Aerospace Information and Control System – Material Control

IBM

Data Processing Application

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FOREWORD

Recognizing the changing complexities of the aerospace industry, IBM established an Application Development Project to study specific functional areas of the industry. To assure as accurate an understanding as possible, members of the project consulted with representatives in the following aerospace companies, and appreciation for their contributions is hereby expressed:

- Aerojet-General Corporation
- Bell Helicopter Company
- Boeing Company
- Douglas Aircraft Company, Inc.
- General Dynamics Corporation
- Grumman Aircraft Engineering Corporation
- Hiller Aircraft Corporation
- Hughes Aircraft Company
- IBM-FSD Space Guidance Center
- Jet Propulsion Laboratories
- Litton Industries, Inc.
- Lockheed Aircraft Corporation
- McDonnel Aircraft Corporation
- Marquardt Corporation
- Martin Marietta
- North American Aviation, Inc.
- Northrop Corporation
- Sundstrand Corporation
- United Aircraft Corporation

The result of the study is a series of preliminary Aerospace Information and Control Systems manuals which endeavor to describe the environments of the functional areas, as well as indicate how computer systems can assist in their operation and control. These manuals, which are offered as guides to both industry and IBM personnel, include:

Title	Form Number
Engineering Summary	E20-8111
Design Information Systems - Structural	E20-8112
Design Information Systems - Electronics	E20-8113
Technical Information Dissemination and Retrieval	E20-8114
Engineering Data Control	E20-8115
Configuration Management	E20-8116
Reliability Assurance	E20-8117
Manufacturing Summary	E20-8118
Planning and Tooling	E20-8119
Material Control	E20-8120
Shop Control	E20-8121
Product Support	E20-8122
Data System for Limited Production	E20-8123
Management Summary	E20-8124
Forecasting and Planning	E20-8125
Estimating and Pricing	E20-8126
Project Scheduling Budgeting, Evaluation and Control	E20-8127

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INTRODUCTION

In the sequence of events from the conception of an idea to the delivery of a finished article, material planning and control is an omnipresent production requirement. Material planning and control encompasses many subtopics and touches upon all the areas described in the other manuals in this Aerospace Information and Control Systems series. In this manual, however, material planning and control is treated as an individual topic. The position of material planning in the information flow of manufacturing data is illustrated in Figure 1.

Product definition provides the information upon which all material planning is based. An airplane, a space vehicle, and all items in the supporting equipment are defined by engineering drawings, specifications, parts lists, and data lists. In addition to the fundamental engineering activities, however, data must be released in order to make engineering information available for production. The release procedure includes the preparation of drawings, drafting check, stress analysis, weight checking, and effectivity determination.

The released data are furnished to the product support activity, where the various component spares requirements are determined. Spares requirements, in turn, are furnished to the parts planners, in order that spares information may be included with the production requirements. The

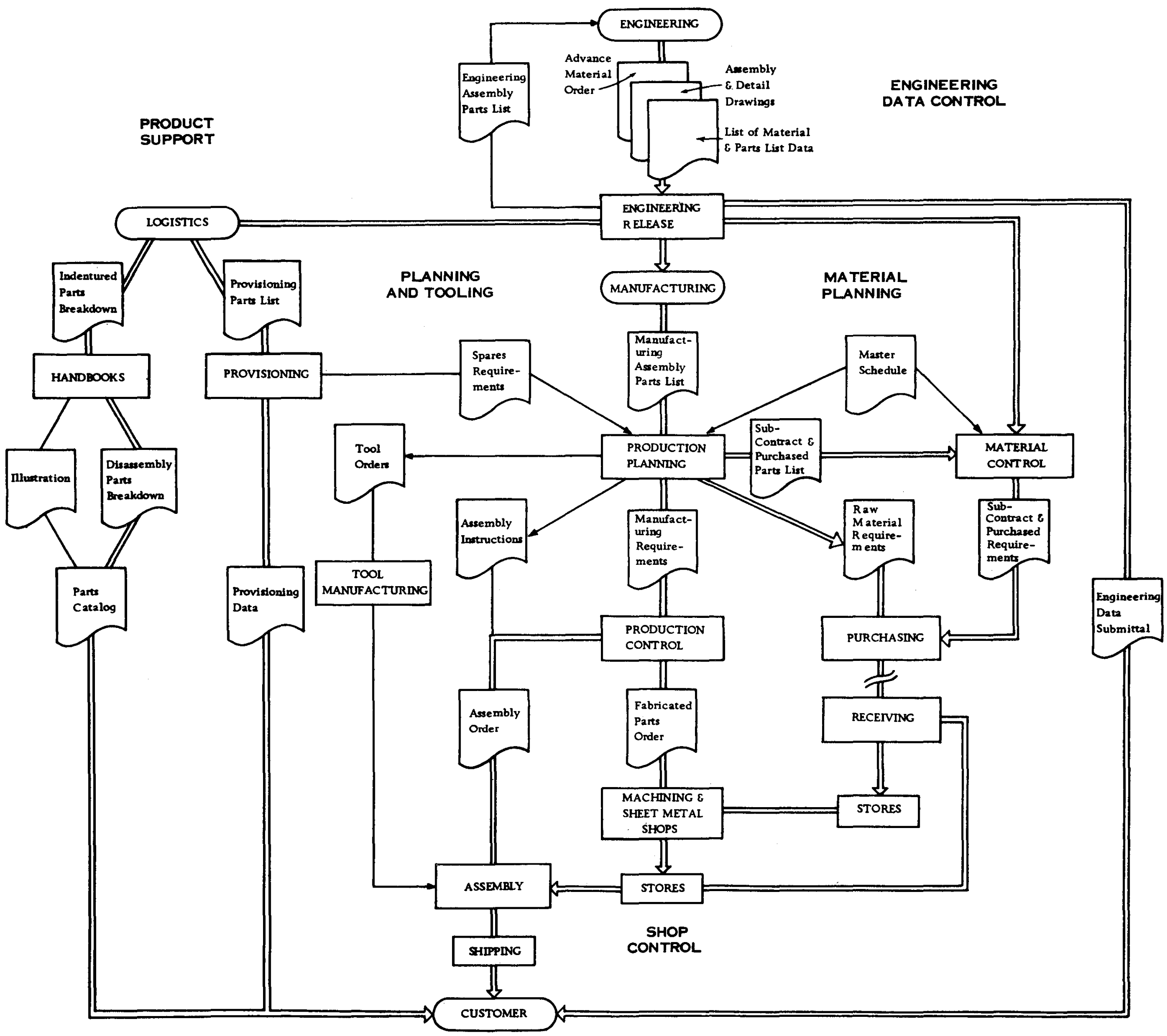


Figure 1. Operational information flow

master schedule stated by the contracts is in the hands of the production planner; as engineering releases are received, such releases are processed against the master schedule in order to cause work authorizations to be generated. From the work authorizations, the required parts are then built to fulfill the contract schedule.

An effective material control system must draw on many sources within the organization to obtain a usable description of the contract, engineering information, the manufacturing plan, purchasing abilities, physical facilities information, and operating statements. This information is drawn together to establish component requirements and statements of how these component requirements are to be filled. These requirements and statements are sent to the manufacturing functions as operating plans and instructions.

It has been stated that the topic of material control permeates all functions. Any attempt to define boundaries for this topic or to state the encompassed subtopics thus becomes completely arbitrary. This manual attempts to show simply how information is acquired from the areas peripheral to material control and how information is furnished to these areas.

PRELIMINARY DESIGN

Product definition data are generated throughout the design cycle, from initial layout through drawing release. Well before detailed drawings exist, information is actually on hand for planning and scheduling many procurement, production, and support functions. One of the objectives of an integrated engineering data control system (see Figure 2) is to make this advance information available.

When the new design is in preliminary development, a section list is established to define the contract master schedule items. This section list, which establishes the master assemblies from which parts lists are generated, is released for data recording before completion of basic design.

As the new design is developed, design layouts are made to establish the basic lines and structure of major assemblies, mechanisms, functional systems, and installations. These layouts, which are conceptual drawings, are usually in sufficient scale and detail to permit detail drawing requirements to be known. A drawing number record is then developed to show the relationship of subassemblies within each end item.

An indentured drawing list, variously known as a "drawing breakdown list", "model breakdown list", or "assembly configuration drawing", is also prepared from the design layout. The list establishes a framework for processing individual drawing releases; it can be released for data recording early in the engineering drafting phase, simultaneously with release of the first drawing for each section. As a new layout is developed, the designer requests a drawing number and title for each new part to be detailed.

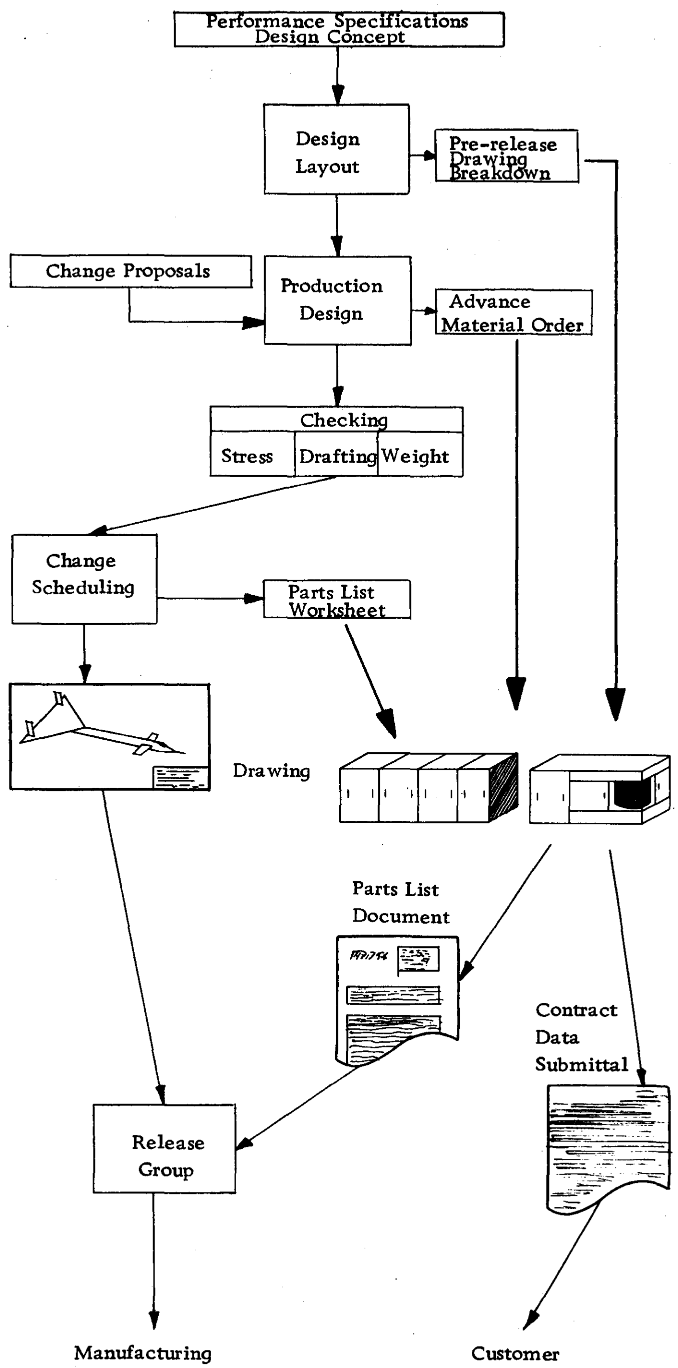


Figure 2. Engineering data system release cycle

The drawing request form includes codes to specify preliminary information for procurement, production, and product support functions. Category codes identify the part to be either manufactured or subcontracted and indicate whether it is an assembly or detail part. A type code indicates use of mechanical fasteners or welding for an assembly; or, for a detail part, it indicates whether the part is sheet metal, an extrusion, a machined or a chemically milled part. A type code may also be used for a detail part to specify whether the part is made from raw material, from a forging or casting, from a honeycomb panel, or from another part, and to provide as well an indication of tooling type and complexity. The designer may know these factors and may include many of them in the drawing request form at the early stages of design; or these data can be added to the drawing record by liaison planners in engineering from later reference to the design layout.

The drawing release schedules are developed in conjunction with the master contract schedule from drawing breakdown lists. These lists are negotiated with the manufacturing organization to determine the sequence in which drawings must be available for production planning. Assembly layouts are drawn before all component parts can be designed in detail; however, the detail parts must be fabricated before assembly can begin. Consequently, a substantial percentage of drawings are released before all design data are known. Although this practice generates many subsequent changes, this early release is necessary to compress the development cycle. Large numbers of orders for supplier parts are released by advance material orders or advance purchase requests, in order to procure long lead-time items. This early release provides a means for procurement action considerably in advance of formal drawing release. Many purchased components require unique fabrication techniques on the part of subcontractors, and the advance material order is necessary to allow sufficient design and manufacturing lead time. Failure to account for items procured by advance material order with a subsequent drawing release can result in duplicated inventory costs.

DRAWING RELEASE

Design data flows from the engineer to the manufacturing and procurement organization by release of new drawings, specifications, and subsequent engineering change notices. During this release procedure, a drafting check group audits the drafting practice and its conformance to shop practice. The stress group analyzes the strength of parts to ascertain whether they will carry the calculated loads. The weights group calculates component weight and center-of-gravity distance from a reference point, for computation of total weight and moments of inertia. A reliability group reviews the data for adequate consideration of reliability factors. After thorough checking, the drawings are sent to a project office for signature and then are given to the drawing release group.

As the drawings are released, the engineering order number, the next assembly number on which the part or assembly is used, quantity required per next assembly, and the release date are recorded. This release record (an example is shown in Figure 3) may be part of the drawing record initially created when the drawing number was first issued.

DRAWING AND ASSEMBLY RELEASE RECORD	CHG	SEC	DOC	DIST	SUBC	GROUP	DWG/PL NO
							55774

USAGE DATA														
CHG	USAGE	DASH	QTY NA	QTY ART.	NEXT ASSEMBLY	NOTE TYPE	NOTE SEQ	EID	NOTE ARTICLE FROM	NOTE ARTICLE THRU	CIC LOWER NO.	CIC LOWER SCH	CIC UPPER NO.	CIC UPPER SCH
	E	7		4	55478			27- 501	3	3			36098	
	E	7		4	55478			27- 501	5	6			36098	
	A	7		1	55478			27- 503	1	1	22331			
	A	7		1	55478			27- 503	3	4	22331		15266	2
	A	7		1	55478			27- 503	7	8	22331		15266	2
	A	7		1	55478			27- 503	13	14	22331			
	A	7		1	55478			27- 503	19	ON	22331			
	A	7		1	55478			27- 507	2	2	21237			
	A	7		1	55478			27- 507	4	7	21237			
	A	7		1	55478			27- 507	10	12	21237			
	A	7		1	55478			27- 507	15	ON	21237			

DWG/PL STATUS					UNINCORPORATED ECNs								
SH	SZ	LTR	CANC	CHG	LTR	REV	CHG	LTR	REV	CHG	LTR	REV	CHG

LEGEND: USAGE CODE				ISSUE NO.	ISSUE DATE	GROUP	PAGE	OF	DWG/PL NO
A . PRODUCTION ONLY	C . REMOVED BY SERVICE ACTION D . ADDED BY SERVICE ACTION E . REMOVED BY MODIFICATION F . ADDED BY MODIFICATION	G . STOP MFG H . STOP INSTL K . KIT	N . NO APPLICATION, RELEASE TO FILES ONLY	0	8 13 63	5474	2	2	55774

Figure 3. Engineering drawing and assembly release record

The release record serves, at the drawing level, as a where-used reference for parts used on two or more assemblies, end items, or models. The quantity required per end item or assembly is developed and entered on the release record. Complete packages of drawings and the associated release records are accumulated and arrayed in drawing-breakdown sequence. The quantities per assembly are cascaded downward and then are recorded at each level.

Parts listing is coincident to drawing release. All contractor part numbers appearing on the list of material for the drawing are recorded. The parts list associated with the next higher assembly release record is updated to indicate release of each component part. The updated parts list provides a complete parts list record for each released drawing. The part numbers entered in a parts list record are coded to signify either that the part numbers have been released or that the numbers have been called out in the drawing list of material, but have not yet been released. Another code denotes drawings which are released, for which the next higher assembly drawing is not yet released. Those records without codes indicating release and appearance in a next assembly's list of material are tagged throughout the basic release period until the drawing is properly released.

The drawing and its authorizing engineering order are then sent to a change control group in the manufacturing organization, where production implementation point and superseded parts disposition are decided. Upon initial release of a drawing, the change control group verifies the effectivity shown on the engineering order and delivers this information to the release group for entry into the release record. The release record then shows the most current drawing change letter, any engineering change notices outstanding, and the effectivity of each. The release of drawings builds up slowly.

By the midpoint of the basic release cycle, approximately one-third of the drawings are released. The predominance of release activity in the second half of the cycle can result in expedited procurement and manufacturing flow times. These expedited flow times are minimized by establishing drawing release schedules and adhering to the schedules as closely as possible. On many projects, typical volume of drawing releases is 300 or more per week at the peak of the basic release period. A small jet transport, for example, requires about 4000 drawings; a major aircraft 12,000 drawings of more than 70,000 parts; complete ICBM weapon system about 80,000 drawings. The engineering drawing, which is the basic document in aerospace manufacturing, is both a graphic portrayal of the product and a description of the material required for production. A drawing usually consists of a title block, a list of material, usage or application data, change history, general notes, and the drawing with dimensions. The following kinds of drawings are typical of those found in the aerospace industry:

- Assembly — a drawing which shows component parts suitably identified in their proper positions. It may include performance or other specifications.
- Detail — a single, self-contained part drawing with design information
- Installation — a form of assembly drawing showing the attachment of subsystems, equipment, and hardware.
- Source (or specification) control — a drawing which establishes the approved source of a procurable component part on an assembly drawing designed for a specific application. It may include configuration, design, and test specifications.
- Design layout — a drawing that establishes the basic lines of major assemblies, mechanisms, and installations. These layouts are conceptual drawings of sufficient detail to define drawing requirements.
in which the actual dimensions are tabulated for each application.)
- Tubing and cable — a drawing which depicts routing, components and their physical locations, arrangement, diameter, type and size of fittings and materials.
- Wiring diagram (or schematic) — an undimensioned drawing that shows the interconnection of components in a system, usually electrical or hydraulic.
- Aerospace ground equipment — a drawing of support, test, and maintenance equipment making up an operational system.
- Packaging and crating — an auxiliary drawing showing provision for shipping.
- Tabulated drawing — a drawing that lists parts to be fabricated or procured in various sizes. The part outline is shown in a single picture with its variable dimensions designated by letters. (These letters are shown in a table in which the actual dimensions are tabulated for each application.)

- Tubing and cable — a drawing which depicts routing, components and their physical locations, arrangement, diameter, type and size of fittings and materials.
- Wiring diagram (or schematic) — an undimensioned drawing that shows the interconnection of components in a system, usually electrical or hydraulic.
- Aerospace ground equipment — drawing of support, test, and maintenance equipment making up an operational system.
- Packaging and crating — an auxiliary drawing showing provision for shipping.

ENGINEERING CHANGES

A significant characteristic of the aerospace industry is the continuous change that the design of an aircraft, missile, or space vehicle undergoes throughout its development and service life. New data are developed as the design progresses from initial concept through research and preliminary design, through mockup and modeling, prototype flight test, experimental production, tooling, manufacturing, functional and environmental testing, and during evaluation after customer acceptance. Often new materials are required, and new manufacturing technologies must be developed. The design is thus continually modified as production proceeds.

Operational tests result both in modifications to the production design and in retrofit of redesigned components to systems already delivered. As operational experience is gained, further changes are made to improve performance and reliability, to extend service life, to improve flight safety, to satisfy customer requirements, to institute manufacturing economy, to improve design, or simply to correct records. The requirement of a design change control system is to provide overall integration and organization, so that changes are not made in one area without related operations being made aware of the modification. The volume of changes processed can range from 50 to 1000 engineering change notices per week. While such notices usually affect approximately three parts, changes affecting as many as 35 parts are not uncommon. An extensive discussion of a change control procedure and the associated data control is found in the IBM publication Aerospace Information and Control Systems — Configuration Management (E20-8116).

When an engineer is considering a change to a drawing, he requests a drawing status report from the release group. The release group forwards the last drawing change letter used, a list of outstanding engineering orders or engineering change requests, pending changes, and the next change letter to be used.

If the change is to a component of an assembly, other applications of the component part are also considered. These applications can be determined by requesting a where-used report for that component part number. It is also necessary to determine what service kits use or affect the drawing in question, as well as the effect of the intended change upon purchased parts. Design changes often require revision of two or more drawings.

The change control group is often located adjacent to the engineering release group and usually is part of the manufacturing scheduling organization. Engineering orders are logged into the release group, then are routed to a change analyst or a change board for determination of the change point.

The change analyst considers the following factors in scheduling the implementation of a change:

- How many parts are due from vendors?
- How many parts have been received from vendors? Where are those parts located?
- How many parts are in stock, and by which engineering orders have such parts been built?
- How many parts are being fabricated in-house? In what stages of completion are these parts?
- Does the part require test qualification? What is the qualification status?
- On what models and programs is the part used? What are the next higher assemblies? If the part is an assembly, which parts that go into this assembly will be affected? Are clearances affected?
- How many have been shipped? How many are spares?

The action taken depends upon the type of engineering change notice, which may be any of the following:

- Part O. K. to use. The shop can work to the changed configuration when the present supply of parts is exhausted. Planning may be asked to stop production of an order that has not yet been released to the shop.
- May be reworked. The current parts are near enough to the changed configuration that the parts can be modified and used.
- Cannot be reworked. The new parts are to be used as soon as available. Except for a product support requirement, any stock balance is to be scrapped.

PRODUCTION PLANNING

The production planning, or routing, function converts the engineering design into a manufacturing plan. Operational instructions tell the shop how to execute the plan. When the engineering change is received, it is in the form of lists of material or parts, drawings, and transmittal documents. Available materials, facilities, schedule requirements, and quality standards are considered, however, before the planner can formulate an effective manufacturing plan.

There are three major types of data which the planner must have available:

1. Engineering data
   a. Identification data
   b. Material data
   c. Effectivity data
   d. Parts cost data
2. Provisioning data (spares)
   a. Parts or assemblies required for spares
   b. Special assembly requirements resulting from the provisioning conference
   c. Stop notices (stop work on a part for spares)
   d. Change notices (spares configuration change)
3. Reference data
   a. Engineering drawing and change information
   b. Schedule and change status
   c. Shop order status
   d. Assembly status
   e. Manufacturing process specification
   f. Tool manufacturing status
   g. Production area layout

Using the engineering data and the reference data shown in Figure 4, the planner devises a sequence of operations which ensures that the product is manufactured by facilities which are within the framework of the equipment and skills available. As each operation is prepared, the planner envisions its contribution to the completion of the end product and its relation to succeeding operations. The type of tooling necessary to provide and preserve location points must be established. The sequence of operations is grouped to minimize materials handling. The planner is familiar with the objectives and techniques of tool designers; therefore, as the planning progresses, the planner visualizes each step with respect to the types of machines and tools which may be required.

If tools are not available, the planner prepares a tool order for their fabrication. The delivery schedule of the tool is established by the manufacturing schedule of the product. To minimize scrap losses, the planner establishes the production points at which inspection is to be performed.

The manufacturing plan is transmitted to the shop via the shop order. Much of the information on the shop order is coded or abbreviated, as this greatly simplifies the preparation and use of the data. Coding is used for department, work center, machine, operation description, etc. These coding and numbering systems are known and understood throughout the company; such systems become, in fact, a part of the language of planning, costing, budgeting, pricing, machine loading, dispatching, expediting, wage payment, performance computation, and reporting.

PLANNING CHANGES

Engineering parts list data are analyzed by the production planning organization to determine fabrication procedures. A manufacturing assembly parts list is often altered to accommodate an assembly sequence. Such an alteration may be necessary for manufacturing convenience, either to gain accessibility to components which must be installed behind or under supporting structure or other equipment, or to associate precision components which must be installed as matched pairs.

An altered assembly sequence may be achieved in either of two ways: First, synthetic assemblies may be included in the manufacturing assembly parts list for intermediate assembly of components in a sequence other than the engineered assembly sequence. Hence, the component parts lists of some assemblies released for production do not correspond to an assembly drawing. Some parts may be deleted for installation at a later point in the production buildup, or components from other assemblies may be installed in a structural subassembly. Second, drawing change requests may be sent to the engineering department to revise the engineering drawings affected by a change in installation sequence. In this way, the engineering assembly parts list actually reflects manufacturing practice. In either method, all parts called out in the engineering drawings and their revisions must ultimately be installed in the shipped article.

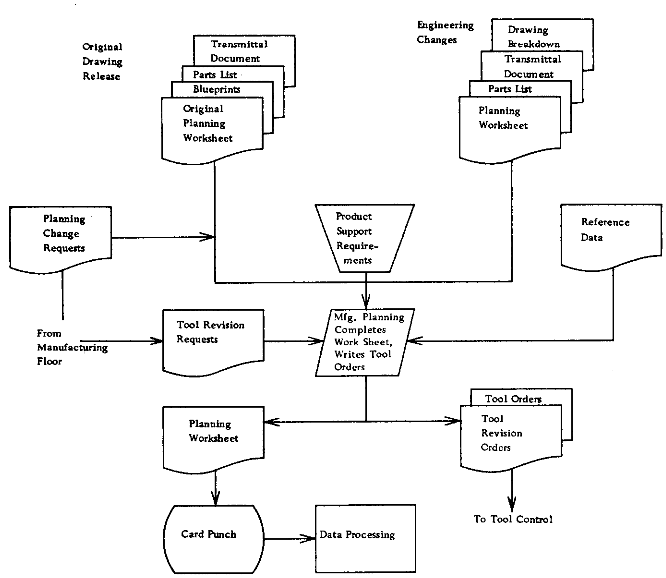


Figure 4. General Flow of planning data

MATERIAL CATALOG

The material catalog is designed to provide a uniform method of identifying material and supplies used in the operation of the company. For the engineer, this catalog assures that obsolete or unapproved procurement items are not inadvertently called out in parts lists.

A usable catalog is prepared to provide an easy means of locating an item. The identification or coding system should also allow easy application to a computer so that the catalog can be used in the various engineering, planning, and procurement functions. Use of the catalog in the engineering procedure for the release of advance material orders is illustrated in Figure 5.

Many code classification systems have been developed for material catalogs. Three are mentioned here to illustrate how such systems are put together.

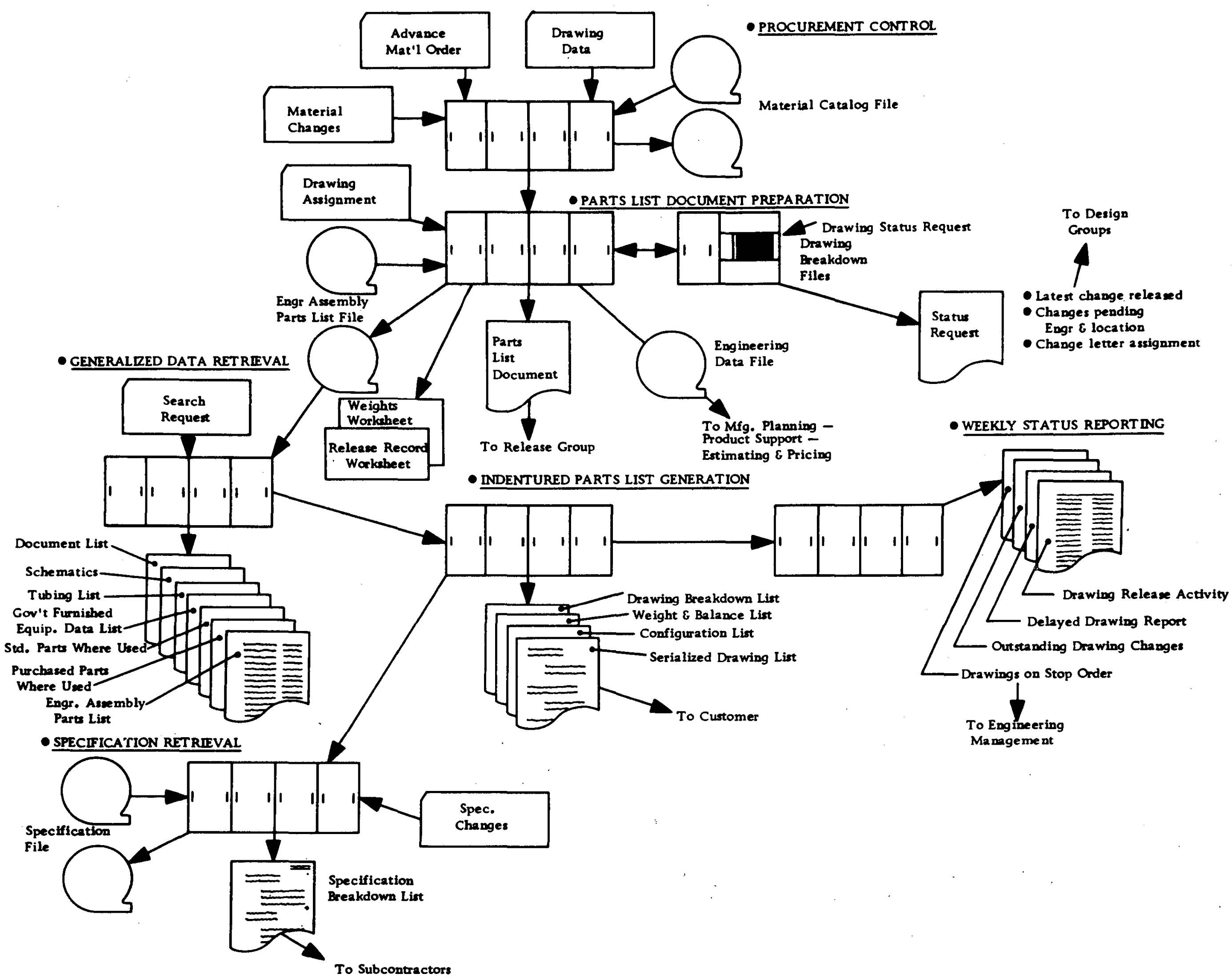


Figure 5. An integrated engineering data system

Ten-Digit Material Code

In a ten-digit code system of cataloging (see Figure 6), the first four digits are used for classification purposes. The first digit of the catalog number designates the respective catalogs. For example:

1 Metallic catalog
2 Nonmetallic catalog
3 Standards catalog
4 Vendor catalog
5 Factory supplies catalog
6 Perishable tools catalog
7 Office supplies and forms catalog
8 Maintenance and repair catalog

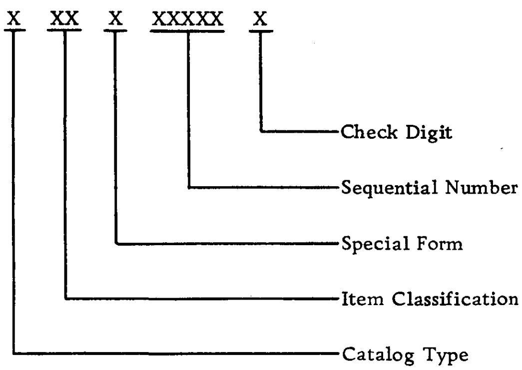


Figure 6. Ten-digit material code

The second digit of the material classification identifies the type of metal from which the part is made:

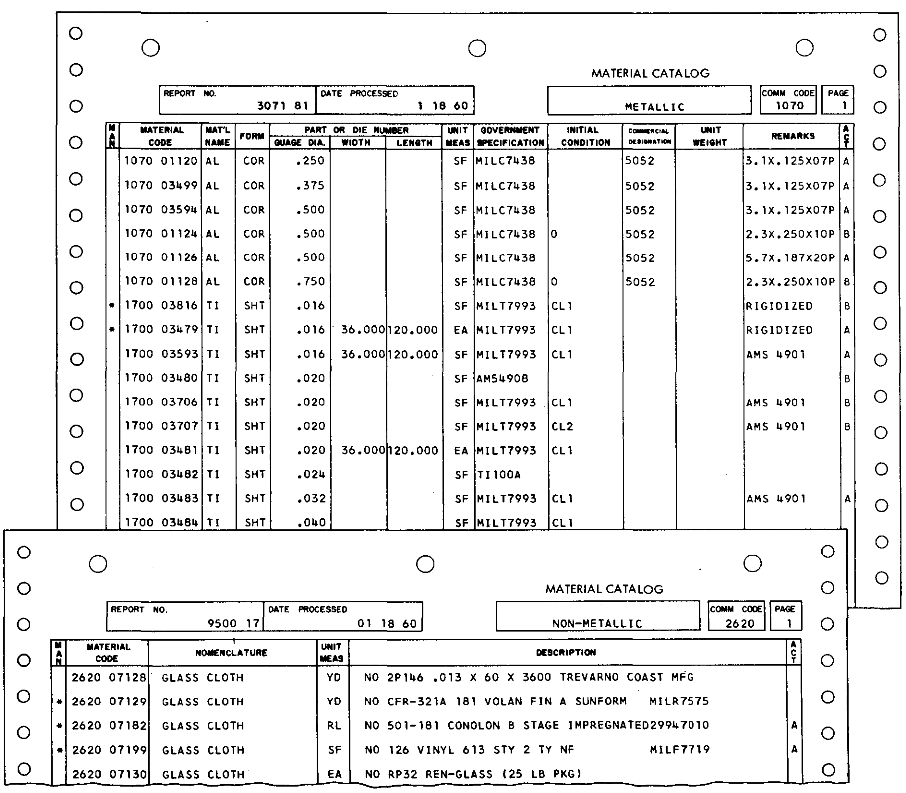
1 Aluminum
2 Steel
3 Bronze
4 Titanium

The third digit refers to the shape of the part:

1 Sheet
2 Bars
3 Rods, etc.

The fourth digit represents special conditions, such as tolerances, finish notes, and references. For example, 1110 identifies metal aluminum sheets with no special conditions.

The next five digits, used for discrete identification, are sequentially assigned. The tenth and final digit is a self-checking digit that is applied by the coding technique to the five-digit sequential number. This digit does not appear on the finished catalog page (see Figure 7), but is generated by the computer to ensure that the number carried in the catalog is correct. With every use, the computer employs the material code and generates a check code. This check code is compared with the check code carried on the record in the computer or in the transaction. If the check codes match, the part coding is correct; if they do not match, the machine signals an error and the transaction coding must be checked.



MATERIAL CATALOG

REPORT NO.	DATE PROCESSED		COMM CODE	PAGE
3071 81	1 18 60	METALLIC	1070	1

MAN	MATERIAL CODE	MAT'L NAME	FORM	PART OR DIE NUMBER GUAGE DIA.	WIDTH	LENGTH	UNIT MEAS	GOVERNMENT SPECIFICATION	INITIAL CONDITION	COMMERCIAL DESIGNATION	UNIT WEIGHT	REMARKS	ACT
	1070 01120	AL	COR	.250			SF	MILC7438		5052		3.1X.125X07P	A
	1070 03499	AL	COR	.375			SF	MILC7438		5052		3.1X.125X07P	A
	1070 03594	AL	COR	.500			SF	MILC7438		5052		3.1X.125X07P	A
	1070 01124	AL	COR	.500			SF	MILC7438	0	5052		2.3X.250X10P	B
	1070 01126	AL	COR	.500			SF	MILC7438		5052		5.7X.187X20P	A
	1070 01128	AL	COR	.750			SF	MILC7438	0	5052		2.3X.250X10P	B
*	1700 03816	TI	SHT	.016			SF	MILT7993	CL1			RIGIDIZED	B
*	1700 03479	TI	SHT	.016	36.000	120.000	EA	MILT7993	CL1			RIGIDIZED	A
	1700 03593	TI	SHT	.016	36.000	120.000	SF	MILT7993	CL1			AMS 4901	A
	1700 03480	TI	SHT	.020			SF	AM54908					B
	1700 03706	TI	SHT	.020			SF	MILT7993	CL1			AMS 4901	B
	1700 03707	TI	SHT	.020			SF	MILT7993	CL2			AMS 4901	B
	1700 03481	TI	SHT	.020	36.000	120.000	EA	MILT7993	CL1				
	1700 03482	TI	SHT	.024			SF	TI100A					
	1700 03483	TI	SHT	.032			SF	MILT7993	CL1			AMS 4901	A
	1700 03484	TI	SHT	.040			SF	MILT7993	CL1				

MATERIAL CATALOG

REPORT NO.	DATE PROCESSED		COMM CODE	PAGE
9500 17	01 18 60	NON-METALLIC	2620	1

MAN	MATERIAL CODE	NOMENCLATURE	UNIT MEAS	DESCRIPTION	ACT
	2620 07128	GLASS CLOTH	YD	NO 2P146 .013 X 60 X 3600 TREVARNO COAST MFG	
*	2620 07129	GLASS CLOTH	YD	NO CFR-321A 181 VOLAN FIN A SUNFORM MILR7575	
*	2620 07182	GLASS CLOTH	RL	NO 501-181 CONOLON B STAGE IMPREGNATED29947010	A
*	2620 07199	GLASS CLOTH	SF	NO 126 VINYL 613 STY 2 TY NF MILF7719	A
	2620 07130	GLASS CLOTH	EA	NO RP32 REN-GLASS (25 LB PKG)	

Figure 7. Sample material catalog

Each major catalog has an index sheet which lists the nine major subdivisions with explanatory notes. The index for each major subdivision is broken down into minor subdivisions. For example, a material such as glass fiber appears in catalog 2 (productive material, nonmetallic). The index of catalog 2 indicates that section 6 of the catalog deals with glass; the subindex then refers to section 2. This process produces a code of 2620. The exact glass fiber is then chosen from the sequential number table.

Additional information furnished by the catalog includes unit of measure, unit weight, die number (for extrusions), gage number, lengths, government specifications identification, initial condition of the material, and any commercial designation. In approximately 10% of the cases, individual remarks are required. These remarks are found either in narrative form on the page itself or in the appendix reference. In some cases where extensive notes, receiving notations, or dimensional sketches are required, or where multiple vendors are available for fairly standard items, insert pages are placed at the end of the section.

Initiation and maintenance of the metallic catalog, nonmetallic catalog, and standards catalog should be assigned to standards engineering, as the engineering department is the source of new requirements. Knowledge of obsolescence is also centralized in this area. The factory supplies and perishable tools catalogs normally are the responsibility of production engineering. The office supplies and forms catalogs are associated with whichever department has responsibility for stationery stores. The maintenance and repair catalog is assigned to plant engineering. Purchasing maintains the vendors catalog.

The continual monitoring required to make certain that the catalogs reflect currently available materials comes from two sources. First, those departments charged with the maintenance of the individual catalogs take the necessary steps to delete from the catalogs items that are obsolete or that are superseded by other products. Second, with the use of the consolidated inventory files, all catalog items become a part of those files and are monitored there.

All the productive material for the first four catalogs is checked for activity. Any inactivity is periodically investigated to see whether the items are a requirement in any of the current bills of material or in logistics and spares support requirements. If the items are not a current requirement, a report is written to the engineering catalog group, requesting authorization to discontinue the items from the catalog. In subsequent printings of the catalog, the inactive items are dropped, as soon as the inventory has been zero-balanced by the transfer of any surplus stock.

Items of the other four nonproductive catalogs are monitored in much the same way. Checks are made on usage, and exception reports are prepared for the responsible catalog manager, showing the activity and the balance remaining. Upon deletion of a catalog item, the five-digit serial number and check digit are put into an aging process for subsequent reissue.

Nine-Digit Material Code

The nine-digit code accomplishes the same purposes as the ten-digit code. Only the method of achieving those purposes is different. The nine-digit code (see Figure 8) is analyzed as follows: The first two digits are used for the material classification, as illustrated in Figure 9. There are unused codes, which allow new materials to be assimilated in a sequence as close as possible to the correct sequence.

The third digit of the nine-digit material code designates the form or shape of the item:

1 Sheet
2 Rod
3 Bars, etc.

The fourth, fifth, and sixth digits indicate chemical composition:

1 Alloy (for metals)
2 Strength of solution (for liquids)
3 Powder or granules (for other materials)

The last three digits indicate size or units of measure:

1 Size (of sheets)
2 Width and length (of strips or coils)
3 Size (of containers)
4 Grit size (for granules)

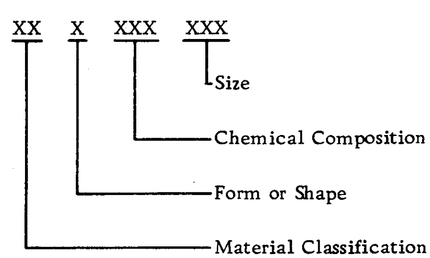


Figure 8. Nine-digit material inventory code

01 ALUMINUM ALLOYS
02
03 COPPER AND COPPER BASE ALLOYS
04
05 IRON
06 STEEL - CARBON
07 STEEL - ALLOY
08 EMERGENCY METALS
10
11 MAGNESIUM ALLOYS
12 ZINC
13 UNCLASSIFIED METALIC MATERIALS
14 CARBIDES
15 CERAMICS
16
17 LAMINATING THERMOSETTING MATERIALS
18 INSULATED WIRE AND CABLE

Figure 9. Classification of raw material

A page from a nine-digit raw material catalog is shown in Figure 10. This catalog can also be maintained on a computer. There is no provision for a check code in this case, as the company developing this system did not feel it was necessary. A check code could be inserted and used as stated in the previous example, which would raise the digit count to ten. A corresponding increase in number of spaces would be required in all of the records.

Sixteen-Digit Material Code

The third material catalog numbering system to be discussed (see Figure 11) comes from a very large aerospace company. The coding is rather elaborate because of the extensive inventory required and the multiplicity of materials constantly undergoing tests and evaluation in the various research and development programs.

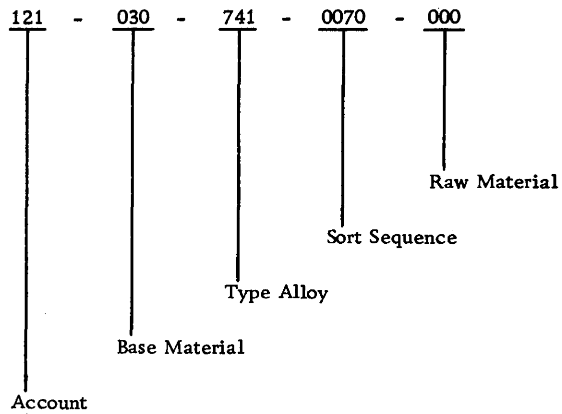


Figure 11. Sixteen-digit material code

In the 16-digit material code, the first three digits make up the account number designation. This is a coded indication to show what contract was charged with the inventory of raw material. If a different account or contract draws some of the material, an appropriate charge can be made. This technique allows for the commingling of stock and provides an audit trail to ascertain the original cost and the subsequent assignment of this cost to the using contracts, that is, an inventory account legend. The coding of the account number is shown in Table 1.

Table 1. A Coding of Account Number for Miscellaneous Small Parts (MSP)

	Account No.	Nontactical	Tactical
Hardware	32-14733	041	414
Electric	32-14743	042	142
AN	32-14753	043	143

RAW MATERIAL CATALOG

REVISED AS OF 2-28-6-

PREFERRED SIZE INDICATED BY SYMBOL ⟶ *

MATERIAL DESCRIPTION	MATERIAL CODE		SPECIFICATION	FORM	FINISH	TEMPER			EDGE	THICKNESS OR OUTSIDE DIAM.	TOLERANCE (X/10,000)		WIDTH OR INSIDE DIAM.	TOLERANCE (X/10,000)		L'NGTH IN FEET		STORES UNIT CODE	
	PREFIX	SYMBOL				SCLE	MIN	MAX			+	-		+	-	MIN	MAX		
CARBON STEEL	171	100100	S 1010	STRIP	CF	RB	50	66	SQ	.0312	10	10	.5000	40	40	8.0	10.0	9	*
CARBON STEEL	171	100100	S 1010	STRIP	CF	RB	50	66	SQ	.0625	10	10	2.2500	30	30	8.0	10.0	9	*
CARBON STEEL	171	100104	S 1010	STRIP	CF	RB	50	66	SQ	.0937	10	10	4.750	40	40	8.0	10.0	9	
CARBON STEEL	171	100107	S 1010	STRIP	CF	RB	75	90	SQ	.1250	10	10	3.3125	40	40	8.0	10.0	9	
CARBON STEEL	171	100109	S 1010	STRIP	CF	RB	90	105	SQ	.1562	10	10	5.3750	40	40	8.0	10.0	9	
CARBON STEEL	171	101112	S 1010	SHEET	CF	RB	50	66	SQ	.0250	10	10	24.0000	50	50	8.0	10.0	9	*
CARBON STEEL	171	101115	S 1010	SHEET	CF	RB	75	90	SQ	.0781	10	10	32.0000	50	50	8.0	10.0	9	*

Figure 10. Raw material catalog

The next three digits designate the basic type of material — for example, 030 for steel, 050 for aluminum, and 070 for bronze.

The third set of three digits designates the particular alloy. For example, 741 identifies 5040 E Steel.

The part sequence is a group of four digits inserted into the catalog for the use of the computer. Instead of having to use all the digits previously described, the computer uses only these four digits, which substantially reduces the machine processing time.

Raw material code, the final three digits, allows a more detailed breakdown of the items. For example, the base metal and alloy field works well for the basic metals and all their variations. However, the catalog carries electronic equipment, parts, hardware items, etc., that do not fit neatly into this type of breakdown. To maintain the same code format, these last digits are used. Maintaining the code format is important because of programming requirements, if the catalog is to be maintained and used by the computer. A page from a material catalog prepared on the computer is shown in Figure 12.

Basically, a catalog is needed to establish a means of communicating the specifications of a requirement to the engineering department, so that everyone involved with a part works to the same specifications. Control is thus established to hold the number of items in stock to a minimum. An engineer who desires to find a catalog number for material for a part first attempts to find the material code in the catalog. If the code is not in the catalog, the engineer then applies to the catalog group to have the required item added. The responsible group determines whether the inventory item should be added or whether some other item satisfies the requirement. If the decision is made to add the item, the material is described, and the description is verified with the requesting engineer. Purchasing then verifies with the vendor the description and procurability of the item. In-house identification is added, so that the particular item being described may be referred to with a minimum of effort.

Another necessary step in a system of material control is the establishment of a standard unit of measure, which is included in the material catalog at the time the item is verified and entered. Tables for conversion from in-house unit of measure to vendor unit of measure are referenced in the inventory phase of the computer system.

Procedures for emergency (walk-through) requisitions must be provided. The catalog number is applied on bills of material, requisitions, tool orders, parts and assembly orders, bins, and quality control specifications. The number is the basis of the inventory control files and appears on purchase requisitions, purchase orders, and receiving reports. The use of the material code number facilitates computer systems inquiry from remote stations, with printed statements in reply which contain not only the code, but the full description for verification.

```
    MATERIALS CATALOG       04 OCT 61       ELECTRONICS SECTION      PG 176

    CONTROL NO           UNIT          ITEM DESCRIPTION

C   003-754433-0000-326  EA RFC-L-22            CHOKE
 V  003-754445-0000-392  EA SG 22               DEVICE,SEMICONDUCTOR
C   499-754445-0000-392  EA SG 22               DEVICE,SEMICONDUCTOR
 V  449-754450-0000-845  EA 22 RJCC             RELAY  8000G-SIL DPDT
 V  499-754450-0000-845  EA 22 RJCC             RELAY,8000G-SIL
L   709-754470-0000-845  EA 22AHPX7   RELAY,ARM. PLUG-IN 2 FORM C MAGNACRAFT
 V  449-754495-0000-928  EA 22EN12-6            SWITCH ASSY
 V  449-754505-0000-804  EA 22-116 ADC          POWER SUPPLY

L   709-754513-9800-966  EA 23 CT 6A        TRANSFORMER SYNCHRO-CONTROL NORDEN
L   709-754514-0000-970  EA 23 CX 6A            TRANSMITTER SYNCHRO NORDEN
 V  449-754517-6000-845  EA TYPE 23-27          RELAY,28 DC 150 OHM SPST 10 AMP
 V  449-754619-0000-804  EA F 25                POWER SUPPLY
 V  469-754619-0000-804  EA F-25                POWER SUPPLY
C   499-754620-0000-966  EA G-25                TRANSFORMER CHAPPER INPUT TRIAD
 V  449-754635-0000-043  EA MODEL 25            AMMETER
C   003-754655-0000-392  EA ZA 25               CRYSTAL

 V  449-755170-0000-845  EA R35GP6B             RELAY
 V  499-755170-0000-845  EA R35GP6B             RELAY
 V  499-755171-1000-845  EA R35HP6B             RELAY
 V  499-755171-2000-845  EA R35PG6B             RELAY
 V  499-755171-5000-845  EA R35PP6B             RELAY
 V  469-755172-0000-804  EA TR 36-8M            POWER SUPPLY
 V  499-755175-0200-043  EA MR36W-020-DC-AA-R AMMETER
 V  449-755175-0250-804  EA RC36V 20 SR         POWER SUPPLY
```

Figure 12. Sample material catalog

PURPOSES OF MATERIAL PLANNING

The purposes of a good material planning and control system are to:

- Obtain adequate descriptions of critical parts early enough in the design phase to ensure that material requirements are introduced into the production cycle, enabling timely procurement action to be taken consistent with the contract and negotiated manufacturing schedules.
- Establish material requirement records by part number, update the records to a current status, and provide the parts and materials planning rapidly enough to enable the company to react to changes.
- Provide capability to apply the authorized master schedule mechanically to the engineering parts listing and to "explode" material requirements to the extent of funding or production authorization.
- Furnish the exploded requirements to the procurement group which obtains the necessary parts and material.
- Physically receive, house, and disburse the parts and material to the appropriate locations in the manufacturing or assembly plan.

The five areas which are considered to be within the realm of material planning and control in the accomplishment of these purposes are shown in Figure 13. These areas perform the following functions:

- Material Planning and Analysis shows how the information obtained from the engineering release, the master schedule, and other sources is drawn together to develop a statement of parts and material requirements by specific time periods.
- Material Procurement deals with the reduction of requirements to order lot sizes, and with the decision criteria which determine whether items are to be made or bought. The orders are then filled either by outside procurement or by in-house manufacture.
- Material Distribution handles the analysis of the transportation, receiving, and assimilation of parts and material into the inventory of the company. It also establishes requisition and stock-handling procedures.
- Material Maintenance covers the physical housing of the part and the workload rotating inventory count.
- Material Disposition determines the handling of material which becomes surplus as a result of obsolescence, scrapping, or changes in operational plans.

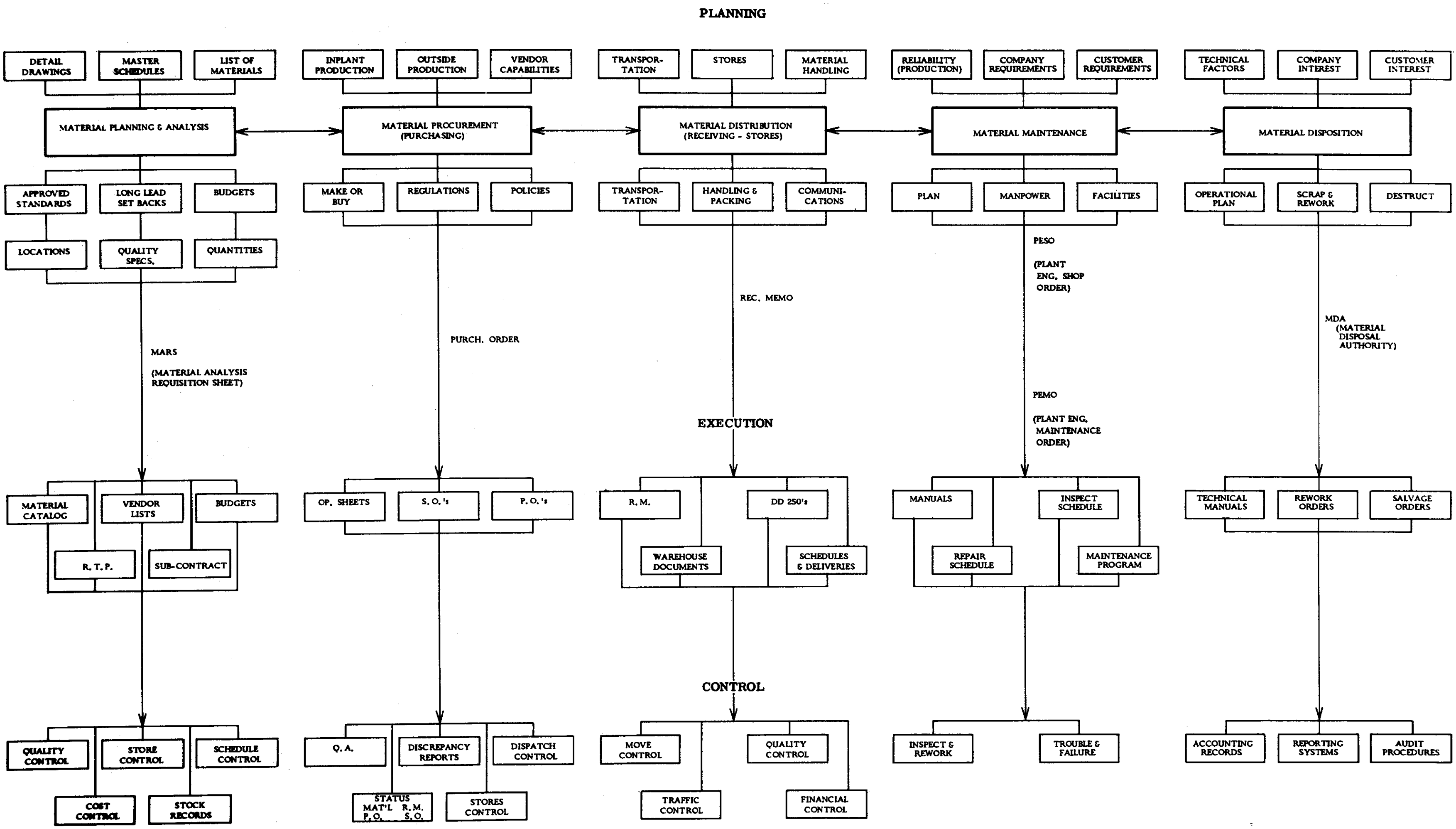


Figure 13. Materials management

AN INTEGRATED MATERIAL CONTROL SYSTEM

An integrated material control system ties together determination of procurement quantities and schedules, the preparation of purchase orders, and the receipt and inspection of shipments for control of inventory. Computer processing makes direct communication across these functions the basis of a fully responsive procurement system (see Figure 14). When fully implemented, computer processing includes the following steps:

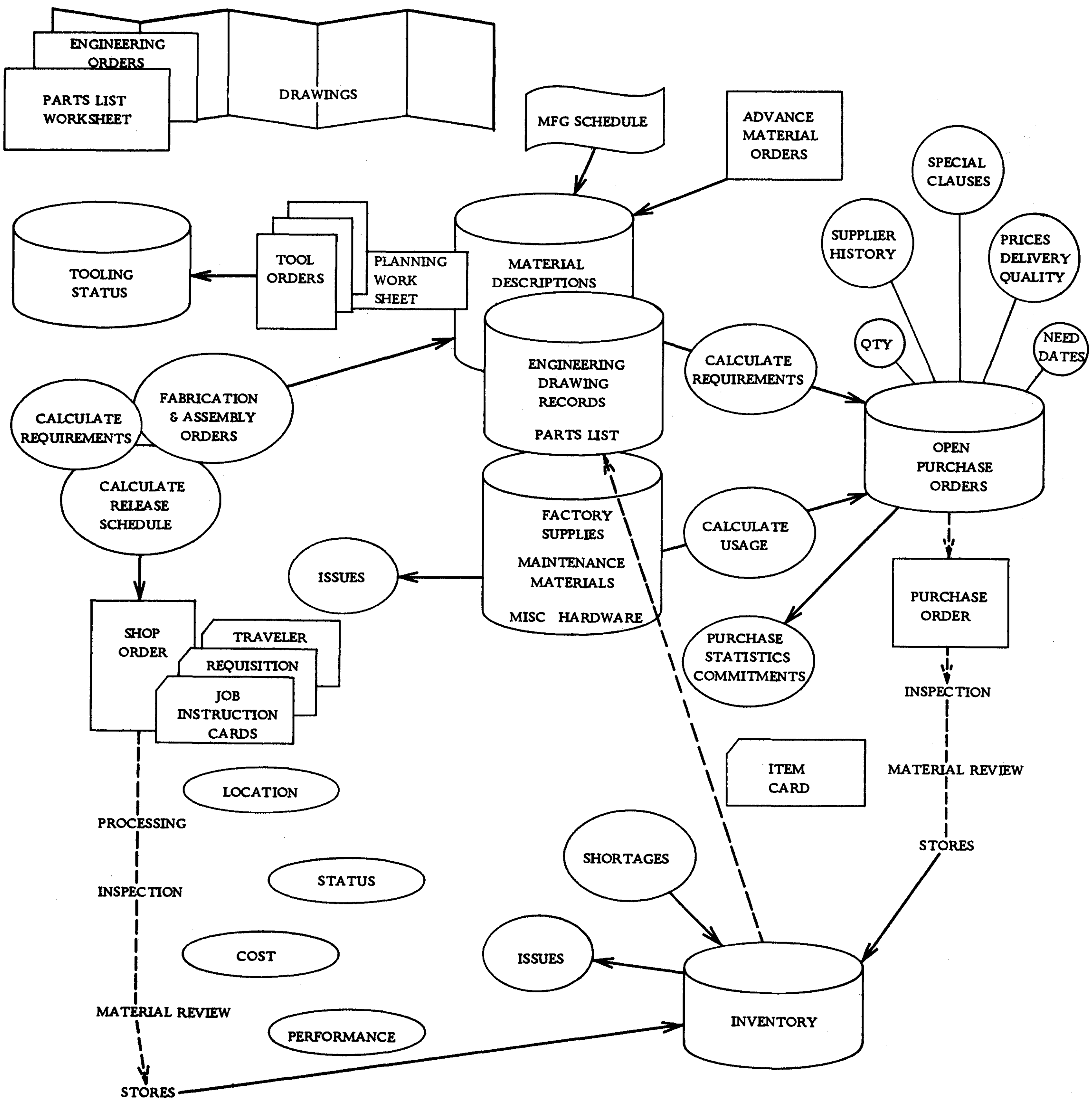


Figure 14. A responsive procurement system

1. Generating material requirements. The computer calculates and schedules release quantities for product-oriented raw material, procured parts and equipment items. Parts list and end item usage data can be obtained directly from a computer-processed engineering data system and a manufacturing planning data system, as described in the IBM publications Aerospace Information and Control Systems — Planning and Tooling (E20-8119) and Aerospace Information and Control Systems — Engineering Data Control (E20-8115). The computer applies the end item billed schedule and production setback factors to parts lists as they are released from the engineering and planning groups. As engineering changes are released, the procurement quantities are adjusted accordingly. The computer screens these parts and material requirements against advance material orders written previously for long lead-time items. Requirements for the same raw material or component used in several parts or assemblies are combined for total usage in a single end item, in a single manufacturing lot, or in monthly production increments. The result of this first processing step is a determination of the quantity needed, by time period, to support manufacturing schedules.

Another class of procurements requires a different method of calculating quantity and need date. This class includes the procurement of maintenance, repair and operating supplies, as well as certain bulk items (such as fasteners) used as required in the production end item. Here the rate of issue or consumption is the basis for determining future requirements. When a minimum balance is reached in inventory, the computer calculates expected usage by averaging past usage or by "exponential smoothing" techniques, computes economic order quantity, and issues a purchase order requisition to the purchasing group.

2. Comparing with open orders and with stock on hand. Before product-oriented parts and material can be purchased, the new requirement must be compared with purchase orders still open and with inventory records, to determine whether a sufficient quantity is already available in receiving, quality control, or in stock. The computer determines "net" purchase quantities by examining open purchase order, receiving location and status, and inventory records. If the new requirement can be covered by existing stock, or if order quantity on an open purchase order is large enough, the computer simply allocates the additional quantity to that order on stock. However, uncovered requirements are accumulated in the computer record until an economic shipping quantity is reached. (This method applies to most items, when procurement lead time has not been exceeded.) When the order date is reached, the computer writes a purchase requisition.

3. Writing the purchase order. The computer relieves the purchase analyst of clerical tasks associated with purchase order writing. Because the revelant reference files are integrated, the computer can pull together the special clauses and inspection instructions to be typed on the purchase order. Procurement quantities are distributed to sales orders. The order is broken down into shipping increments. Since the computer has access to data on previous orders, vendor selection logic can be applied for some commodities. The computer then prints supplier name, address, and shipping instructions to complete the purchase order.

If the source is selected by the buyer, the computer prints data on the last purchases, together with the purchase order requisition. The detailed purchase prices, delivery performance, and quality acceptance history are shown for the buyer's guidance. The buyer adds source selection information and any additional data necessary to cause the computer to prepare the purchase order for mailing. At the same time, the computer sets up a record of the purchase order. This record is used for follow-up as a source of answers to inquiries concerning the material on order, and as a source of receiving and inspection instructions. The computer prepares purchasing statistics and commitment reports from the purchasing data captured in its files.

4. Reporting the receipt of a shipment. When the shipment arrives at the dock, the purchase order number is keyed into a communications terminal. Receiving data is retrieved by the computer to verify description and quantity. The receiving communications terminal punches an item card which will travel with the order through inspection, material review, and into stores. This card, used to show the status of the order, finally reports the quantity stocked in inventory.

As shortages occur in the shop, inquiry is made to determine expediting action. The computer tracks continuously the progress of each order in order to flag certain orders for priority processing and for direct delivery in the shop.

5. Writing the shop order. The final step in an integrated material control system occurs when the shop order is written for production. The computer can look up material availability. If a shortage exists, expediting action can be started immediately. The material requisition card, prepared by the computer with the fabrication order, and the assembly parts lists, trigger computer action to record issues from inventory.

The procurement data recorded by the data processing system just described is the basis both for maintaining financial inventory records and for processing accounts payable records. The computer can be programmed to match invoices with the purchase order record, to reconcile the purchase order record with shipments received, and to prepare the check register. On request, the computer provides an exact picture of inventory valuation and of outstanding commitments for any commodity. If shortages are being experienced, or if stocks are building up in inventory because issues are lagging behind receipts, the computer recognizes the condition. Information pertinent to that condition is organized and edited by the computer to inform management that an exception has arisen which requires action.

This description illustrates a key aspect of integrated systems: Once entered in the system, data need not be recopied for use in another application. For example, when parts listings have been entered into the engineering release system, those parts listings need not be recopied for requirements calculation. When part descriptions, vendor data, and special instructions have been entered into magnetic storage, there is no need to type purchase orders and material change notices from worksheets.

By designing communications capability into the system (providing a "window" into these files), volume printout of requirements ledgers and reference listings is eliminated. An integrated system with direct access to magnetic storage provides the responsiveness required to process releases and changes to critical items as they occur. There is no batching of work to be processed at the end of the week; there is no stack of drawings and change notices waiting on someone's desk. An integrated system reacts to changes as they occur, provides notification of action required, and reflects the effect of action taken for continuous follow-up.

PILOT LINE OR ENGINEERING MODEL PARTS CONTROL

The bulk of this manual is aimed at general production, subsequent to the release of the initial models of a production item. However, some mention should be made of the prerelease aspect of production activity. A specific approach which supports the limited production activity is discussed in the IBM publication <u>Aerospace Information and Control Systems — Data System for Limited Production</u> (E20-8123).

From a requirement standpoint, the production effort on a new item usually begins with a prestated quantity produced and assembled on a pilot line basis. The purpose of the pilot line is to:

- Locate, define, and correct documentation, fabrication, assembly, inspection, procedural problems, and other problems in the production program.
- Proof and rework tooling not previously proofed.
- Prove the mechanical compatibility of components produced through tactical production, subcontractors, and vendors.

Supporting efforts for the pilot line are accomplished in accordance with released designs, inspection procedures, production procedures, and tools at a production level.

To accomplsih these objectives, a task force is established to detail a line plan. In addition, this group gathers data, analyzes problems, arrives at a solution, and institutes corrective action. The task force is composed of representatives from the engineering, quality assurance, test services, manufacturing, material, and manufacturing engineering departments, and perhaps of a customer representative.

To release development drawings so that hardware can be built, documentation in the form of an experimental memorandum is used. Its function is to initiate the design, procurement, fabrication, and installation of development hardware in the item and its support equipment. A properly approved experimental memorandum is the authority to release and procure for development only. These memorandums are not used to procure, fabricate, or install production hardware items.

The memorandum provides the following information on the pilot line:

- The quantity of hardware required
- Intended use
- Inspection requirements
- All drawings, specifications, test procedures, and data pertinent to the completion of this item.

Experimental memorandums are coordinated by a coordinating engineer, who authorizes changes (or refers changes to the design change committee) and updates his records and drawings accordingly. After the procurement and installation of the hardware, the coordinating engineer then commits all updated records to the change control board or to the release group for normal release. All changes must be made in accordance with standard procedures. Interchangeability rules must be observed; noninterchangeable changes require reidentification.

On the pilot line, a production control area representative or a liaison engineer is assigned to each area, in order to ensure immediate action when problems arise that require changes. The appropriate group then works under the authority of the experimental memorandum engineering order. A record of the change is maintained by the coordinating engineer and is passed on to the design change control with the release previously described.

As can be seen from this discussion, the generation of requirements is a manual procedure. The precise number of items is known. This number is either one or a very few. The requirements procedure then becomes "If you need one, order one." This can be assisted as described in the IBM aerospace publication mentioned previously A Data System for Limited Production (E20-8123).

After release from the pilot status, the material planning and control system takes over, and the procedure becomes more formalized and sophisticated.

MATERIAL PLANNING AND ANALYSIS

Many methods for handling requirements planning have been developed over the past several years, from the primitive manual methods to very highly automated computer systems. A great deal of emphasis has been placed on statistical forecasting for the finished end products. The aerospace industry's problem in this area consists of determining exactly what parts, assemblies, and raw materials are required to manufacture the finished products on schedule and within cost allowances for a specific contract. Normally, little emphasis is placed on forecasting.

With a catalog of parts and assemblies numbering in the thousands and spreading across several finished prototype product lines, parts planning becomes a unique and highly complex systems operation within the industry. The problem is compounded also by the high frequency of engineering changes affecting the original product, because of engineering improvements and reliability or safety changes. A method is necessary to determine these needs in various quantities and scheduled times, so that the materials can be on hand in the right quantities and at the scheduled time to fulfill the delivery requirements of the end product.

The requirements planning system should be compatible and should be integrated with other systems, such as:

- Planning and tooling
- Shop control
- Engineering
- Accounting
- Logistics and spares
- Inventory control
- Purchasing

Generating accurate requirements is a problem which is faced by every aerospace company. The concept of requirements generation is an explosion, by assembly levels, from the end product into its assemblies, subassemblies, parts, and finally into the raw materials needed to produce the end product.

The processing of the requirements planning systems is cyclical in its operation. The time of the cycle varies according to management viewpoint and experience in this area, the method of handling related systems, the volumes to be processed in the cycle, and the speed of the hardware available for the system. The length of the cycle can vary from online processing to periods as long as one month. A reasonable time cycle for offline systems is weekly. If inquiry ability is wanted, an online system is required to provide the latest current status of the bill of material file. Inquiries can then replace many of the status forms that are presently printed at various cycles by offline systems.

The requirements planning system generates many printed reports. Some of the departments which make use of these system documents are the following:

- Engineering. This department has ability to determine the latest manufacturing configuration. Because of this ability, engineering can follow the project and determine the contract specifications and the intent of specifications design are incorporated in the end product. Engineering changes can occur for various reasons: product structure changes and safety or performance changes, as well as possible cost reductions to be incorporated. The engineering department's interest is, therefore, in the latest product structure, in the manufacturing bill of material, and in where-used information.
- Logistics and Spares. This department determines, from the product structure, the requirements for spares contracts in the manufacturing plans. The where-used data allows the location of components in manufacturing that can be utilized when quick delivery is required to replace a faulty component at a field installation.
- Financial. This department uses systems documents for budget analyses and for developing component costs, based on the product structure of the end products, assemblies, and subassemblies.

The engineering release procedure described in the IBM publication Aerospace Information and Control Systems — Engineering Data Control (E20-8115) generates the engineering assembly parts lists (see Figure 15). The lists are organized by drawing part number. Each parts list is printed separately and describes the next assembly usage and all of the component parts. These lists, the usage data, and any associated notes are written on keypunch forms, are keypunched, and are entered into the computer. The machine-printed parts list is obtained from this computer information file.

This manufacturing parts list forms the basis for the generation of requirements. The assembly parts list and the manufacturing parts list, referred to here, are defined as a single-level assembly or manufacturing parts list. Other synonymous terms for this segment of information are bill of material, list of material, or drawing list. These terms are used interchangeably. These lists are the basis for the generation of requirements; however, the arrangements of the information within the computer or the technique of examining these lists determines the actual method of requirements generation.

Developing an Indentured Parts List

An indentured parts list can be generated by one of several iterative techniques. A tape technique is described here; however, a similar process can be performed using disk storage for the assembly parts list.

On the first pass, an abbreviated assembly work tape is generated, as illustrated in Figure 16. For each drawing record, this work tape contains the number, change letter, manufacturer's code, quantity per end item, and the numbers of all the components.

To establish the first or end item assembly level, the machine is provided with a statement of the components in the end item. This component list is passed against the previously prepared extract work tape. The matching records are merged with the end item statement tape which was used to start the procedure. This merge begins the formation of the indentured parts list tape. From the matching tape, the components of the first level are written on the indentured print tape. The matched records are then consecutively numbered. These numbers

NOMENCLATURE: PANEL ASSEMBLY - ELECTRONICS BAY

PARTS LIST
AEROSPACE DESIGN AGENCY
LOS ANGELES, CALIF.
CODE IDENT. NO. 09876

DRAWING NO.: PL 550-79132
REV: NEW | DATE OF ISSUE: 3-15-
SHEET 1 OF 1 | ISSUE NO. 1

USAGE DATA — READ DOWN

			NEXT ASSEMBLY / PART OR IDENTIFYING NO.	END ITEM DESIGNATION / NOMENCLATURE OR DESCRIPTION	EFFECTIVITY FROM / MAY BE PROCURED FROM / KIND, FORM	EFFECTIVITY THRU / GAGE — O.D. — T, STOCK SIZE	MODEL / CODE IDENT / MATERIAL SPECIFICATION	QUANTITY REQUIRED NA / ITEM FIND NO.	QUANTITY REQUIRED ART / ZONE	NOTES
*	*	*	* * * *	* * NOTE NARRATION	* *	* * * * *	* *	*	*	*
FOR	PROCUREMENT OR PART NUMBER SEE SPECIFICATION CONTROL DRAWING 598-13200									A
*	*	*	* * *	* * * USAGE DATA	* * *	* * * * *	* *	*	*	*
	-501		550-79101	1234	1	12	RS-10	1	2	
		-1	550-79101	1234	13	SUBS	RS-10	1	2	
*	*	*	* * *	* * * PARTS LIST	* * *	* * * * *	* *	*	*	
	REF	REF	AA0110-104	WIRING SPEC.						
	1	1	MS25005-5	CIRCUIT BREAKER				14	B-3	
	AR	AR	AN426AD4-6	RIVET						
	1	1	MT144RN	MOUNTING	AIRTRONICS	LOS ANGELES CAL	13999	12	B-3	
	1		BC788-2	RECEIVER-TRANS	AIRTRONICS	LOS ANGELES CAL	13999	13	A-2	
		1	BC788-1	RECEIVER-TRANS	AIRTRONICS	LOS ANGELES CAL	13999	13	A-2	
	2	2	AS333AP	ANTENNA	AIRTRONICS	LOS ANGELES CAL	13999	11	A-3	
	AR		598-13200	WIRE				10		
	5	5	550-79132-10	CLIP	ALALY2024T4	.040 X 1.5 X 3.5	QQ-A-267	9	A-2	A
	2	2	550-79132-9R	CLIP	ALALY2024T4	.060 X 1.5 X 3.5	QQ-A-267	8	A-2	
	2	2	550-79132-9L	CLIP	ALALY2024T4	.060 X 1.5 X 3.5	QQ-A-267	8	A-2	
	1	1	550-79132-6	CHANNEL	ALALY7075T62	.125 X 3.0 X 24.0	QQ-A	7	A-2	
	2	2	550-79132-5	DOUBLER	ALALY2024T6	.060 X 6.0 X 24.0	QQ-A-277	6	A-2	
	2	2	550-79132-3R	ANGLE	ALALY2024T4	.060 X 1.2 X 4.0	QQ-A-267	5	A-3	
	2	2	550-79132-3L	ANGLE	ALALY2024T4	.060 X 1.2 X 4.0	QQ-A-267	5	A-3	
	2	2	550-79132-2	PANEL	ALALY2024T4	.125 X 13.0 X 24.0	QQ-A-267	4	A-2	
	1	1	550-79126	SHELF	ALALY7075T62	.125 X 12.0 X 24.0	QQ-A-277	1	A-2	
	1	1	550-79125	BRACKET ASSY				2	A-3	
	2	2	550-79133	DOUBLER ASSY				3	A-2	

PROCUREMENT SOURCE — MATERIAL DESCRIPTION — KIND, FORM TYPE, GAGE — O.D. — T STOCK SIZE

550-79132-1
550-79132-501

PARTS LIST — READ UP

QUANTITY REQUIRED PER NOTED ASSY.

ERROR FLAGS

Figure 15. Engineering assembly parts list

allow the records to be sorted back into the original sequence after subsequent processing. The component breakdown tape is then sorted into component part number sequence. The component numbers are compared with the extracted engineering assembly parts list work tape in order to extract the matching record onto a new components breakdown tape. These components are merged into the indentured print tapes. The extracted components are in turn given a sequence number.

Each iteration consists of sorting the components breakdown tape into its drawing number sequence for comparing with the engineering assembly parts list work tape. The matching drawing records are copied and resorted into sequence for merging drawing description with the indentured print tape. The drawing components are then sequence-numbered and written out on a new components breakdown tape. This process is repeated as many times as component parts lists are selected from the file. When no further parts lists appear, the merged, indentured print tape is ready for printing, as shown in Figure 17. When the listing is printed, the actual level of indentures can be shown by having the machine physically move the entries one position to the right for each level of indenture. Thus, visual reference is given as to the items' indenture level. From a processing standpoint, the indenture is very significant, as it is used in determining lead times at a later point in the processing cycle.

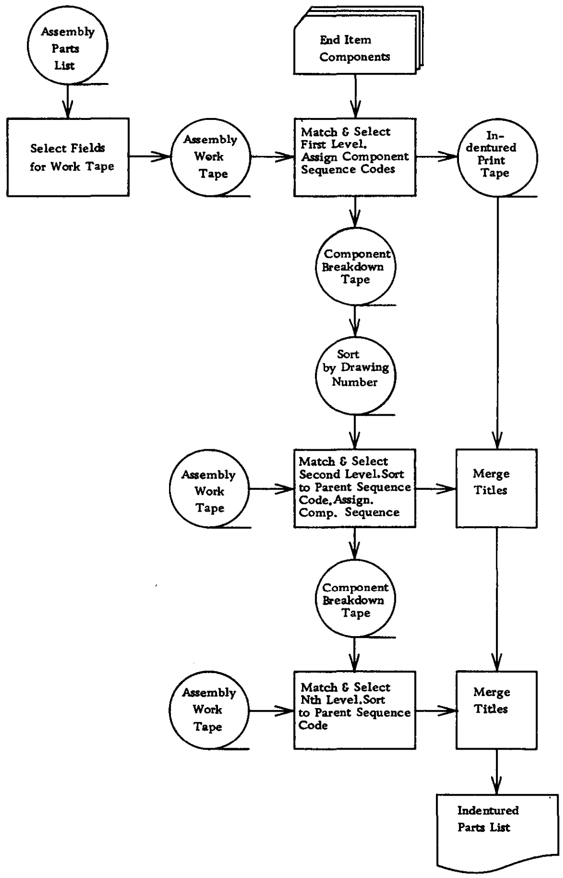
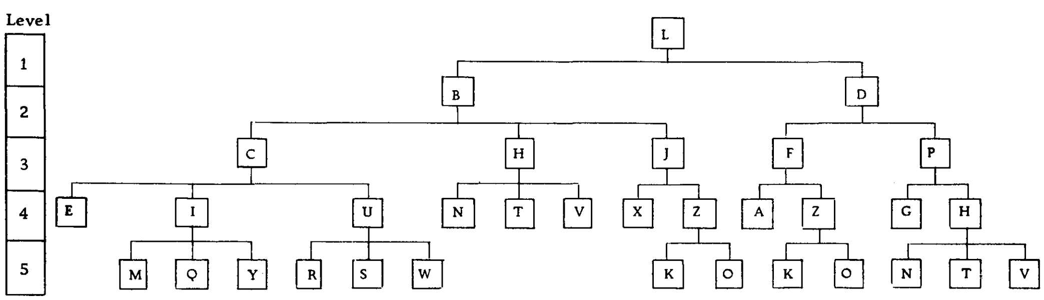


Figure 16. Indentured parts list processing



L	AIRBORNE COMPUTER, GUIDANCE
B	.FRAME, INPUT SIGNAL CONVERTER
C	..MULTIPLEXOR, AIR DATA
E	...DESIGN SPECIFICATION
I	...CARD, DETECTOR CIRCUIT
M	....TRANSISTOR, S4317 NPN
Q	....DIODE, SILICON-FD106
Y	....RESISTOR 33K 1/10W
U	...CARD, AMPLIFIER CIRCUIT
R	....TRANSISTOR, 4320 NPN
S	....TRANSISTOR, 4321 NPN
W	....CAPACITOR, 30 UUF
H	..DRAWER, LOGIC, TYPE4W
N	...CARD, GATE
T	...CARD, DRIVER
V	...CARD, INVERTER
J	..DATA BUS
X	...MODULATOR, FREQUENCY
Z	...ADAPTER, CHANNEL
K	....OSCILLATOR
O	....CLOCK
D	.FRAME, DATA ANALYZER
F	..DATA SET, LINE ADAPTER
A	...LATCH, SINGLE SHOT
Z	...ADAPTER, CHANNEL
K	....OSCILLATOR
O	....CLOCK
P	..REGULATOR, VOLTAGE
G	...DESIGN SPECIFICATION
H	...DRAWER, LOGIC, TYPE 9W
N	....CARD, GATE
T	....CARD, DRIVER
V	....CARD, INVERTER

Figure 17. Indentured parts list

In lieu of generating a unique parts list, the indentured parts list can be maintained and updated with the release of engineering changes. When any engineering assembly parts list is released, the used-on information is given. A reference to this used-on record provides the assembly level of that item by adding one to the released assembly and two to its component. It is possible to record the levels without a generation procedure. This procedure requires an increased amount of reference, but reduces the number of sorting passes required. An examination of the time required for the references in comparison with the time required for the generation shows which procedure is most advantageous as a processing requirement for the particular company.

Requirements Generation Using the Indentured Parts List

In addition to the proper arrangement of the item and an indication of the indenture, a statement of the quantity per end item is contained in the generated indentured parts list. The generation procedure then consists of identifying the specific manufacturing parts list for the end item for which the requirements are to be generated. The master schedule tells the quantity desired in any of the periods under consideration. By multiplying the quantity per end item by the quantity of end items desired, the user obtains the total number of parts desired.

By using the indentured manufacturing parts list, the user obtains the number of component parts at each level. A tape is written which contains the component number, the total required for that usage, and the assembly level indenture number for that usage. The entries are then sorted by component number, which puts all of the various usages of that part together. By noting all of the level numbers associated with these usages, the user can determine the time that each of the quantities is needed. For example, part number 374876 may have three usages, the level number and quantities of which are shown in Table 2.

Table 2. Level Numbers and Quantities

Level	Quantity
5	23
7	14
8	37

The level with the highest number is the lowest assembly level, indicating the quantity that is required first. From the tables it can be seen that the level 8 quantity of 37 is needed first. By use of a standard time offset per level, the need date can be established. For example using a standard offset of 20 days, if the end item for which these requirements have been developed is to be shipped on manufacturing day 600, the eighth-level quantity is needed 160 days (20 x 8) before the end item shipping date. Thus, the eighth-level quantity is needed on manufacturing day 440 (600-160). A work authorization card is prepared, indicating that for part number 374876, a quantity of 37 parts is needed on manufacturing date 440. The same mathematics can be performed on the other two entries, and additional work authorizations can be released which state the need for those items.

To stop unnecessarily small quantities from going to the production area, the computer tests the quantity. If quantity is below a predetermined amount, the "following quantity" is added to it, and the need date of the earliest quantity stated. This technique assures an adequate quantity for both requirements. By combining the production of both quantities on the earlier date, the first requirement is satisfied and the quantity for the second requirement is stored until its need date is reached; the second quantity is then released to the manufacturing area.

Using this technique to generate requirements has the advantage of shortening the actual requirements generation time. The parts list can be generated in an off period prior to the requirements generation, or the parts list updating can be performed continuously as the changes occur. With all of the preliminary work done, the actual generation takes place in a single pass on the machine; this tends to level the machine load over the month. The disadvantage of this method, however, is the lack of relationship between an assembly and its components. This lack of relationship is important because of on-hand inventory. If there is any inventory of assemblies on hand, that inventory is not considered when the requirements for the components are generated. This lack of relationship therefore generates excessive inventory on the component and all lower assembly levels.

Requirements Generation Using a Where-Used Index

Random access storage has made it possible to have any particular record available, on call, without having to search through a series of records. This ability can be put to good use in the generation of requirements.

Instead of periodically building a parts list completely or maintaining a parts list, it is possible to store the released or advanced bills of material (single assembly parts list or lists of material) in the disk file. The advantage of storing the bills of material instead of the complete parts list is that fewer records are required.

In addition to bills of material stored in the disk files, a where-used index is generally maintained. This index designates the next highest assembly level of usage. By having a where-used index available on a random access basis, a technique of generation is possible that would be most costly, in processing time, on a tape system.

This technique is a level-by-level generation procedure, cascading the requirements downward through the sequential assembly levels. Level-by-level generation is possible without a where-used index; but even with high-speed random access equipment, the necessity of multiple exploding of the bills of material which are used more than once increases the cost of the generation procedure. In addition, if in-stock and open-order parts are to be properly allocated, it is necessary to have all the requirements available prior to the explosion procedure. This knowledge of requirements is necessary because in a level-by-level generation the assembly levels using the parts last are the first usages encountered, while the parts needed earliest on the lowest assembly levels are the ones encountered last. To allocate in-stock and on-order parts properly, all requirements should be accumulated, the inventory allocated to the earliest requirements (the lowest levels), and new orders created for those requirements not covered (the higher levels). Correct allocation can be accomplished by consulting the where-used index during the generation.

The bill of material number is known for the highest level end item. The machine seeks the bill record for this assembly and retrieves the bill of material. The machine now has the assembly number and a list of all the parts that are put together to make the assembly. Using its random access ability, the machine can seek the where-used record for each of the component parts of the assembly. Retrieving this record, the machine can find the where-used notation for this assembly and check it off. The machine can check to see whether all of the usages of this component part have been found. If all usages have not yet been found, the new requirements for this usage can be accumulated with any others previously found, and the where-used record can be returned to the disk file.

If all the other usages for this component part have been found and checked off, and this usage is the last one, the machine then begins to allocate the in-stock and order quantities to the stated requirements. If these quantities are sufficient to cover all the requirements with not too large a surplus, no additional action is required. If, however, there is not sufficient inventory to cover all the requirements, an order must be placed to replenish the stock. In addition to placing the order, it is necessary to determine that there are sufficient components in stock to cover these requirements. This determination requires retrieving the bills of material for the component parts that are assemblies, exploding the assemblies, posting the requirements, interrogating the where-used index to see whether the usages have been checked off, and so on, until all usages for all bills of material have been found, and until the accumulation, allocation, and explosion of materials have been completed.

The advantage of the procedure explained above is that the time consumed is reduced by requiring the explosion of the bill of material only once, instead of every time the bill is encountered. In addition, the inventory usage and open-order structure are monitored to reduce the exposure to excess inventory. An audit is also performed with every generation to make certain that a bill of material is used and that an item called an assembly is truly supplied by a bill of material. If these two conditions are not met, the machine can request action to correct the situation.

Given the ability to start at random with any component number and to trace the usages of that component up or down the assembly sequence, a requirements generation can start with any component number at any assembly level. A random access technique can be the basis of such a generation procedure.

Contained within the header record of a where-used record is a requirements area. This area allows the accumulation of requirements from any higher-level source as the generation procedure takes place. When the number itself is to be generated, these requirements can be used and the balance from any additional source can be included for generation. As an example, the file contains a product structure. The program calls the part number to be interrogated for requirements. The access mechanism seeks the header record for part number 1. On the master record is a check number indicating the number of entries in the generation chain. This check number is compared with the number of entries in the requirements area. If the numbers do not match, the machine begins to follow the chain of usages. As it proceeds to each component usage sector, the home assembly cross-reference address refers to the next-higher-level assembly that uses the part. The machine can refer to the header record of that assembly to obtain the requirements for the next higher level of assembly. If in turn there are no requirements or incomplete requirements at that level, the machine interrogates the chain of that assembly. This interrogation continues upward until firm requirements are encountered. The machine then starts back down the chain, leaving behind the requirements from that line of generation. The accumulation, in which the usage is multiplied by the requirement of the assembly, continues downward, with the results always being left behind, until the number originally interrogated has all its requirements for every chain represented.

If the first interrogation is at a relatively low assembly level, the inquiries upward are extensive. However, as additional inquiries are made upward, the resulting generation downward performed, and more and more requirements left behind, the number of inquiries beyond the interrogated level diminishes. With this technique, no preliminary generation and no sorting is required.

A similar technique of generation has been developed for a relatively specialized type of product. This product is one that is made of a series of similar types of assemblies. The assemblies carry the same routing instruction for the manufacturer even though the actual parts assembled are different or are placed in a slightly different arrangement. The release document is shown in Figure 18. In the terms of the originator, it is called the "model net". The first entries are the sequential operation record instructions. These entries are followed by a record of each of the various parts that uses this routing instruction set. In the illustration there are four operations. The first operation is to be accomplished at work station 120, the second at 172, etc. Each operation carries its own operation time.

The second segment is the list of all the various parts that use this routing, and the indicative data associated with each part number; that is, part number 700100 is shown with a normal manufacturing lot size of 20 pieces. The where-used notation indicates that this item is used on 700100. The balance of the information is used in other machine programs.

This procedure is written for a computer with very large memory. The model net in its entirety is maintained on tape. The first computer activity is to read this tape, strip the basic part number, usage, and where-used information from the model net tape, and to arrange it in a table in the memory

DATE	PRODUCTION CONTROL MODEL NET TRANSMITTAL SHEET	PROJECT NAME	ANALYST	SHEET OF

PART NUMBER	WORK STAT.	MACHINE	SHIFT	OPERATING TIME	MANNING	FUNCT'N	NORMAL LOT SIZE	USAGE	WHERE USED	W/S/C	SCRAP	LEAD TIME	LINE OF BAL NO.	W/U TOP LEV	DESCRIPTION	CARD CONTROL
1 2 3 4 5 6	7 8 9	10 11	12	13 14 15 16 17 18	19	20	21 22 23 24	25 26 27 28	29 30 31 32 33 34	35 36	37 38 39 40 41	42 43	44 45 46 47 48	49 50 51 52 53 54	55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	73 74 75 76 77 78 79 80
	120	01	1	.75	0	1										1.
	172	01	2	1.25	0	1										2.
	165	04	3	.25	0	1										3.
	140	01	1	.50	0	1										4.
700175	140	02	1	1.00	0	2	020.	002.	700100	05	000.0	10	0009	900000	Regulator	5.
700275							020.	002.	700200	05	000.0	10	0010	900000	Regulator	6.
700375							010.	001.	700300	05	005.5	10	0011	900000	Regulator	7.
700475							010.	001.	700400	05	005.5	10	0012	900000	Module	8.
700575							020.	002.	700500	05	010.0	10	0013	900000	Module	9.
700675							010.	001.	700600	05	001.0	10	0014	900000	Transformer	10.
700775							005.	001.	700700	05	000.0	10	0015	900000	Transformer	11.
	095	01	1	4.50	0	2										12.
	100	01	7	.50	0	1										13.
	110	03	1	.50	0	1										14.
	200	01	1	1.00	0	3										15.
700100							002.	001.	900000	04	004.0	05	0002	900000	Harness	16.
700200							004.	002.	900000	04	005.5	05	0003	900000	Harness	17.
700300							004.	002.	900000	04	010.0	05	0004	900000	Harness	18.
700400							002.	001.	900000	04	000.0	05	0005	900000	Harness	18.1
700500							004.	002.	900000	04	015.0	05	0006	900000	Harness	19.
700600							004.	002.	900000	04	000.0	05	0007	900000	Harness	20.
700700							002.	001.	900000	04	033.3	05	0008	900000	Harness	21.
900000	400	01	1	20.00	0	1	001.	001.	900000	01	000.0	02	0011	900000	Computer	22.

Figure 18. Production control model net transmittal sheet

of the computer. The procedure then continues as outlined. The generation can start with any part number. The machine seeks the master model net record for that item. If all its requirements are not present, the where-used reference is consulted and that part number sought. By building upward in this manner, eventually the top level is encountered or a previously generated requirement is found. When either of these is found, it can be extended and cascaded back down through the same chain leaving the accumulated requirements behind for subsequent interrogation.

After the where-used chain has been completely interrogated, the requirements have been generated for that item. Depending upon the contract, orders can be released for the generated requirements, for predetermined lot quantities, or for computed economic lot-size quantities. These orders can be created at the completion of the generation of requirements for an item, or the orders can be created from the requirements on a subsequent machine run.

Requirements Generation Using a Requirements Master File

This approach to the generation of requirements is developed for those items of manufacture in which the engineering phase is so extremely close to the production or manufacturing phase that the end item has to be under way before the complete engineering is done. The files normally do not have a sufficiently complete bill of material structure to allow a level-by-level generation of requirements, or even to allow the generation of a continuous where-used structure. The purposes of the system are:

- To obtain adequate descriptions early enough in the engineering design phase to ensure that material requirements are introduced into the material system, allowing timely acquisition to take place to meet the contract and negotiated schedules.
- To establish material records by part number, to update these records to a current status, and to provide ability to react to changes.
- To provide capability to generate requirements mechanically to the extent of funding.

Normally, new and long-lead-time items are introduced into the system by an advanced material requirement or by an engineering release. To handle the advance material requirement, a bank is established showing the part number, quantity model, and the start serial number for a vehicle requirement or a specific job number for a nonvehicle requirement. In addition to the advance release, the system shows an "interrogation date" (that is, a deadline for engineering releases to cover the advance material requirements). This provides a built-in purge for the system. Normally, the bank is reduced as the engineering releases occur. On the interrogation date, if the release has not been received, an advance material requirements exception report is prepared for review.

From each released bill of material, a skeleton bill is prepared. This document provides the material analyst with all the necessary engineering data. The variable procurement data are added.

The requirements master file contains both the advance material requirements and the released engineering bill of material. When a new or changed requirement enters the system, either from an advance material requirement or from an engineering bill of material, the change is related to any previously established requirement. The net result of this addition is forwarded to the inventory section as a suggestion to indicate either a potential overstock condition or a shortage due to increased requirements.

The machine generates requirements for any regular item of release or for any item for which a repetitive requirement occurs. This generation is accomplished by notifying the machine of those end items of manufacture that are now funded for manufacture. The basic engineering document contained an effectivity number which was posted to the requirements file. The funding notice contains the number of the items to be released. By making a search of the entries in the requirements master file, the machine finds those items with effectivity numbers within the range of the funding notice. Work authorization notices or purchase requisitions are printed and/or punched, by the machine and forwarded to the appropriate functions for action.

New engineering releases and new advance material requirements (released for end items that are within the range of released funding notices) are immediately released by the machine as work authorizations to the factory or as purchase requisitions to purchasing.

When the machine processes the orders for detail parts, the raw material is calculated with a view to placing an order against existing stock or an order for purchase. The quantity is calculated to satisfy the requirement for parts needed, plus a scrap factor, and the results are rounded to the next highest unit of measure. On a subsequent machine run, all the requirements for the same material can be summarized to take advantage of purchasing efficiencies.

When an engineering change reduces or cancels the quantity per end item or the effectivity range for a part, such a change may require disposal of a quantity of this part. When the engineering change is processed, a decreased requirement report is prepared for review and appropriate action.

MATERIAL PROCUREMENT

Regardless of which technique is used, the material requirements generation procedure has examined the known product structure, plus the released advance material requirement, and has developed a statement of requirements, plus an indication of the time when these requirements will materialize.

The material procurement system takes these requirements and develops work authorization documents (see Figure 19) stating the part number, quantity, and the exact date the parts or assemblies authorized by this order must be received.

Whether an item is to be manufactured inside the company or purchased outside is indicated by a "make or buy" code inserted into the record maintained in the machine. This code is obtained from the released engineering documents. It can be as simple as:

- M Manufactured in-house
- P Purchased outside

or it can be moderately extensive:

- A Purchased complete
- B Purchased incomplete, completed in-house
- C Started in-house, completed outside
- D Parts or material supplied, manufactured or assembled outside
- E Interplant purchase (same division)
- F Interdivisional purchase (different division)
- G Purchased shelf item (standard item)
- H Manufactured assembly (assembly to be routed to machine floor)
- I Manufactured complete
- J Assembly item

Make or Buy

Decisions to make or buy parts or assemblies are normally made before engineering release. Most of the decisions are based on an analysis of equipment availability, personnel capability, or schedule limitations. After the engineering package has been released, there may be additional "buy" decisions. These are normally based on shop overload and are the result of a joint analysis by the planning and manufacturing departments. In those instances in which the decision to buy has been made after engineering release, the planner indicates this by creating a buy authorization for the part or assembly.

Another decision made early in the design cycle is whether or not to subcontract major sections of the end item and its support equipment. The subcontractor is often responsible for design, fabrication, assembly, and testing of major structures and systems. In these cases, performance and functional specifications describing the design for the subcontractor are prepared to assure successful integration into final assembly.

Many sections built in-plant require parts supplied by outside sources. Typically, these are hardware and equipment items, such as pumps, controls, actuators, and electrical and electronic components. Purchased components are designated and identified by the engineers on individual assembly and installation drawings.

Other procurement items are raw materials, normally designated by the engineer as to type and form for each part to be fabricated, forgings, castings, miscellaneous fasteners, bearings, seals, and other bulk material. At the time a design is in development, qualified subcontract procurement sources are determined. Invitations to bid are issued by the purchasing organization. Engineering provides qualified bidders with drawings and specifications to define the design. Successful bidders are named in a qualified source list. Source control drawings are then issued to define components procured for the project.

An item designation number is used to identify similar purchased parts available from various qualified suppliers; or alternative supplier part numbers (with their corresponding code numbers, names, and addresses) may be shown directly in the drawing list of material.

Generating the Parts Order

The requirements generation procedure has produced the quantity of parts that will be needed for a specified period. These requirements are either accumulated into a total or are arrayed to show the pattern of requirements. The pattern of orders to fill these requirements is not always the same, nor are the quantities always the same. This difference in quantity is especially true on new items, as a greater quantity of scrap is generated during the learning process. In any case, an order request must be produced. The basic information for an order is part number, quantity, and date needed.

The quantity of an order can be derived in a number of ways. Quantity may be calculated and prestated by engineering in terms of:

- Container size. When, in the course of the engineering release cycle, the packet is forwarded to manufacturing engineering, one of the considerations is how the item is to be transported. If the item is critical or fragile, special containers are provided to keep the parts from being damaged. The order quantity lot size can be stated in terms of the quantity that can be conveniently or safely carried in the special containers provided.
- Material limitation. As the materials become more specialized or costly, the quantity on hand is closely monitored. The material may come in strip, coils, rods, lumps, sheets,

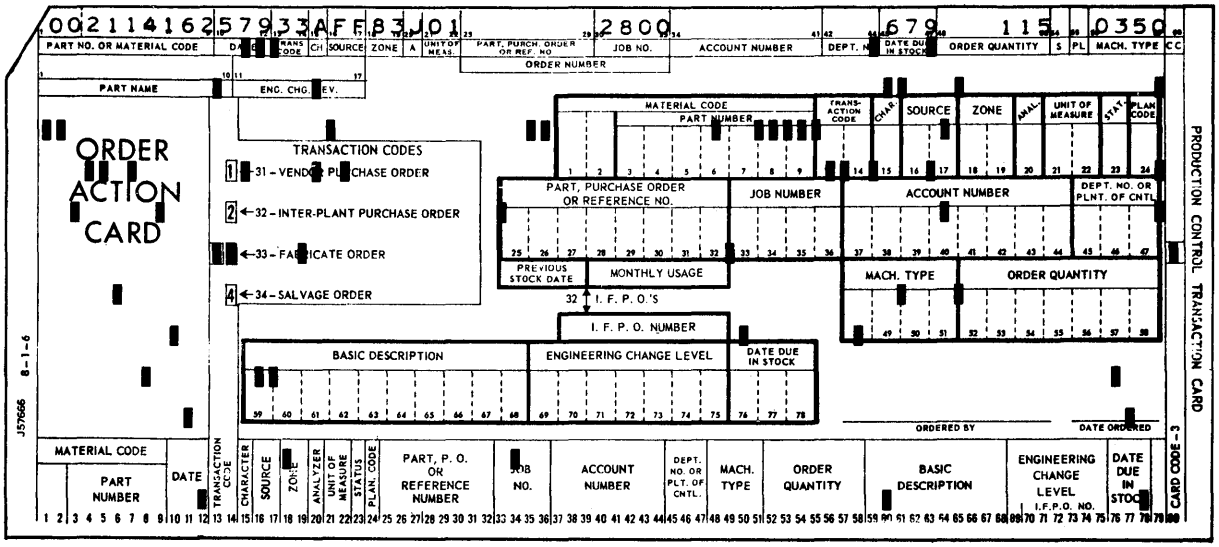


Figure 19. Order Action Card

etc. The limiting factor for an order size can be predicated on the number of parts that can be obtained from a predetermined standard size piece of material. This eliminates excess inventory in partial raw material quantities.

- Cost of material. If the material to go into a part of assembly is critical or costly and is subject to loss, the quantity of the order may be predicated on the largest quantity that can be exposed to the possibility of loss. This quantity is calculated by the cost of material per item divided into the maximum amount which can be exposed to the risk of loss.
- Cost per order. Where there is a desire strictly to reduce the work-in process inventory, the amount invested in an order can be cut to the minimum. The amount determined may be a strict dollar amount ($1,000, $8,000, etc.), or it may be a monthly requirements value or a unit cost value, scheduling the delivery of the item to arrive just when it is needed.
- Inventory turn. The order can be predicated on a desired number of inventory turns per year. The quantity to achieve this number of turns is calculated and then checked against other criteria to make certain other restrictions enumerated in this section are not violated.
- Tool limitation. Where the item under consideration uses a machine or a tool that has a prespecified maximum life in hours, strokes, passes, or heats, etc., these factors should be taken into consideration. The number allowed by such parameters may limit the quantity of an order; or the quantity of an order should be compared with these limitations to see whether the relationship between the two is close enough that the order should be altered to this maximum. An anticipated order size may bring a machine tool so close to the need to be sharpened, rebuilt, or refurbished that any subsequent orders would require two setup charges: (1) the normal charge, and (2) a charge for the re-setup after the tool has been torn down to be redone. This is an important consideration, as setup charges can be high or the scrap generated can be excessive, if the tool is run past its recommended life.

Economic Order Quantity (EOQ)

The objective of an economic order quantity is to reduce total cost by balancing order costs and carrying costs. Order costs are reduced by decreasing the number of orders while inventory carrying costs are reduced by a decrease in inventory.

The use of an economic order quantity is predicated on the principle that for every part there is an optimum order quantity that entails a minimum total expense at the balance of these two costs. Ordering by economic order quantity instead of by exact quantities required generally results in the maintenance of an inventory position which is slightly higher than is strictly necessary for manufacturing purposes. Maintaining inventory on a slightly higher level increases the costs of insurance, storage facilities, obsolescence, physical deterioration, etc. On the other hand, manufacturing costs as well as purchasing costs are higher when smaller quantities are ordered at more frequent intervals. In the case of manufacturing, such elements of cost as machine setups, waste, time per unit operation, etc., all tend to increase as the number of lots per year increases.

There are several equations for computing economic order quantities, each formula employing basically the same factors. The most widely used and simplified formula is:

$$Q = \sqrt{\frac{2\text{ (annual demand x order costs)}}{\text{unit cost x \% carrying cost per year}}}$$

In addition to the above, other formulas used for determining manufacturing lot quantity consider the following:

- Cost of storage per unit, annually
- Desired annual return on capital in percent
- Number of days worked per year
- Number of pieces used (or shipped) per day
- Number of square feet of net storage space required to store one unit
- Annual unit charge for storage space (expressed in dollars per square foot)
- A lot factor, expressing the influence of lot or batch production on the economy of manufacturing
- Lot factor = 2 (ratio of quantity at order point to quantity used while awaiting delivery) - 1

In calculating the EOQ, there is a tendency for a plateau to develop around the flat part of the total cost curve, as illustrated in Figure 20. Between the extremities, the difference in savings is usually negligible. Consideration should be given to selecting the lowest approximation resulting from the square root fraction.

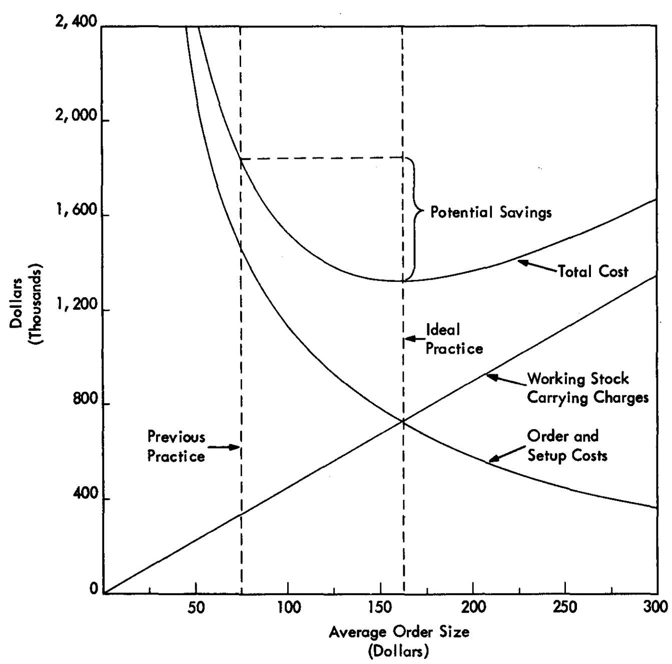


Figure 20. Order costs versus inventory carrying charges

Modification of the calculated EOQ is based on the same extrinsic factors as were enumerated in the preset order quantities. Other factors worthy of consideration are:

- Storage limitation in process floor space or in the stockroom
- Extreme fluctuations in raw material or parts
- Limited working capital
- Deterioration

This modified figure now becomes a manufacturing lot quantity (MLQ).

ORDER ACTION

The inventory master record now contains the requirements and an order quantity based on the quantities generated by one of the previously discussed procedures. The next step is actually to develop an order. The order action notice system determines whether a part should be ordered during a particular time period or whether no action need be taken during the next few manufacturing days (M days). The complete processing cycle with the end result of the production of the parts action notice is shown in Figure 21.

The basic inadequacy of a manual system is overcome by an order action system which collects and examines all activity against all parts. The machine processing links inventory, requirements, and work in process (or purchase commitment). The linkage of these three systems provides

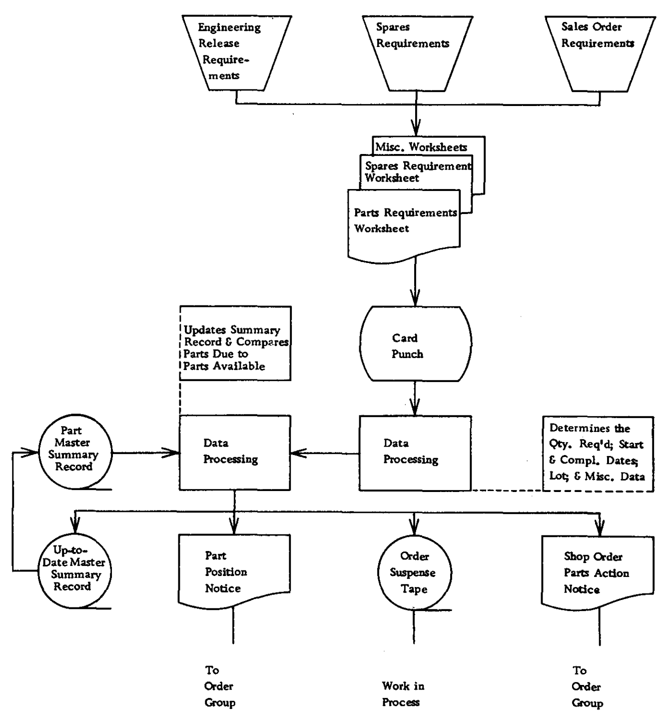


Figure 21. Shop order parts action notice system

correlated information that enables the production control department to:

- Schedule and release orders according to inventory need
- Automatically produce the order variable to cover a finite distribution of this order quantity
- Maintain minimum excess stock quantities
- Measure order completions on schedule
- Measure the impact of contract changes on schedules resulting from cutbacks or follow-on contracts
- Monitor stockroom disbursements
- Reduce crash expedites and reduce surpluses by rapid and frequent examination of inventory records
- Develop a more reliable scheduling and ordering sequence

As is required in all data processing, a reliable factual feedback system must be provided. One example of this feedback is the reporting of loss of parts as a result of assembly or manufacturing scrapping, modification, or cancellation of parts requests. Any necessary parts follow-up or reorder can be initiated.

A shop order parts action notice is shown in Figure 22. This particular notice initiates a manufacturing order rather than a purchase order. The order action card illustrated in Figure 19 can serve for either manufacturing or purchase orders. The particular type of order is designated by a punch in the transaction-code field in columns 13 and 14. These cards can be sorted or simultaneously put on tape to trigger subsequent order activity, actually to produce the purchase requisition or manufacturing order.

PURCHASING

Purchasing is an integral part of any inventory system — a system precisely designed to provide maximum profits for the manufacturing concern through the effective utilization of materials, machines, and manpower. For this reason, prudent purchasing is a major determinant in a concern's effort to make a profit and to advance its position in a competitive market.

SERIAL NO.	LATE ORD	NO. VAR.	CLERK	DESK	ZONE	USE	ORD. DATE	ITEM	STA.	IND.	CLS.	START	DUE	TOTAL QUANTITY	LOT	PART NUMBER	CHANGE LTR.	CHANGE NO.

QTY.	WORK ORDER	ASSIST	MOD-EID	EFFECTIVITY	QTY.	WORK ORDER	ASSIST	MOD-EID	EFFECTIVITY

DATE ______ SHOP ORDER PARTS ACTION NOTICE PAGE ______

PART NAME	ORD DATE	START	DUE	ZONE	USE	ITEM	STA.	IND.	TYPE	CLS.	D/M	PART NUMBER	CHANGE LTR.	CHANGE NO.

CODE	QUANTITY	WORK ORDER	MOD-EID	EFFECTIVITY	SERIAL NO.

REQUIREMENTS			DUE TO DATE			BANK	ORDERED	W. I. P.	COMPLETIONS		
PLANNED	OTHER	TOTAL	PLANNED	OTHER	TOTAL	POSITION	TO DATE		VARIANCE	TOTAL	STATUS

Figure 22. Shop order parts action notice

Purchasing as a function in the manufacturing process is a portion of the procurement activities. In fact, when the term "procurement" is used, most people equate this term with purchasing. When the release (either an advance material release or a normal engineering release) has taken place, a material request is forwarded from material control, as illustrated in Figure 23. The material request triggers the activities of purchasing through the negotiation, ordering, follow-up receipt, and evaluation phases.

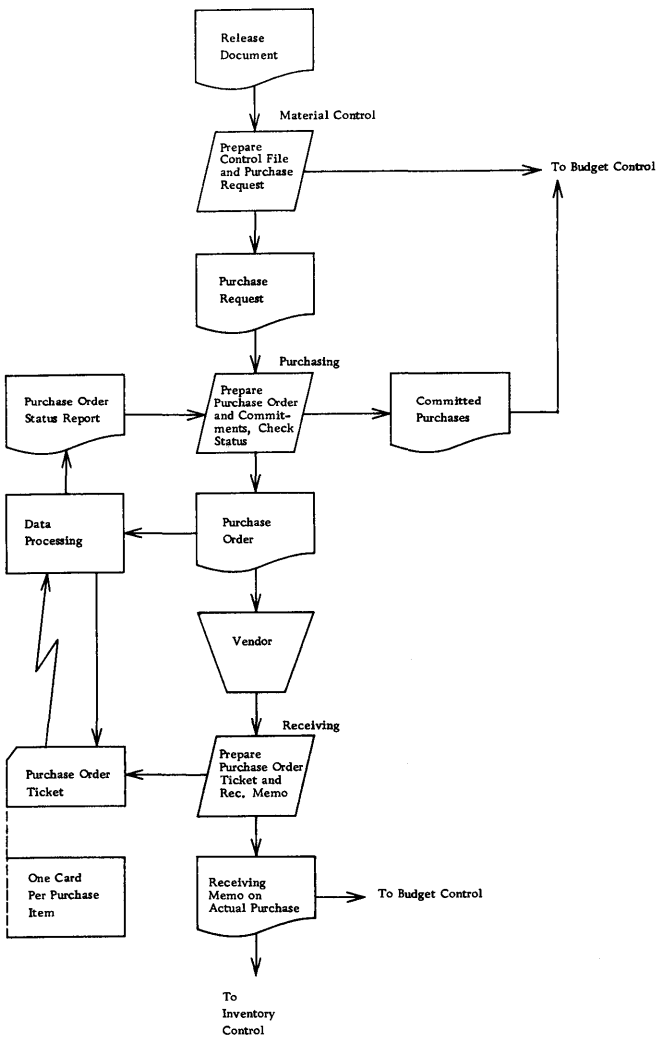


Figure 23. Purchase procedure

The objectives of sound purchasing are generally stated as the procurement of materials of the right quality, in the right quantity, at the right time, at the right price, from the right source, for delivery at the right time and place. Purchasing is thus a continuous operation demanding prompt decisions and action for greater profits — profits which result from the latest facts being brought to management attention while there is still time for decisions to be put into action. Experience dictates that purchasing agents and their buyers be free to consult with fellow executives upon a moment's notice. Purchasing agents must interview visiting salesmen; must exchange information with plant managers, engineers, and shop foremen; must constantly search for new sources of supply; and must keep abreast of new processes, types, and qualities of parts and materials. All of these duties are accomplished while stacks of paperwork, exacting in detail and demanding in importance, are cleared across their desks.

To achieve its objectives, purchasing management (along with the sales, production, and financial members of the corporate team) must establish a plan, execute it, and then evaluate it. A good data processing system automates the clerical aspect of these functions, employing the following concepts:

- Economic purchase quantity (EPQ) — the formula used to calculate the quantity to be procured.
- Purchase order follow-up — the execution of the plan, ensuring that the right quantities and qualities are available at the right time and place.
- Purchase performance index — an evaluation of vendors, buyers, commodities, and products against performance targets.

These three concepts constitute an integrated systems approach for purchasing. Of the three, purchase order follow-up is the most likely to be looked at first. Purchase order follow-up is potentially a successful as well as profitable application in its own right; it is a control system employing the principle of management by exception to provide automatic follow-up at each stage of the purchasing cycle, from the time the purchase order is issued until the last payment is made.

The third concept, purchase performance index, is a statistical measurement of the raw data furnished by the follow-up system to evaluate objectively the tangible factors of both vendor and buyer performance. Knowledge of past performance is the key to management's effort to improve future performance, and the link to greater profits and product superiority. Once the follow-up system is operative, the purchase performance index can be implemented almost immediately.

The concept of the economic purchase quantity is part of the purchase requisition and order-writing procedure. EPQ is the quantity which results in a minimum annual total cost. EPQ takes into consideration quantity discounts, carrying costs, setup charges, and order processing costs. The purchase requisition processing automatically prints out the annual total cost for four stock replenishment quantities and the history of the last five completed purchases, in addition to providing a completed requisition for the EPQ quantity. Purchasing makes its decision on the basis of these enlightening facts. The purchase order is then printed by the data processing system.

Purchase requisition and order writing is predicated upon the establishment of a history of past purchases. Over a period of time, the follow-up system automatically develops such a history. For this reason, the EPQ concept is normally the last of the three concepts to be implemented.

The use of disk storage enables purchasing personnel to inquire as to the status of any order, part, material, or vendor and to obtain a reply. All records are updated in a single operation. The transactions may be processed in random sequence in order of occurrence, which avoids batching and permits the records to be up to date at all times. Exact specifications for the individual data processing system vary according to the number of records and transactions involved.

Transaction (run) frequency should allow a sufficient flow of data to support the purchasing operation. A suggested indication of transaction (run) frequency is listed in Table 3.

Table 3. Transaction Run Frequency

Type of Transaction	Frequency
Purchase Requisition	Daily
Purchase Order	Daily
Receiving Ticket	Daily
Invoices	Daily

Disk storage is organized into four separate files, as illustrated in Figure 24, and is described below:

- The part or material history file contains the part number, name, descriptive data, the last five purchases, and price quotations for up to eight separate price-quantity combinations.
- The open requisition file contains the outstanding requisitions awaiting approval or change action.
- The order status file contains the part number, purchase order number, and descriptive, received, inspected, invoiced and paid data for all outstanding purchase orders.
- The vendor name and address file contains name, address, ship to, terms, conditions, and the open purchase order numbers.

Today, more than ever before, management must concentrate its efforts upon the executive aspects of its responsibilities. The suggested system assists purchasing management in the preparation of a master plan, directs management's attention to

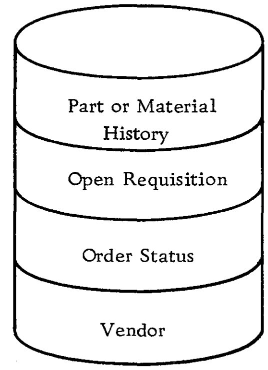


Figure 24. Purchase file organization

exceptions which occur in the execution of the plan, and provides an objective basis for improved performance.

The increasing complexity of today's business threatens to make "firefighters" of purchasing personnel. The system discussed permits such personnel to be orderly, to preplan, and to schedule the purchase of parts and materials on the basis of:

- Organized information
- Ready reference information
- Relief from clerical details
- Management by exception
- Guidelines for improved performance

Economic Purchase Quantity (EPQ)

Continuity of operations is of critical importance to any company. The purchasing function must be conducted so as to minimize disruptions in production resulting from a lack of parts, materials, or equipment. On the other hand, to conserve capital, the investment in inventories must be kept to a minimum. Reconciling these two considerations requires a delicate balancing of the risk of production bottlenecks or shutdowns, the cost of carrying excessive inventories, the savings available through volume purchases, and the cost of processing orders.

The economic purchase quantity is that quantity of a particular part or material which results in a minimum annual total cost consistent with good inventory management practices. EPQ is a formula designed to balance the various factors in the order placement process.

$$\text{Total annual cost} = \text{Number of orders} \times \text{Purchase order cost} + \text{Inventory carrying cost} + \text{Order processing cost}$$

The significance of EPQ lies in the realization that the cost of carrying inventories for an industrial concern averages 25% per year. Assuming a constant rate of usage, the average inventory represents one-half the purchase quantity. This means that on an annual basis, the cost of carrying inventory can be as much as 25% of one-half the dollar value of an order. EPQ differs from the EOQ (economic order quantity) in that it considers not only annual usage, order processing costs, and inventory carrying charges, but also the following factors:

- Multiple price-quantity combinations
- Variable setup costs
- Variable tool charges
- Multiple vendors

Ninety percent of the procurement requests are for repeat purchases. These requests are submitted on handwritten forms (see Figure 25) indicating the part or material number, job number, ordering department, suggested order quantity, and date required. These items are punched into a card, which is fed into the data processing system. For installations which have implemented an inventory management system, either the EPQ may be incorporated into the inventory processing, or the request card may be produced as part of the inventory processing.

The central processing unit selects the part or material history record from disk storage and computes the total annual cost for up to eight price-quantity combinations, as follows:

1. The price is multipied by the quantity, and the setup and tool costs are added to provide the purchase order cost.

2. The daily usage is determined by subtracting the last order date from the current date, and dividing the last order quantity by the difference. The estimated number of days' supply is then obtained by dividing the given quantity by the daily usage. The purchase order cost is multiplied by 25%, and this product is multiplied by the estimated days' supply over 365 days. The product is the inventory carrying cost.

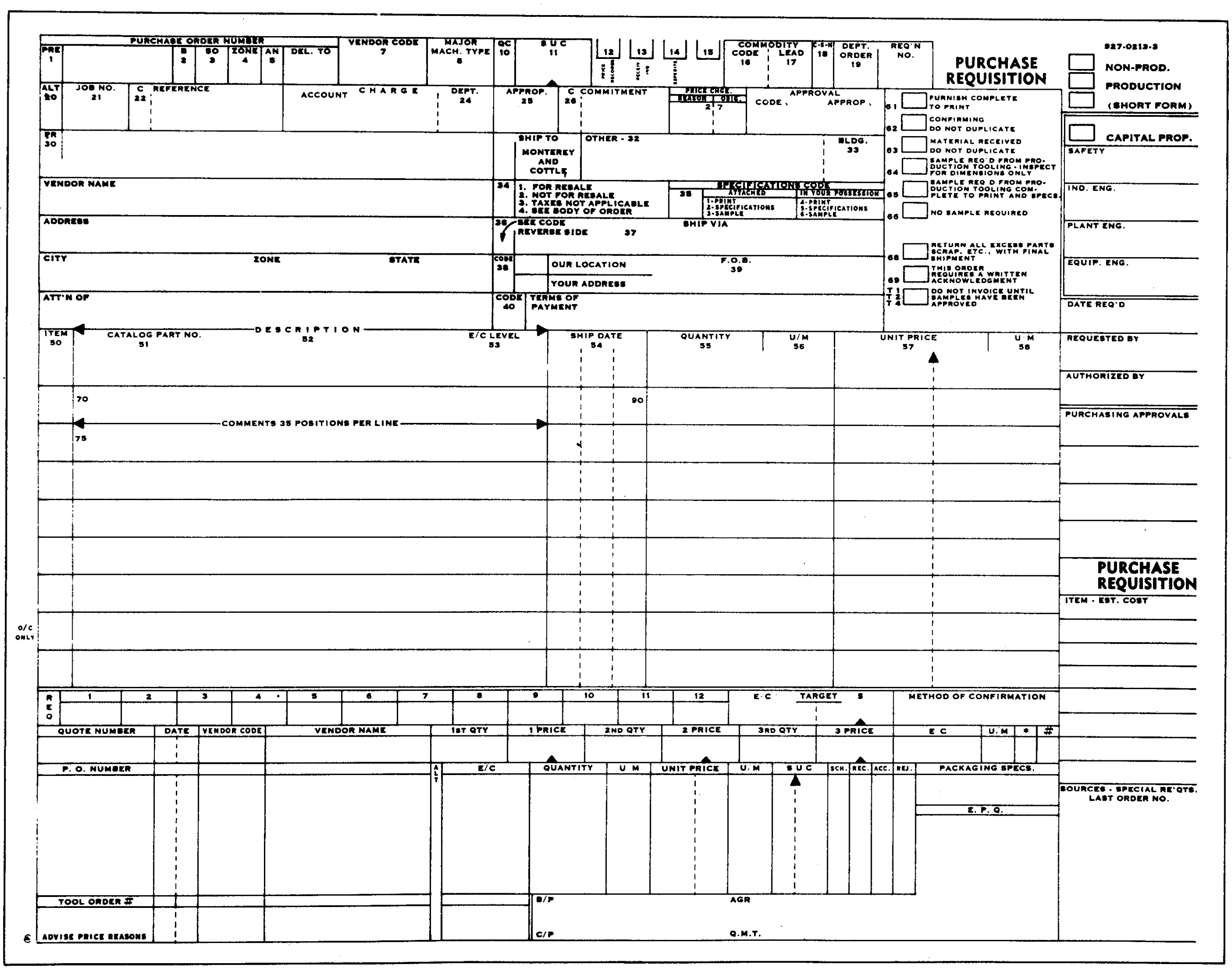

PURCHASE REQUISITION
NON-PROD.
PRODUCTION
(SHORT FORM)
CAPITAL PROP.
PURCHASE ORDER NUMBER
VENDOR CODE
MAJOR MACH. TYPE
COMMODITY CODE
LEAD
DEPT. ORDER
REQ'N NO.
JOB NO.
REFERENCE
ACCOUNT
CHARGE
DEPT.
APPROP.
COMMITMENT
APPROVAL
FURNISH COMPLETE TO PRINT
CONFIRMING DO NOT DUPLICATE
MATERIAL RECEIVED DO NOT DUPLICATE
NO SAMPLE REQUIRED
SAFETY
IND. ENG.
PLANT ENG.
EQUIP. ENG.
DATE REQ'D
REQUESTED BY
AUTHORIZED BY
PURCHASING APPROVALS
SHIP TO
MONTEREY AND COTTLE
OTHER
BLDG.
VENDOR NAME
1. FOR RESALE
2. NOT FOR RESALE
3. TAXES NOT APPLICABLE
4. SEE BODY OF ORDER
SPECIFICATIONS CODE
ADDRESS
SEE CODE REVERSE SIDE
SHIP VIA
CITY
ZONE
STATE
OUR LOCATION
YOUR ADDRESS
F.O.B.
ATT'N OF
TERMS OF PAYMENT
ITEM
CATALOG PART NO.
DESCRIPTION
E/C LEVEL
SHIP DATE
QUANTITY
U/M
UNIT PRICE
COMMENTS 35 POSITIONS PER LINE
PURCHASE REQUISITION
ITEM - EST. COST
O/C ONLY
TARGET
METHOD OF CONFIRMATION
QUOTE NUMBER
DATE
VENDOR CODE
VENDOR NAME
1ST QTY
1 PRICE
2ND QTY
2 PRICE
3RD QTY
3 PRICE
P. O. NUMBER
E/C
QUANTITY
U M
UNIT PRICE
PACKAGING SPECS.
E. P. Q.
SOURCES - SPECIAL REQ'TS. LAST ORDER NO.
TOOL ORDER #
ADVISE PRICE REASONS
B/P
AGR
C/P
Q.M.T.

Figure 25. Purchase requisition

3. The purchase order cost, inventory carrying cost, and a standard cost to process each order are added together. The standard cost of processing an order is an estimate of the variable costs of operating the purchasing department due to an increase in the number of orders processed, divided by this estimated increase in volume. The increased volume is caused by taking into consideration inventory carrying costs.

4. The annual factor (365) is divided by the number of days' supply determined in step 2, to obtain the number of orders annually.

5. The number of orders annually is multiplied by the sum of the purchase order cost, inventory carrying cost, and order-processing cost. This product is the annual total cost for the given quantity at the given price.

6. Each of the price-quantity combinations is computed as indicated in steps 1 through 5.

7. The four lowest total annual costs are held for printing on the purchase requisition.

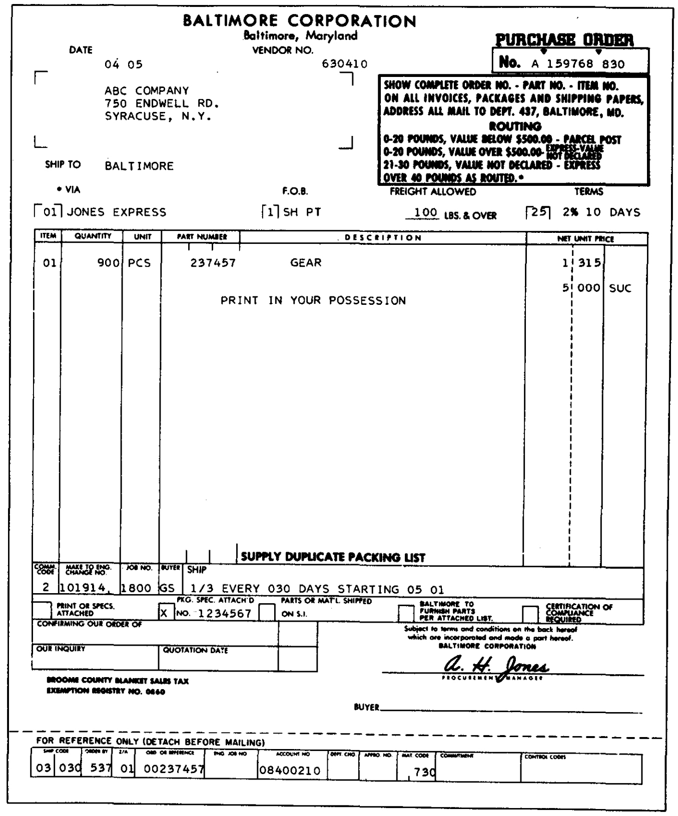
8. The EPQ is selected to complete the purchase requisition.

The data processing system which computes the EPQ, also contains the necessary information to complete and print the purchase order illustrated in Figure 26. The requisition illustrated is for 900 gears, as specified in engineering change number 101914 for part number 237457. The order is being placed with the ABC Company at a unit price of $1.315, determined by the EPQ formula.

While the calculation for EPQ takes into consideration the factors available to the machine, purchasing applies extrinsic factors as the purchase order is reviewed for approval. Some of these factors are:

- New products to be phased into production
- Old products to be phased out of production
- Pending engineering changes affecting part and material specifications
- Warehouse space requirements
- General market trends and conditions

The maintenance of the vendor quotations in disk storage is an integral part of the purchase requisition and order-writing procedure. Whenever a new part or engineering change is required, specifications are determined by product engineering. The specifications, along with a request for bid, are forwarded to the vendors by the purchasing department.


BALTIMORE CORPORATION
Baltimore, Maryland

PURCHASE ORDER
No. A 159768 830

DATE 04 05
VENDOR NO. 630410

ABC COMPANY
750 ENDWELL RD.
SYRACUSE, N.Y.

SHOW COMPLETE ORDER NO. - PART NO. - ITEM NO. ON ALL INVOICES, PACKAGES AND SHIPPING PAPERS, ADDRESS ALL MAIL TO DEPT. 437, BALTIMORE, MD.
ROUTING
0-20 POUNDS, VALUE BELOW $500.00 - PARCEL POST
0-20 POUNDS, VALUE OVER $500.00- EXPRESS-VALUE NOT DECLARED
21-30 POUNDS, VALUE NOT DECLARED - EXPRESS
OVER 40 POUNDS AS ROUTED.*

SHIP TO BALTIMORE

• VIA	F.O.B.	FREIGHT ALLOWED	TERMS
01 JONES EXPRESS	1 SH PT	100 LBS. & OVER	25 2% 10 DAYS

ITEM	QUANTITY	UNIT	PART NUMBER	DESCRIPTION	NET UNIT PRICE
01	900	PCS	237457	GEAR	1 315
					5 000 SUC
				PRINT IN YOUR POSSESSION	

SUPPLY DUPLICATE PACKING LIST

COMM. CODE	MAKE TO ENG. CHANGE NO.	JOB NO.	BUYER	SHIP
2	101914	1800	GS	1/3 EVERY 030 DAYS STARTING 05 01

PRINT OR SPECS. ATTACHED
X PKG. SPEC. ATTACH'D NO. 1234567
PARTS OR MAT'L SHIPPED ON S.I.
BALTIMORE TO FURNISH PARTS PER ATTACHED LIST.
CERTIFICATION OF COMPLIANCE REQUIRED

CONFIRMING OUR ORDER OF
OUR INQUIRY
QUOTATION DATE

Subject to terms and conditions on the back hereof which are incorporated and made a part hereof.
BALTIMORE CORPORATION
A. H. Jones
PROCUREMENT MANAGER

BROOME COUNTY BLANKET SALES TAX EXEMPTION REGISTRY NO. 0660

BUYER

FOR REFERENCE ONLY (DETACH BEFORE MAILING)

SHIP CODE		ORDER BY	Z/A	OBD OR REFERENCE	ENG. JOB NO	ACCOUNT NO	DEPT. CHG.	APPRO. NO.	MAT. CODE	COMMITMENT	CONTROL CODES
03	030	537	01	00237457		08400210			730		

Figure 26. Machine prepared purchase order

The bids are returned, and cards are punched from the quotation register illustrated in Figure 27. The data processing system examines each bid and records the bids for the lowest price-quantity combinations in disk storage. New quotations may be requested as often as the buyer desires. The system automatically prints the last quotation date on each requisition and punches out quotation requests for those which are more than a year old.

A small portion of the procurement requests is for nonrepeat purchases. Cards are punched for these miscellaneous items. The cards contain all the necessary data to write the purchase order. Each card is processed through the data processing system for automatic follow-up and for a consolidation of purchasing records.

Alterations to outstanding purchase orders are punched in the same manner as requests. Alterations are also similarly processed, with the exception of the updating of the open requisition file.

BALTIMORE CORPORATION — QUOTATION REGISTER

Card Code	Part Number	Purchase Code	Basic Name	Inquiry No.	Inquiry Date	Engineering Change No.	Vendor Number	Unit of Price	Unit of Measure	Freight Allowed	Set-up Charge	Buyer Code	Packaging Specs.	Ins. Code	Rec. Code	Buyer Ref. Code
1	124650	843	SCREW	GB7540X3	3/-	140915	270105	C	PCS			GB			/	
1	137466	322	CAM	GM7255X3	3/-	59023A	'150120		PCS			GM			/	
1	132849	461	SPRING	CE6497X3	3/-	123860	036091	M	PCS		25.00	CE			/	
1	394765	825	CONTACT	CY8604X2	3/-	151705	325060	M	PCS		30.00	CY			/	
1	428621	820	RELAY	CY8845X4	3/-	125417	325060		PCS			CY	124560	S	/	
1	237457	730	GEAR	GS8903X3	3/-	101914	630410		PCS		5.00	GS			/	

Card Code	Part Number	Tool Cost	1st. Quantity	1st. Price	Max. Del.	2nd. Quantity	2nd. Price	Max. Del.	3rd. Quantity	3rd. Price	Max. Del.	4th. Quantity	4th. Price	Max. Del.
2	124650		10,000	2.500	3/3	50,000	2.255	5/5	100,000	2.000	9/9			
2	137466		1000	.480	1/3	5000	.450	2/2	10,000	.385	2/2			
2	132849		100,000	42.500	—	250,000	37.500	—	500,000	25.000	—			
2	394765	450	50,000	12.750	—	200,000	10.500	—			—			
2	428621		500	1.765	1/9	1000	1.543	1/9	5000	1.385	2/9	10,000	1.200	5/5
2	237457		450	1.400	3/3	900	1.315	3/3	1500	1.300	3/3	3000	1.250	3/3

Figure 27. Quotation register

Purchase Procedure

To illustrate how all of the various elements knit together into a complete system, the following flowcharts show the various inputs being processed against the master records contained in the file.. As was stated, the basic information is stored in the central file, which allows for processing as well as for inquiry.

The flowcharts show a somewhat arbitrary division into sections. The first chart illustrates purchase order writing (see Figure 28). The actual trigger is the request for parts, which may be in the form of a one-time request for the item when it is anticipated that additional quantities of the item will not be required. If the requester has a source that is approved, this source can be fed into the file and the purchase order can be prepared directly (see Figure 26).

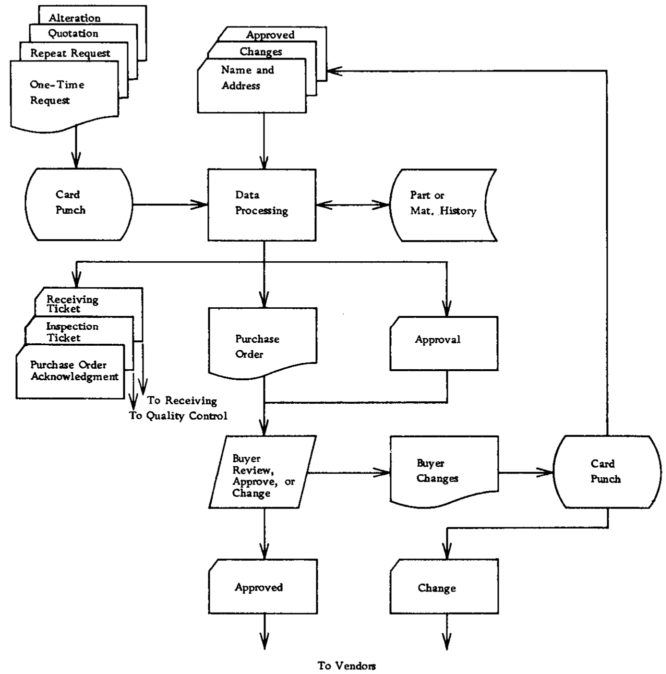


Figure 28. Purchase order writing

The second type of request is a repeat request. If the item has been requested before, the information can be extracted from the history file and the vendor data file and applied to the purchase order printout. If the order is approved, it can be sent directly to the vendor, or alterations can be inserted. If additional information is needed, such as current price quotations, new vendors, etc., the buyer can obtain this information and insert it into the machine. When the approval of the purchase order is communicated to the machine, receiving and inspection tickets are punched and forwarded to receiving and quality control to await the arrival of the material. A monitor is set up in the machine to make certain that an acknowledgment is received from the vendor.

Order status follow-up is maintained in the machine, as illustrated in Figure 29. The program searches the file periodically to ascertain the following information related to order status:

- Received, not shipped
- Closed purchase order
- Inspection past due
- Payment past due
- Shipment past due

In addition, the system prints shipment confirmations and follow-up notices.

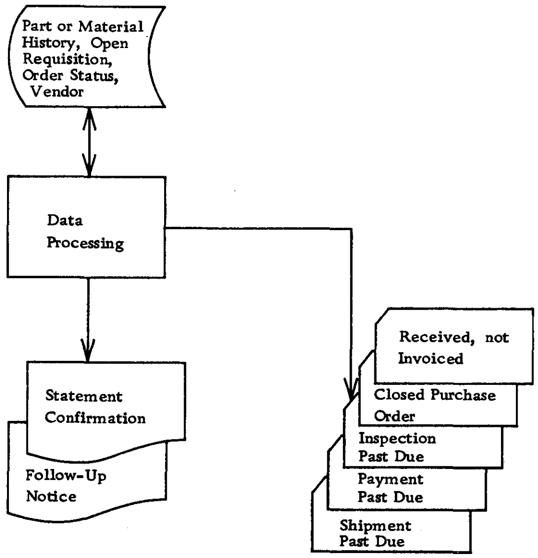


Figure 29. Order status follow-up

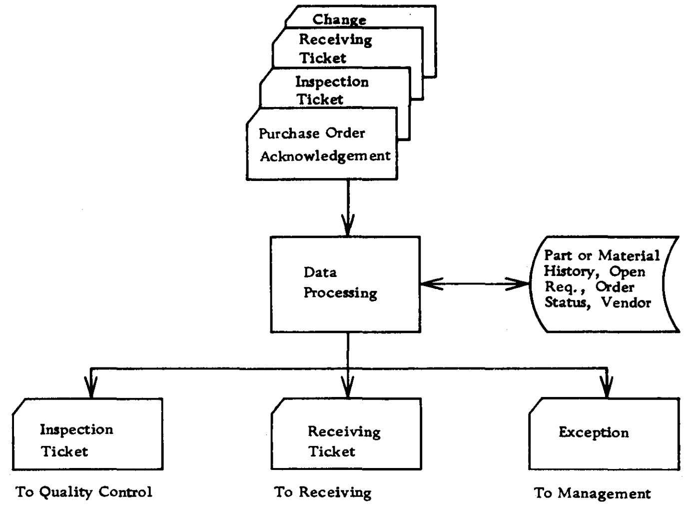


Figure 30. Purchase order follow-up

These reports and cards are forwarded to the buyers who have specific charge of the particular part, and also to management as an indication of current operations.

When the purchase order is prepared by the machine, the data pertinent to the order is recorded in the order status and open requisition portion of the file. One of the first pieces of information to be monitored is the receipt of the purchase order acknowledgment (see Figure 30). This document is important, as it constitutes an assurance that the vendor has received the order and, if no alteration has accompanied the acknowledgment, that the order will be filled as indicated on the current data. As the orders are received, the receiving ticket is processed to indicate that the parts are in the building. The actual disposition is not indicated until the inspection ticket is processed. The inspection ticket (see Figure 31) carries indicative information as to how the item is to be inspected and conveys the results back to the machine. The illustration carries five coded disposition notices:

4 - Return to vendor
5 - Scrap
6 - Accepted for rework
7 - Accepted by screening
8 - Accepted on "off-spec"

The difference between the quantity received and the quantity removed by the above assignment is the quantity accepted into stock. When any rework is performed, the additional quantity is then accepted.

Any changes to basic data, quantity, delivery date, delivery sequence, etc., are communicated

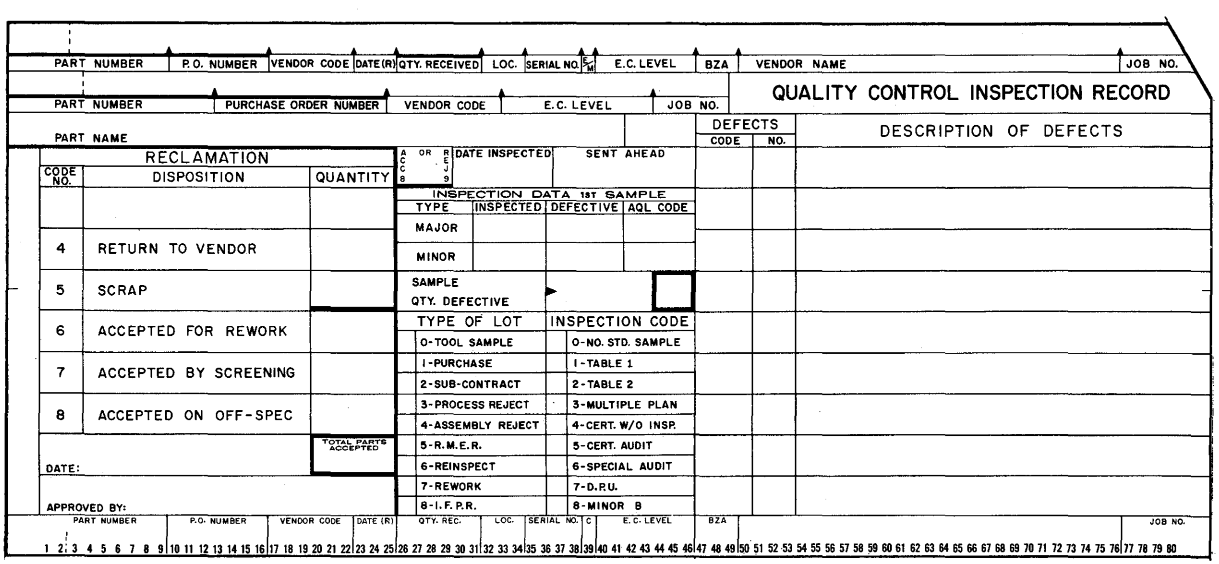


Figure 31. Inspection ticket

to the machine via a change card. The records are updated and an output exception notice is then generated to make certain that management is aware of the net result of the change. In every case, whenever data are accepted into the machine, all records in the random access file are updated simultaneously, so that all of the records are maintained completely in phase.

The order record is deleted from the order status file when the order has been received and the record can be closed. The vendor record is updated to record performance and the fact that the services of that vendor were utilized. The invoice amount can then be aged, and the invoice paid at the proper time within the term period. The machine then affects the accounting distribution, prints the check, and records any unusual conditions on exception cards. The various check registers, remittance, and invoice registers are prepared and printed.

When the material has been received, inspected, and accepted, the invoice amount can be furnished to the purchasing program. The various files are updated and the vendor paid (see Figure 32). The details of this transaction are: the invoice amount coupled with the data from the receiving inspection report updates the part history record to record the latest transaction. This record includes the quantity, cost per article, and the last vendor from whom purchases were made. The latest cost per article is put in the cost history file. The evaluation portion is the final phase.

Statistical and analytical examinations are performed with regard to:

- Buyer
- Vendor
- Product
- Commodity
- Part

These reports, submitted to the vendor as well as to company management, present the results of the analysis to purchasing, corporate staff, and the suppliers. One specific report that has proved advantageous is the quality conformance report (see Figure 33). This report communicates to the vendor

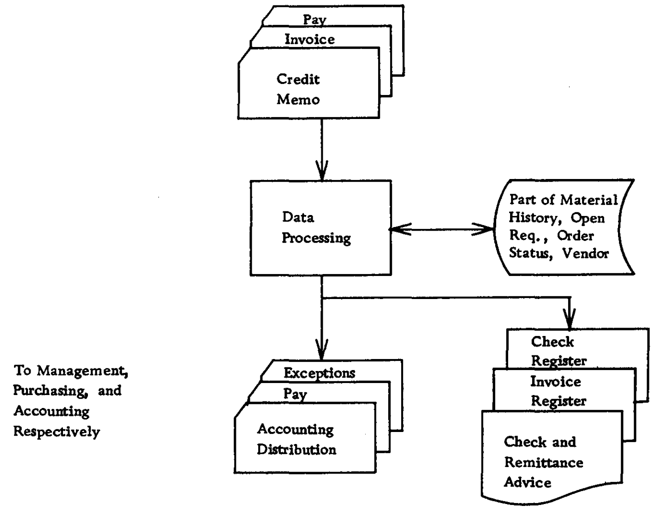


Figure 32. Invoice and check writing

the evaluation of his products. The conformance report is issued on a periodic basis, normally monthly or quarterly. A conformance reporting system of this nature is the first step toward a vendor certification program. When a vendor's quality conformance establishes itself at a consistently high level, it no longer becomes necessary to test his products, and the quality control function becomes simply a monitoring activity. Finally, commitment control is a system which records, monitors, and reports procurement commitment status by pieces, by dollars, or by schedule. Any variance in the quantities negotiated for on the purchase requisition and the final delivery quantities is reported on exception statements. The various exceptions are:

- Aged, open purchase orders
- Overshipments
- Overpayments
- Budget performances by department, project, program, and vendor

To accomplish this, the system edits and audits the transaction into a suspense record. The suspense record is interrogated periodically to produce the actual commitment reports (see Figure 34).

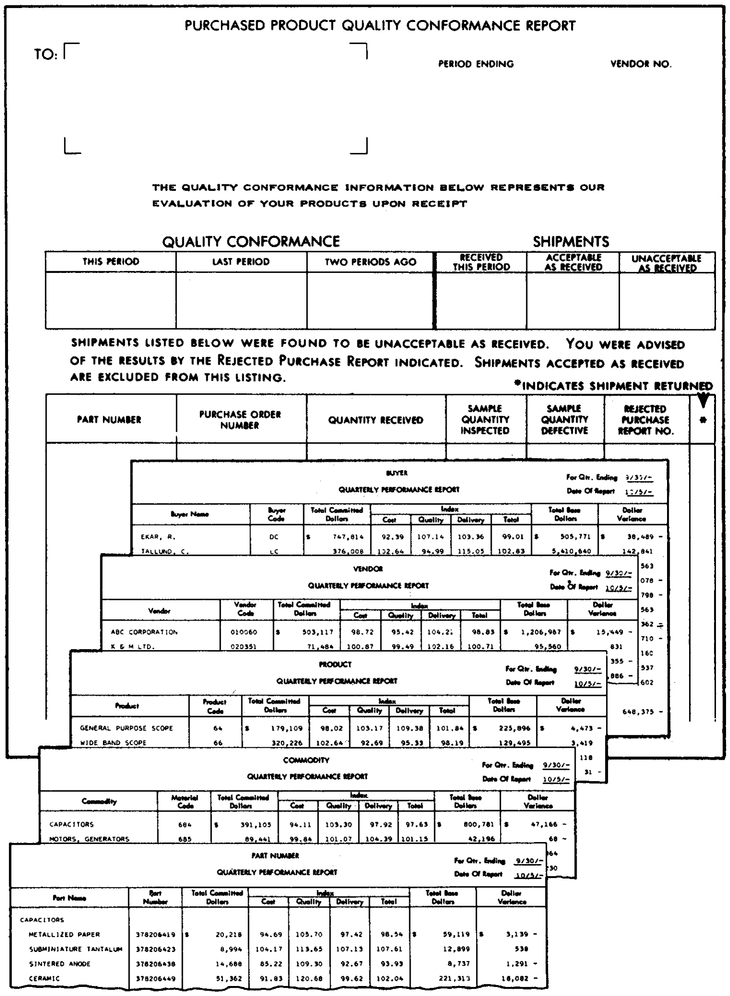


Figure 33. Quality conformance reports

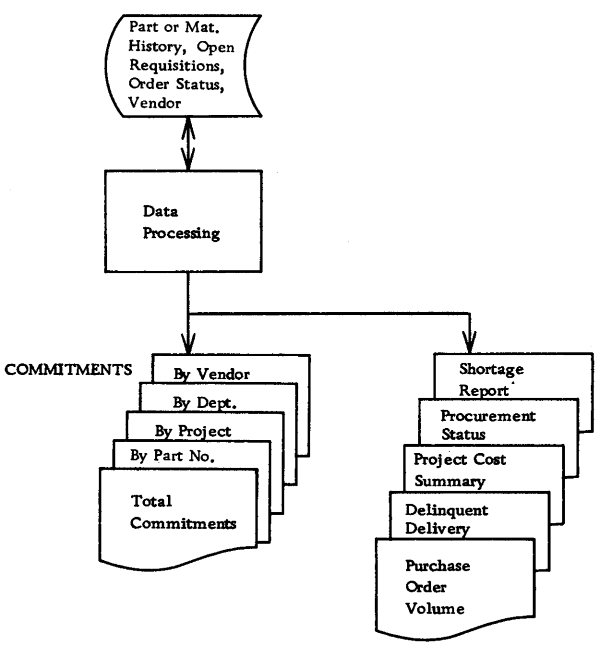


Figure 34. Commitment reporting

MATERIAL DISTRIBUTION

The question basic to all inventory applications and one which involves the maintenance of a record is, "What is on hand?" While at first this appears a simple question, it becomes complicated as the details are introduced. How much is at a supplier? How much is in transit? How much is on the receiving dock? How much is in receiving? How much is in inspection? How much that is rejected can be reworked? How much that is rejected can be accepted on an off-specification deviation? How much is enroute to the stockrooms? How much is in which stockroom? How much is in transit to the manufacturing floor? How much is in floor stock? How much is hidden in personal stock? How much is retrievable from higher assemblies? How much must be held for lot control? How much is reserved for spares? How much is earmarked for nonproductive activities? And so on. The list seems endless.

From this series of questions, it appears that the answer to our basic question, amplified by the subsequent detailed questions, resolves itself into a need for a good feedback system, through which the answers to all the previous questions can be transmitted rapidly into a disk file. The file can be interrogated and the latest information supplied to the interrogator. The data transmission system appears to offer a solution shown in the schematic in Figure 35.

The terminals would be of two types. One would be capable only of transmitting data. This type has the ability to accept information from cards, plastic identification badges, and from manual entry. The record type is able to receive as well as transmit information. It is able to read and punch cards, to accept manual entry, and to create printed output on a printer. The computer would then accept data, process the information, and feed back instructions or other data to key points. In addition to immediate acceptance or rejection of the data, reports can be prepared or exceptions noted. By installing these data transmission devices at various locations, as the material passes any point, inventory information is transmitted via the terminal to the file to update the record.

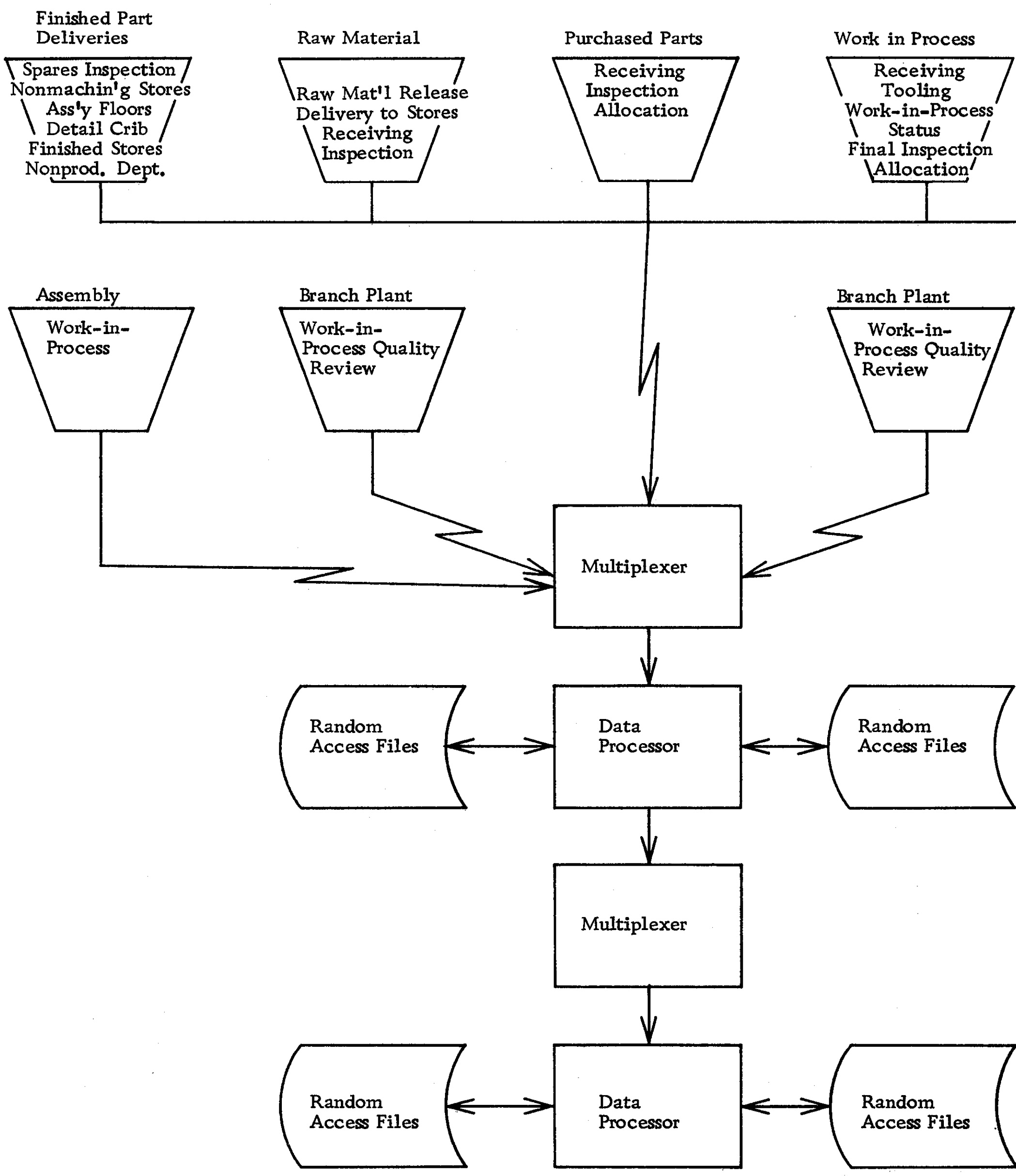


Figure 35. Data collection system diagram

The most basic inventory record appears as illustrated in Figure 36. This basic record is substantially expanded (see Figure 37) because of the complications introduced by the questions stated

Stock No.	Description	Opening Balance	+ Receipts	- Issues	= On Hand
11398	TRANSFORMER	210			210
11402	MOTOR ASM 50	1205	500		1705
11610	CAM	10341		1423	8918
11682	LEVER	433	3500	1255	2678

Figure 36. Basic inventory record

Part Number Drawing Number Section Number Model Number Segment Authority Change Letter Control Prefix Drawing Assembly Number Drawing Assembly Number	
Change Letter Transaction Code Drawing Assembly Manufacturing Code Number Quantity per Assembly Effectivity Start Effectivity End	Repeated for Each Change
Required Quantity Required Date Incremental Delivery Scrap Fallout	Repeated, Depending on Technique of Generation
Quantity on Hand Stockroom # Change Letter Ident. Lot Control Reservation Rec. Unacceptable Released for Build Build Funded Quantity Ordered Quantity Committed Quantity Funded	Repeated by Change Letter, Lot Control, and Stockroom
Outstanding Order by Order Ident.	Repeated for Multiple Outstanding Orders

Figure 37. Expanded inventory record

at the beginning of this section. It is further complicated by the inclusion of engineering change and lot control. At first glance, the reporting and tracing of all the information mentioned seems most complex. To straighten out the complexity requires the selection of salient reporting points. In almost every question cited at the beginning of this section, the area involved has a controlling desk, a supervisor, a dispatcher, or a clerk who is responsible for the checking in and out of material and people. The reporting can be done at these points.

The receiving mechanism for the reporting function, in the form of a random access file, can receive the information instantly and update the files immediately. This method is referred to as real-time processing or online processing. Some concerns do not require such immediate updating; however, to minimize the chance of loss, strayed, or late reporting, they install the same transmission and collecting devices, but accumulate the transactions on tape. At a predetermined time, the tape is sorted and passed against the basic inventory to post all the transactions. A detail transaction register is printed, and current balances are printed on a report or punched into a card for distribution.

This computer method by which inventory records are established provides a reliable basis for management decisions related to procurement, surplus disposition, and other action. Data accepted include information about requirements, procurements, receipts, issues, transfers, and adjustments. This information, when processed, produces reports to indicate additional procurement action, quantity required (adjusted by attrition allowances), and specific dates by which material is needed.

Another function accomplished by the computer is the mechanical transfer of accountability between contracts whenever available material charged to one contract is to be used by another contract. One interesting potential of controls such as this is the practicality of commingling fixed-price and fixed-fee inventory materials to reduce cost, time, and space.

The computer maintains perpetual inventory records for control of inventory balances, as illustrated in Figure 38. These records provide an immediate reaction system in which the varied effects of requirements, procurement, and usage activity are recorded, correlated, and analyzed to make available reports noting exception conditions. These reports of history, action, and operations are provided as the basis for future operations; they become the authority for exercising selective inventory control management. This management-by-exception concept, brought about by a combination of catalog data and a computer-programmed formula, ensures that action conditions are detected and immediately reported. It also ensures a consistent standard of performance regardless of volume.

The source documents illustrated in Figure 38 represent issues from stores, generated requirements, accountability transfers, interim physical inventory adjustments, returns of material to stores, and realignments of material and reworked parts. These transactions are fed into the computer and are processed to update the master records. To assist the planning function (especially in the early phases of a computer installation, when data must be constantly verified), an inventory summary card (see Figure 39) has found wide acceptance. This card is furnished from the computer to show the planner the end result of the transactions on any run. The final balances are available for immediate reference. If the balances appear unusual, reference to the other exception reports and to transaction reports provides detail and follow-up information.

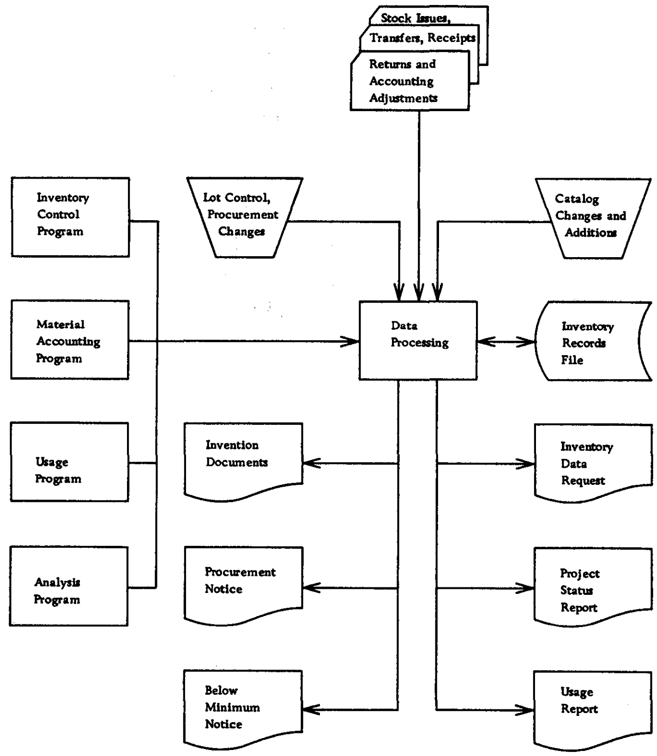


Figure 38. Inventory processing

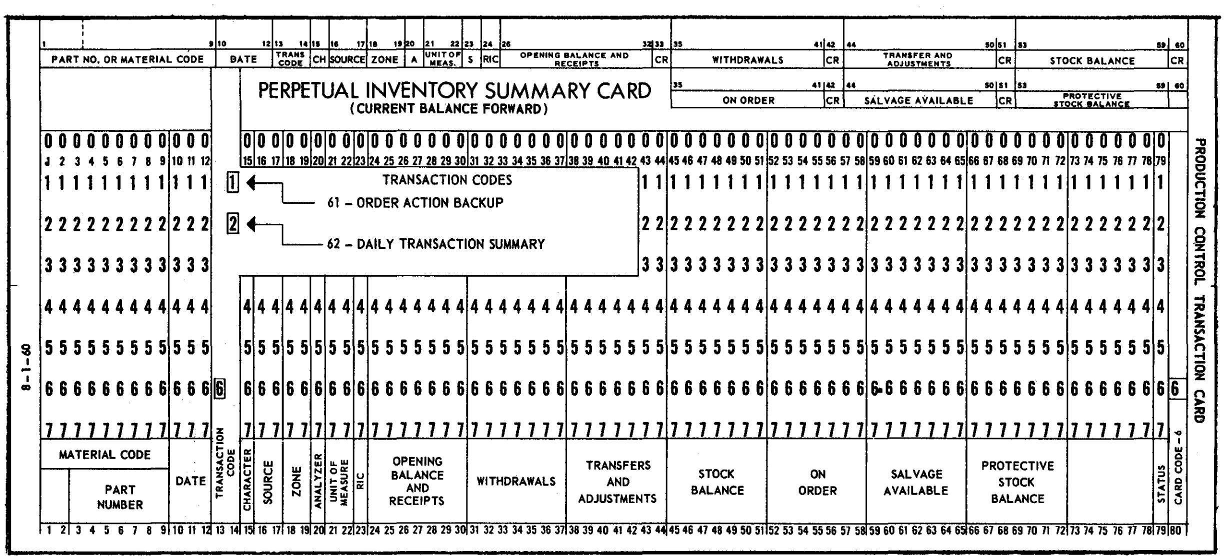


Figure 39. Perpetual inventory summary card

Receiving

Parts or material received into stock are recorded on stock receipt cards and are transmitted to the computer via the data collection device. If the items were purchased, the purchase data were updated with the receipt notice when the items were received. In a similar manner, open-order information was updated and job-order costs were computed with the receipt of manufactured parts into stock. A move ticket, used to move the items into their locations, is illustrated in Figure 40. The location as well as the quantity is noted on the face of this card to allow the information to be communicated to the computer. The stock balance is increased by this quantity and the location is noted in the computer record. Any accumulated back orders can now be filled in the normal manner. Usually, back orders are accumulated in a tub file adjacent to the stock area. The stock clerk checks this file when the parts are physically moved into the area, so that the back-orders can be released first.

One additional source of stock is a "return to stock". This condition arises if the material released to the manufacturing floor is in excess of the quantity needed for production. Normally, the generation procedure should allow only the necessary quantity of parts to be manufactured, but three factors can contribute to an overstock condition:

- First, the anticipated attrition of parts in use does not materialize
- Second, a cutback in production requires that stock be returned to the stockroom
- Third, an engineering change becomes immediately effective. All material in the assembly or manufacturing floor must then be returned to stock for spares or for disposition to be determined at a later time.

Stock is returned on an authorized receipt or on a credit requisition. In any case, the machine adds to inventory and credits work-in-process inventory.

Requisitions

The documentation used to release material from stock is normally one of the following types of requisitions:

- Planned requisition
- Unplanned requisition
- Blanket requisition

Within each of these types, there can be many actual formats but the handling of each within the types is the same.

Planned Requisitions

A planned requisition is the device used to withdraw parts or material, the requisitioning of which was anticipated at this time. To achieve this, the requirements generation procedure discussed earlier predetermines the pattern of requirements. The material procurement procedure provides for an orderly flow of material, so that as any particular day comes about, the anticipated withdrawal of parts or material actually materializes. Under one method of processing, the computer program can be constructed so that the predetermined timed requirements are prepunched requisitions which are forwarded to the stock area for filling, after the quantity has been checked against the quantity on hand as reflected by the stock balance in the inventory record. The prepunched requisition is filled and sent back to the computer to confirm that the material has actually been taken out of stock.

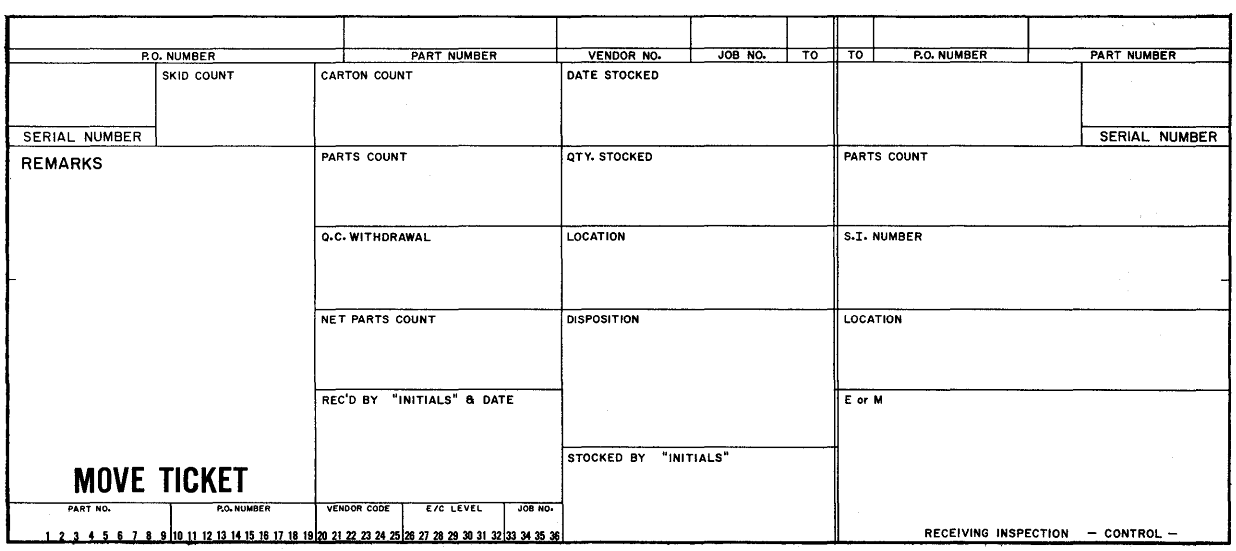

P.O. NUMBER
PART NUMBER
VENDOR NO.
JOB NO.
TO
TO
P.O. NUMBER
PART NUMBER
SKID COUNT
CARTON COUNT
DATE STOCKED
SERIAL NUMBER
SERIAL NUMBER
REMARKS
PARTS COUNT
QTY. STOCKED
PARTS COUNT
Q.C. WITHDRAWAL
LOCATION
S.I. NUMBER
NET PARTS COUNT
DISPOSITION
LOCATION
REC'D BY "INITIALS" & DATE
E or M
STOCKED BY "INITIALS"
MOVE TICKET
PART NO.
P.O. NUMBER
VENDOR CODE
E/C LEVEL
JOB NO.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
RECEIVING INSPECTION — CONTROL —

Figure 40. Move ticket

A second method of processing requisitions is to do the planning in the generation procedure. When the day arrives for use of the material, the scheduling group releases the authorization to begin construction. The engineering list furnishes the information as to what material or parts are needed, and the manufacturing or assembly area originates the documentation to withdraw the necessary material. When the withdrawal is accomplished, the computer is notified and the source of the withdrawal tells the computer that it is a planned source. The stock balance and the planning quantity are then reduced. The machine continually compares the planning quantity with the in-stock and on-order quantities in order to determine when additional parts or material are required. If the part is in the category that requires a formal requisition, the machines can punch requisition cards and print the necessary paperwork. For those items that are controlled by a balance level, a below-minimum notice is prepared (see Figure 41). This notice is forwarded to the material analyzer in inventory control, who takes action to acquire additional stock.

When the prepunched requisitions are released to the stockroom to be filled, they can be accompanied by a prepunched identification and delivery ticket. The requisition itself is returned for processing to reduce the inventory balance. The identification and delivery ticket has a double use: to identify the parts themselves and to provide a record in case it is necessary to trace the movement of the parts. The identification tag can perform these functions. The parts identification tag illustrated in Figure 42 is perforated so that it can be torn into two pieces. The first section is forwarded to the ordering department to indicate that the parts have left the stockroom. The smaller portion can be attached directly to the parts container to identify the parts. If the parts become lost and are returned to the stockroom, they can be identified immediately and rerouted or returned to stock. A positive identification of this nature is necessary to make sure that different parts are not mixed. This card is machine-generated. Since it will not be fed through the machine, it can be stapled to a sack or folder, or, by using the string hole provided, it can be tied to the parts or to the container.

BELOW MINIMUM NOTICE

REGISTER NO.		
MO.	DA.	NR

INVENTORY RECORD STATUS

MATERIAL NUMBER	AVAILABLE BALANCE	INV. BAL.	ON ORDER	OPEN REQMT.	STATUS

PART NUMBER/DESCRIPTION

PROCUREMENT FOLLOW-UP DATA

P. O. NUMBER	OPEN QTY.	VENDOR	DELIVERY PROMISE

INVENTORY CONTROL   DATE   PURCHASING   DATE

Figure 41. Below minimum notice

Unplanned Requisitions

Unplanned requisitions are those requests for parts or material that were not anticipated before the time of actual need. If sufficient time exists, an order can be prepared and the material obtained. If there is insufficient time remaining and there is inventory on hand, this inventory is used and a "procurement change notice" (see Figure 43) is prepared to expedite subsequent orders into stock. These unplanned requisitions can come about because of line scrappage, engineering usage, education, display, etc. In many cases, the usage may not be large, but cumulatively it can become significant. Unplanned requisitions are usually handwritten, as illustrated in Figure 44.

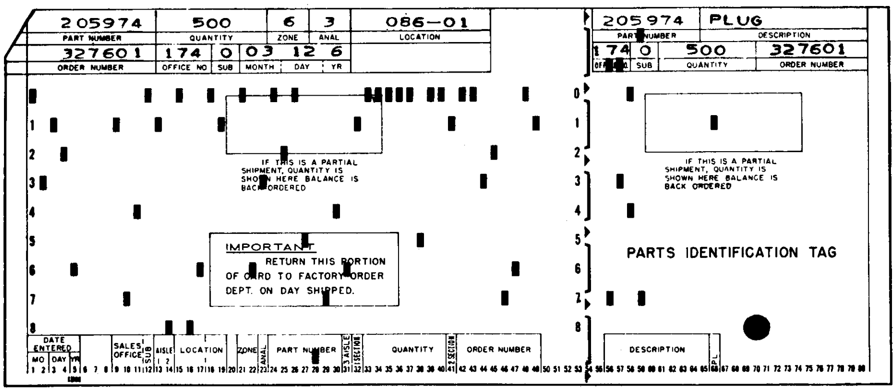


Figure 42. Parts identification tag

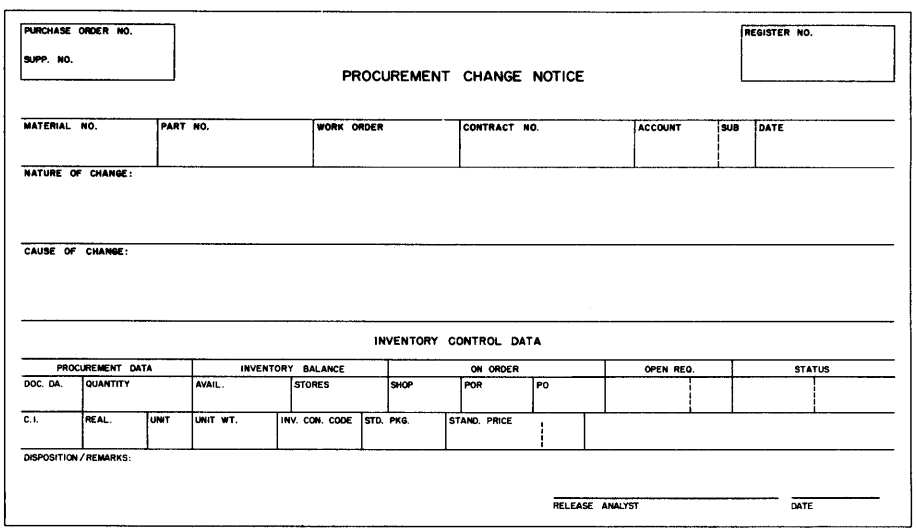


Figure 43. Procurement change notice

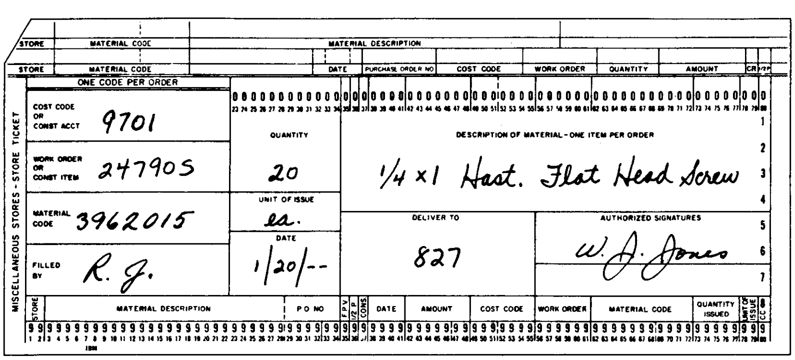


Figure 44. Handwritten requisition

Blanket Requisitions

The third type of requisition is a blanket requisition (see Figure 45). For assemblies that are placed in kits or that are assembled in a dependent sequence, the total requirement list is made up and released. It is then necessary to fill this list completely, or to obtain a deviation permission from the assembly department which receives the parts. The requisition list can be accompanied by a deck of cards that is returned to the computer to update the quantity.

STOCK ROOM

COST DEPARTMENT

MATERIAL REQUISITION

THIS REQUISITION NOT GOOD FOR GREATER QUANTITY THAN QUANTITY AUTHORIZED

ACCT. NO.	START DEPT.	ASSEMBLY NUMBER	RAMAC ADDRESS	ORDER QUANTITY	ORDER NUMBER	STANDARD COST START	FINISH	DATE ISSUED	CODE NUMBER
63	176	HM 200750	16490	1500	05000	055	060	053	630269

PART ACCOUNT	STOCK ROOM	PARTS REQUIRED	UNIT	QUANTITY PER ASSEMBLY	QUANTITY AUTHORIZED	SHORTAGE QUANTITY	MATERIAL	LABOR	BURDEN	TOTAL
63 P		GA 100104	1	010000	1500		150			150
63 M		BC 200536	1	010000	1500		575	1150	1500	3225
63 P		BN 100093	1	010000	1500		225			225
63 P		GA 100088	1	010000	1500		130			130
63 M		HP 200540	1	010000	1500		163	322	491	976
63 M		PL 200533	1	010000	1500		829	1631	2256	4716
63 P		RG 100041	1	010000	1500		225			225
		PAGES	1							
					ASSEMBLY LABOR & BURDEN					
					TOTAL STANDARD COST					

UNIT CODE

1 PIECES	6 SQUARE FEET
2 POUNDS	7 SPOOLS AND ROLLS
3 FEET	8 OUNCES
4 COMMON PART	9 GALLONS
5	10

Figure 45. Blanket requisition

Safety Stock

To protect the production line from being stopped by the lack of parts, a safety stock (or protective stock) is maintained. Safety stock is a small quantity of overstock maintained as insurance against unforeseen demands or late deliveries. This buffer can maintain the production level while delivery of the anticipated stock is expedited. Safety stock quantity is either stated as a predetermined quantity (the total cost of which is relatively small) or as a calculated amount. The size of the safety stock can be calculated quite simply by determining the average demand for a given number of periods and extending this by an arbitrary safety time factor. To make this method useful, distortions introduced by extremes and fluctuating lead time must be smoothed out.

Without extensive explanation, one mathematical formula used to calculate safety stock is given here as an example:

$$SS = SF \quad \frac{(X^2)}{N}$$

where

SS = safety stock

SF = safety factor (a number between one and three, depending on how close to 100% service is required for that part)

X = the amount more or less than the sample average of the demands for each of the statistical periods used in the sample

N = number of statistical periods used in the sample

A second, less complicated method is to determine what percent of standard lead time is required to expedite stock into inventory on a crash basis. The calculation for safety stock then becomes:

SS = CLT (ADU)

where

SS = safety stock

CLT = crash lead time in number of production days

ADU = average number of parts used per production day

Safety stock quantity thus determined is always deducted from the current stock balance or from the first order due in, before figuring the number of production days that the current stock and open orders will cover. This quantity is then maintained as the safety or protective stock.

Status

The flow of parts and material into, through, and out of the plant constantly generates transactions to report the movement of these items. Periodically, it is necessary to provide management with milestone reports on the current status of inventory activities. Exception and summary reports then furnish the next level of detail to allow the alteration of old plans and the formulation of new ones. The number and complexity of the reports actually depend on the company organization, the recipient of the information, and any coordinating functional areas that need to be informed.

Some of the reports that have proved useful to various companies are shown in Figure 46. With the information collected by the previously discussed programs, many informative and analytical reports are possible, in addition to notices of unusual conditions that are constantly being generated as the transactions are processed and the balances are updated. Examples of reports are:

- Stock status
- Consolidated stock status
- Inventory by class of material
- Inventory analysis
- Velocity
- Activity
- Usage analysis

These reports are generalized reports, documents that are used by the active management of a company. In addition, there are reports required by the government or commercial customer. Examples of these are cited in several IBM manuals*. In these cases, the format and frequency of the reports are specified by the terms of the contract. They generally conform to standard government formats to allow the government to have a standard reference rather than many different reference formats.

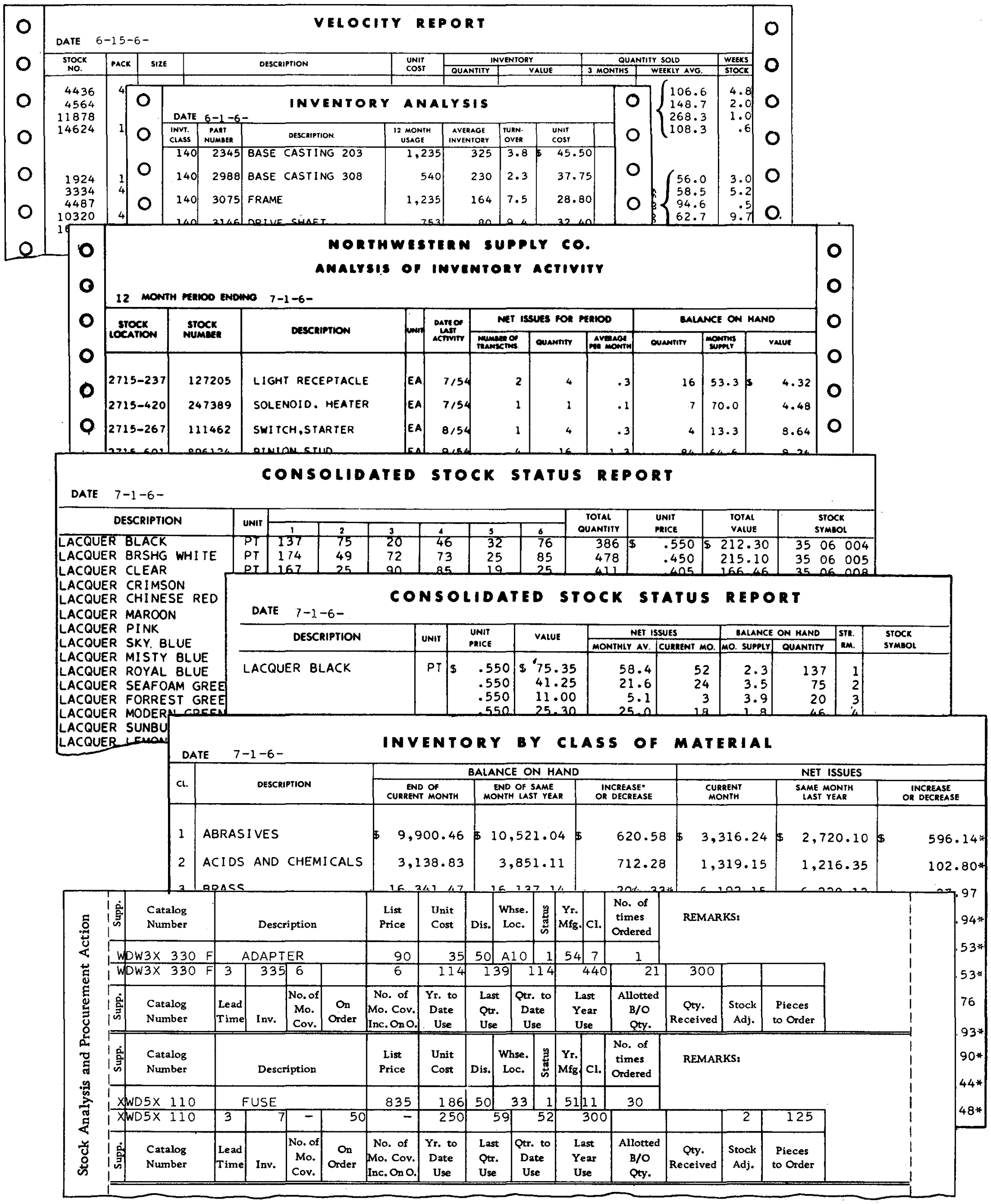


Figure 46. Inventory reports

* See Aerospace Information and Control Systems — Product Support (E20-8122); Aerospace Information and Control Systems — Configuration Management (E20-8116); and Aerospace Information and Control Systems — Project Scheduling, Budgeting, Education and Control (E20-8127).

With the increased use of computers in government agencies and in private industry, many contracts now specify the requirement for tapes prepared on the contractor's site, using a prespecified, tape record format. These tapes can then be processed by the government agency to its own specifications. Furthermore, tapes can be used as many times and in as many conditions as may be necessary; this appears to offer many advantages over the mere furnishing of printed reports.

The consideration of reports is important, as a great many reports require interrogation of the requirements, inventory, on-order or the in-process inventory, all of which appear in the master inventory record. Not only are interim reports produced from these records, but documentation to support requests for partial or interim payment is made through the accounting system, which is fed inventory information from the inventory master file.

Material charges are generated when the requisitions that withdraw the material are processed through the computer. Withdrawals chargeable to the contracts for which the inventory was intended can be discerned, and summary totals can be accumulated to show the progress of the project. Likewise, the machine discerns when material is withdrawn to be used on a project other than the one originally designated. The machine then reduces the inventory charges for the original contracts, increases the charge for the contract using the material, and prepares detail or summary transfer notations, depending on the degree of detail desired. All this is accomplished in addition to the normal inventory record updating and preparation of material charges reports (see Figure 47).

External Transportation

An integral part of material planning and inventory management is external and internal transportation of goods and work in process. Specifically, transportation affects the inventory level, the investment required for service, the manufacturing lead time, the location and number of warehouses, and, ultimately, the cost of the product.

Transportation of the end product or receipt of material from the vendor is classified generally as external transportation. The three functional areas of external transportation are shipping, traffic, and receiving.

Shipping

The shipping department is responsible for preparing the finished goods for shipment according to schedule and in conformance with standard or con-

MATERIAL CHARGES

[*] PRODUCTION ORDERS — W.I.P. DEBIT

[ ] EXPENSE ACCOUNTS — DEBIT

DATE 7-15-6-

PRODUC. ORDER / EXPENSE ACC. #	DEPT. CHGD.	MATL. CLASS	STOCK NO.	QUANTITY	AMOUNT	TOTAL
12248		310	20400	786	$ 1,083.18	
12248		310	38942	500	2,574.60	
12248		340	53814	526	2,540.58	
						$ 6,198.36 *
12253		320	10005	60	$ 1.74	
12253		320	20001	54	20.20	
12253		340	30730	85	96.41	
12253		410	27804	60	143.50	
						$ 261.85 *
12315		310	41693	212	$	
12315		310	52634	210		
12315		320	61056	216		
12315		360	14702	220		
12331		310	20400	786	$	
12331		320	20012	710		
12331		480	36840	790		

Direct Issues Are Charged to a Work in Process

MATERIAL CHARGES

[ ] PRODUCTION ORDERS — W.I.P. DEBIT

[*] EXPENSE ACCOUNTS — DEBIT

DATE 7-15-6-

PRODUC. ORDER / EXPENSE ACC. #	DEPT. CHGD.	MATL. CLASS	STOCK NO.	QUANTITY	AMOUNT	TOTAL
800010	1	410	59135	21	$ 26.25	
800010	1	410	86284	17	18.70	
800010	1	425	65139	5	70.93	
						$ 115.88 *
800010	5	300	62135	500	$ 625.00	
						$ 625.00 *
						$ 740.88 ¤
800015	3	200	17200	100	250.00	
800015	3	305	25070	50	112.50	
						$ 362.50 *
800015	25	450	17680	12	$ 421.20	
800015	25	700	67500	1,000	500.00	
800015	25	825	43750	15	19.50	

Indirect Issues Are Charged to Expense Accounts

Figure 47. Material charges reports

tract practices. Packaging materials, such as boxes, liners, pallets, and special material for critical or fragile items, must be in stock and available for use as each order arrives for shipment. Lack of packaging material can mean delays in shipment, affecting the fulfillment of customer contracts. Particularly sensitive are those contracts with a penalty clause for late delivery. Occasionally this deficiency has the far-reaching effect of shutting down a production line.

For the reasons stated above, many companies are maintaining packaging inventory controls on critical materials, such as containers, boxes, wooden crates, and special liners. The requirements for these items are developed by maintaining packaging bills of material and calculating the quantitative requirements for use coinciding with the final assembly or the post-inspection time period.

Some items, because of their nature, size, shape, or composition, require not only specialized containers, but even specialized modes of transportation. These modes can be water transports, trailers, specialized planes, or rail cars. All of these requirements must be planned during the engineering phases so that the transportation is available when the item is ready. It then becomes necessary for shipping to work in close cooperation with design, engineering, production, and assembly, as well as with transportation companies, to achieve the end result of delivery of the article in good condition.

Traffic

The specific responsibilities of a traffic department are to select the best mode of transportation (considering the product to be shipped, the distance to travel, and the time provided for delivery), process damage claims, and prepare and authorize bills of lading. The bill of lading is automatically printed on data processing equipment during order-writing or invoicing applications; it is then forwarded to the traffic department for final authorization.

The traffic group is charged with the responsibility of investigating and instituting more efficient and less expensive means of transportation and distribution of goods. Automated statistical analysis of massive sales data, categorized by geographic area, customer order frequency, and volume, is required for this purpose.

In line with any of the specialized needs outlined above, traffic must be responsible for the negotiation with transportation firms or government agencies for the actual shipping of the article. If surface transportation is to be used, clearances, licenses, and permits must be obtained where required; and physical factors, such as height, width, and weight clearances for overpasses, underpasses, and roadways, etc., must be checked.

Receiving

The basic receiving functions are unloading and unpacking materials, checking the quantity received against the receipt notice prepared at the time the purchase order was written, and routing the material through inspection to manufacturing or storeroom locations.

Many companies combine the functions of receiving and inspection at the receipt point, while others maintain an inspection area where all material is directed for sample or 100% testing. The traffic department is responsible for receipt approval and for filing claims for any material damaged in transit.

Data collection equipment plays an important role in notifying the purchasing, materials control, storeroom, and accounting departments that an order has been received and in what condition it is received. This is accomplished through the use of a prepunched receipt card, the entry of variable data through key control, the transmittal of information to the data processing area for quick updating of pertinent control records, and the notification of the departments concerned in regard to any exceptional variances requiring management review and action.

The internal information transfer has been discussed in the inventory section of this manual.

Internal Transportation

Stock pulling for assembly and shipping can be handled effectively by recapping orders with similar stock locations and destinations. The establishment of active and reserve stock locations serves to concentrate order filling in a smaller area and to eliminate time-consuming back tracking on the part of stock pullers. Sales and production analysis of item activity provides the statistics needed to evaluate warehouse and storeroom layout plans.

The performance of a shop is directly related to the efficiency of internal transportation. Dispatching, priority scheduling, and lap-phasing operations are dependent on efficient material handling and on the availability of equipment as required. Scheduling of conveyer equipment, such as forklift trucks and pallets, and overhead cranes, provides operating management with an additional tool for meeting order/shipping schedules on time. By prespecifying the equipment needed, the computer can schedule the equipment to determine load and possible conflicts. The result can be communicated to the traffic department.

MATERIAL MAINTENANCE

Between the time that parts and material are checked into inventory and the time when they are checked out to be used, they have to be physically housed and cared for. Care must be taken to assure that they are properly identified when received, properly located in storage, and the location noted so that they can be retrieved when needed. These storage locations must be correlated to other quantities of the same material.

If age is a factor of consideration, parts must be rotated and the oldest stock used first. If they are serialized, the serial numbers must be available and the parts used in sequence.

Care must be exercised so that parts (especially similar parts) do not become mixed. Quantities received into stock and quantities removed from stock must be carefully and constantly monitored, so that the quantity expected to be on hand is actually there. If physical deterioration is possible, the facilities provided must prevent this deterioration to every possible extent. Items subject to pilferage must be protected and monitored. This section is not meant to be a treatise on warehousing; however, good warehousing techniques must be in effect if the inventory quantities stated in the records truly reflect what is in stock.

Most of the transactions affecting stock receipt and issuance have been discussed in other sections; therefore, only the actual transactions affecting the stock while it is under the care of the stockroom are reviewed here.

Lot Control

With the advent of high-precision items, and especially of chemical and electronic items, lot control has become extremely important. In some current contracts, quantities of items are manufactured in lots, to a predetermined compound or degree of accuracy. A portion is used in production, and the balance is then stored, not to be used except as individually specified. In the area of missiles, for example, where constant systems checking is performed or where it is operational continuously, if a component goes wrong, it is most advantageous to replace that component with one that is identical. A component manufactured at the same time out of the same block of material best suits this description. By maintaining a predetermined group of these items in stock, one can be withdrawn and used.

Another use of the lot balance inventory is this: if the item continually fails in use, the balance of such items can be tested to determine the source of the constant failure. The failure can thus be pinpointed to design, material, or production error, and the situation corrected.

To reduce the tremendous inventory in maintained lot inventory, some contracts are negotiated to allow the maintenance of the balance lot inventory for a predetermined time or until a particular "shoot". The maintained lot balance is then released and absorbed into inventory as a new lot, with a new (and smaller) quantity to be held as a balance lot inventory.

The balance lot inventory is normally a percentage of the original receipt quantity. The items themselves are usually stamped with the lot number or are serialized by item, and the lot consists of items between two serial numbers. If lot control is present, the lot numbers or the affected serial numbers must be maintained in the inventory records. The inventory on-hand balance then must be reduced by the reserved balance lot inventory quantity, as well as by the safety stock, before calculating the balance available for production activities. When a serialized item is withdrawn from stock, a transmission is made via the data terminal to the file records. This transmission records the withdrawal, updates the balance, removes that serialized item from the available list, and updates the configuration statement of the end item into which the item is placed.

Rework and Repair

The need for physical care of the material and parts in inventory has been discussed; however, in the event that the inventory is handled and broken, or that it deteriorates with age to the extent that it has to be repaired, a procedure is necessary which will check damaged items out of stock. When inspection indicates that repair is necessary and that it is more economical to repair the item than to scrap it, a work authorization is prepared. The work authorization not only gives authority to withdraw the item from stock, but allows the accumulation of cost for accounting purposes. The shop orders for repair usually carry a specialized order number (such as all 9's or an equivalent treatment) so that they can readily be identified as repair orders. When the items are withdrawn from stock, the inventory record must indicate that the items are on a repair order. This means that the material can be expedited rapidly into stock, but it should be considered unavailable for allocation. After the repaired items have been inspected, they can be received into stock like any item, after which the inventory balance is increased, the shop order closed, and the cost totaled and charged to the appropriate account.

Although it is administratively handled the same way as repair, rework usually comes about in a different way. When an engineering change is undertaken against any part, one of the determinations is whether this current design is sufficiently similar to the new design to allow the current design to be reworked into the new design. If the part can be reworked, the engineering change is coded "rework in stock and in process". In material planning, the engineering change analyzer makes out the work authorization to rework the parts to the new configuration. The cost of rework must be part of the consideration as to whether an engineering change is to be done. The rework costs are accumulated and charged against the budget for that engineering change. The withdrawal and return procedures are the same as for repair.

During test or after an item has become operational, constant feedback of failure reports is maintained. If excessive failures are reported for a particular part, the balance of the inventory on hand is pulled out of stock for inspection. If it is determined that the items can be reworked into an acceptable condition, a work authorization is prepared and the items are reworked. Here again, the actual activities are the same as for repair, the main difference being who signs the work order and whose budget is charged for the work performed.

Inventory Count

One of the most important items on the balance sheet of an organization is cash. Every precaution is taken to not only protect it, but also to account for its acquisition and disbursement. A good part of this cash has been or will be converted into materials. However, this is a mere change of form; it still represents money and is an important item on the balance sheet. This concept of materials

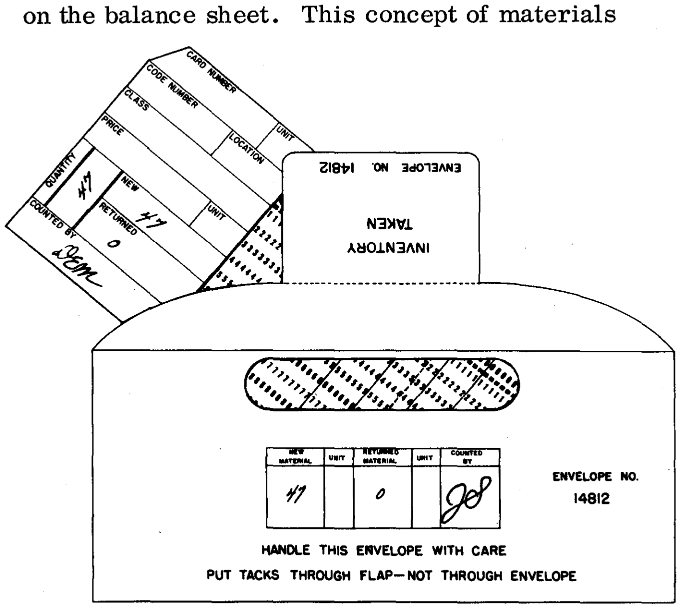


Figure 48. Card and envelope inventory set

makes desirable the same caution with regard to materials in inventory as with actual cash.

No matter how complete and comprehensive the inventory book records may be, they must be verified against the inventory on hand by a physical count. This count is the physical inventory. To be of any value, the physical count must include every item of inventory. When the count has been compiled and verified, its value is computed and the book value adjusted, if there is any difference. If revisions are downward, they have essentially the same effect as a cash shortage.

Many plants suspend operation while the inventory is being taken. However, there are situations where the inventory count on specific items must be taken too frequently to suspend operations; or the load may be so great that other measures must be taken not to disrupt operations.

A complete physical inventory is usually taken annually, and because of the magnitude of the job, the element of time is critical. Delays can be avoided if the procedure is planned in advance.

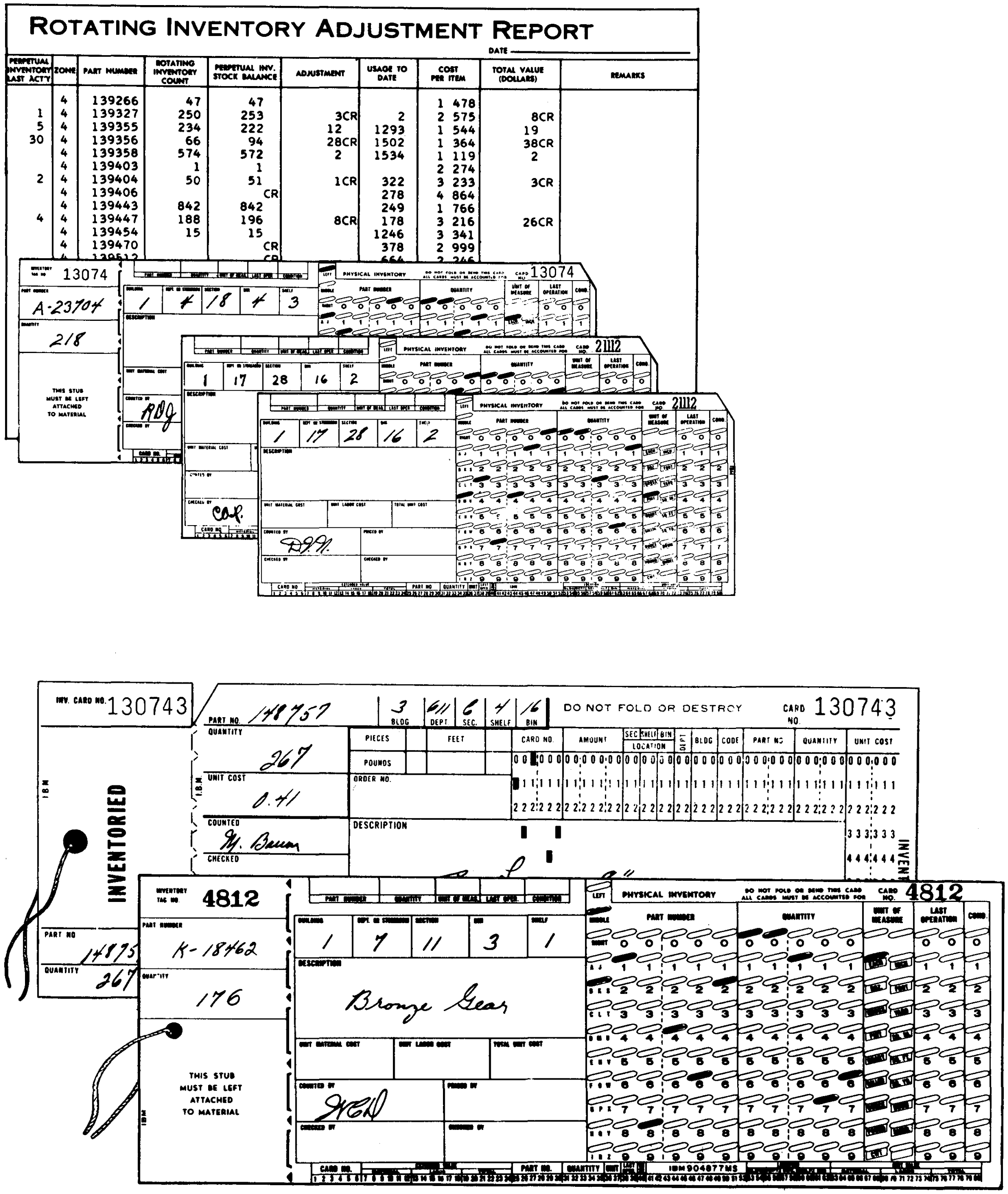
One technique to ease the burden of taking inventory is the installation of a rotating inventory count (RIC). By definition, RIC is a planned periodic program for counting each stocked item at lease once a year, and more frequently for items of greater value. The actual plan is related to the value classification of the inventory, which requires the more valuable items to be counted more frequently. An example of this count stratification is shown in Table 4.

Table 4. Count Interval Based on Unit Cost

Unit Cost	Count Interval	Times per Year
$ 0 - 9	0 bin stock level	-
9 - 99	240 days	1
100 - 399	120 days	2
400 - 998	80 days	3
1800 - up	60 days	4

To accomplish the rotating inventory count, the cutoff for receipts and issues of any item must be carefully monitored. One method of accomplishing this without disrupting the steady flow of material is illustrated by the card and envelope in Figure 48. The clerk handling the rotating inventory count performs the count and fills out the inventory count card in the envelope. He tears off the numbered tab on the flap of the envelope and retains this tab. The envelope is left in the bin location with the parts. If additional receipts or issues take place during the balance of the day, the stock receipt card or the requisition cards are left inside the envelope. The parts themselves are placed in the bin if the stock transaction is a receipt, or they are removed if the stock transaction is a requisition. The transactions prior to the count are processed in the machine. The count card is then processed to verify the computer balance. The transaction cards for the balance of the day are in the envelope in the bin. The very first thing the following day, the inventory clerk circulates through the inventory area and retrieves all the envelopes. The clerk verifies that all envelopes are present by comparing the numbers on the retrieved envelopes with the flap stubs removed from the envelopes when they were placed in the bin. The transaction cards in the envelope then go in with the current day's transactions, and the count is then in phase with the transactions.

In the event the transactions involving the inventory are transmitted via a data collection terminal to the data processing center as they occur, it is


ROTATING INVENTORY ADJUSTMENT REPORT

DATE

PERPETUAL INVENTORY LAST ACT'Y	ZONE	PART NUMBER	ROTATING INVENTORY COUNT	PERPETUAL INV. STOCK BALANCE	ADJUSTMENT	USAGE TO DATE	COST PER ITEM	TOTAL VALUE (DOLLARS)	REMARKS
	4	139266	47	47			1 478		
1	4	139327	250	253	3CR	2	2 575	8CR	
5	4	139355	234	222	12	1293	1 544	19	
30	4	139356	66	94	28CR	1502	1 364	38CR	
	4	139358	574	572	2	1534	1 119	2	
	4	139403	1	1			2 274		
2	4	139404	50	51	1CR	322	3 233	3CR	
	4	139406		CR		278	4 864		
	4	139443	842	842		249	1 766		
4	4	139447	188	196	8CR	178	3 216	26CR	
	4	139454	15	15		1246	3 341		
	4	139470		CR		378	2 999		

Figure 49. Sample inventory cards and reports

not necessary to leave the envelope. The count is performed. The clerk verifies that all the inventory transmissions have been completed up to that point in time and then transmits the balance he counted. The computer will insert the count in the record and perform the necessary comparisons with the balance previously maintained in the file.

Items not controlled by the rotating inventory count procedure are counted during the annual inventory. For the annual inventory, one of the types of cards illustrated in Figure 49 is used. The normal procedure is to count the items and record the count on the card. The stub of the card is left with the items counted; the main card is processed as the inventory count. The stub with the minimum information left on it is used for two purposes: first, it allows an auditor to choose at random any item he desires to verify. The auditor selects the item, performs his count, and checks his count and identification against the count and identification on the stub. If the counts are identical, the auditor has proved the veracity of the original count. Second, leaving the stub with the item allows any count supervisor, auditor, or manager to verify visually which items have been counted and which remain to be counted. In addition, the stub stops another clerk from counting the same items. If the items are tagged with a stub card, they have been counted; counting them again would distort the inventory figure. For inventory in a known location, prepunched cards can be prepared. These cards contain only the part number and location. The balance of the information is inserted on the face of the card.

One other card technique is the use of mark-sense cards. An illustration of this is shown in Figure 49. When the count is performed, the figure is recorded by marking the appropriate position under "Quantity" on the face of the mark-sense card. A machine that can read these marks is then used to read the figure and to punch a hole in the desired field in the face of the same card. This method saves considerable time that normally would be used keypunching the count into the card.

An alternate method is to perform the count, insert the amount on the face of the card, and give the card to a clerk at the data transmission terminal. The clerk merely inserts the prepunched card into the terminal and keys in the amount. The information is transmitted to the computer center.

The count cards from either the rotating count or the annual count or both are processed through the computer as illustrated in Figure 50. The sum total of all the inventory locations of any particular part is compared with the inventory or record. To speed the processing, if the difference in count is either less than 10% or less than $1, the count is accepted and the plus or minus difference is noted on an inventory adjustment report (see Figure 49). For those items for which the count is outside the tolerance limits, a recount card is cut and a recount is performed. If the difference still exists, an adjustment is made. An additional exception report is made to allow an inventory clerk to attempt to reconcile the difference.

The accepted cost of the item is on the inventory record. By extending the quantity obtained on the count times the cost per item, the value of the total inventory of that item is obtained. The sum total of all the values of the parts is the value of the total inventory. This total value plus or minus the adjustment should equal the book value of the inventory.

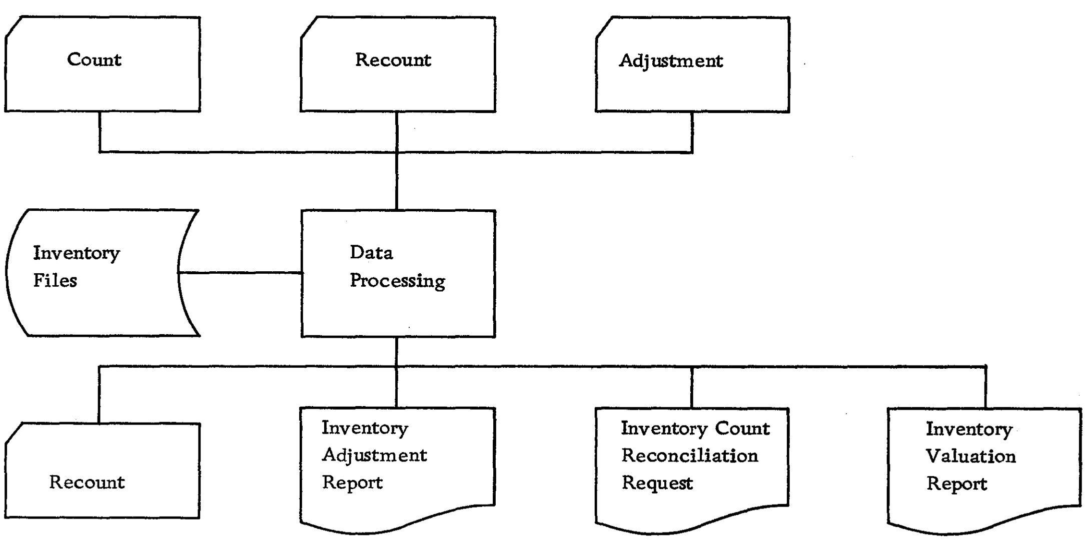


Figure 50. Inventory card count processing

MATERIAL DISPOSITION

The final area of material control to be discussed is that of material disposition. Normally, material is received into stock in relatively large quantities and, in turn, is sent out to a customer or to the production activities of the plant as required. In other words, the pattern is one of normal receipts and requisitions. However, from time to time there are excess materials and parts for which a disposition must be made.

In the previous sections, the generation of requirements and the analysis of current stock balances have been discussed. The items most interesting from the disposition standpoint are those items for which there is stock but no stock requirements. After unwanted stock has appeared on the inventory report for a specific length of time, it must be reviewed for surplus declaration.

Surplus items can be raw materials, purchased parts, fabricated parts, and line flow and fabricated assemblies in excess of known requirements on contracts. Government-furnished property (GFP) items, company-owned equipment, special tools, and special test equipment are normally excluded from this consideration, as they are handled by terms of the contract, or are advertised and sold on bid.

If, after the review of the stock by production planning, it is determined that no additional contract requirements will materialize in the future, the item is declared obsolete and surplus. An obsolete and surplus notice (see Figure 51) is prepared by the machine. The computer searches the activity for a cause of the surplus condition and identifies this cause on the document. The format of the document has space for subsequent stores handling.

The advantage of the computer analysis is that it ensures that surplus material is promptly detected, identified as to cause, and an aged follow-up provided to ensure that action is taken.

Production items become surplus as a result of any of the following:

- The advance bill-of-material details are not called out on production release drawings.
- Advance bill-of-material details are altered on the production release drawing.
- Engineering changes are made to production units.
- Engineering changes are made to spare items.
- Material is made surplus by contract termination.
- Reduction of master schedule items takes place.
- Removal of spares requirements takes place.
- The anticipated attrition is not experienced in the manufacturing cycle.
- A reduction in interplant requirements occurs because of any of the preceding changes in activity.

OBSOLETE & SURPLUS NOTICE — REGISTER 12 40153

MATL. NO.	PART		UNIT	DATE
06 701057	87-95900-066	TRANSISTOR	PC.	DEC. 15, 1963

QUANTITY REQUESTED	STORES QUANTITY TRANSFER	CAUSE
54		NET CHANGE LIST CIC 36994

ITEM STATUS					CATALOG	
ON HAND	ON ORDER	REQ'D	REALIZATION	STATUS	RLZ	UNIT COST
357	0	275	28	54	110%	1.47

LINE VALUE	WORK ORDER
79.38	123-0114-260

DISPOSITION	BY	DATE

Figure 51. Obsolete and surplus notice

With the identification of the cause of the surplus, the responsible department is designated so that the cost accounting procedure can properly allocate the charges. The rule of thumb generally applied is that the department originating the change is the department responsible for the charges, unless an alternate department is designated. Inventory control is normally charged for surplus resulting from unrealized attrition except in a few selected cases:

- Products manufactured in excess of order quantities
- Excess material discovered in the manufacturing area and returned to the home inventory

In these cases, the reason and supporting documentation is referenced on the surplus document.

When a purchase order is written, a card is created which is sent to the proper raw material receiving area. When the material arrives from the vendor, the card is entered in a data collection terminal which transmits a record of raw material to the central computer. When the raw material is moved to inspection, the card is used again in a data collection terminal, with a different transaction code to signal that the material is in inspection. Disposition of raw material stores is also recorded with this card. When the material arrives at raw material stores, its receipt is recorded via a data collection terminal using the original card as input.

When raw material is to be released to the shop, a raw materials release is generated at the output terminal in raw material stores. The release is a punched card which is reentered in the data collection terminal to transmit a record of raw material being physically sent to the shop. The inventory record can be printed to allow inspection of the current condition, or an inventory record card can be maintained by transfer-posting the current transactions and their result onto a record card (see Figure 52).

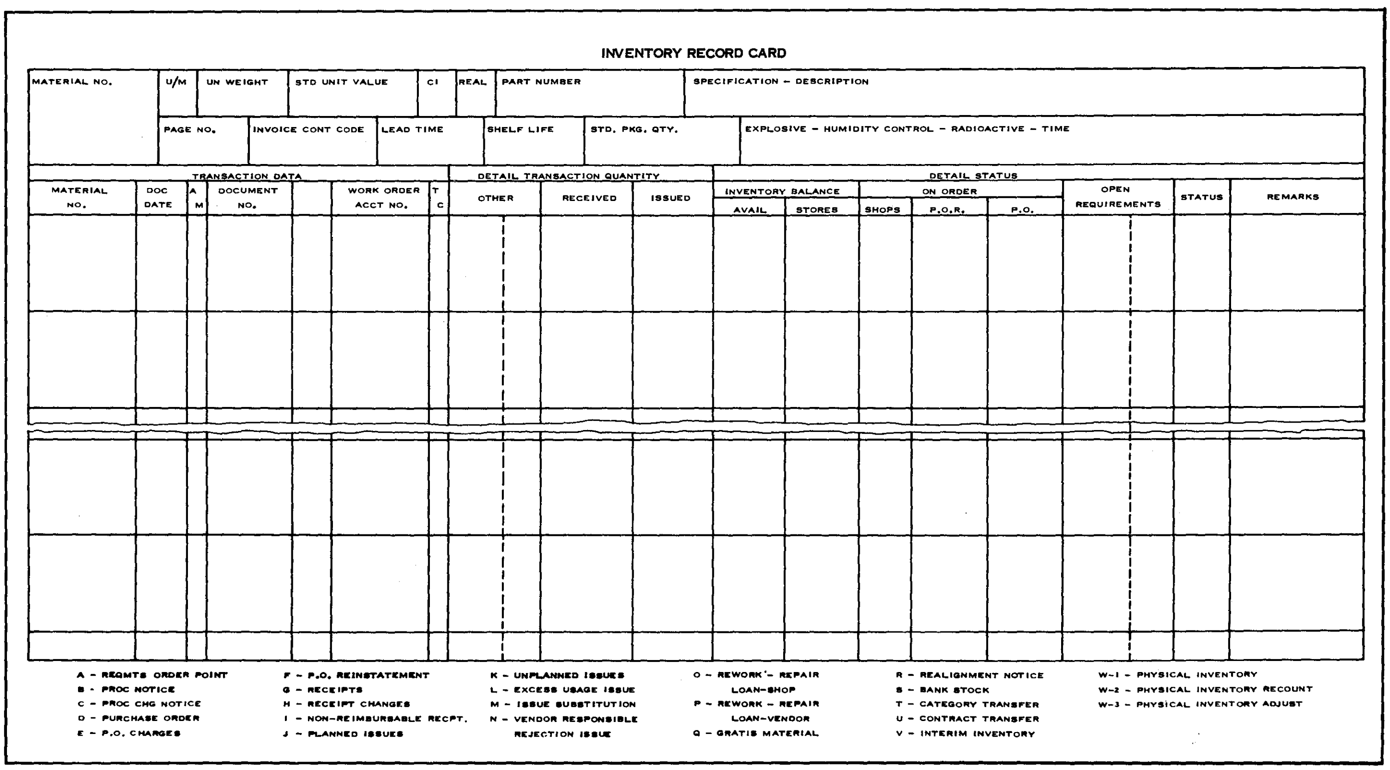


Figure 52. Inventory record card

SUMMARY

A good material control system is a management tool which provides accurate, useful, and timely data to all levels of an organization and supports the operational activities. Efficient data collection, ready access to comprehensive data, and elimination of redundant data handling and redundant data files are its principal features. Data files are organized for use by multiple system functions to achieve greater efficiency in processing and data organization. Through the data transmission terminal, data captured at original sources are entered into the files with reduced possibility of error. Coincident with the reduction in potential errors is the immediate updating of the master files. From the master files reports are generated, parts are ordered, and decisions are made. This eliminates information file phasing problems.

The approaches discussed here have been tailored to the aerospace industry. Some of them have proved to be useful in other industries. The objectives of all approaches however, are to indicate that:

- Material planning cycles can be reduced, with a consequent reduction in cost and a substantial reduction in time, through the use of computer processing.
- Purchased items can be negotiated, acquired, and their flow monitored with reduced effort by means of a purchase system supported by data processing equipment.
- Inventory balances and supporting records monitored by the computer can be constantly examined for new order requirements, and any unusual inventory circumstances can be brought immediately to planning's attention.
- Count requirements for constant verification of record balances are computer-monitored to verify the record accuracy and to comply with auditor requirements.
- The cost of maintaining inventory can be cut by closely matching the need dates to quantities of inventory on hand based on production need. This improves inventory turnover and aids in meeting production schedules.
- The cost of operating the material release and control department can be reduced. Computer processing can handle varying production levels without wide fluctuation in personnel requirements.
- A material control system can react to production problems, delays, and losses by triggering order adjustments as needed. Any major schedule change can be examined overnight. New releases are processed in a single cycle instead of requiring weeks of extra effort.

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