shipping?

  How long is it taking to process an order through each phase of handling?

Functions of Customer Order Servicing

Orders received by manufacturing companies range from the single order for many high-cost items for delivery over an extended period, to the order for immediate delivery of a single item to replace a worn part. Despite the difference in value, each of these orders will pass through the same phases, and the total cost of processing an order will be similar.

Figure 3 illustrates the basic functions of CUSTOMER ORDER SERVICING:

- *Order analysis and entry.* Orders are entered via a terminal either at a central location or from branches, field warehouses, or direct from customer premises. The order is checked for validity and the customer credit is checked.

  For orders requiring immediate shipment, available inventory is allocated. Back orders are created for items not available.

  Orders for nonstandard products can also be handled.
- *Determining availability for future delivery.* Future production is allocated to a customer order. Capacity availability is checked for orders above current planned production.
- *Order control.* The order is monitored from time of receipt to time of shipment. Requested changes are incorporated and immediate notification is given of any alterations to the delivery date.
- *Handling customer inquiries.* Inquiries for new orders or customer inquiries as to the status of their orders are rapidly handled via terminal entry.
- *Shipping.* Orders are released to the shipping department as products are ready. Shipping department and transport workloads are planned on the basis of known delivery schedules.
- *Evaluating order servicing performance.* Performance of the CUSTOMER ORDER SERVICING function is monitored for response to inquiries and operations, maintaining delivery promises, and reducing order processing times.

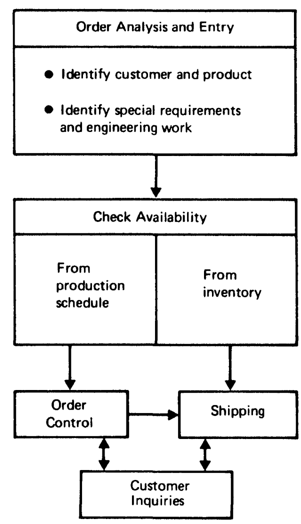


Figure 3. Basic functions of CUSTOMER ORDER SERVICING

Interplant orders are orders placed by other plants in the company. Since they are usually handled by Production Control rather than by CUSTOMER ORDER SERVICING, they are discussed in *Chapter 4, Master Production Schedule Planning* and *Chapter 5, Inventory Management.*

Relationship with other application areas

CUSTOMER ORDER SERVICING obtains information on the production status of each order from the other parts of the system. Its relationship with the other application areas is illustrated in Figure 4. These other areas provide detailed and current information regarding the assemblies and component parts needed to make the product, inventory position, capacity availability, and the status of shop and purchase orders – information that makes improved customer order servicing possible.

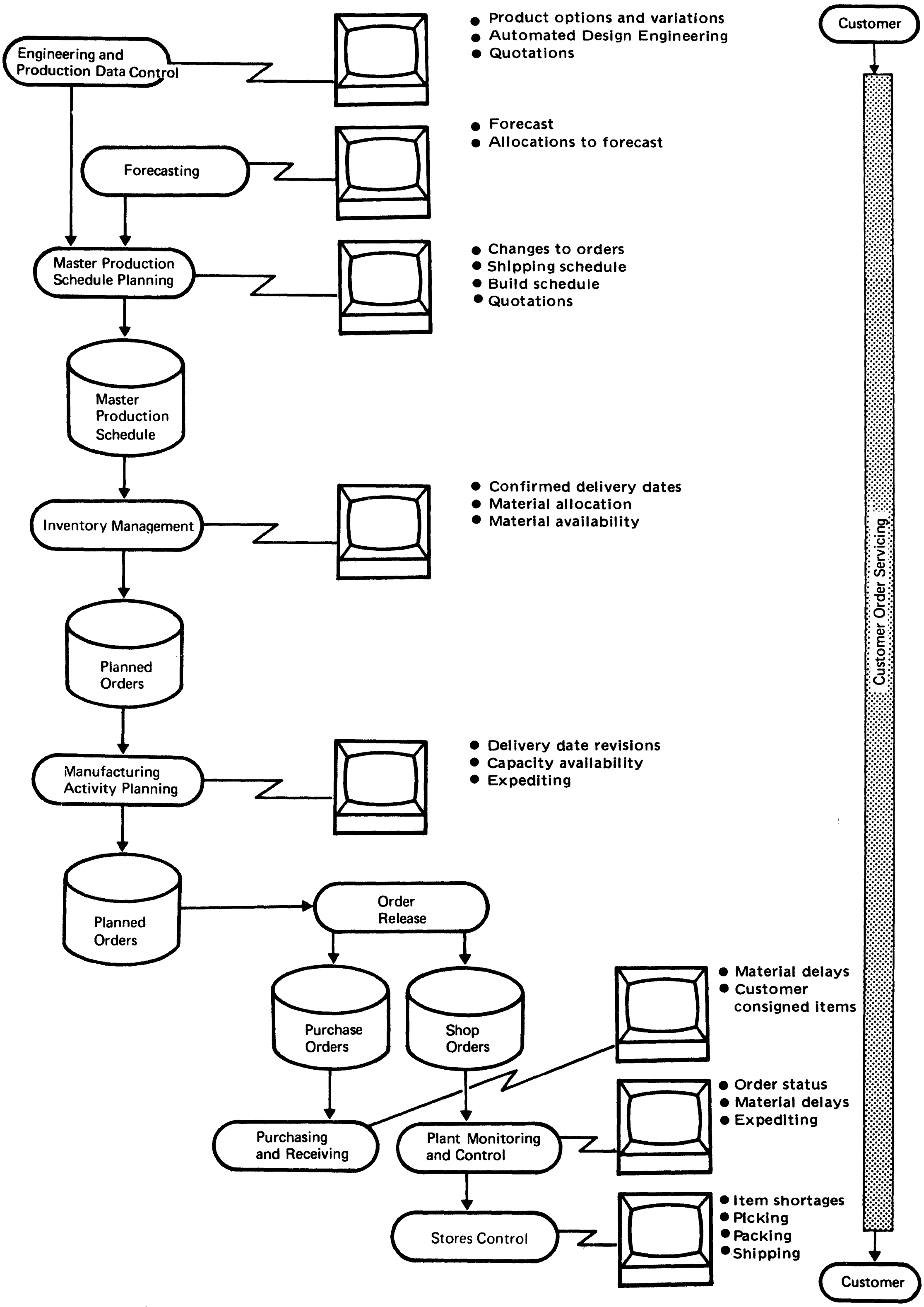


Figure 4. Relationship with other application areas

Order Analysis and Entry

Figure 5 illustrates the steps used in analyzing a customer order and entering it into the system. The operator types in an identification number and, in doing so, signs on for the day's work. The operator ID number will be attached to every order record.

The first order processed is for a customer named J. B. Thomas Company; no customer number is present. The order clerk enters THOM. A list of all customers whose names begin with these letters is immediately displayed. The operator selects the line containing J. B. Thomas Company by typing in the appropriate line number. The customer list is then replaced by information relating to that specific customer. This consists of the customer number, invoicing and shipping address, shipping instructions, billing information, etc.

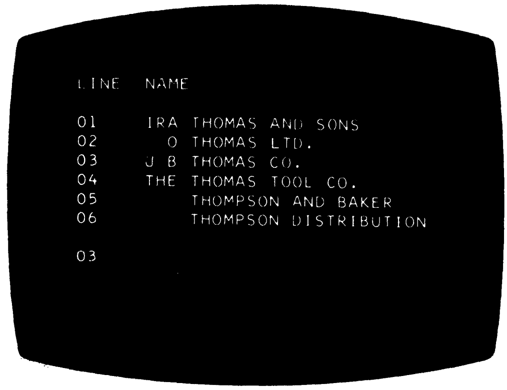
What is happening? The order clerk is using an interactive method for entering order information. The clerk has quickly searched through a customer list, identified the required customer, and has automatically obtained most of the data needed to enter the order. In the example shown, only five digits had to be entered to obtain the necessary information.

Data transcription is significantly reduced, and as long as the information in the file is correct, it will be correct on every order document on which it appears. If the conversational data entry method is extended to item data, the same level of work saving, accuracy, and consistency is achieved for other order information, including product descriptions, prices, discounts, packing instructions, etc.

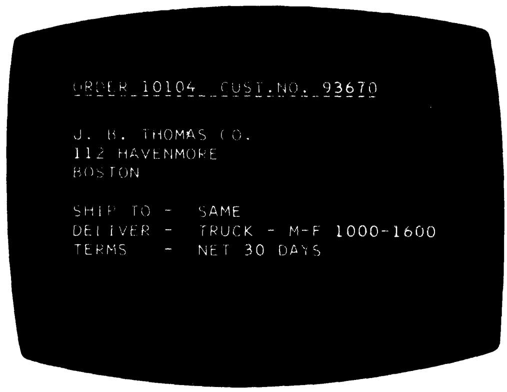
This section discusses this terminal approach to customer order servicing in more detail for items supplied originally from stock. The handling of orders for items manufactured to a customer specification is discussed in "Order Entry for Nonstandard Products".

The scope of order analysis and entry covers the activities between the receipt of an order and the establishment in the system of an order record used for production or shipping purposes. This order record may result from a single terminal entry (in the case of a stock item) or from a series of entries over a period of time (in the case of a quotation for a complex, specially engineered product). Figure 6 illustrates some of the information established by the system in the customer record and the order record.

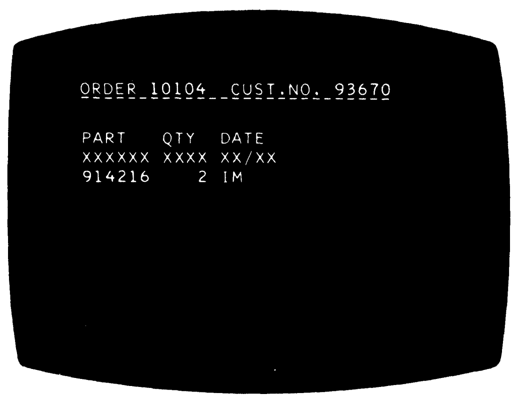
To enter order from J.B. Thomas Co. operator keys in "THOM" and selects correct customer from displayed customer list.



The system assigns an order number and displays the customer record which contains the customer number, the billing and delivery address, the standard delivery and order instructions held in the customer record.



Operator enters item number, quantity, and required delivery for first line of order. "IM" is code for immediate delivery.



Item description is displayed with earliest availability date. Data is checked against order. Order control totals are displayed.

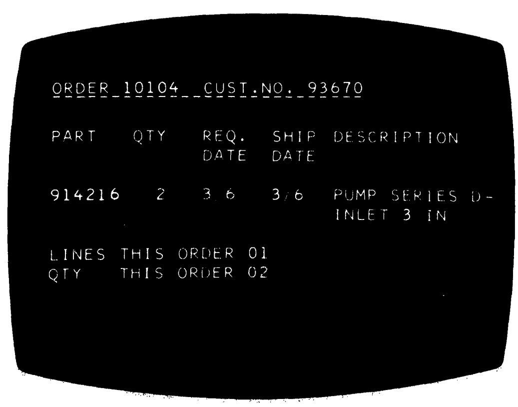
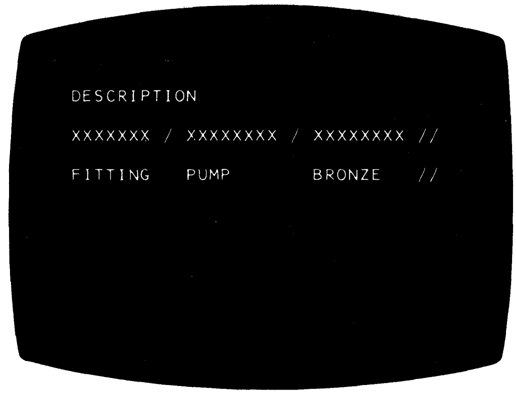
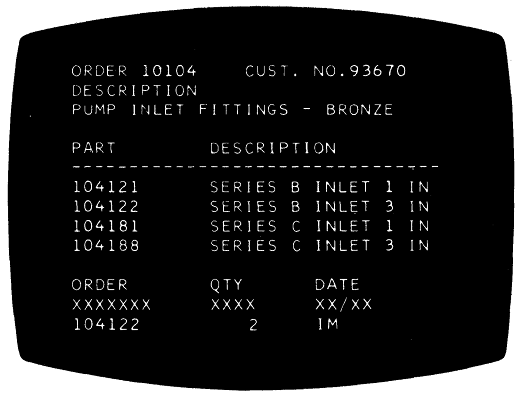


Figure 5. Interactive order entry (sheet 1 of 2)

The second line of the order quotes a description without an item number. Operator begins catalog search by entering description.



The section of the catalog requested is displayed. The operator selects correct fitting and enters quantity and date.



As before the system displays item number, description and earliest availability date, and order control totals.

Figure 5. Interactive order entry (sheet 2 of 2)

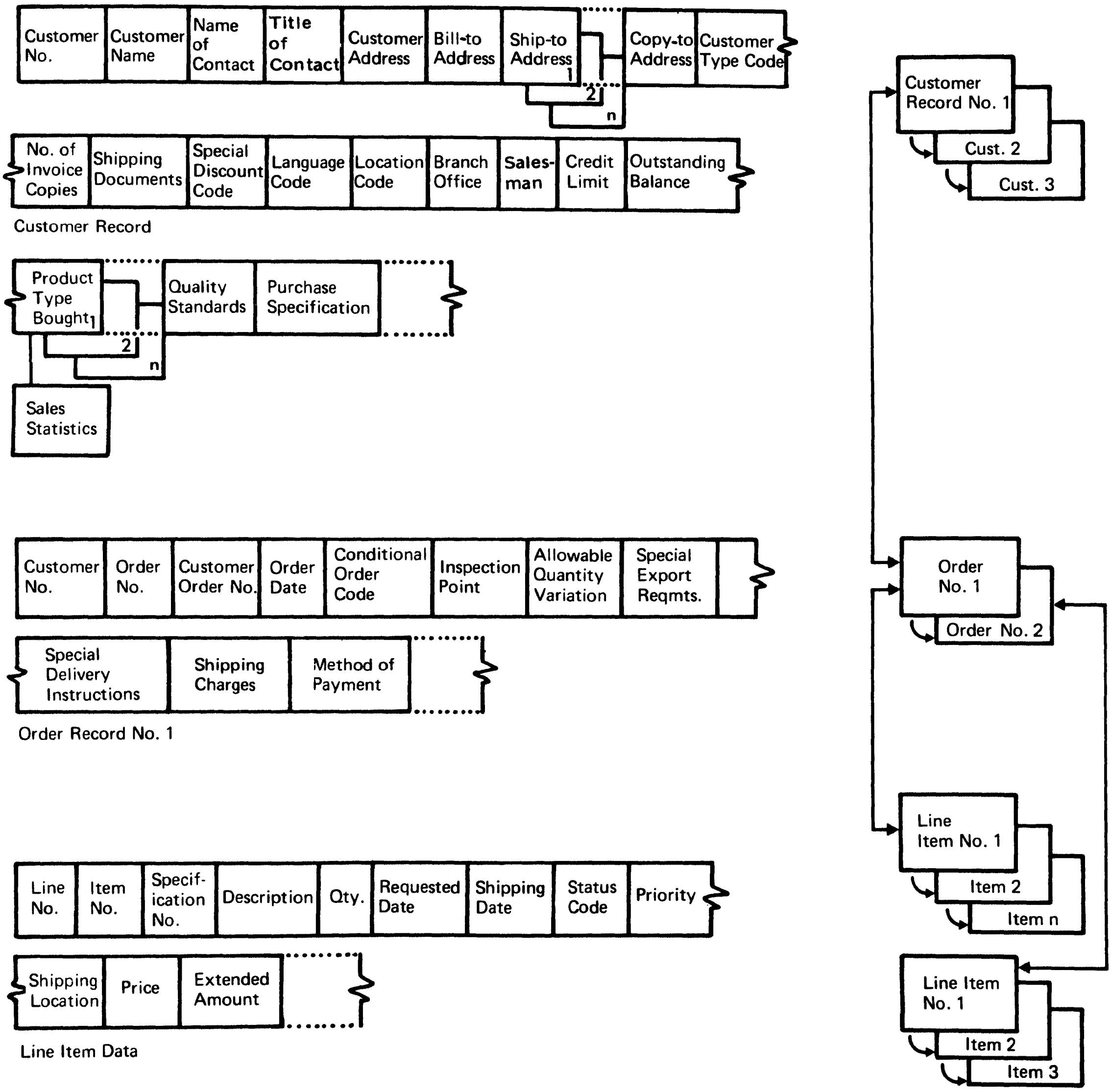


Figure 6. Customer and order record

During order analysis and entry the following functions are covered:

- *Order preparation* – checking the order before entry into the system and establishing initial controls
- *Identifying the customer* – confirming the correct address, entering special delivery and billing instructions
- *Credit control* – checking the customer's credit position before accepting the order
- *Identifying the item* – seeing that the correct part number is assigned even if the identification information is incomplete or inconsistent
- *Allocating inventory* – ensuring that items previously committed are not shipped on some other order

Except for order preparation, these functions are performed at one time. That is, one operator, using a terminal, performs every required operation before proceeding to the next order. This reduces paperwork flow through the department responsible for order entry, thereby:

- Reducing paper handling costs significantly
- Improving order processing time
- Reducing the incidence of lost or misplaced orders

As each function is completed, the information generated is stored in the Customer Order File. The system checks that all essential information is supplied before it allows the operator to proceed to the next phase of order entry.

Order Preparation and Control

A manual review is normally performed before customer orders are processed. The primary purpose of this review is to establish control. Control procedures may include:

- Time-stamping the order document.
- Assigning a controlling serial number and registering the number, date, and customer name in a control register. This register will ensure that all orders are processed.
- Establishing order control totals, such as the total number of lines on the order and/or the total quantity of all items ordered. The order entry clerk will use these totals to help ensure that all ordered items are entered into the system.
- Highlighting special customer requests such as filling out the customer's own order confirmation card, supplying extra copies, entering unusual packing or shipping instructions, etc. Highlighting may take the form of underlining the request on the customer order form or indicating the presence of special requests on a preprinted attached control sheet.

- Assigning someone who will handle customer and internal inquiries relating to the order. In high-volume order entry situations, where items are shipped from stock, this is not usually done. Inquiries can be made by any control clerk. When products are complex and manufacturing lead times long, much of the order entry process is carried out by technically qualified sales engineers. This is because the handling of inquiries and changes to specifications demands knowledge of both the customer and the products involved. In this case, a controlling employee number should be assigned.
- Assigning an order number. When the order entry clerk enters the assigned serial number, or otherwise initiates the terminal entry of the order, the system automatically assigns an order number. A control record containing the order number, serial number, and a number identifying the clerk who entered the order, is immediately established.

These or similar control techniques help ensure that orders are not lost between receipt and entry. They also establish controls to make sure that all line items on the order are entered.

Specifying Customer Data

The next major step in order entry is to locate the correct customer record. The order record will be linked to the selected customer record (Figure 6). This allows fast retrieval of information concerning all open orders for a customer. It also means that the information in the customer record can be quickly retrieved when preparing order documentation or handling a customer inquiry. That is, static information such as customer name and address, shipping instructions, payment terms and conditions does not have to be transferred to the order record. This saves computer memory capacity and simplifies order maintenance. However, nonstandard information that is to be used in lieu of data in the customer record does have to be stored in the order record.

Determining customer name and number

Because customer orders are generated from a variety of sources (from salesmen, over the counter, by telephone, by letter, etc.), order information is often slightly different from the information maintained in the data base. This is particularly true of the way in which the customer is identified. The customer number may be missing, or the name on the order may be incomplete, and, as a result, a search for a match between order information and the Customer File may not be successful. In these cases a technique for searching the Customer File using an abbreviated customer name offers a faster and more precise means of obtaining the correct record.

As previously indicated, an entry of only a few characters can result in a display of all customer names containing a word beginning with these characters (see Figure 5). The display is created from the system's alphabetic index to the customer file. If there are more customer names within the range than can be displayed at one time on the screen, a command from the clerk causes the next "page" of customers to be displayed. When customer names are misspelled, the clerk must select the name most nearly corresponding to the name on the order.

When the operator selects a customer name by keying in a line number, the customer data is displayed. Confirmation that the correct customer record has been selected is achieved through visual comparison of addresses. If the displayed billing address agrees with the address on the order, the clerk enters a code confirming that the display matches the order. If the order contains a different shipping address, the normal alternative shipping addresses in the customer record are displayed until the correct address is recognized and entered. The clerk enters a code confirming that this is the correct shipping address.

Orders received from a division or a subsidiary of a company often require a copy of the order acknowledgment to be sent to a central location. Such "copy to" addresses may be held in the customer record and are automatically included in the order.

If the billing or shipping address cannot be located, the clerk cancels the entry and submits the order to a control point for approval and assignment of customer identification. The order is reentered once the necessary data has been placed on the Customer File.

Delivery instructions

With manual transcription of order information from the customer's document there is no certainty that shipping instructions will be transferred accurately. The more complex these instructions are, the more probable it is that errors will occur or instructions will be omitted. The system includes the ability to provide comprehensive delivery information.

Standard delivery instructions are stored in the customer's record and include such information as:

- Shipping method – truck, rail, air freight
- Days of the week and time of day that deliveries are accepted
- Maximum weight and package size that this customer can handle
- Special packing instructions normally requested by the customer
- Name of freight handler normally specified by the customer

The standard delivery instructions in the customer record are displayed on the terminal (Figure 7). If the instructions required for a particular order differ from the standard delivery instructions, the display is manually altered to bring it into line with the order, and the resulting instructions are included in that particular order record. The standard instructions remain in the customer record.

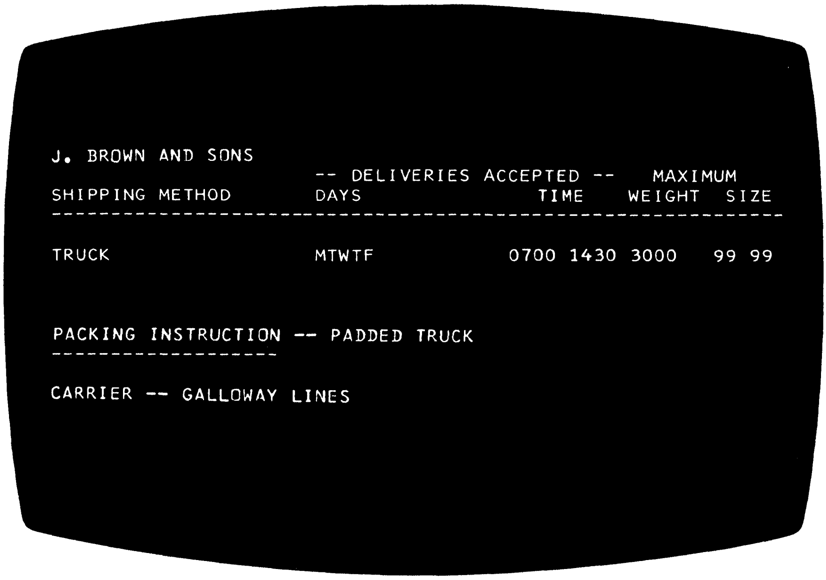


Figure 7. Standard delivery instructions are displayed when the order is entered

Payment and discount terms

The customer record also includes data concerning:

- Special payment terms. This may include, for example, a percentage discount if paid within a designated number of days from the billing date.
- Discount terms. This may vary from a standard discounting scheme based on the type of customer to a very detailed arrangement where each product class can have a different discount for each class of customer.

This data is displayed and altered in the same way as standard shipment data.

other special arrangements

Some customers may have special purchasing arrangements.

- The customer may allow an order quantity to be varied by a fixed amount (say, plus or minus 10%).
- The customer may be allowed to make quantity changes after a fixed minimum time in the future.
- There may be a financial commitment by the customer for materials ordered on their behalf, should an order be canceled within so many weeks of the delivery date.

Such details would be maintained in the Customer File. Changes to orders would be monitored against these agreements.

Credit Control

The system can compare the customer's outstanding debt position against his credit limit at two points during order entry:

- During the initial display of customer data. If the credit limit has already been reached, further processing may be halted after the customer has been identified. This has the effect of placing a "stop" order in the customer record. In these cases, when the customer data is displayed, there is an indication that further orders are to be reviewed by management before being accepted.
- At the end of order entry when the completed order is priced. The value of the order being entered is added to the credit balance and to the value of any other in-process orders. The total is then compared with the approved credit limit held in the customer record.

It must be emphasized that the computer is not carrying out automatic order rejection, but is only providing the information on which the credit manager makes decisions.

When an order has to be checked, the information needed from the customer record is displayed in the credit manager's Action File. This includes amounts recently invoiced and payments recently received (Figure 8).

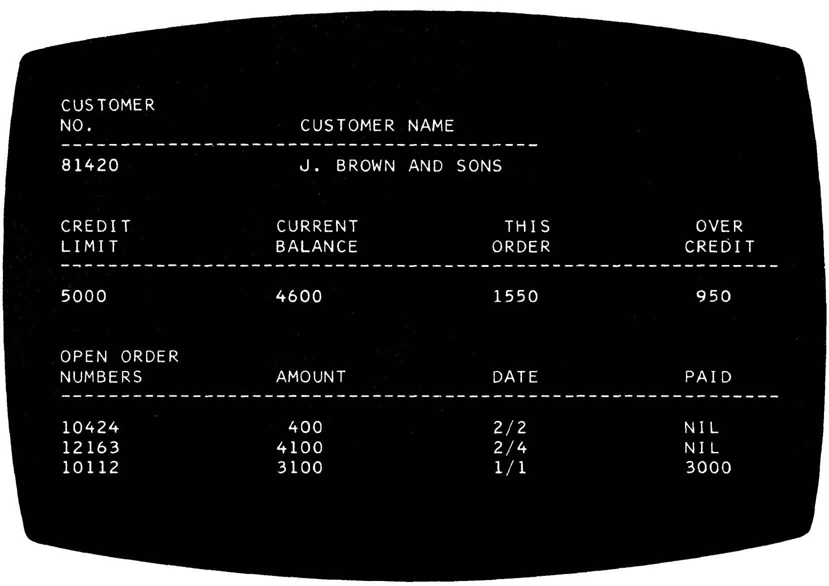


Figure 8. Outstanding balances and recent payments can be reviewed

Item Identification and Control

The data so far entered relates to the entire order. An order usually contains a number of individual items, and each of these items has to be separately identified. Proper identification will result in assignment of the correct description and price. The system automatically applies any discounts to the price before it is placed in the item record.

Line identification and control

For control purposes each item is assigned a line number. If the customer specifies splitting the order quantity into two deliveries, the quantity should be broken into separate line items. If the need to split deliveries arises during manufacture, the record of the original line item is replaced by two (or more) new line item records. Billing can then be carried out against the line number and need not be delayed until the entire order is delivered.

The approach to item identification is determined by the method a customer uses to describe his requirements. The product may be specified by:

- Item number
- Preprinted order form
- Verbal description

  5 HP Motor, Induction Wound,
  Flame Proof, 16" Base Plate

- Verbal description together with a reference to a previous order

  5 HP Motor as last supplied
  or
  Replacement Drive Coupling
  for Motor/Gearbox No. 470716 –
  supplied 10th January.

Item ordered by item number

When the item number and quantity required are keyed into the terminal, the item number, description, and earliest date at which the quantity can be supplied are displayed. If the customer has placed an item description on the order, it is checked for agreement with the displayed description.

Several possibilities may arise:

- If no description is quoted on the order, the quantity ordered is checked against the description on the screen for feasibility. For example, an error may be indicated when an entry from a car repair work shop for a quantity of 1000 items generates the description "engine block".
- If the descriptions fail to agree, a catalog search technique (see "Item Ordered by Description") produces a display of all parts bearing a description similar to that quoted on the order. This list can be searched for an item number that may indicate a simple error like transposed numbers – say, 127692 instead of 126792.
- If the item number on the order refers to an obsolete item, the Product Definition file will contain a record indicating the current item number. This is displayed with its description on the terminal:

  ITEM NO. 970462 OIL SEAL FOR LAY SHAFT,
  REPLACES ITEM NO. 970234.

Item ordered by preprinted form

When the product line is limited, the salesman often uses an order form preprinted with the item number. A facsimile of the form can be displayed on the terminal (Figure 9). In this case the clerk need enter only the quantity ordered. The system assigns the part number and description on the basis of the position of the quantity on the face of the display screen. If the form is long, several *pages* of the order form can be displayed for one order.

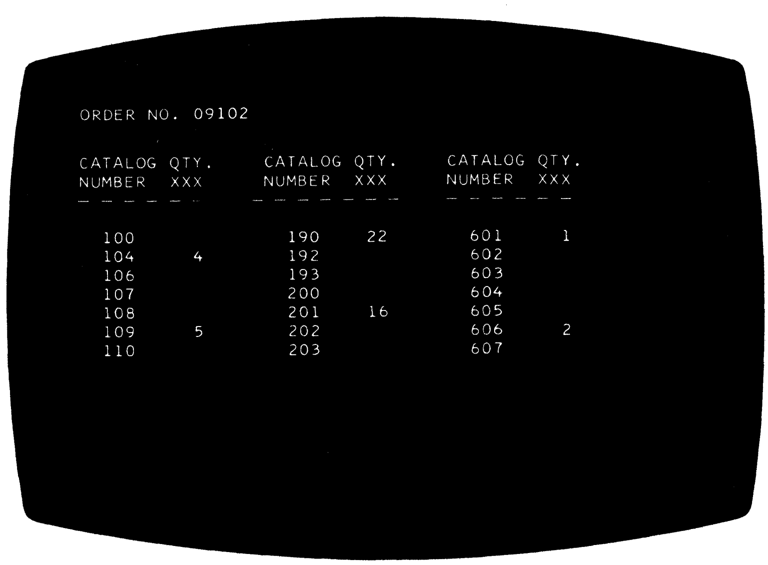


Figure 9. A preprinted form can be reproduced on a terminal. This means the operator does not have to enter the item number

Item ordered by description

Products are often ordered by description when the customer does not know the item number. In a manual system, the item number is identified by searching a sales catalog. This can be performed by the system, so that the search can be carried out during online order entry (see Figure 5). As with the identification of the customer, it is based on a "narrowing" search; that is, the bulk of the information is supplied by the system instead of the order clerk.

An index (based on keywords in the item description) to the product definition data base is used. The structure of this index is similar to that of a sales catalog except that an item may appear several times if it has more than one keyword. The operator uses the keywords to describe the product lines (Figure 10). Entry of the keywords generates a display containing item numbers and descriptions of all products within the performance range specified.

The item data in the product definition data base must contain a standard item description based on the keyword description in the catalog. The sales catalog can be created initially from the product definition data base by using these descriptions.

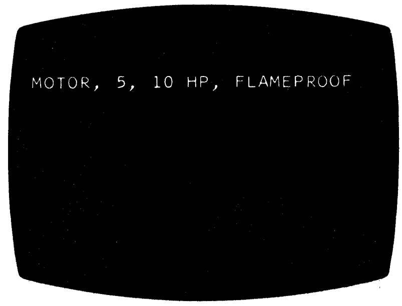
Orders based on previous orders

Information on previous orders can sometimes help identify an ordered item. This is the case where the customer may commonly specify a service part by its description and by the number of the end product on which it is used. The customer order history contains information relating to each past order, such as:

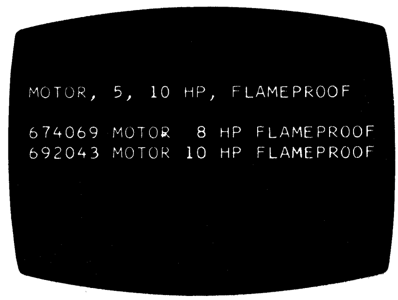
- Customer number
- Order number
- Customer order number
- Date of order
- Date of shipment
- Item number
- Item serial number
- Quantity

The Engineering Change History File and the Product History File (see *Chapter 1, Engineering and Production Data Control*) make it possible to find the correct engineering change level of the item at the time of manufacture.

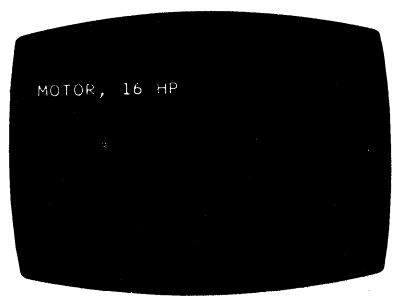
Order Clerk requests all flameproof motors between 5 and 10 horsepower inclusive



Sales catalog search results in the display of two motors with their item numbers and descriptions



Order Clerk requests all 16 horsepower motors



Sales catalog search results in display of 2 motors with their item numbers and descriptions

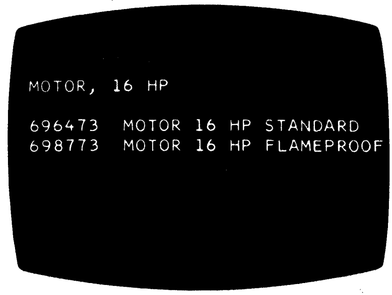


Figure 10. Terminal inquiries into sales catalog based on description

Allocating Available Inventory

Orders for items shipped from stock are of two types:

- Orders filled immediately on presentation (sometimes called "off-the-shelf" sales)
- Orders shipped via some method of freight handling, such as mail, truck, or rail

These two types are processed in a similar manner.

Off-the-shelf sales

A customer with this type of order may not wait until the order entry procedure is accomplished. Therefore, the order will be entered after the items have been withdrawn from stock. Since orders of different customers may be contending for the same stock, this type of order must be entered as soon as possible so that the reduction in inventory can be reflected. However, the customer at a large warehouse will not experience a significant delay if a terminal is used to obtain item allocations. The counter clerk enters his identification number and the item number and quantity required. If stock is available, an allocation is made, and an order document is produced that contains:

- Order clerk's number
- Order number
- Item number and description
- Quantity
- Location in the warehouse

This is used as a picking document in the warehouse. When the items have been collected, the issue from stock and removal of the allocation are initiated by keying in the order number. Order entry can be completed by identifying the customer in the normal manner.

Orders for shipment from stock

As each line item on the order is entered at the terminal, the available balance maintained in the inventory portion of the Product Definition File is checked. Available inventory is the quantity now on hand minus the quantity allocated to orders not yet shipped. If inventory is available, the quantity ordered is immediately designated as "allocated". When the order is filled, the allocated quantity is reduced at the same time that on-hand stock is reduced. This prevents allocation of the same stock to different orders.

If the item is not presently in stock, the system checks the master production schedule, Purchase Order File, or Shop Order File to see when it will be available. The date is confirmed to the order entry clerk and the allocation is performed against the on-order record rather than the on-hand balance. This ensures that the backlog of late orders is filled equitably.

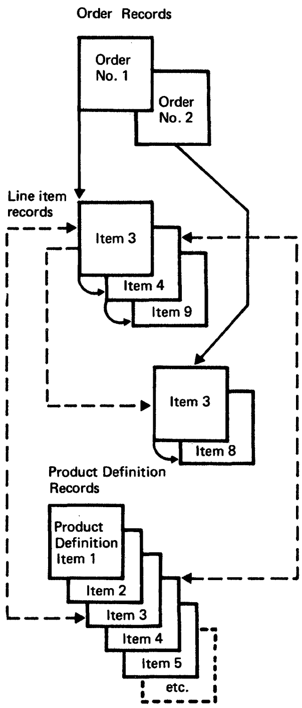


Figure 11. Unfilled orders are connected to the item's product definition record

The system connects the line item record to the product definition record (Figure 11). This allows all open orders for a particular product to be quickly retrieved. If a shop order or purchase order is delayed, this file organization also allows the fast retrieval of all affected orders.

Conditional orders

A verbal commitment of available stock is sometimes made as a result of an inquiry. The actual order may not be received for several days.

However, the inventory that was available at the time of the commitment may have been reserved or issued during the intervening period. This is a normal risk accepted by customers. In some cases, however, customers can be protected by creating a "conditional" order at the time of the commitment. The order record contains an indication that the order is conditional. The system can be instructed to hold the order for a fixed number of days, after which, if the order is not confirmed, it is automatically canceled.

For this type of order, available inventory is allocated normally. If it is subsequently canceled, the reserved inventory is automatically made available by removing the allocation.

Order Entry from Field Warehouses

A network of warehouses or distribution centers (Figure 12) can take advantage of central inventory management to improve customer service and reduce inventory. Orders are accepted at the remote location and pass through local customer and item identification phases of order entry. They are then transmitted to the central location.

At the central location these orders are processed in a system that controls inventory at all field warehouses. When this processing has been completed, shipping documents are transmitted back to the warehouse from which delivery will be made. Billing and accounts receivable are performed from the central location.

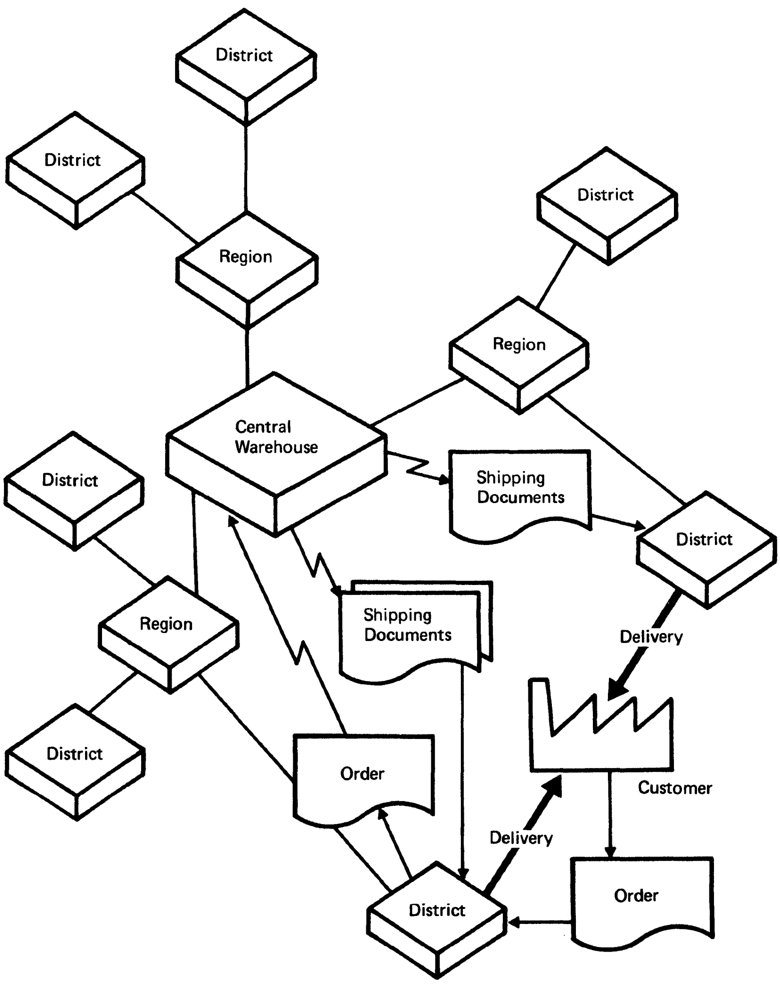


Figure 12. Order processing at a central location enables stock at field warehouses to be reduced without degrading customer services

The advantages of this approach are:

- Shortages at a field warehouse are recognized and alternative sources checked immediately. The nearest warehouse capable of supplying the item is designated as the shipping point, and the shipping papers are transmitted there.
- The number of items stored at each warehouse can be reduced. For example, the district warehouses may store only the 20% of the items which represent 80% of sales volume. The regional warehouse may store the fast moving items plus another 20-30%. The central warehouse stores all items. This approach significantly reduces inventory investment, and high-speed data transmission between the field warehouses and central processing ensures that customer service is not affected. Figure 12 illustrates an order shipped from two field warehouses; more than two locations, however, can be involved.
- Stock movements at the warehouse are known immediately, and replenishment is initiated by the central inventory management system.

Terminal Order Entry Direct from Customer

Companies that place large numbers of orders with certain suppliers can justify the transmission of purchase orders in a medium directly readable by a computer system – for example:

- Magnetic tape or cards
- Data transmitted directly into the system from a terminal in the customer's office

The receipt of orders in computer-readable format can significantly reduce order entry costs. Order alterations can be incorporated faster and delivery made sooner. This reduces inventory shortages and inventory investment.

"Controlling" an order usually means different things to different people:

- Making sure the order is not held too long at any stage of processing. To do this effectively, *order status* must be monitored and the system must signal when an order spends too much time in one processing phase.
- Making sure that the exact configuration specified by the customer is, in fact, supplied. *Configuration control* may continue after the product has been delivered.
- Making sure that orders are serviced or filled in a particular sequence. This is accomplished by assigning a *priority* to each order.
- Making sure the agreed delivery date is met. *Modification of delivery date* may have to be made because of such things as unpredictable material delays or production load leveling efforts.

Monitoring order status

Control over order progress depends on knowledge of its location and how much time it spends at each stage of processing. The system keeps track of how long it takes to service an order at each phase. Alarms are generated if an order spends too much time in any of the following stages:

- The quotation has been sent but a customer reply has not been received. Inventory may be reserved during this time.
- The order is incomplete and entry is frozen until the necessary information is supplied. The system specifies which area must supply the required information.
- The order has been entered and is waiting for the assignment of a delivery date from the production planning systems.
- The order is available for shipping but has not been completely shipped.

Once the order has been shipped, control is turned over to the accounting systems, namely invoicing and accounts receivable. (These accounting systems are not covered by COPICS.)

Orders suffering excessive delays are highlighted via Action File notices (Figure 13).

D E L A Y E D   O R D E R S

ORDER NO.	CUSTOMER	SHIP DATE	STAGE	NUMBER OF DAYS IN STAGE PLANNED	ACTUAL	REASON
10926	M. LENART	180	ENTRY	2	5	PRICE
10966	R. IBSEN & SON	185	ENTRY	2	7	CREDIT
10969	R. ERICSON ASS.	XXX	QUOTE	30	33	REPLY
10972	O'CONNORS CORP.	183	SHIP	3	6	MATERIAL
10988	G.H. DYER FARMS	190	ENTRY	2	4	DATE
11002	ETWOOD & ETWOOD	190	SHIP	4	2	REPLY
11037	R. IBSEN & SON	191	ENTRY	2	5	CREDIT

Figure 13. When orders are subject to excessive delays, the system automatically generates an Action File notice

Configuration control

The system maintains control over the configuration of the customer's order throughout the time the product is in manufacture. That is, the system ensures that what goes out the door is what the customer has specified. Configuration control is thus a procedure to control the inclusion of customer-specified modifications and internal engineering changes into a specific customer order.

The system generates control information, such as a specific bill of material or engineering change history records, for the order (for details see *Chapter 1, Engineering and Production Data Control*).

Configuration control can extend throughout the life of an individual product or group of products by recording in the order history record all changes installed after delivery.

Order priority

Chapter 6, Manufacturing Activity Planning describes a priority system used to control the sequence of manufacturing orders. This priority system has a provision for external priorities. The external priority may be assigned at order entry time and used for weighting the urgency of orders. Orders with a penalty clause, orders having to meet a sailing date, etc., have high priority. This external priority is taken into account, together with other factors, in determining which shop orders should be processed first. The use of order priority enables a very critical customer order to be pushed quickly through manufacturing.

The length of time required for handling rush orders has in the past led to a need for special procedures. CUSTOMER ORDER SERVICING handles rush orders from stock without special modification. An appropriately high external priority is assigned and the order is presented for immediate terminal entry. If there are no errors, it is entered within minutes. The entry procedure reserves the inventory and the order is released automatically for shipping. Its high priority will move it to the top of the shipping list.

Shipping notices are provided to STORES CONTROL via terminal throughout the day. The shipping papers for high-priority orders are immediately transmitted to the warehouse. This means the order can be on its way in a very short time and the only requirement is the addition of an external order priority.

Management must control the assignment of priorities if the system is to be effective. For example, if 50% of all orders are coded as top priority, the value of a priority system is lost. For a detailed discussion of order priority and its control see *Chapter 6, Manufacturing Activity Planning.*

Modification of delivery date

Through a technique called "pegged requirements" (see *Chapter 5, Inventory Management*), each customer order affected by a late shop order or purchased material shortage is identified.

Order delays that cannot be resolved are reported to CUSTOMER ORDER SERVICING, and the expected order completion dates are altered. A report indicating what orders have been displayed is transmitted to an Action File.

Orders may also be completed ahead of time, for example, to fill idle time in assembly. If an order is scheduled early, the revised schedule is passed to the customer order file. If the order is significant, the customer can be contacted to see whether he will accept early delivery. If he will, the firm shipping date maintained on the order file must be altered to the new date. This will avoid later automatic date alteration by the planning systems.

The system can automatically prepare date alteration notifications (Figure 14). Thus the customer can alter his plans on the basis of current information.

TO LASSEN DRY PUMPING CO.
BOSTON

FROM THE MILLER PUMP CO. LONDON

YOUR ORDER(S) DETAILED BELOW
WILL BE AVAILABLE FOR SHIPPING ON
THE DATES BELOW.
PLEASE CONFIRM IF DELIVERY IS
ACCEPTABLE.

YOUR ORDER NUMBER	ITEM	DESCRIPTION	ORDER REQUIRED	ORDER AVAILABLE	DAYS EARLY	DAYS LATE
12764	876420	PUMP 50 GPM	OCT 12	OCT 1	11	
14620	892670	PUMP 80 GPM	NOV 2	OCT 18	15	

Figure 14. MANUFACTURING ACTIVITY PLANNING notifies CUSTOMER ORDER SERVICING of changes to order dates

Order Entry for Nonstandard Products

The discussion so far has been concerned primarily with standard items normally shipped from stock.

Many companies, however, offer product options or variants, or make custom-built products to a unique specification. The order entry problems in these situations are different and will be discussed as follows:

- *Selecting product variations and options.* This addresses selecting bills of material from a choice of standard variants or options added to a basic product – for example, a choice of an automobile with:

  Radio or no radio

  Automatic or regular transmission

  Regular or power steering

- *Developing product specifications.* The problem is to generate a bill of material from a customer's functional specification – for instance:

  Electrical measuring instruments requiring a specific voltage or current range

  Hydraulic valves specified by flow rate, pressure, etc.

  Industrial buildings, specified by dimension

  Lifting gear specified by weight, speed, size

- *Entering custom-designed products.* Customer-manufactured products designed to meet very specific requirements (generators for electrical power stations, large alternators, turbines, etc.) require order information to be entered over an extended time period.

handling quotations

Many orders for nonstandard products are preceded by a request for quotation. Quotations are entered as normal orders except that they are stored in customer order records with a status code reflecting that they are "awaiting completion of quotation" or "quoted".

Customer acceptance of a quotation results in the changing of the order record status to that of a current order. The order record is displayed and compared with the details on the acceptance; after verification and any alteration the status code is modified so that the order can be processed as firm.

This approach eliminates much of the data transcription between the quotation phase and the order phase. It also enables standard controls to be placed on the quotation. For example:

- The potential load resulting from quotation requests can be quickly evaluated and used as a basis for manpower planning.
- Unusually delayed responses to a quotation request can be highlighted and any areas of the business that may be delaying this information can be determined.
- Automatic follow-up of unaccepted quotations can be initiated; that is, notices of pending or actual cancellation of quotes can be generated.
- The system can easily summarize the volume of outstanding quotations and use it as a basis for modifying the forecasts. This is essential to developing the master production schedule.

Selecting product variations and options

In many companies the specification bills of material for products containing options have to be developed in the design department. Often, however, end item bills of material can be organized to allow unique bills of material for these products to be developed during order entry. This type of organization is described under "Bills of Material" in *Chapter 1, Engineering and Production Data Control.*

An example would be a domestic appliance built for the French market in which 110-volt supply, 50 cycle, French language nameplates, and particular color options apply.

A unique specification for each order can be developed by selecting from options or variants displayed on a terminal, as shown in Figure 15. The option codes are used to select option bills of material from the product definition data base. These are assembled with a bill for the product minus any options, to form a bill for the specific product. This bill is then used by INVENTORY MANAGEMENT and MANUFACTURING ACTIVITY PLANNING to plan the manufacture of the product.

The terminal entry procedure can include edits to make sure that required variations are selected and that the selections are consistent with each other.

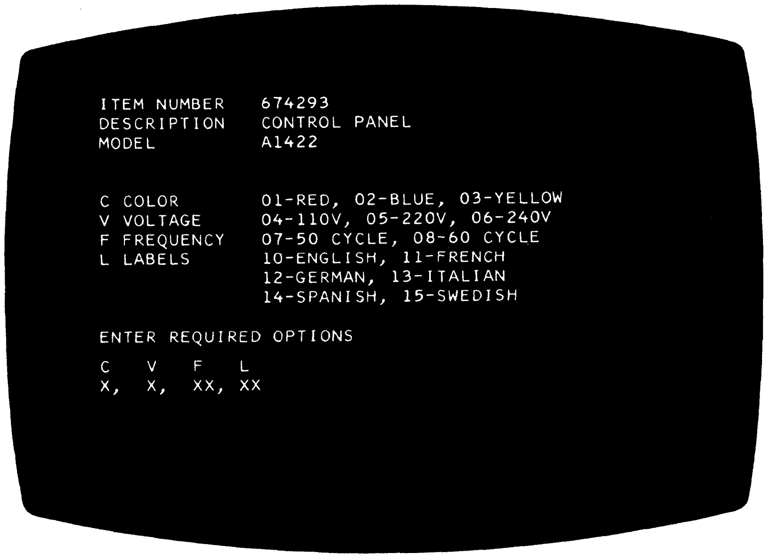


Figure 15. Available variants and options for a product can be displayed for selection by order entry personnel

Developing product specifications

Automated Design Engineering (ADE), described in *Chapter 1, Engineering and Production Data Control*, allows specifications for unique products to be developed by the use of decision tables. In this case, unique products can be developed, through the specification, for example, of alternative dimensions, or alternative electrical properties. Figure 16 illustrates the use of ADE to design an armature to customer specifications. From a series of decision tables stored in the system, a specification is automatically developed.

A complete costed quotation for the order can be developed in a matter of minutes. This allows rapid response to customer inquiries and provides the ability to bid for more contracts than would be economically possible with manual design methods.

In addition to the bill of material, the system can also produce a technical description built up from standard narrative to accompany the quotation. In some cases a basic drawing of the finished product can also be reproduced on a graph-plotter attached to the computer system.

Automated Manufacturing Planning (AMP) is a variation of Automated Design Engineering that uses decision tables to develop a manufacturing routing instead of a bill of material. Normally it is used for machined products or families of products that flow through the same manufacturing process but are unique by virtue of size, finish, or material. An example would be the production of piston rings.

SPECIFICATION

Name	Value
● Service	DC
● Application	Speed
● Rating units	Millivolts
● Rating value	100
● Number of phases	1
● Scale size	8 inches

Table No. 1	Rule 1	Rule 2	Rule 3	Rule 4
Service	DC	DC	AC	AC
Application	Temperature	Speed		
Rating Units	MV	MV		
Number of Phases	1	1		
Type of Armature	Moving Coil	Moving Coil		
Number of Windings	1	2		
Part No.	012526	012526A		
Assembly Drawing No.	A26	A26A		
Next table	2	2		

Table No. 2 NEXT Table No. 3	Rule 1	Rule 2	Rule 3
Type of Armature	Moving Coil	Moving Coil	Electrodynamic
Rating Units	MV	MV	
Rating Value	10-75	76-200	
MW Number of Turns	52	13	
MW Wire Material	Aluminum	Aluminum	
MW Wire Diameter	16	16	
MW Number of Layers	4	1	
Drawing No.	012526-1	012526-1A	

Table No. 3	Rule 1	Rule 2	Rule 3
Scale Size	4	4	8
Rating Units	MV	MV	MV
Rating Value	10-75	76-200	10-200
Number of Windings	2	2	2
DW Number of Turns	24	45	Half the number of turns in the main winding
DW Wire Material	Copper	Copper	Aluminum
DW Wire Diameter	16	8	12
Drawing No.	012526-1A	012526-1A	012526-1A

Armature

Type	Moving Coil
Item Number	012526 A
Number of Windings	2
Main Winding	
Drawing Number	012526-1 A
Number of Turns	13
Material	Aluminum
Wire Diameter	16
Number of Layers	1
Damper Winding	
Drawing Number	12526-1 A
Number of Turns	7
Materials	Aluminum
Wire Diameter	12

Figure 16. Development of a detailed specification for a unique armature using Automated Design Engineering (ADE)

A semistandardized and well defined manufacturing process is required, where a relationship exists between key dimensions and materials on the one hand, and the machining steps and times on the other. The specifications (dimensions and materials) for the item are entered during product identification. The system retrieves the material or casting number and develops the manufacturing routings, including operation sequence and times per operation. This can be used directly for quotations or cost to the customer and be input directly into the production planning systems.

Both ADE and AMP can substantially reduce the time it takes to develop specification documentation needed for completion of order entry.

Entering custom-designed products

The methods already described that enable items to be identified and specified during online order entry cannot be used for products requiring extensive design engineering. Where this type of product is concerned, the order or quotation request must be transformed into an internal specification, and estimates of the engineering and manufacturing costs must be developed to provide a quotation. A lengthy delay for engineering design work is usually necessary. Changes to specifications may be received throughout the engineering and manufacturing periods (Figure 17).

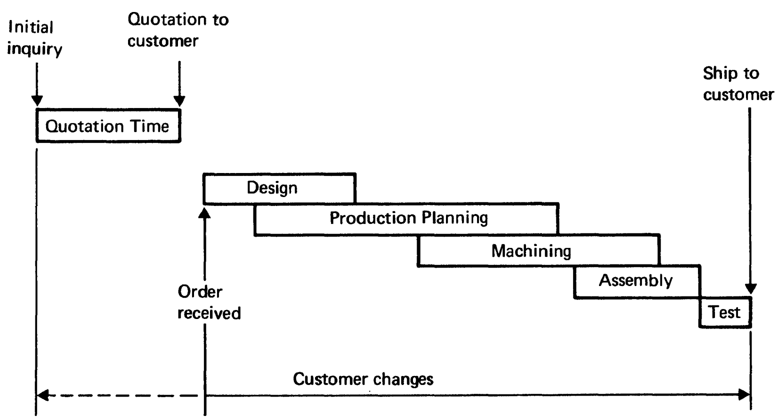


Figure 17. Changes to custom products are received from start of order entry until shipping time

For the volume producer, one of the principal objectives of CUSTOMER ORDER SERVICING is to provide improved control over the customer order during three key phases of order life:

- The period of order entry – from receipt to acknowledgment
- The open order period – before and during production
- Shipping and delivery

With custom-designed items two of these phases are significantly extended. That is, order entry cannot be completed until design is complete, yet production planning must start (Figure 17). In many cases, manufacturing lead time is very long and the functions of manufacturing and engineering usually overlap. Because of the special nature of these products, many changes occur between the start of order entry and final production.

The extended time period and frequent changes make order control difficult. CUSTOMER ORDER SERVICING tracks quotation requests from the time of their receipt, and monitors their progress during each phase of quotation development, design, and manufacture.

The customer order data base can help provide the necessary measure of control. For example:

- A temporary order record is created at the time of the request for quotation.
- Quotation status and review dates are used as a basis for searching the data base to control each step of quotation development and engineering design. Missing data is requested via prioritized Action Files. This is the same method of control outlined under "Item Data" in *Chapter 1, Engineering and Production Data Control.*
- Because of its flexibility, the order record can be expanded progressively by the staged entry of data, from the initial temporary record (Figure 18).

The developed specifications should be transferred to the product definition data base when the quote is accepted. The system can do this automatically.

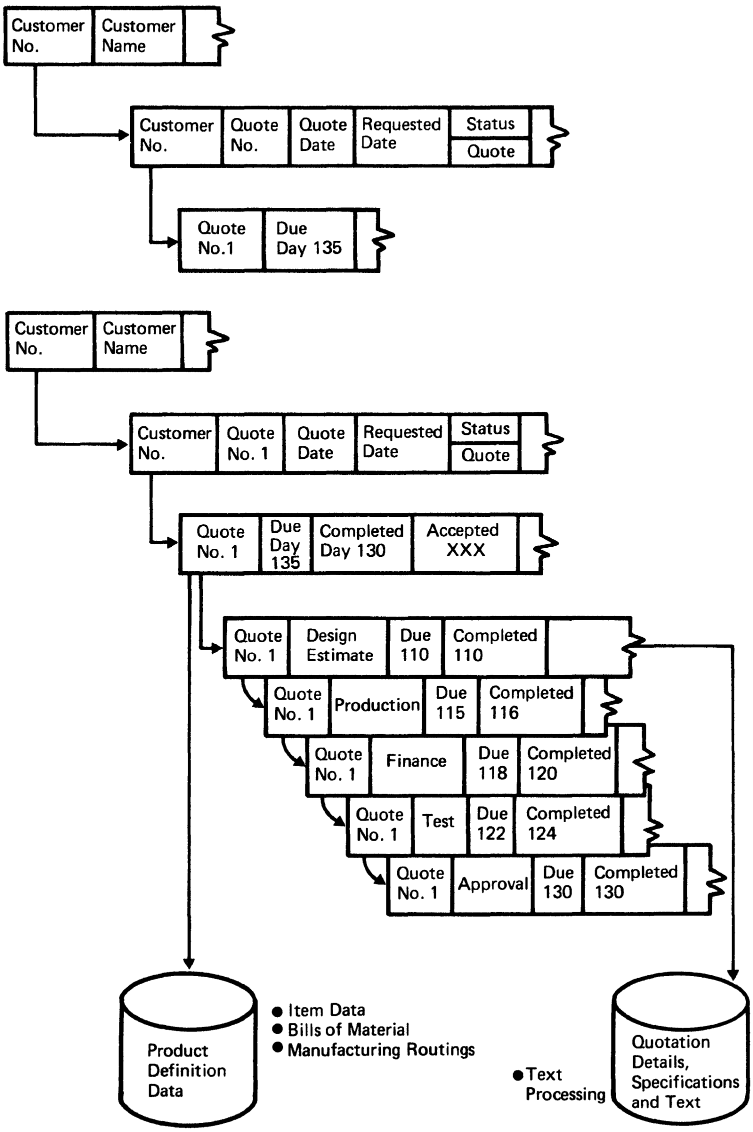


Figure 18. The order quotation record for a custom-designed product must be built up over a period of time

Determining Availability for Future Delivery

Customer orders specifying future delivery often allow for a lead time to design, develop specifications for, and manufacture the product. This time allowance is reflected as a quoted delivery lead time. In many cases, however, the requested delivery date allows less lead time than the supplier would like.

The system checks the feasibility of the customer's request; that is, it asks:

- Is the item available from stock or planned production?
- Can the item be supplied when the customer wants it in view of the existing master production schedule?
- If not, can it be supplied by incurring extra costs (overtime, subcontracting) or by moving other orders?
- If not, what would be the earliest possible delivery date?

Allocating available inventory or planned production

Orders for future delivery may be supplied from:

On-hand inventory

Planned production

Future production not yet planned

Allocation of on-hand inventory to an order that is to be delivered three periods ahead could prevent acceptance of an order for the same item for delivery two periods ahead. Therefore, the system allocates inventory in the period in which it is required. Figure 19 shows the sequence in which inventory and production are examined:

- For future delivery in less than the manufacturing lead time, current production is checked before current inventory is allocated.
- For future delivery beyond the manufacturing lead time, future production is checked before allocations are made from current production or current inventory.

Checking for availability is carried out by INVENTORY MANAGEMENT and MANUFACTURING ACTIVITY PLANNING. Quantities and requested delivery dates are entered into CUSTOMER ORDER SERVICING and passed to these systems. The techniques used by these systems to develop the required information are discussed in the appropriate chapters. The results are passed back to CUSTOMER ORDER SERVICING.

When the information received by CUSTOMER ORDER SERVICING shows that the requested delivery date cannot be met, or can be met only by an excessive increase in costs or by delaying other orders, the solution has to be negotiated both internally and subsequently with the customer, before the order can be accepted. The order is assigned a status reflecting that it is "frozen" pending a delivery decision. When agreement is reached, the agreed-upon delivery information is entered. The status is modified and the item can then be processed.

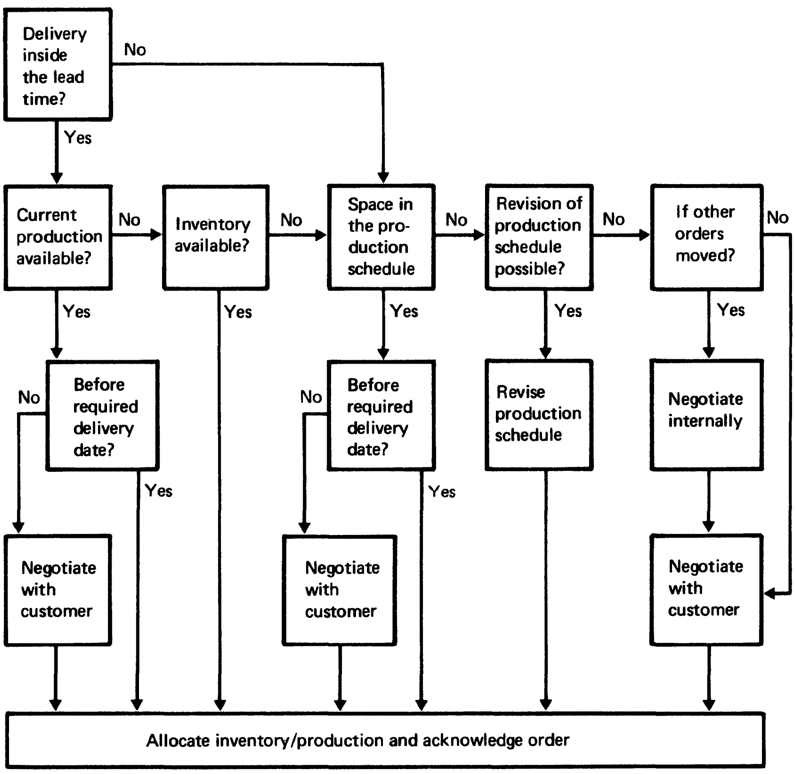


Figure 19. This sequence of checks for item availability avoids reserving available inventory unless essential

Handling Customer Inquiries

The ability to answer inquiries quickly and accurately concerning price and possible delivery dates can significantly affect a company's success in securing and retaining new customers.

For customers, nothing is more frustrating than to be told that no one knows the status of his order. If information concerning order status is available, it is often incomplete or inaccurate. Centralized recording and control of customer order records provides the means for quickly obtaining accurate information to answer customer inquiries relating to:

- Availability and price before placing a new order
- Status of or changes to existing orders

Inquiries resulting in new orders

Price and delivery inquiries can be handled by the same procedure as that used during order entry. When the order clerk enters the item number at the terminal, the required information – description, price, and availability – is displayed. The availability date quoted is based on inventory on hand and the unallocated portions of the master production schedule.

If the quoted price and delivery are satisfactory, the inquiry may result in an order; if so, this order is processed as conditional (awaiting confirmation). If it is processed purely as an inquiry, neither inventory nor production is reserved, and the availability of the item may change by the time the actual order is received.

Existing orders – inquiries or changes

Any inquiry into or change to an order already in the system must first involve identifying the order and retrieving the information.

order/item identification

Information provided by the customer to identify the order varies widely. It may include:

- Internal order number
- Customer name and order date
- Customer name and ordered item number
- Customer's own order number

When the internal order number is supplied and entered, the order record can be directly and rapidly retrieved by the system and displayed.

When inquiries are based on customer names, the technique used during order entry (see "Determining Customer Name and Number") enables the correct customer record to be obtained.

When inquiries are based on the customer's own order number, a cross-referencing system based on customer order number/internal order number can be used, or all orders for that customer can be displayed so that the operator can check visually for the customer order number in the record.

When only the item number is supplied, the system reviews each item line in all orders placed by the customer until the item is found. The organization of the customer order data to handle these inquiries is shown in Figure 20.

on-order status inquiry

The inquiry may be a request for information or a status check such as "Where is my order?" or "Will the order be delivered on time?" Alternatively, the customer may require a change to the order.

In answer to a check regarding status, information can be provided as follows:

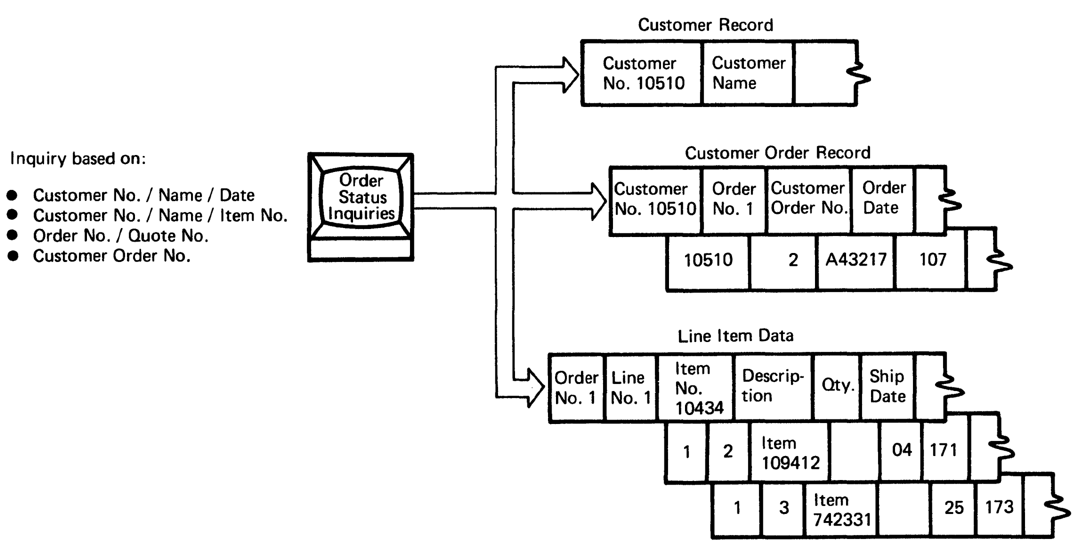


Figure 20. Organization of customer and order data

When the order status shows that the order is in the shipping department or has already been shipped, the probable delivery date can be given immediately. When, however, the status record shows that the order is still in production, delivery depends on the status of open shop orders for the item.

CUSTOMER ORDER SERVICING is informed of customer order delays as soon as delays to shop or purchase orders are severe enough to affect customer orders. Consequently, on-time completion is expected unless MANUFACTURING ACTIVITY PLANNING has reported an order delay.

Pegged requirements (see *Chapter 5, Inventory Management*) enables identification of each shop order required to complete a customer order; conversely, it allows MANUFACTURING ACTIVITY PLANNING to identify all customer orders affected by any particular shop order. This allows the impact of any component delay to be quickly reflected at customer order level.

changes to orders

Changes to orders are often prefaced by inquiries regarding the extent to which change is possible. The requested change may be modified when the current status of the order has been determined. Common types of change inquiries are:

- Can the order be canceled – at what cost?

  PLANT MONITORING AND CONTROL maintains a constantly updated record of all direct labor and material charges accumulated against the order. The terminal entry of a code will immediately halt further production by removing the shop orders for the canceled order from the Work Sequence List (see *Chapter 8, Plant Monitoring and Control*).

- Can the order be delivered earlier?

  MANUFACTURING ACTIVITY PLANNING provides a summary indicating how many orders carry high-priority ratings. If the number of high-priority orders is low, a tentative delivery improvement may be possible. The request can then be entered into the normal planning system for detailed analysis and firm delivery commitment. The output of the planning systems indicates the effect on overtime and other orders (see *Chapter 6, Manufacturing Activity Planning*).

- Can the order quantity be increased?

  Unallocated planned production can be immediately displayed and committed (or reserved pending written confirmation). If all planned production is allocated, the increase can be processed as an incremental change to the master production schedule and the delivery, if feasible, confirmed via inclusion in ORDER RELEASE PLANNING.

The system allows the effect of changes to be determined rapidly and accurately. When it is established that a particular change can be made, the system immediately incorporates that change and reflects it through all records, thereby minimizing the impact on production.

Shipping

After entry, the order is monitored by the system until it is due for shipping. Those orders shipped from available stock are released to Shipping upon completion of the order entry function. Orders with future delivery specified are held pending release.

releasing orders to shipping department

The customer order data is checked daily to identify all orders due for shipment now or within the next few days. If the ordered items are available, the shipping documents are printed and shipping is initiated. If the items are not yet available, the order status is changed to "due for shipping".

Shipping documentation can be printed either centrally or on a terminal located in the shipping department itself.

The choice of sequence for printing orders can be based on achieving maximum effective use of available shipping facilities. Transport availability is entered at a shipping department terminal, in the form of a vehicle number, or destination, together with the time of its availability. The system then chooses the orders to utilize the shipping facility (see "Transport Load Planning").

The system triggers the release of the orders in sufficient time to allow for picking and packing. High-priority orders can be rushed through the system, if desired, overriding the transport usage plan.

Orders overdue in shipping are reported to management via Action Files. The system can highlight significant problems by displaying:

- Overdue orders with high priority, in priority sequence
- Overdue orders for specific customers
- Orders overdue more than, say, 10 days

Shipping Department Planning

Release of the necessary shipping documentation authorizes the physical packing and shipping of the order. Release of orders to the shipping department can be controlled to minimize fluctuations in workload and to ensure that orders will be handled in the right sequence.

CUSTOMER ORDER SERVICING helps to plan effective use of the shipping department and transport facilities by:

- Shipping Department Workload Planning
- Shipping Materials Planning
- Transport Load Planning

Workload Planning

Workload Planning in the shipping department is based on a form of shipping standard. Since most orders pass through the same sequence of operations (picking, packing, loading), shipping department standards can be established. Since the standards are not generally used as a base for payment, the need for accuracy is not as great as for production standards. The labor required for these operations often shows a correlation with some aspect of the product – possibly weight or cubic volume, or both (Figure 21).

Weight / Volume	0 - 1	5	10	20	40	60	80
	Standard Labor Hours						
0.001	0.008						
0.01	0.018	0.022					
1		0.035	0.040	0.080	0.240	0.380	0.450
2				0.280	0.330	0.440	0.600
5				0.330	0.360	0.500	0.750
10					0.390	0.570	0.960

Figure 21. Shipping labor standards can be based on item size and weight characteristics

Standards can also be based on item type or, for very high-volume items, be established for individual items and carried in the item record.

On the basis of expected release date, the system can project an expected workload by days or weeks (Figure 22). This serves as a basis for manpower planning and overtime planning.

Figure 22. Shipping foreman requests pending workload on the department from his Action File

Shipping Materials Planning

Packing materials, such as labels, crating material, cushioning materials, etc., can be subjected to the inventory control techniques outlined in *Chapter 5, Inventory Management*. The usage of items commonly required to pack shipments can be forecast on the basis of historical usage. Control can therefore be established using inventory control techniques outlined for *independent demand* items.

For larger items, or for material used specifically for one item, the packing material requirement should be carried in the same manner as a subassembly bill of material (see *Chapter 1, Engineering and Production Data Control*). Then, on the basis of the master production schedule, detailed material requirements can be developed by time period. Material requirements planning can then be accomplished via the techniques outlined in *Chapter 5*. This technique will result in lower packing material inventories and fewer shortages.

Transport Load Planning

Automatic review of orders due for release to Shipping can provide the basis for planning the load on transport facilities. The load depends on the form of transport used (long distance or local deliveries) and the shipping time. This technique is applicable mainly to shippers of large volumes of items.

Long-distance deliveries. Truckloads are often delivered over long distances to redistribution points, where the bulk load is split between a number of local delivery routes. A code in the customer record will indicate the nearest distribution point to the ship-to address. Orders due for release to Shipping are searched for common destinations, and collected together by the system. Their weight and volume are accumulated until a suitable container or vehicle load has been determined. These orders are then released together to Shipping. Collection of orders due for release may be stopped as soon as there is a possibility that the delivery date will be overrun.

In addition to the normal shipping documents, a bill of lading can be printed for the combined orders.

Vehicle route planning. A regional or district warehouse supplying a smaller area may take advantage of computerized methods of planning vehicle routes.

Vehicle route scheduling assigns delivery points to individual delivery routes on the basis of order volume, required level of customer service, and travel time.

The customer location code enables a bill of lading to be printed in accordance with the vehicle route plan and to be used as a physical loading plan. The sequence of the bill of lading is the reverse of the "drop-off" sequence that will be used during delivery. (A separate list, in warehouse location sequence, is also printed to enable the load to be assembled.)

The technique minimizes the distance traveled and balances the load between different kinds of delivery facilities. It usually reduces the number of delivery vehicles required and the total distance driven, while maintaining a high level of customer service.

Reporting Shipping Activity

The shipping department provides information covering:

- Actual shipments. This initiates the system's preparation of the invoice.
- The reporting of materials usage, labor, and shipping charges for billing and costing.

Terminal entry of a code to denote that the order has been shipped, together with the order number and any shipping charges, causes the customer order record to be updated with a "shipped" status. Partial shipments are recorded by the entry of the line numbers and quantities of the items not shipped.

The terminal is also used to report detailed shipping information. A preprinted punched card can be used to identify the carrier. More detailed information, such as vehicle number, can be entered on the terminal keyboard.

If packing material and shipping labor are to be charged directly to the order, a preprinted order identification card is prepared as part of normal shipping documentation. When shipping department personnel start work on an order, they enter this order identification card, together with their employee identification badge, in a terminal. The time they spend on the order is recorded in a manner very similar to that used for reporting direct production labor (see *Chapter 8, Plant Monitoring and Control*).

The order identification card can also be used to requisition shipping and packing material from the warehouse. This is done only if material is to be charged directly to the order. The procedure is identical to that used to requisition direct production material (see *Chapter 8, Plant Monitoring and Control* and *Chapter 11, Stores Control*).

billing the customer

The billing system reviews the customer order records for shipped orders and prepares invoices. When payment is made, the sales order billing system changes the order status to complete. The order is then removed from the customer order data base and added to order history data.

Evaluating Order Servicing Performance

Customer service is made up of factors other than avoiding out-of-stock situations. These include:

- Fast response to inquiries and quotes
- Maintaining delivery promises
- Reducing order processing times

To set objectives and control performance against them, it is necessary to measure, as far as possible, all the factors contributing to customer service. The following are some of the factors that CUSTOMER ORDER SERVICING can measure and monitor:

- Speed of order entry, giving more time to plan and produce the goods or reduce the overall lead time
- Speed of responding to requests for quotation, giving an improved company image and the ability to tender for more quotations
- Speed of picking and shipping, reducing the overall lead time

For each phase of order processing, the system can establish a normal time range based on historical performance. The system also enables each order to be evaluated on the basis of how long it spends in each phase of order processing.

Current performance can therefore be evaluated on the basis of the total number of orders that stay in each phase of order processing more than the normal time. Measurement could also be based on the type of product, value of orders, or tonnage. This information is extracted from the customer order records.

Performance indicators automatically generated for management can include:

- Number of orders held up pending pricing, credit approval, engineering, etc.
- Number of requests for quotes that have not been answered in, say, ten days
- Number of quotations that have lapsed
- Number of orders shipped late

These action notices allow management to react quickly to possible out-of-control situations.

Summary

Through a better internal control of orders, CUSTOMER ORDER SERVICING addresses the problem of improving service to the customer. It achieves this improved control through the recording of all customer orders in a centralized order control system. The methods discussed are applicable to large-volume producers as well as to manufacturers of custom-built items.

Extensive use is made of terminals to permit a standardized method of order entry. This approach ensures faster order processing and a reduction in data entry errors. Faster handling of requests for price and delivery quotations, through methods for online specification of product variants, allows a higher volume of more accurate quotations to be submitted. Faster order entry reduces lead time, which provides a competitive advantage.

Planning in the shipping department is assisted by advance workload information from the system, and by techniques that improve the utilization of shipping facilities.

Customer and management inquiries relating to order status can be answered accurately. Management can monitor performance in all departments that are directly involved with the processing of the order, and can thus pinpoint possible trouble areas.

Notes

Notes

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