ENGINEERING DOCUMENTATION CONTROL HANDBOOK

Configuration Management

Second Edition

by

Frank B. Watts

EC^3 Corporation
Winter Park, Colorado

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About the Author

Frank Watts is a consultant with over forty-three years of industrial and consultation experience. He founded his own company to specialize in configuration management.

Formerly, he was a Director of Engineering Services, Director of Operations and a Director of Manufacturing Engineering, also managing Configuration Management, Cost Estimating, Industrial Engineering, Test Engineering, Pilot Production and Repair Operations. He has contributed as a Design Engineer, Industrial Engineer, Manufacturing Engineer, Systems Analyst and Project Manager.

Frank has guided the development of the engineering change control process at many companies and made significant contributions toward improving the new product release process, installed MRP II systems, new numbering systems, helped companies attain a single BOM databaseand guided reengineering of the CM processes.

A graduate of the University of Illinois, he also did graduate work at the University of Iowa. His industrial experience was with Caterpillar, Collins Radio, Control Data, Storage Technology, UFE and Archive. He is an ADPA (now NDIA) Certified Configuration Manager. He has a variety of products and services available (see www.ecm5tools.com).

Frank Watts currently resides in Grand County, Colorado, and may be reached at the following address: EC^3 Corp, P.O. Box 205, Winter Park, CO 80482, telephone (970) 887-9460, ec3corp@RkyMtnHi.com.

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1

Introduction

Why Engineering Documentation at all? Why control of that documentation? The mere use of the word "control" puts most engineers into a very defensive posture. Are we trying to stifle the engineer's creativity? What is there to "manage" about the configuration of a product?

Why do architects make drawings and specifications for a home or plant? Does the architect do this for his own pleasure? Or for the trade magazine or show? Isn't the documentation done so that the customers get what they want? Aren't the documents for the builder who has to build the house and for the eventual owner who will have to maintain it? Try building or maintaining a product without adequate drawings and specs, it becomes especially difficult and error prone when changes are being made. Try controlling the cost without controlling the changes. Still, most businesses operate to some extent without proper, timely or adequate control, on their documentation. The symptoms are usually everywhere. A look at symptoms:

Manufacturing says:

- I don't understand what I'm supposed to build
- What criteria do we test to
- Where is the change I need to:

  Reduce costs

  Avoid making scrap

  Avoid making parts that will have to be reworked

- Will this change increase the "bone pile" of down-level material

Sales says:

- You mean the product isn't ready for the market window
- Where is that new feature you promised
- Why didn't we deliver a product with the options the customer asked for

Customer says:

- I didn't get what I ordered
- Where is the fix you promised me some months ago
- Where is that new feature or option

Dealer/Field Service says:

- Shouldn't my documents match my product
- Where is the fix for this nagging product or software problem

Repair says:

- It would help me to fix it if I knew what is in this product
- What changes should be and shouldn't be incorporated upon repair

Quality says:

- Is this cost in our Cost of Quality
- Should we treat ourselves or our customers this way
- How can we meet our customer's standards
- We can't meet ISO/QS/AS standards

Employee says:

- I asked them to do something about this a long time ago

Do any of these symptoms sound familiar? The cure is—simple, fast, accurate and well understood Engineering Documentation Control/Configuration Management. Good design documentation and its control is the solution for the root cause of these symptoms. Thus, Configuration Management is the medicine that cures the root cause problems and, therefore, the symptoms disappear.

CM, kept simple, results in many benefits to the company. What are the benefits of a fast, accurate and well understood CM system? Take a look at the potential benefits of a carefully planned CM strategy.

Benefits:

- Helps to get new products to the market faster and reduce delivery time for customized product
- Happier customers because they see the new option, change or feature they requested much quicker
- The customer gets what they ordered with fewer missed delivery commitments
- Reduce the "bone piles" of down-level material
- Get real cost reductions implemented quicker
- Reduce significantly the Manufacturing rework and scrap costs
- Improve Bill of Material accuracy and save the corresponding material waste and correction time; make the corresponding improvement in product quality and inventory accuracy
- Eliminate multiple Bills of Material and save the costs of maintaining the bills, not to mention eliminating the risks associated with multiple Bills
- Evolution of Bills of Material in lead-time to produce the product
- Reduce field maintenance, retrofit, and repair cost
- Reduce MRP/ERP run time
- Know exactly what is non-interchangeable in each product
- Improve the understanding and communication between Design Engineering and the rest of the world
- Clarify responsibilities to eliminate finger pointing
- Save wear and tear on Configuration Managers, Master Schedulers, and all types of Engineers
- Comply with applicable customer or agency standards
- Sort out changes that are not needed or aren't cost effective

- Save many dollars a year in paper and copying costs alone
- Significant reduction in the cost of quality
- Allow the company to qualify as a best in class or world class producer

The ways and means of achieving these benefits is not secret, high tech, or cost prohibitive. These benefits are attainable. The following will outline the who, what, how, why, when, where, and how much is required to achieve an exceptional Engineering Documentation Control system.

What Is CM

Configuration Management is the communications bridge between Design Engineering and the rest of the world. (See Fig. 1.1.) This is the single most important function performed by the CM organization.

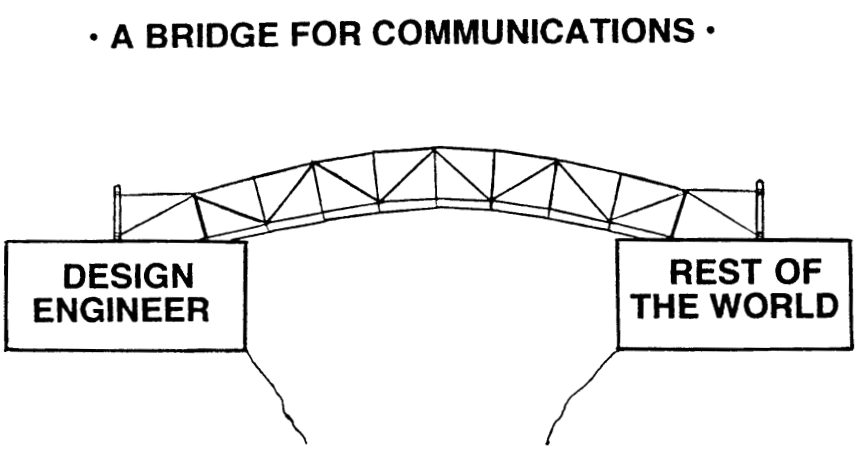

Figure 1.1. CM defined.

The critical nature of the CM discipline cannot be over emphasized. American manufacturing has developed a near tradition of Design/Production/Service adversarial relationship. It results substantially from the "Throw it over the wall" syndrome—the new design release or engineering change that is done without consultation from the key people at the right time. Many CM systems are often unwittingly designed to foster that traditional kind of thinking. The enlightened CM Manager can tear down the wall or at least build a bridge over it. Let's face it, by in large, the Designers are thinkers and creators while the Operations people are movers and doers. They will naturally have difficulty communicating. The CM Group can enhance communications and assure that these folks cross the bridge at the right time for necessary communications.

The CM function must assure that what crosses the bridge is properly documented, timely, minimally controlled, available as and when needed, and that feedback is obtained as to when changes occur in the product. All this must be done at minimum cost. All this, while appearing "transparent" to the creative design people and the rest of the world.

While not getting in the way of the design engineer,[1] it must be kept in mind that the engineer's product is not just a working prototype unit, it is accurate specification and drawings for all the parts in that product. The CM product is thus, Design Documentation. The primary customer for this documentation is not Design Engineering, it is Manufacturing,[2] Field Service, and your company's customer. The company's customer must be paramount among these "users" (a term that is much less acceptable to this writer than "Customer"). The vast majority of the design documents are prepared for Manufacturing and Service use. In this sense Manufacturing and Field Service people are often the most important customers.

Some of the symptoms crying for improved CM are in every company. The benefits of having a world class CM organization and system are a significant business strategy.

Between Engineering and Manufacturing, is an article the author wrote for Mid-Range Enterprise Resource Planning in May 1998 which may shed further light on the need for having/improving this discipline:

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[1]In this text you can usually substitute the title "Programmer" or "Software Engineer" for "Design Engineer" and "Program Code" for "Design Documentation." This will be the case as long as we are referring to product application software or firmware Program Code.

[2]Function titles vary widely. The titles used in this text are most common in industry, although not universal. The word "Manufacturing" will be used both in the larger sense as an industry and in the narrower sense as the operations function.

Most product manufacturing companies suffer from the "wall syndrome." The "manufacturing side" went out and bought MRP; the "engineering side" went out and bought CAD and the two systems don't "talk" to each other. The engineering folks are, by in large, analytical and cautious (Ready → Aim → Fire); the manufacturing folks are, by in large, shakers, movers and doers (Fire → Aim, Fire → Aim, Fire → Aim). The people don't communicate very well. The manufacturing folks say that engineering "throws it over the wall." Engineering folks say that you can't find anyone who knows how the product will be produced when you need them. Many of the modern MRP/ERP and CAD/PDM systems also don't communicate very well. This all results in a huge "gap" between engineering and manufacturing.

There is a discipline that is gradually emerging that can, properly done, bridge this gap. It is Engineering Documentation Control, sometimes referred to as Configuration Management. The term "emerging" is appropriate because the typical Documentation Control function is usually inadequate and the emerging function/discipline, Configuration Management, is very poorly understood and often clouded with claims from the software on both sides—ERP and PDM. Those who came from a military/Department of Defense regulated world have applied configuration management requirements that are too complicated and usually resulted in too much control. Many times the document control function is manned by one or a few low paid people who are ill trained, buried in the organization structure, frustrated and ready to change jobs. A configuration management function, properly managed, trained, and manned, can tear down the wall/bridge the gap between engineering and manufacturing. Properly manned doesn't always mean hiring new people. Often the people are there, they are just scattered in many parts of the organization.

The software applications people all seem to have a claim for doing configuration management. Some do address some parts of the processes involved. The military definition of the discipline is based on the terms identification, control, status, accounting, and planning, some real put you to sleep terms. A much better way to define the term is by the processes that it encompasses—the new item release, the bill of material, requesting changes, and making changes. Now we're talking about processes that most readers can relate to. Are there any ERP or PDM systems out there that will address all your needs for these processes? Maybe, if you pay enough, if you buy enough consulting weeks to accompany the software, if you know what you need and if the consultants understand the discipline, that is a lot of ifs.

Software programs can help after you understand what job needs to be done and what processes are best for you. The processes must be fast, accurate and well understood. Get educated first, buy software that claims to do configuration management last. Something more substantial is needed between engineering and the rest of the organization, it's called CM.

The CM Ladder

Many people believe that when they have been ISO certified they have adequately covered the documentation control and configuration management requirements. This is true as far as ISO is concerned, but ISO doesn't care how fast or efficient, or effective or simple the processes are. As is often said: *"ISO merely wants you to document what you do and do what you document."* This is a good step out of chaos, but a long way from best in class or world class. Examine the CM Ladder in Fig. 1.2

The CM Discipline

First a definition: a simple, fast, accurate, systematic, and well understood process approach to planning, identifying, controlling, and tracking a products configuration from its inception throughout its life with minimum cost.

We engineers hate the word "control." Too much control detracts from speed. Notice the emphasis on speed. This is a factor missing in many companies. Also note the time frame—birth to death of the product. Notice that the term "tracking" is used instead of the classical "Status Accounting" term. These are the traditional elements of CM—plan, identify, control, and track. The challenge for the CM Manager is to mix just the right amount of each of these elements into the CM processes—Product and Document Release, Bill Of Material, Request, and Change.

Also notice the emphasis on training—"a well understood system." In order to be systematic and well understood it must be documented. The discipline must be depicted in a set of standards and the people trained on those standards.

"Configuration," as used herein, has a narrower meaning than the dictionary definition—*the technical description and arrangement or combination of parts and materials which are capable of fulfilling the requirements defined by the product specification, other specifications, and drawings.*

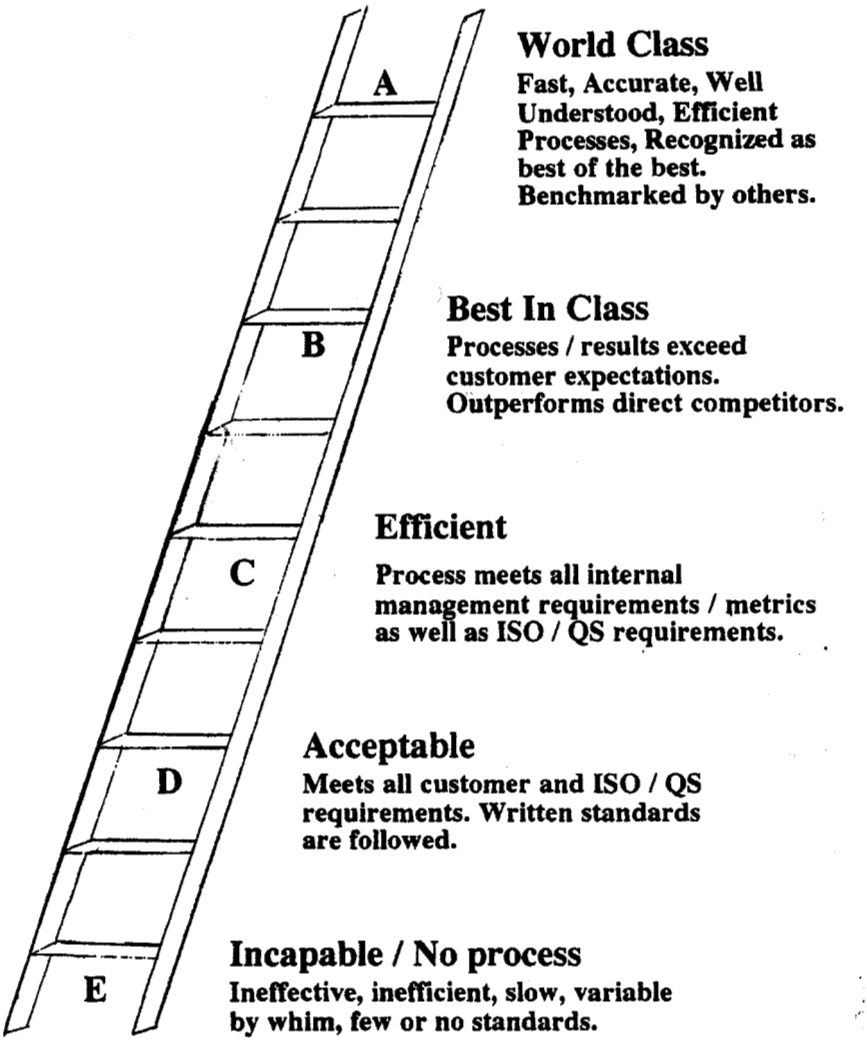


Figure 1.2. CM ladder. *(Adapted from the article "How to Stay Flexible and Elude Fads" by Irving De Toro and Thomas McCabe in "Quality Progress," March 1997.)*

The discipline can be applied to companies who produce a product that is either parts or process driven—discrete product manufacturing or process manufacturing. The product can be a building or an atomic power plant. The principles apply, with some care, to any "product." This book will, however, concentrate on the discrete product manufacturing.

On the other end of the spectrum, where does the Program Code fit into this definition? It is also included in the sense that the code is "assembled" onto a tape or disc that then becomes one of the "components."

Notice the emphasis on The Product Specification. It is surprising how many companies try to get along without a product specification, or they have one, but don't release it, or they produce or release it much later than is desirable. This issue will be discussed further in Ch. 2.

The CM System

The total CM system is made up of four major processes. These are generally referred to as Product Release and Change Control. More specifically, the processes are:

Product/Bill Of Material Process

Product and Documentation Release Process

Change Request Process

Design Change Process

Thus, 1 CM System = 4 major processes.

The Change Request Process and the Design Change Process are often combined under one term, Change Control. This will not be done in this text for reasons that will become apparent later. The product or part or document "obsolescence process" is combined with the Design Change Process and treated as a special kind of design/document change. These four processes must cover any product from inception to obsolescence—birth to death.

There is a temptation to say that these processes occur in series. First, we document the product and release the documentation, then create a Bill Of Material, etc. Although some companies try to do business "in series," it is not desirable. The processes overlap almost totally. For example, the Product Specification should be created and released very early in the product life cycle. The product specification should be put under a simplistic form of change control, then, long lead parts should be released in lead-time. This may well be done long before a BOM is "structured." Some documents may be obsolete before they are released, thus, the processes should not be "serial," but very "parallel."

In fact, trying to do these processes in series creates a problem. If, for example, we try to create all the documentation for a product before proceeding, then the need to release long lead items (in lead-time) creates

a quandary. Shall we hold up the project until all the items are documented before releasing the long lead items? Shall we wait for their assemblies to be released? Grouping any of the documents for release creates an artificial bunching of the work. Much better to design the processes to encourage item by item release in lead-time to produce, since that is the way they are needed and used.

History Of Configuration Management

The real beginning of CM occurred when Eli Whitney designed and built his cotton gin with interchangeable parts. That concept of interchangeability has come to be expected in all manufacturing. Today, when industry exchanges items that are replaceable (including the end product), they are expected to interchange, or reasonable notice is required.

Many companies have CM standards and practices that date back to the early years of their conception. Industry standardization of certain CM practices began with the government during the space program in the late 1950s. This was a necessary and natural occurrence since the assurance of interchangeability between the many contributors in a space program was very difficult. In the late 1960s the Department of Defense recognized that each agency and branch was developing its own set of standards. They brought all the CM standards under the purview of the Department Of Defense. In the 1990s they have begun to adopt industry practices—EIA and ISO standards.

At this first edition, almost all the existing standards and books in the field have been Military/DoD driven. Since that time the IEEE (Institute of Electrical and Electronic Engineers), SAE (Society of Automotive Engineers), EIA (Electronics Industry Association), APICS (American Production & Inventory Control Society), ANSI (American National Standards Institute), and ISO (International Standards Organization), have all made some contribution in the field. The most significant contributors are EIA and ISO.

The following quote from this first edition is no longer true: *"Industry by and large, however, has been satisfied to let the DoD take the initiative. The result is an IRS like, bureaucratic maze of forms and regulations. It is time for the commercial CM world to stand up and be counted."* ISO and EIA have helped, since the first edition of this book, but a lack of continuity exists. This text will answer that challenge and keep it simple, that is the goal!

The Organization

Lets examine the CM organization starting with the names it is called—the organizational names that is. The terminology varies depending upon the company. Some common names are:

Engineering Documentation Control

Revision Drafting

Documentation Control

Engineering Services

Design Drafting

Configuration Management

Documentation Control may be a proper term if that is all the function does. There may be several Documentation Control functions in the company or division—engineering, manufacturing, service, etc. One of these functions should be designated as the CM function—will control the total processes by which all do business.

The CM title is preferred when the responsibilities are roughly as outlined in this book. When the responsibilities are broader (include functions such as Publications, Reproduction, Microfilm, CAD/PDM control, etc.), then the preferred name is Engineering Services.

Presuming that your Company or Division organization is "slim" (few total levels of management), the CM function should answer to the VP of Engineering. In larger organizations there may be an Engineering Services function between CM and the VP of Engineering. If the function answers any "lower" in the organization, it will not have the necessary clout; communication of needs will suffer, and the result will be more of the "symptoms" described earlier.

Some companies have the CM function answer to QA, Manufacturing, Operations, or even to the President. If the results are very good, don't change the reporting relationship. It can and does work well or poorly in any organization. Most companies have the function answer to Engineering. The question is often asked, "Isn't that like having the fox watch the chicken coop?" The answer is; "Of course, but they're Engineering's chickens!" We are talking primarily about design documentation! If Engineering has the function and the described symptoms exist, reorganization may or may not solve the problems. The Design Engineering management, however, runs the risk of loosing the function if too many problems persist.

Location of the function in Quality Assurance tends to produce rigid "over control." No matter which organization has CM, there is always a risk that they will "grind their own ax."

Large multi-plant companies should have a CM organization in each business unit or division. They should also have a slim corporate function to assure minimum standards are met. This minimum level of standardization should be based upon three criteria:

1. Moving a product from business unit to business unit.
2. Customers contact with more than one division or business unit.
3. Field service by a single person of products made in more than one division.

The most difficult of all worlds is confronted when Engineering is in one location and Manufacturing is in another, or several, locations. A different building, across town, across the country, across an ocean—the bridge gets longer. When one of the Manufacturing locations is off shore, add another level of complication. The ideal results are more likely obtained when the Engineering (or at least the "Continuation/Sustaining Engineering" function), Configuration Management and the Manufacturing functions are in the same location (small business unit). This is desirable regardless of the company size.

Within a small business unit, placing CM responsibilities within multiple "Project Offices" is inviting chaos. Too many groups will develop their own rules for CM practices. In large business units it may be the only way to attain fast action. If this is done, a slim "corporate" type CM function will be necessary to maintain minimum standardization.

Document Control Functions

The typical document control function does the following:

- Assign all part numbers, change numbers, and document revision levels.
- Control master design document after the appropriate point of initial release (master file and "fire file," either hard copy or electronic).
- Change request monitoring.
- Change control and facilitation.

- Chair the Change Control Board (CCB).
- Back up document databases.

These are necessary and important functions although, as you will see later, the CCB often takes on a counterproductive character.

CM Functions

As a minimum, the CM function should have the following responsibilities:

- Standardize and document the CM System
- Train all key personnel on the basics of CM and the company CM system
- Develop metrics, measure and report on the CM System
- Revision (Incorporation) "Drafting" for design documents
- Input and accuracy of the BOM database (design information)
- Trace the change to actual date or units affected
- Maintain the traceability database and produce reports as required
- Auditing the system/assure that it is followed
- Benchmarking the CM system and continuous improvement of the CM processes

If any of these functions are not included in the CM Managers responsibilities, the results will be likewise limited. Some companies vest the CM group with other responsibilities, such as:

- Assisting the design engineers in the performance of their responsibilities
- Microfilming/Digitizing
- CAD/PDM control
- Engineering library
- Product Support documentation preparation (Publications/Manuals)

- Manufacturing document control
- Support document control
- Control of the approved manufacturers list

The first five of these "other responsibilities" would make the function a second level Engineering Services" management responsibility with CM not directly responsible for those five.

Placing the last three of these functions with CM should generally not be done. It is far too easy to overload the CM Managers plate with control of manufacturing and support documents or lists. Better to keep the responsibility with the organization that authors the documents, "but that will make several document control functions" you are thinking. Yes, it will, but it also places the responsibility for control with the organization that authored the documents. Of course, it must all be tied together with flow diagrams, standards, audited, and controlled. That responsibility would rest with the design document control function that would, thus become the CM function.

Helping the design engineer with their responsibilities is a very desirable CM function. It must be chartered and staffed to be effective. This is one excellent way to have the CM organization viewed as part of the solution. It must be clear, however, that the responsibility for certain functions belongs to the engineer and not to CM or any other organization that is "helping" the engineer. For this reason, many organizations choose CAD/Drafting/Designers/Technicians to help the engineer rather than CM. Reference will often be made in this book to "Design Engineer is responsible for ....." This is not to say that they don't have help in the performance of a task, but that they must be finally responsible for that task.

Distributed CM

As previously mentioned, Document Control functions can and should normally be distributed. Can the CM functions be successfully distributed? Many small business units have the CM functions scattered throughout the organization. Sometimes the functions occupy fractions of people's total job. The functions need to be brought together into one group. This recognition and emphasis is the first step toward attaining world class CM. Some discussions of "distributed CM" are now taking place. Some companies try to make each engineer responsible for their "own" CM. Since this author hasn't seen such an arrangement work in an

acceptable way, it remains unproved. It also remains an unmet challenge. Better data processing systems will eventually help in the distributive process. Companies with several small business units should distribute the CM responsibilities to each division with minimum control from the corporate function as mentioned previously.

In this writer's opinion, it is better to bring the functions together into one group, document the processes, improve the processes based upon the legacy data processing systems, and then further automate those processes in that order.

The Manager's Job

A seminar attendee asked the writer if he had a job description for a CM Manager. The result was to write one. The result is an interesting and different perspective on CM. It presumes that the Design Documentation Control and the CM function are one.

Manager Of Configuration Management

Responsibilities

- Owner of the Configuration Management process and standards for this (company or division). These processes include the release of new items, the design portion of the BOM and item master files, design change requests, and design change control.
- Owner of the Engineering Documentation Control process and standards for this (company or division).
- Assure that the processes between departments are documented in form, form instruction, policy, flow diagrams and standard practices, as necessary.
- Assures that all necessary training on these standards are well understood by conducting the necessary training for those involved in and affected by the system.
- Control the master design documents after the appropriate point of (pre-release or release). This includes all CAD master, word master and hard copy master files.

- Accurate incorporation of all changes into the master documents after the changes are appropriately signed.
- Monitor all design change requests, route to the responsible engineer, route responses to the requesters, and assure that a list of requests is maintained and regularly addressed.
- Control all design changes, assure proper conformance to standards, knows the actual effectivity of every change, and produces such status accounting (traceability) reports as may be required.
- Measure and report on the process accuracy, volume, and thruput time; assure that process time and accuracy are continuously improving, report to the senior management monthly, report to other involved managers and key people weekly.
- Assign and control all (part numbers and/or document numbers), change numbers, request numbers, and document revision levels.
- Owner of the BOM part master and parent component files and screens; responsible for BOM accuracy with regard to design data elements.
- Know what changes are to be retrofit/affect the field and what units were changed in the field/where to find that information readily.

Optional Responsibilities:

- Maintain the off-site emergency back up files for all design documentation
- Control all CAD/PDM/CM software seats and systems; assure maximum up time
- Maintain an engineering library with appropriate supplier manuals, outside organization specifications, etc., for reference by any responsible engineer

Not Responsible for:

- Filing or control of manufacturing documents—fixture drawings, assembly instructions, fabrication instructions, etc.

- Filing or control of service documents—maintenance, installation, service manuals and lists
- Maintenance of the AML (Approved Manufacturers List)

Notice that this description goes into what the CM Manager shouldn't be responsible for as well as what the manager should be responsible for. More later on this issue and on the AML

Organization Within CM

When the function grows beyond one person, how does the CM Manager organize their people? After all, one group may have three and the next thirty-three people! There are two basic approaches to use, as well as combinations of the two.

The first is the "production line" approach. That is, each person does some steps and passes the release or change to another person, and so on, until complete. The other method is the "job enriched" method. In this method a person does all steps in the process. The job enriched method is preferred, that is, one person will be responsible for all CM functions for a product, set of products, or a customer. This requires a considerable amount of cross training.

The Manager's goal should be for every person in the group to be fully trained in all aspects of the work. This makes the people fully interchangeable. This writer calls these people CM Technicians. Three levels of CM Technicians are ideal—entry, learned, and teacher. In this fashion you can assign the people to a product, project, customer, or whatever, depending upon the complexity. When someone is sick or goes on vacation the interchangeability of people avoids delay. This does require a significant amount of training. Training is expensive, however, if you believe that training is expensive, try ignorance! Training within the CM group and in related functions is the best way for the system (and all its processes) to become accepted, improved, and used.

Configuration Management—What is it? An article the author wrote for Mid-Range Enterprise Resource Planning, September Issue, gives another interesting perspective—defining Configuration Management (CM) is very much like the old story about the Company President hiring a Controller. Each applicant was asked: "What is two and two?" The person that was hired answered: "What do you want it to be?" In some

companies CM is a clerical function that keeps document files. The next company might keep files and process/facilitate the design changes. Folks doing DoD or FDA business have extensive organizations that control every aspect of the product configuration as required by specifications and contracts. A few commercial product manufacturing operations have tight controls on all the interfaces between Engineering and Manufacturing.

The DoD/military folks invented the CM term. Most commercial enterprises use the term Engineering Documentation Control (EDC). Since we engineers hate the word "control," the military term is superior in that regard. There are some who say that if the proper data processing applications are in place then no CM/EDC is needed. Since the writer has not witnessed such a utopian environment, the conclusion must be that it is like "paperless systems," a good long term goal, but we would currently be satisfied with "less paper." Some folks use boards or teams in the processes, some don't. The natural conclusion is that CM/Document Control is whatever you want it to be.

What should you want it to be? The answer varies with the size of the operation, the culture, the organization structure, the legacy software applications, regulating agency requirements, and the experiences of the management. In general, it is the function that bridges the gap (or tears down the wall) between Engineering and Manufacturing, an interface between Engineering and the rest of the company.

A company that has Engineering and Manufacturing in the same small business unit is thus going to have a different answer than a company that designs in the U.S. and manufactures in several domestic and international sites. A small operation might not need a change request process whereas a large operation probably does. A company regulated by the FDA has different traceability requirements than one working to industry standards. If the management has seen boards in their prior experience then a board seems to be a necessity. It is easier to attain shallow BOM structures in a JIT manufacturing operation than in traditional manufacturing. What do you want it to be?

Since processes are the essence of business, the answer would lie in defining the CM/EDC processes. If we look carefully at the interface between Engineering and the rest of the company, there are four processes at work; *(i)* the new product/part/assembly/document creation and release (called the "Release Process"), *(ii)* the creation, structuring, and control of the Bills of Materials (the "BOM Process"), *(iii)* the requesting of engineering changes (the "Request Process"), and *(iv)* the making of engineering

changes (the "Change Process"). So what you should want "it" to be is four processes, each fast, accurate, documented, and well understood.

These processes touch the very souls of the Engineering, Materials, Production, Purchasing, Service, QA, Order Entry, Publications, and other company functions. The cross functional nature of these four processes makes the CM/EDC discipline a very hard discipline to define, let alone to control. On top of this complication, add the fact that several of these functions have documentation that can easily be defined as "engineering" documents. Often times a product design document will contain manufacturing process information/specification. Who should control these documents? Should they all be controlled identically? If all engineering documents are not controlled by the same department, how is it all tied together? Thus, the plot thickens. Small/start-up companies often give the control of Engineering, Manufacturing, Publications, and Quality documents to the same department. In small operations the manufacturing process responsibilities often lie with the design engineers. They may not have a quality engineer nor a publications person. As companies grow, however, a quandary develops. "Too many cooks spoil the broth" goes the old saying, but shouldn't the documents be controlled by the group that authors the document? What if a design change affects several functions and documents?

In this writer's opinion, technical documentation should be controlled by the department which authors them. This would mean that there are several document control functions. Engineering would control design documents, Manufacturing would control process documents, Quality would control quality documents, and Publications would control service documents, etc. This requires a standard to list all the technical documents and the corresponding responsible function. How are they tied together? One function should be designated the Configuration Management function. That function would assure that minimum control is exercised and that the methods used in the individual document control function are not in conflict. That function would assure that the processes are in place to attain fast, accurate, and well understood results. When a design document is released, the process would assure that the affected functions are involved in that items development, that the author signs the document, that the proper "acceptor" (primary user) signs the document, and that those who need to know are informed of its release. When a design change is made that function would assure that these same events occur and it would also assure that the change to the design documents are not held up while the other documents are being assessed/changed. In other words, the CM

function would develop the standards and flow diagrams to designate fast and accurate processes. They would also assure that the necessary training takes place to make the processes well understood. Thus the CM function develops the policy, standards, forms, form instruction, and flow diagrams (a picture is better than a procedure), required for all four processes and trains all those necessary about those processes. The CM function would also measure the processes' speed, volume, and quality, and report to the management on these measures of merit.

But will the various regulating agencies and ISO/QS/AS accept this arrangement? Their specs do seem to encourage but do not seem to prohibit distributed control. Personal experience, consulting experience, and seminar customer's reports indicate that distributed control is acceptable providing the overall minimum control is present. There seems to be a high amount of pressure from some regulators to "do it all in the same group." It is convenient for them if all the control is done in the same group but is it best for the company? Not in most companies!

Thus, Configuration Management will be whatever you want it to be and you should want it to be four fast, accurate and well-understood processes.

Summary

The approach used in this book will be definition, execution, and emphasis of the basics. Keep it simple, but recognize and address complexities in the simplest terms possible. Build upon these basics to develop the processes by use of an example product—electronic ignition, programmable, front end loader (see Fig. 1.3). We will develop documentation for this product, release that documentation, develop the BOM, request changes, change the product by changing its documentation, and follow the change to implementation in the product. We will also go into development of the release, request, and change, processes with an emphasis on speed, accuracy and training.

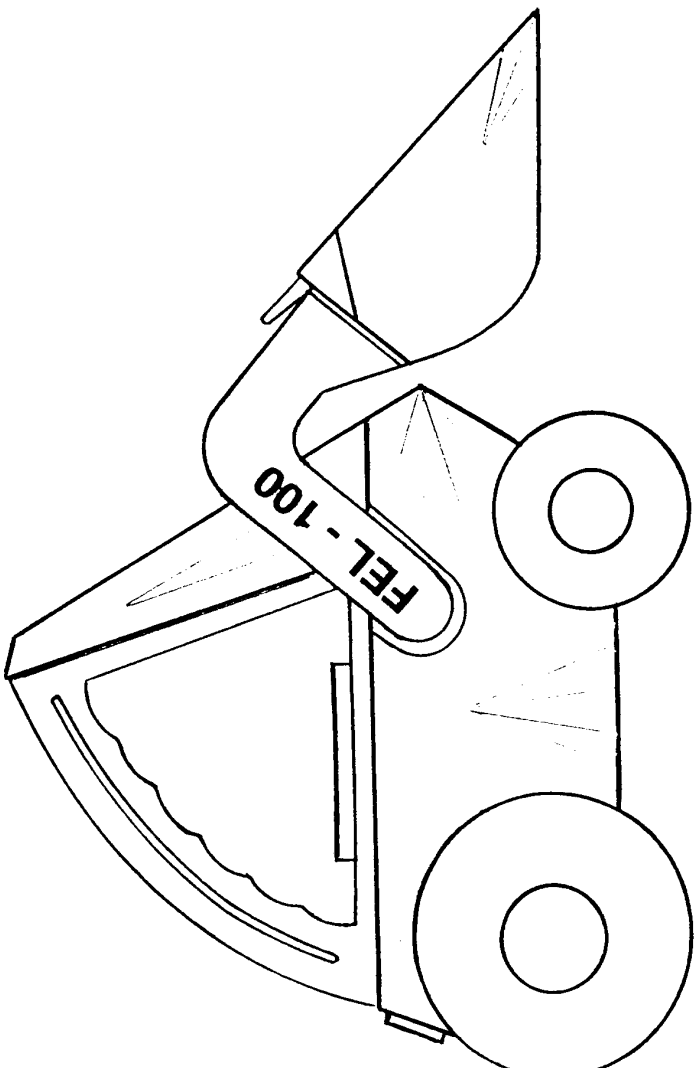


Figure 1.3. Electronic ignition front end loader.

2

Product Documentation

It is not the purpose of configuration management or this text to specify drawing standards. It is important, however, to assure that certain elements are present on drawing formats. It is also very important to emphasize that certain data elements should not be on those formats.

Document Formats and Standards

Keep as few formats active as possible. A well thought out drafting standard will help in this area. Use ANSI Y 14.5, DoD STD 100 or the commercially available *Drawing Requirements Manual* (DRM) as a guideline for your own standard, taking care to assure that all the following rules and guidelines have been taken into account as well. In other words, don't just invoke one of these standards, read and modify it according to the parts of this text that you wish to adopt, deleting those parts that are not applicable to your business. Also, delete change control sections as they are poor and even counterproductive, as discussed in Ch. 10.

Some general definition of the parts of design documents, regardless of size; drawings, specs, lists, and other documents, should have a common format. They should all have a *Body*, *Title Block*, and *Revision Block*, as seen in Fig. 2.1.

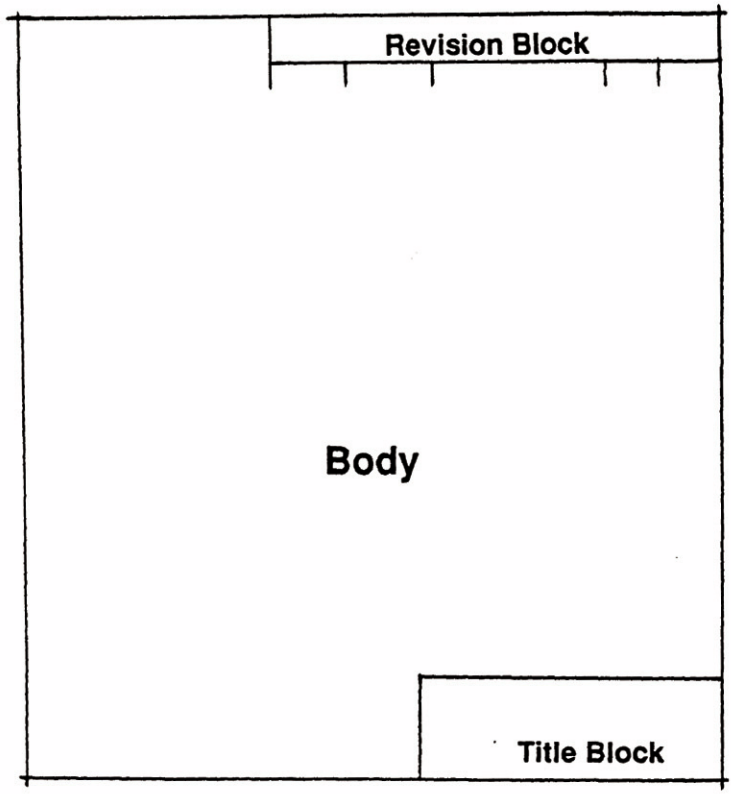


Figure 2.1. Terminology.

Title Block

The typical information found in the Title Block of a drawing or specification is shown in Fig. 2.2.

Unique company requirements may call for more data than that shown. For example, if you are doing business with the government a CAGE (Commercial And Government Entity) number will be required. Simplicity should be the rule however, thus, it is most important to cover the data that should not be in the title block.

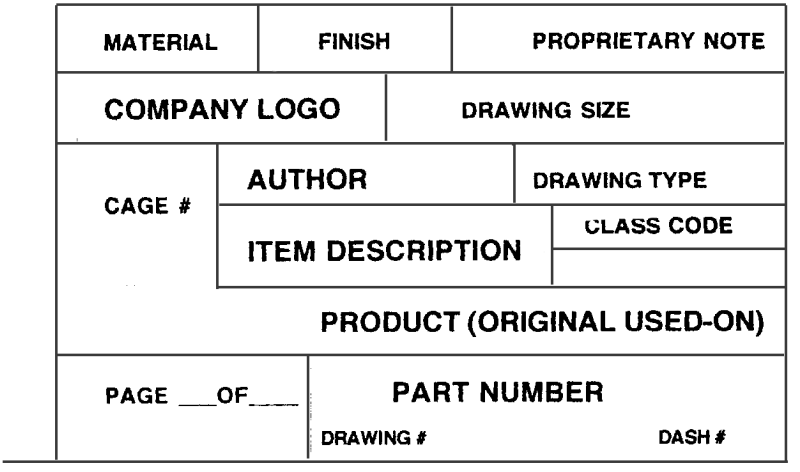


Figure 2.2. Title block data.

Notice that the title block does not show the current revision of the document. Although some companies show the revision in the title block, the practice is not recommended. In one extreme, a company's *"A"* size drawing showed the revision in no less than four places.

Rule: Show the revision once in the Revision Block on the first page and once on each subsequent page of the document and make sure it is current there.

Reason: Other appearances of the revision level only add work to keep them current and add risk that confusion and errors will result when they differ.

Some companies that are still partially in a hard copy mode may have a high need for the revision to show in the corner of a folded hard copy. If this is a worthy need, add one more appearance of the revision on the first page.

The *Original Product Used On* is shown in the title block, but no attempt will be made to keep other Used On up-to-date on the document.

A separate file should be set up for maintenance of the Used On relationships, usually in the MRP/ERP system.

Rule: Do not maintain Used On information on Design Documents, Set up a separate file for this data

Reason: You may use any item over and over again in other products; it is wasteful to get the originaldocument out/ access it to revise it each time you use the item elsewhere

If the company doesn't currently have a computer program for doing this, as you grow you should have, so keep it separate. Most CM groups have access to a PC that can be used to maintain the used on. Most MRP (Manufacturing Resource Planning) or ERP (Enterprise Resource Planning) systems have used on capability. If you have an MRP/ERP system, make that your only place to maintain it.

The Material required to make the part is often shown in the title block, in a separate *Material Block*, or in the body of the drawing. The important issue here is that it is in a consistent location to make it easy on your customers.

A simple material parts list may be in order. If you have or foresee problems with the material tracking, inventory control, material shortages, or material formula, you may wish to consider making the part into an assembly. That is, making the material specification(s) a call out on the item assembly parts list.

Example: A sheet stock manufacturer wishes to control the roll stock material that a variety of sheets are produced from. This can be done by preparing a one-item parts list for each assembly produced:

SAE 1010 steel	1/4" nominal	x qty.

Example: An injection molding company needs to control the material content or formula of the part. They can do so by preparing an assembly parts list such as:

Virgin Material	x qty.
Re-grind Material	y qty.
Coloration Material	z qty.

Whether or not this material parts list concept is used also depends upon how vertically integrated a company is. It should not be done without careful benefit analysis, since it adds a level to the BOM structure.

It is sometimes said that CM principles are difficult to apply to a process industry. This is often true because the company has not developed a parts list for their product. The materials required are not clearly specified in a separate list, but are buried in the process documentation. Step one for those companies is to develop their formula into an assembly parts list. The quantities may be per piece or, in the case of a compound or liquid, a fraction of the total mixture. This allows separate control of what is normally the critical design aspect of process industry products. This also sets the stage for computer control of each part of the material content.

The Drawing Type is typically an alpha code that indicates whether the drawing is a:

P	=	Part
AY	=	Assembly
PL	=	Parts List
LD	=	Logic Diagram
etc.		

Some Companies use this code as part of their Part Number. As a separate field, this information is more readily maintained and expanded should you not set aside enough digits in your part number. In any event, develop a standard (and keep it up to date) which spells out your acceptable abbreviations. Keep it simple—one standard covering only this subject.

Note: The term standard will be used in this text when one might say policy, procedure, or standard operating practice, etc.

The definition of an Assembly is often debated. The simplest definition is "any physical item with a Parts List." It follows then that a part is any physical item without a parts list. The term item can refer to both. The term component will also be used. Component is a general term much like item in that it may refer to a part or an assembly. If a company has a Drawing Type code or processes that treat parts and assemblies differently, it is critical to develop clear definitions. A definitions standard may be in order.

The author should be the name of the single, primary person responsible for the item creation. Avoid having more than one signature since at least one standard (ISO 9000) calls for the same signature in the change process that originally approved the document/release (unless specifically stated otherwise). In order to minimize the signature gathering and to fix responsibility, have only one name here.

One acceptor of the document should be added to the title block. This would be the manufacturing engineer or other single responsible person

that would speak for the manufacturability, testability, serviceability, etc., of the item. The margin of the document can be used in an unofficial manner for the checker, CAD designer, or drafts-person, to sign.

If computer access codes are secure, a computer printed signature is acceptable in most environments. This single responsibility practice is the beginning of an important concept, the responsible or cognizant engineer list. This list will be discussed later. It is kept separately from the drawing as opposed to changing the author name on the document. This avoids changes to documents for changing responsibilities.

Revision Block

Information typically found in the revision block of a drawing or specification is shown in Fig. 2.3.

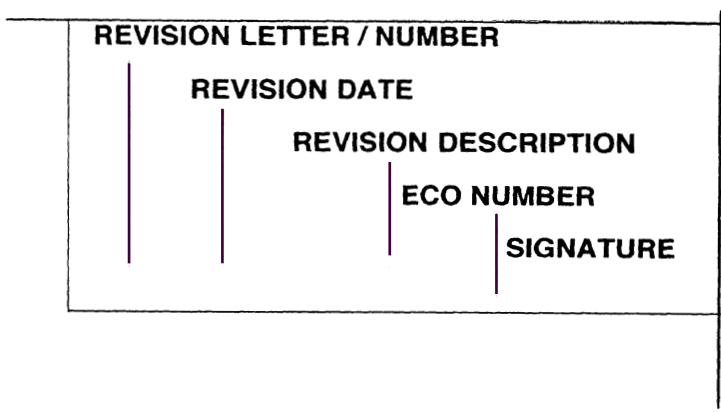


Figure 2.3. Revision block data.

Note that the Revision Date is the date on which the change was incorporated into the document, not necessarily the date the change was written or approved.

If the description of the change is short, it may be placed here. If the description is long, it is perfectly acceptable to enter a minimal word description of the change. Saying "See ECO" is unacceptable.

Rule: Always enter a phrase which encapsulates the reason for change.

Reason: When troubleshooting a problem, an engineer can rule out certain changes from the search by reading a brief description. This will thus avoid the step of pulling the ECO to identify what thechange did when doing future troubleshooting.

The ECO (Engineering Change Order) Number should be a separate field as opposed to entering it into the Description. When it is not a separate field, it is typical to occasionally omit it. Without this number associated with the change the traceability to the ECO form that documents the change is lost. Thus, the reason for change , other dates, change details, etc., are then not readily found. A separate field improves the chances of always having this traceability.

This signature is that of the person who incorporated the change into the document. If your change system is sound there should be no need for any other person to sign in the revision block. This is to say that the ECO must be a stand alone document. If it is, then the signature of the person who incorporates the change into the master document or file should be the only one required on that action. This should be a lettered signature (acceptable in most environments) to assure readability.

Rule: The signature column should be signed by the person who incorporates the change into the document. No other signatures should be required.

Reason: If more than one person signed, which will assure that incorporation of the change was done correctly?

More than one signature also adds to the process time. The critical issue is the responsibility for incorporating the change correctly and rapidly. More about this in the change process.

Body of a Part Drawing

The following information should appear in the Body of a part Drawing:

- Pictorial
- Dimensions and tolerances
- Notes and Specifications

It is important to keep notes and specs short and crisp. If the spec or note information is long or has use on several drawings, then a separate document should be created. The part number of the separate spec or detached notes should be referenced on the body of this drawing.

An example of a part drawing for the Bucket of the Front End Loader is shown in Fig. 2.4.

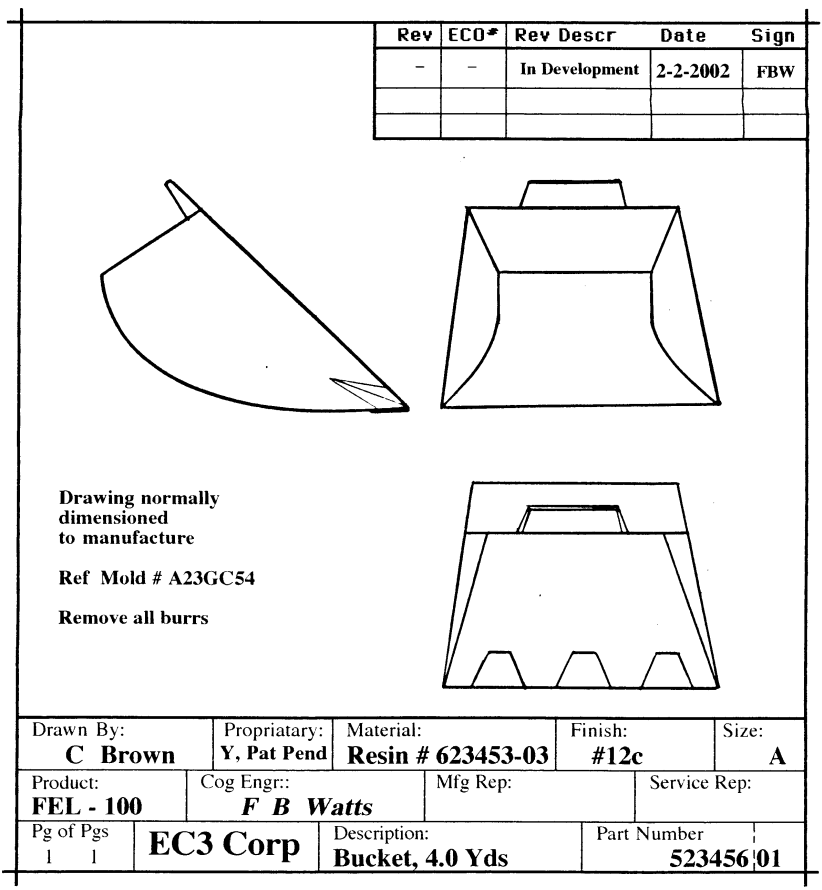


Figure 2.4. Piece part drawing.

The dimensions are left off the example drawing so as to focus on the issues that are most important to Configuration Management. On a part drawing, the primary issue is reference to notes and specs. In this case the mold to make the part is a referenced specification. It is done by referencing the mold tool number. Since the note "Remove all burrs" is short and crisp it is shown on the body of the drawing. If the company develops a lengthy de-burr specification, then that specification would be given a separate item number and referenced on the body of this drawing.

English or Metric

If we had shown the dimensions on our drawing, should they be in inches, metric, or both?

Rule: Pick either the American or Metric dimensioning system, do not do both.

Reason: It is at least twice the work to *dual dimension.* Most of your parts (where most dimensioning exists) are made under one system. When a mistake is made and the two dimensions do not agree(happens all too often), engineering intervention and a design change is needed.

Manufacturing Engineering can and should do the converting in the production processes when necessary. Make it as difficult as possible for foreign companies to carbon copy your designs. Some multinational companies have chosen to dual dimension their drawings. Most have wished, based on informal polls taken in the University seminars, that they had picked one method.

Document Signatures

Typically, several design engineering signatures appear on each document. A designer, a checker, an engineer, and a manager, all sign. Do several signatures for the same function assure better quality documents? Where is the primary customer for the document?

Notice that in the Loader Company the engineer *(Responsible/ Cognizant Engineer)* of this document has signed his/her name in "authored by" in the title block. The primary customer for this document signed as acceptor. This clearly separates the responsibility for the design from responsibility for manufacturability, etc. In this case, the Manufacturing

Engineer (ME) signed because it is a manufactured part. If it were a test specification, the test engineer would sign; the product specification would be signed by the sales or marketing representative; a spare parts list by the service representative—Field Engineer (FE).

The ME signs in order to assure optimum manufacturability. The Manufacturing Engineer must be aware of and trained in the needs of Suppliers, Receiving Inspection, The Production Floor, Repair, etc. The service representative might sign individual documents that represent spared items (subject to wear, failure or damage), but in this company there will be a spare item parts list that the FE will prepare with the cognizant engineer so there will be no need to sign individual documents.

Certainly no more signatures are required than the ME and FE. If you have more than these two people (three counting the author) signing your drawings and specs, it will unnecessarily delay the process. More signatures, based on the author's experience, tend to make responsibilities unclear. Thus, the more signatures the more problems that can go undetected.

Some companies have the ME and FE sign the release form. This is an undesirable practice since it usually places the burden for obtaining their signatures on the CM function rather than the creating engineer. It also doesn't assure that they view the drawing rather than the form. The object must be for the engineers involved in this project to converse, face to face, "up front," in the development. To talk directly about problems, reservations, ideas, etc., as opposed to having CM obtain the signatures upon release of the document. The team concept is fostered by the Design Engineer getting the ME and FE (if required) to sign the drawing. More about teams later.

Do we print the name of the responsible person or sign? Lettered "signatures" are adequate for most companies. If you or your regulators or customers require signatures, it is best to also require a readable hand or CAD lettered name as well.

Rule: Design documents should be signed by the ME (and FE, if necessary), and those signatures should be obtained by the creating design engineer rather than CM.

Reason: Engineers should be functioning as part of a team and talking directly to each other. Having CM obtain the signature creates a wasted and counterproductive step in this process. Whenever there are questions, CM is merely acting as a go between. Communication can be lost or misinterpreted in the process.

The ME should sign the drawing/specification rather than the release or change form since the manufacturability, maintainability, repairability, and similar issues, are on the drawings and the specifications not on the forms.

A computer manufacturing company had a problem wherein a critical adjustment was covered up in the original design. A subsequent change was required to open an access hole to allow adjustment at final test. When the ME was asked how this was allowed to happen, the response was, "I didn't know that was the reason I was signing the release form!" It is also a good idea to develop a standard that crisply explains the responsibility that goes with each signature.

On Line Signatures

Most companies prepare pictorial part and assembly drawings with some version of CAD (Computer Aided Design/Drafting). Should a hard copy be printed out in order to sign it? Why can't the CAD file be the master document? In most commercial environments this can be done. A security on the system to assign a PIN (Personal Identification Number) to each author and acceptor is needed for good business practices and for liability purposes. The signature can then be lettered or scripted into the drawing title block.

Notes

If notes are brief they are placed on the body of drawings (such as De-burr all edges). If they are multiple use (can be or are used on more than one drawing) or too long to be in the body (such as finish requirements), they are detached on a separate document. They are usually given a separate part number and that number is referenced on the drawing body. This is an area wherein using the alpha prefix to the part number, has some merit. That is, if one for one use the same number (different alpha prefix) can be used and the detached notes more readily found. The number should still be on the body of the drawing. Placement of the reference document on the assembly parts list is discussed later. When the design engineer specifies the process to be followed in producing the item the same comments would apply to these Process Specifications.

Body of the Assembly Drawing

The face or body of an assembly drawing should contain:

- The Assembly Pictorial
- Assembled Dimensions and Tolerances if any
- Notes/Specs
- Find/Balloon Number

The most prevalent mistake made on assembly drawings is to put the parts list on the body of the drawing. This is a carry over from the old days—before the advent of data processing. Prior to computers, the accepted practice was to place the parts list on the body of assembly drawings. Unfortunately, when computers came along, they gave a powerful capability to produce detached parts lists. It was also easy to leave them on the body of the drawing. The parts list should normally be on a separate detached list. The find or balloon number relates the picture to the list. With the advent of data processing the detached list can be obtained from CAD/PDM (Product Data Management), MRP/ERP, or another database.

Rule: Do not put parts lists on the body of an assembly drawing unless they are put there by a singular BOM database. If you have them on the body of the pictorial drawing, start a planned program to detach them.

Reason: As you grow, the parts list on the pictorial will be redundant to a parts list in a database. Thisredundancy is not just wasteful, it is dangerous as it allows a possible diverging design.

An exception to this rule might be for inseparable assemblies such as a *weldment.* In this case it may be best to document all parts on a multiple page drawing that shows their individual dimensions as well as the assembled dimensions. A find number should be used instead of part numbers for the pieces.

Another exception might be wherein the company has one database (such as CAD/PDM) which feeds the drawing as well as the other data processing systems, such as the MRP/ERP. In this case, the existence of one database is the desired result. At the initial writing of this text, the ability to connect MRP to CAD or vice versa was nil. Today the connections are becoming more prevalent, either resident in the CAD or MRP/ERP or through a PDM system. Unless your systems are automatically connected,

the conclusion should normally be to detach the parts list and not to develop parts lists in CAD. Much more on this subject in Ch. 5.

A typical design pictorial drawing for the Front End Loader looks like Fig. 2.5.

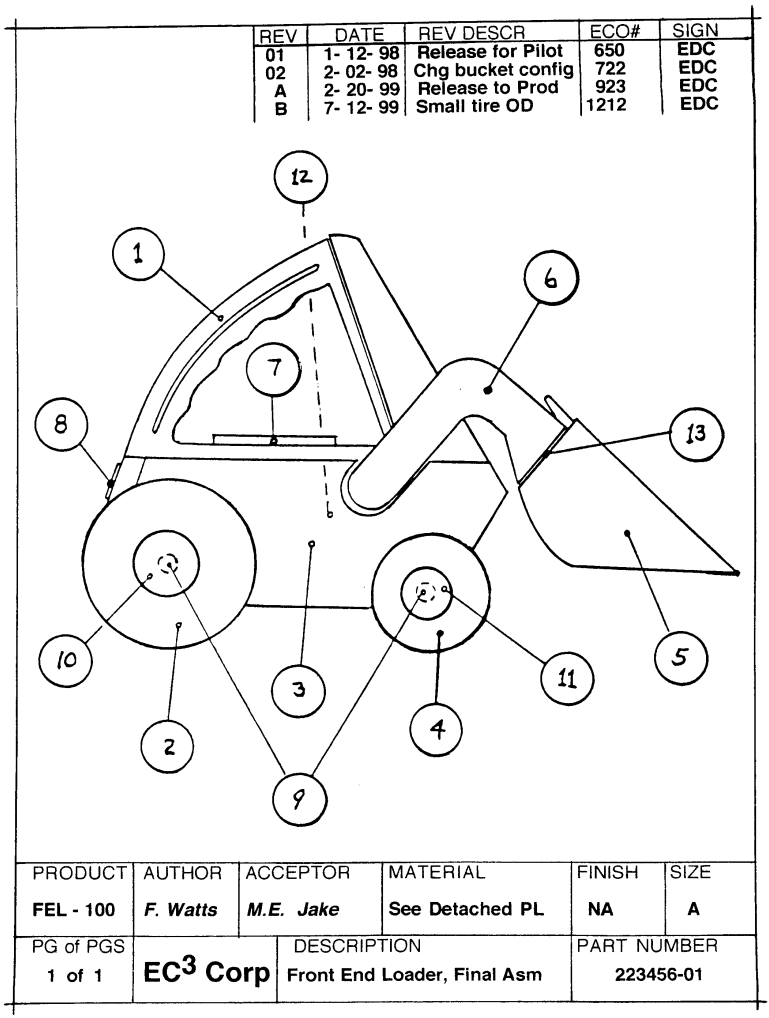


Figure 2.5. Assembly pictorial drawing.

While in the product development stage, the designer should control iterations of the design by use of the date field. The revision field should be left blank. This leaves numeric and alpha revisions for subsequent forms of release. In our example, the final assembly pictorial and parts list were released for limited quantity build (pilot production) at Revision "01."

They were both revised during the pilot production phase, the change the bucket (Rev. 02). They were again revised to change the revision level to an alpha (A) when the team agreed that the item is ready for production. Then, when the small tire OD change occurred, the revision level changed to "B." Much more on revision levels in the release and change sections.

In start up and smaller companies, the design assembly drawing is often used as the pictorial for the Manufacturing assembly operator. With the advent of CAD this pictorial can be three dimensional, very powerful aids to production. The Manufacturing or Industrial Engineer will want the pictorial made to best suit the operator. Difficulty begins when the production rate doubles or is cut in half. What one operator did, is now the job of two or half the job of one. Shall we run a design change to revise the picture and parts list to accommodate the new production rate? Instead of preparing and changing these pictures to suit Manufacturing, give Manufacturing access to the CAD database to make production process pictorials as they require.

Assembly Parts List

The corresponding final assembly parts list for the Front End Loader parts list looks like Fig. 2.6.

DATE	REV	DESCRIPTION	ECO #	SIGN
7-12-99	B	Small Tire OD	1212	FBW

EC3 CORP	DESCR	P / N	SIZE	PG OF
FEL - 100	Final Assembly	223456-01	A	1 1

FIND #	DESCRIPTION	PART NUMBER	QTY	UNIT MEAS	IN/OUT DATE
1	Motor Mount Asm	223356-01	1	ea	
2	Tire, Large	423456-01	2	ea	
3	Frame Asm	723456-01	1	ea	
4	Tire, Small	423456-02	2	ea	wk 48
5	Bucket, 4 yard	523456-01	1	ea	
6	Bucket Arm	823456-01	2	ea	
7	PCB, Elect Ign Asm	923456-08	1	ea	
8	Nameplate	323456-01	1	ea	
9	Axle	103456-01	6	in	
-	Product Spec	123456-00	Ref	Doc	
-	Material Spec	623456-00	Ref	Doc	
10	Wheel Hub, Large	113456-01	2	ea	
11	Wheel Hub, Small	121456-01	2	ea	
12	Motor Asm	114456-07	1	ea	
13	Adhesive	115456-01	2	oz	
-	Spare Parts List	623457-00	Ref	Doc	

Figure 2.6. Detached parts list.

Note: Part numbers are shown with a "-" (dash) for the sake of example. The dash would not be necessary nor desirable in actual application because key strokes do add up.

The part number of both assembly pictorial and parts list documents is identical. Notice that the find number allows easy cross-reference between the two documents. The revision level of both documents is identical. Keep them that way to avoid confusion, even though all changes do not affect both documents.

Some companies have chosen to make the two documents different item numbers and to cross reference by listing the pictorial number on the parts list. This is a workable scheme. It allows CM to only change the affected document and to allow their revision levels to be different. This scheme favors the CM department, but not the customers of the documentation. Better from the customers' viewpoint to spend the extra CM effort to make them the same part number and keep them at the same revision level. Start up companies or companies changing their documentation system should seriously consider this issue. Established companies with a workable two number system should not change to a one number system unless they are changing their part numbering system for some other reason.

There are three items on the parts list that are not physical items—the Product Spec, the Material Spec, and the Spare Parts List. They have been entered because they are part of the design requirements for product. They have been entered with quantity "Ref" and Unit of Measure "Doc" in order to flag the fact that they are only documents. If the programmable electronic ignition was at this level, the program code part number of the latest software release would be shown as a referenced document. If the code were in the form of deliverable media (a disk for example), then the programmed disk part number would be called out in quantity one.

The revision field will be reserved solely for the use of Configuration Management. Thus, if you are using CAD, establish standards to prevent assignment of revisions by anyone except CM. This is essential to the minimum control aspect of Engineering Documentation Control. Unfortunately, most CAD systems do not allow security on the Revision field, so you will have to achieve this control by policy and procedure. You will see this concept develop further in Ch. 10.

Our parts list has an "in/out date" column. Most parts lists produced by MRP systems have a similar *effectivity planning* capability. The use of these fields is discussed in Ch. 10.

Engineering Parts List

What is the official engineering parts list? In the Front End Loader Company, we will program a report from our MRP that looks like Fig 2.6. It will be double spaced to allow clarity of workup. It will not have revision levels on the components in order to avoid "rev rolling." It might have reference designators included in the body of the parts list if they can be obtained from a singular database. It is the controlled engineering document from the company's singular database.

Units of Measure

The parts list depicts the items *Unit of Measure*. Develop a standard on the allowable units of measure. That is, will you allow use of inches, feet, spools, boxes of ten, ounces, pounds, etc. This must be agreed upon by Design Engineering, Manufacturing (Materials/Purchasing), and Field Engineering. This may seem like a trivial point, however many companies have confusion and wasted effort as a result of not agreeing. Engineering specifies one unit while Purchasing would like to buy another. Someone ends up in the middle converting the unit used by design to the unit used for purchase. Some MRP/ERP systems allow for a difference and do the converting for you, but why limit choices of an MRP/ERP to those which allow this problem? Why not standardize and get everyone on the same units? The CM function needs to address this issue. This is another way to bridge the gap between Design Engineering and the rest of the world.

Specification Control and Source Control Drawings

Items that are commercially available (off the shelf) are documented by a control drawing. For the Loader Company, a screw, fuse, cassette tape, disk, etc., would all fall into this category. Some companies choose to use the vendors catalog number and trust the vendor to maintain interchangeability. Using a vendor number also restricts Purchasing to that vendor. Better to specify those characteristics that are important to you on your own document.

These drawings, typically, are both part pictorial and part specification matter. The envelope dimensions are shown. Critical specification matter is stated. If the pictorial or envelope drawing is not required, the data

may be all digital and placed into the database (MRP/ERP Item Master file for example). All of these drawings have the same basic definition:

Definition: Specification Control Drawings contain critical form, fit and function design criteria that is necessary to assure that the item will consistently meet the intended purpose(s).

What is the difference between the Source and Specification control drawings? The body of the Source Control Drawing shows the supplier from whom Purchasing may buy the item. No suppliers are shown on a Specification Control Drawing. How then does Purchasing know whom to buy from?

AVL - QVL - AML

A separate listing is kept for Specification Control Drawings that show the acceptable supplier(s) for each part number. This list is variously referred to as a QVL (Qualified Vendor List), AVL (Approved Vendor List), or AML (Approved Manufacturers List). Regardless of what it is called, the concept is the same. The drawings need not be revised each time a supplier is added or deleted.

The AVL/QVL/AML must be controlled in such a way that Design Engineering, Manufacturing (Purchasing), and Quality Assurance (QA), all agree to any vendor changes on the list. Why bother you say? Ask your Purchasing Manager what is preferred! Almost without exception they prefer Specification Control Drawings with an AML. Their reasoning is quite simple; they can negotiate a better package for the company when the supplier does not know who the competition is.

Rule: Do not show suppliers names on the face of drawings nor use supplier catalog numbers.

Reason: Better purchasing power and fewer drawing changes.

An exception to this rule might be for a company that has made a concerted effort to adopt the one supplier policy, such as many Japanese companies do.

The AML is best maintained by QA, although others can and do maintain the list. The important thing is that all three functions mentioned must agree to all adds and deletes from the list. Control problems have prompted some companies to put the AML under CM control. I believe this is not a wise choice since it will detract from their primary mission—fast and accurate Engineering Documentation Control. No matter who controls

the list, an ECO is not required. A simple standard with a simple e-mail process with data entry controlled by QA is all that is required.

Do not include distributors on the list. Let Purchasing buy from any source as long as they buy only from the approved manufacturers. (The venerable Dr. Demming also strongly disliked the term vendor.) For this reason, the author prefers the acronym AML.

Some companies have tried to handle this issue by assigning a different part number to each supplier and then specify preferred and alternate on the parts list/BOM. In the writer's opinion this is a form of insanity. Much better to use the AML concept.

An example of a Source Control Drawing for the nameplate for the FEL-100 model Front End Loader is shown in Fig. 2.7.

An example of a Specification Control Drawing for the Front End Loader tires is shown in Fig. 2.8.

These drawings are frequently tabulated. That is, a dash number (part of the part number) is assigned. In this case two tabulations of the tire have been charted on the body of the drawing, denoting size variations of an otherwise identical tire. The question often arises, how many variables can be handled on one document? The answer must be made in terms of the readability of the document.

Guideline: Tabulations of similar items on one drawing should typically not exceed three variables.

Reason: Easy readability on the part of the drawing customers is the key issue.

How should we maintain form, fit, and function interchangeability with our suppliers? Well engineered Specification Control Drawings are a key solution. Place all critical characteristics on this drawing and leave the supplier free to make other changes as he sees fit. Of course, if parts of a purchased assembly are to be spare parts, then those parts must be similarly specified.

This Specification Control Drawing concept is critical to successful Design/Purchasing/Supplier relationship whether it is for a screw or a computer system integration. It requires well thought out criteria of mechanical fit (envelope), form, and function. It is lack of this document that often causes some people to want to control suppliers interchangeability by reviewing or approving all his design changes.

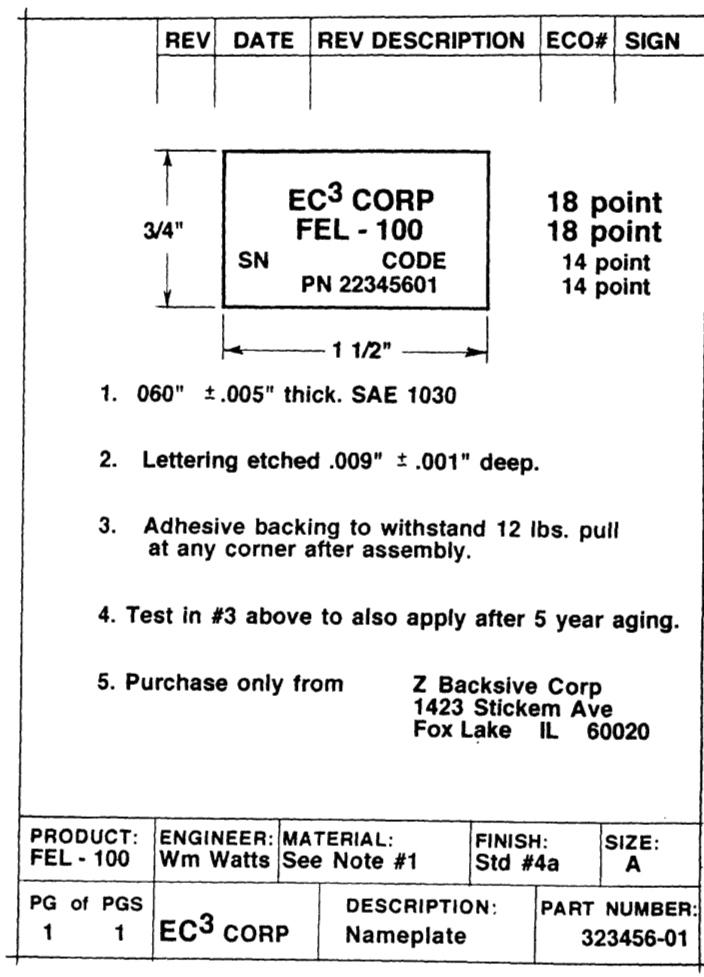


Figure 2.7. Source control drawing.

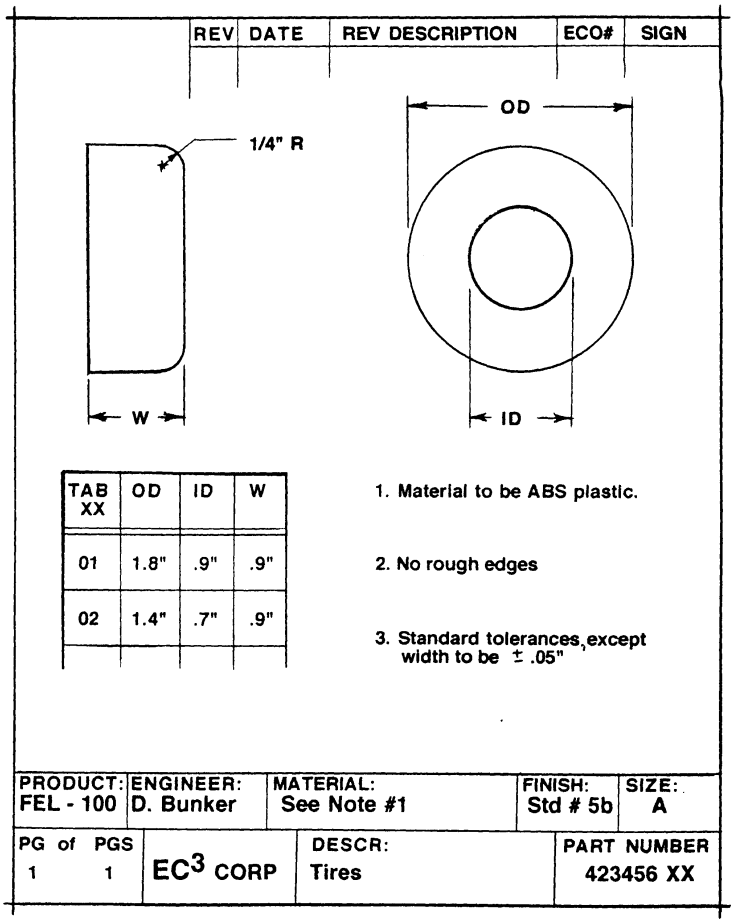


Figure 2.8. Specification control drawing.

Item Specifications

Specifications are words that describe an item. They are generally in a text format, but may have text, charts, graphs, envelope drawings, or combinations of these and other techniques. They are generally prepared to describe the end product, but may be defining a sublevel of the product. The definition, therefore, becomes fairly general.

Definition: Specifications define the critical characteristics of an items form (appearance), physical, or functional nature.

Specification Control Drawings are item specifications. Certain assemblies may be described by a specification, whether made or purchased. An assembly that is tested is usually defined by a test specification.

There is one level of the product that must have at least one specification, that is the end product itself. These take various forms and names. They will be called *product specifications* in this text. Whatever they are called, they are so important that they need to be a released document and under change control.

When several products are combined into a system, the product specification may be referred to as a System Integration Specification.

Product specifications requirements vary depending upon whether you are in a make to stock, make to order, or make to print environment.

Make-to-Stock Product Specifications

The single most important of all Design Documents is the Product Specification. This document must be agreed upon by key company management. This agreement must occur very early in the product definition phase. The key functions which must agree include Marketing (representing the Customers), Design Engineering, and others as your President may designate. Our Loader Company FEL-100 Product Spec is outlined in Fig. 2.9.

Front End Loader FEL - 100	EC3 CORP pg 1 of 1	size A	by fbw	PN 123456-00

- Four yard bucket capacity - struck level.
- Maximum lift height - eight feet. With special arms - 10 feet.
- Peak Engine RPM - 4400.
- Electronic ignition.
- Engine cannot be shut off without bucket and arms in lowered position.
- Minimum turn radius - 16 ft.
- Comes in four colors - yellow, red, white, and red & white.
- Electric or gas starting engine.

Rev	date	Rev Descr	ECO #	by
	12-01 78	Development Release		J Besch

Figure 2.9. Product specification.

This specification is obviously very general, too general. For example, a product specification should delineate the expected Mean Time Between Failures (MTBF), the Mean Time To Repair (MTTR), and safety criteria. On the other hand you can be too detailed, such was the case in the seventeen page government specification for fruitcake.

A clear crisp specification of the critical criteria is needed, however, if this is the best available definition of the product at the start of the development project it should be put on the correct format and released. This is a numeric revision level release that assures that all changes can reach all the people who need to know. More on release phases in Ch. 7.

Rule: The Product Specification should be the first document released for the product and it should be released as soon as the project is established.

Reason: It should be the hymnal for all that work on this product. Every change to that document must be carefully distributed to all who need to know. Everyone should be in the same church, with thesame hymnal and on the right page (even though everyone can't sing well enough to be in the choir).

The best way to accomplish this is to release the end product part number with a one item parts list—the Product Specification. You now have a "top" to build under. This is the beginning of an ever evolving product structure. More on the evolution of release in Ch. 7.

Marketing/Sales will prepare literature from the product specification to aid in the product marketing.

The above product specification discussion has described the make to stock environment. The Configuration Management requirements are incumbent upon the manufacturer. What is different about other types of manufacturing?

Make-to-Order Product Specifications

In this case, the Sales Order may constitute the product specification. Material accompanying the Sales Order (such as features and options lists) may also constitute part of the product specification. When companies have a customer(s) who must agree on product specifications, there is sometimes a Design Specification prepared in addition to the Product Specification. The Design Specification is a hedge against reality. In other

words, the Design Specification targets what is believed attainable, while the Customer Specification has slightly less ambitious commitments. Some companies develop a Test Specification as well. This document defines how the Customer/Design specifications will be measured.

In the make to order environment, product specifications are often unclear. Sales Orders sometimes, in fact, sell configurations that are not designed, tested, or even manufacturable, especially in the time frame specified.

Rule: In the make-to-order company it is critical for Customer, Marketing, Design Engineering, and Manufacturing, to agree on the product parameters before a customer commitment is made.

Reason: Anything less than review and commitment from these functions risks late delivery to the customer, delivering something different than the customer expected, or (in some cases) not being able to deliver what the customer ordered at all.

One company was plagued with late deliveries of a make-to-order customized product. Investigation showed Sales was frequently accepting orders for feature and option combinations that had not been piloted (not built and not tested). The time to do the piloting was not considered in the Sales Order. In some cases they found that they had to go back to the customer and explain that the combination of features requested was not a workable combination. Since the number of possible combinations was several thousand (real world sold configurations considerably fewer), they had to have Engineering examine each new combination to assure that each was a viable product. The result was more realistic delivery commitment dates.

The Sales Order, accompanying and referenced material, may constitute the product specification. Some companies and/or customers insist that a specific specification be written. Whether the product specification is one formal design document or several documents it is critical to obtain agreement before commitment—during the quote phase.

The ideal situation is to have a unique part number (tab) assigned to each sold combination. A later discussion of modular Bills of Material (Ch. 5) will show how this was achieved.

In the make-to-order company the manufacturer is responsible for assuring CM requirements. This starts with a clear product specification, again, the most important design document.

Make-to-Print Product Specifications

The customer print and possibly parts of the Purchase Order make up the product specification. Again, it is very important to reach agreement on the parameters before committing to the customer. Again, they constitute the most important design document. Sales, manufacturing, and the design engineering functions must agree on the customer requirements. The trap in this kind of manufacturing is that sometimes the Purchase Order contains new or changed item specifications. The company order entry process must allow for a technically competent person to watch for such nuances and to add them to the customer print. This creates a complete product specification.

Another specific issue that arises in the make-to-print environment is the end item part number. Should we use the customers part number or assign our own?

Guideline: Whenever practical, the customers part number should be used as the end item identifier rather than assigning your own.

Reason: Using the customer part number eliminates the need for a cross reference list/program and the many, many references to it (forever). This also eliminates probable error in conversion from one to the other and back again.

If a supplier has several customers who may assign identical part numbers, analysis of those occurrences as well as the pros and cons is necessary. If customers use alphanumeric part numbers and your data processing system has difficulty handling that condition, further analysis of that situation is necessary.

Design of Process Specifications

In many companies the product (manufacturing) process and routing design is the responsibility of Industrial, Process, or Manufacturing Engineers. On some occasions, however, the Design Engineer feels compelled to enter this arena. When Design Engineering feels that it is necessary to control an element of the process, a design process specification or note on a part drawing is required. In high-tech products the design engineer often prepares the Product Test (process) Specifications that spell out how a test is to be performed and, in some cases, what equipment is to be used.

In the FEL-100 the design engineer might feel that the printed circuit board cleaning method is critical to the product performance. A cleaning spec would be written. These are examples of design process specifications. They are design documents and will be treated as design documents in subsequent processes.

This writer feels that as companies grow they should avoid process specification development and control in design engineering. Much better to specify the criteria that needs to be met and to have manufacturing in control of the part or assembly process.

Document Sizes

The physical size of hard copy masters or copies made from the master digital file should be standardized.

Rule: Use multiples of 8½" × 11" sizes. Use "A", "B", and "C" sizes whenever possible and avoid using larger sizes.

Reason: Reproduction of the larger sizes is difficult and expensive. The microfilming and subsequentreadability and reproduction of the image is very difficult. Paper stock is standard in these sizes.

Those who are in a paperless environment do not need to worry about this issue. Most companies are not paperless, however, they are merely trying to create less paper.

Proprietary Note

Place a note on drawings and specifications of your own design to the effect that the information contained thereon is proprietary to your company. This may discourage one form of industrial theft, however, do not rely on this note as a sole solution.

Document Groups

Divide all your companies technical documents into at least three categories:

- Design Documents—Define the product or critical process elements
- Support Documents—Support or maintain the product
- Manufacturing Documents—Define the manufacturing process

Support Documents do not define the product, they define the information necessary to install, use or maintain the product; they are typically referred to as service manuals or publications. Manufacturing Documents define the manufacturing process/routing. An example grouping (by no means complete) is shown in Fig. 2.10.

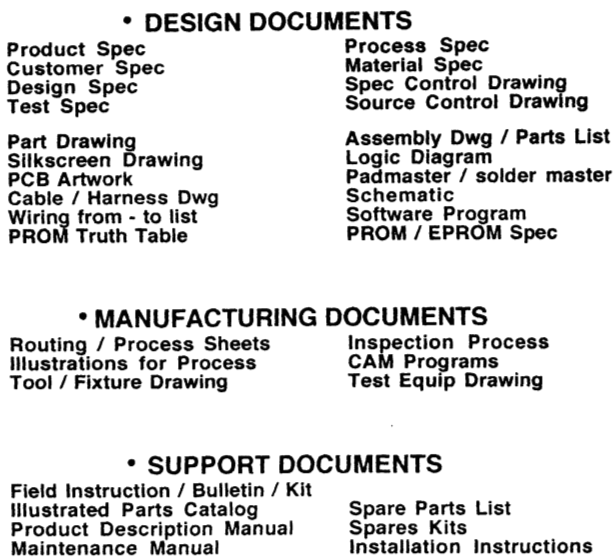


Figure 2.10. Grouping document

Other groups of technical documentation could easily be added to this list/standard. Quality Assurance documentation, for example. It is desirable to make this simple distinction in order to determine the treatment of each group in further processes.

Rule: Each document control function will control the masters for their group after release

Reason: Keep the responsibility for control with the organization that authored the document

Designate one of the control functions as the Configuration Management function. This would, in most operations, be the design document control function. Again, although this function is normally in Design Engineering, it might be in Quality Assurance, Operations, Project Office, etc.

Rule: Configuration Management will hold the Master of Design Documents after release. They will be released only by the company's release rules and process. They will also be changed only by the change process and rules.

Reason: To assure minimum control in all of the CM processes.

It is not necessary or wise to treat all three groups of documents identically nor by the same function.

Rule: The masters of Support Documents and Manufacturing Documents need not be under CM control. In fact, they may not be controlled directly by the design document release or change process.

Reason: These documents should be maintained by the function responsible for creating them. They are released as a result of a product design release and changed as a result of a product design change. The control systems (managed by the functions responsible for them) may be similar to design document control, but will probably be less stringent.

Each Document Control Function should be under the umbrella process control of the CM function. In the case of FDA regulated companies, the control of manufacturing process documents must be equally stringent to the design document control, but need not be controlled in the same function.

Making Manufacturing or Support documents part of the design document process will easily cause a distraction from, and a delay to, the Design Document processing. The argument frequently is; "They don't get changed if we don't include them in the design change package." The question that must be asked is: "Should the process be held up while waiting for something to happen now which isn't needed until later?" The solution

is never to hold up a product release or change to assure the support or manufacturing documents are up to date. Of course, the support and manufacturing documents must change as a result of many design changes. This will be controlled by the overall CM process at the appropriate point.

This is an easy rule to violate in a small company because the same person is often designated to care for Design, Support, and Manufacturing Documents. That person, however, can treat each type separately in preparation for the eventual split that should occur with growth.

The support or manufacturing documents affected must be updated as part of the change implementation. The CM process developed will assure that these documents are completed before closing the change. Each document control function can develop their own document control practices within the CM process overall requirements.

Minimum control of all documents needs to be tied together into an overall CM system.

Rule: The CM function will write the standards and design the overall CM processes. They will assure that the support documents and manufacturing documents are minimally controlled in the overall processes.

Reason: To assure minimum control in all of the CM processes.

See more about process documentation in Ch. 6, “Potpourri.”

Distributed DOC Control/CM

Some say that the document control/CM responsibilities can be distributed in various parts of the organization. Indeed they can because they most often are. Does this mean that this condition is most desirable? Read the following exchange of e-mails and decide for yourself:

> Hi Frank,
>
> Hope everything is well with you. Thanks for the knowledge you shared with all at the Doc Control course. I began applying what I learned as soon as I returned to work. The timing was perfect in that we are reorganizing the quality system here. As such, we are redefining processes and their flow site-wide. I am leading several teams in this effort and, as a result, I have an opportunity to impact how our processes will be restructured. We are an ISO 9000 certified company, in the

electronics industry, a contract manufacturing house (small form factor PC boards w/passive and active components), and part of a global corporation.

One of my functional responsibilities is to manage the Document Control Unit. Many managers feel that DCU should control just about every document produced on the site. What are good selling points to raise to get them to buy-in to the fact that DCU need only control design documents and ISO procedures (site procedures, level 1, 2, and 3, docs). The remaining documents generated are primarily Manufacturing and Support. Some feel DCU should control docs like job descriptions, equipment maintenance manuals, tool and fixture drawings, etc.

Am I on the right track? Your thoughts? Thanks in advance

Larry

The response:

Larry,

It was good to hear from you. You have identified one of the hardest elements of the CM discipline to explain. Let me try.

Folks generally agree that the responsibility belongs with the authority and vice versa. Translating that into document control would mean that it is best to place the document control authority with the organization that has the responsibility for creating/using them. Manufacturing documents (tool drawings, assembly instructions, fabricated part processing/routing, etc.) with manufacturing; Support documents (installation, service, parts manuals, etc.) with Field Service/Publications; Design documents with engineering, etc. This leaves, however, some unanswered questions as to the overall rules and assurance that each will fit in or be in sync with the other. That is why one of those functions (typically engineering document control) should be designated a CM function. The CM function would tie together the various document control functions by writing standards (and auditing same) to assure

that each is minimally controlled. The "tie together" would be the work flow diagram, certain standards, especially numbering and revision related standards.

The discussion gets especially difficult in smaller operations because the Design Engineering folks are often responsible for the publications, manufacturing process, etc. As an operation grows, however, my premise is that the responsibilities should be split and eventually spun off to the organization that should be the owners of the documents. I believe this because the engineer who is good at design is generally not good at manufacturing processing or technical writing and vice versa.

The discussion is also difficult because the assembly drawing is typically produced by design, but manufacturing is the primary user. Publication writers are also significant users. The ideal, according to Frank, would be for engineering to produce the three dimensional file necessary to produce part drawings and specifications and manufacturing and publications would produce from that file the needed pictorials for step by step assembly and step by step maintenance.

The other critical point is that the tendency to bundle up all the affected documents during the change process is uncontrollable when the same function is responsible for their creation or control. The bundled change is the slowest change. The design documents would be marked up/from-to, be released/changed first, then the manufacturing documents and publications should be changed (as a second step) if affected. The CM work flow diagram and standards will assure that they are in sync.

Thanks for asking, hope this helps.

Frank

Files and Masters

This is a subset of an entire body of expertise that is generally referred to as Data Management. This is a subject that can have, and has, many volumes written about it. The subject includes product liability implications, PDM systems, etc.

The goal here will be to cover only the basic data management necessities for Configuration Management. Chapter 4 on BOM/Databases will also touch on this subject. The critical aspects of file and document management to Configuration Management are:

- CM must be the keeper of the Design Document masters. The masters may take the form of the original hand drafted hard copy. The master may be a CAD file and controlled by a PDM system. An aperture card, microfiche, or roll microfilm, may constitute the master. An electronic code set/image may be the master, thus, the CM master file need not be in hard copy form. The various files should be programmed to allow only CM to assign revisions. CM can thus control the revision level as it is released or changed.
- The key to the master file must be held only by CM. In the same sense that CM manages the Print Room they must manage all design document masters regardless of the form. Hard copy and electronic media files should normally be in a locked room or locked files when not attended.
- CM must be the only group who can assign revision letters or numbers. It is by this device that they can assure that the system is being followed, capture a master document, file it, and assure that anyone can obtain the latest revision document. Can a note, stamp, or some other code be used instead of the revision level? Yes, but why add another factor to confuse the issue?

- A disaster file must be kept in a physically different building. This file is necessary in case of a fire or other disaster to the master file. Its format might be any or a combination of several of those previously mentioned. In one small CAD based medical company, the Engineering Services manager took backup disks to her home almost daily. This back up file is also a convenient place to keep each revision level document.
- Hard copy masters must be capable of at least two generations of reproduction. The master is used to produce a copy for red-lining and a copy of the red-line must be highly readable. For companies using microfilm, three generations is desirable; a copy for ECO red-lining can be reproduced, a highly readable microfilm copy made, and prints from it must be highly readable.
- CM must control all revision, part, document, hardware mod/software release, and ECO numbers.
- The master files should include all number assignment logs and ECO masters.
- Orderly files, handling of the masters only by CM personnel, all CM personnel being familiar with the filing system, are necessities for good file management.

Take care when considering PDM systems. Many of them claim to do CM, some of them do some CM. Finish this book and then ask yourself "What are our CM requirements and will a particular PDM system satisfy them?"

Now that the Loader Company documents are defined, what does go on the documents as well as what does not go on the documents, let's discuss how to identify documents and product.

3

Identification Numbers

Introduction

As if life in general isn't filled with enough numbers already, EDC/CM abounds with numbers. Product, Model, Catalog, Part, Item, Document, Spec, Serial, Mod, Block, VIN, Series, Release, Change, Deviation, etc., etc., enough already!

How in the world should this subject be approached? Trying to cover all the known numbering schemes would take a book by itself. In the interest of simplicity, the necessary numbers will be developed for the Front End Loader as the first product of a start up company. A company with a fast growing future and, hopefully, the wisdom to see what is best for the future. As this is done, variations that might be more applicable for another kind of company or industry will be discussed.

Product and Model Number

If you are a component manufacturer, or a make to print manufacturer, you may not have a number like this to worry about. Most other manufacturers do. This is the number where Sales/Marketing people usually call the shots. They pick a number (sometimes a name) which they believe will capture the attention of the market place. The "Whiz Bang Number." It is then Design Engineering's job to work with Marketing to place the number on the product where it will enhance the Whiz Bang.

The nameplate should, of course, prominently display the product number. In the case of the Front End Loader we used FEL-100. The important point to the company and to CM people is that this number is not precise with regard to options, nor can it usually be changed to indicate when certain changes have been made. It is, therefore, useless to CM.

Part Number Cycle

Sometimes product numbers are used in the sales catalog without a precise part number. Remember, the Product Specification for the FEL-100 came with electric or gas start as well as other choices. If a customer orders an FEL-100, just which options does he expect to get? Any ambiguity at this stage can easily result in the customer receiving something different than expected. It is, therefore, critical that Engineering and CM develop specific part numbers for sold items. Sales must recognize those part numbers and work with the customer to sell an FEL-100 identified by the specific part number. By using a part number at the top level, the company can make sure that what the customer wants is what the customer gets. The diagram in Fig. 3.1 depicts the complete part number cycle.

If this part number cycle is broken at any point, the likelihood of error occurring is substantial. The result is that the customer receives the product and it is not configured as expected.

One of the places where the chain is often broken is at the beginning, when Sales and the customer fill out the Sales Order. If there isn't a design document that helps Sales translate the options into a specific part number, breakdown will occur. Thus, when the Order Entry Department tries to convert the Sales Order to a specific part number, they can easily make a bad assumption about what the customer desired. This design document might be a matrix, catalog number, or a selected number that does define the specific configuration.

If the Product number (or catalog number) is precise and unique, it should not be necessary for Engineering to assign a part number. The catalog number should be brought under CM control and used as the top level part number.

The other place where this chain is often broken is upon making a functional non-interchangeable change. Regardless of the level or place in the product that a functional non-interchangeable change is made, interchangeability rules will require CM to "roll" the part number change up through all replaceable levels. Some companies even change the part number of the end product. After all, it to is functionally not interchangeable.

Interchangeability rules and issues will be discussed later, but in the meantime consider the affect of changing the end item part number. It breaks the chain every time a functionally non-interchangeable change is made. This creates havoc if you have very many non-interchangeable changes.

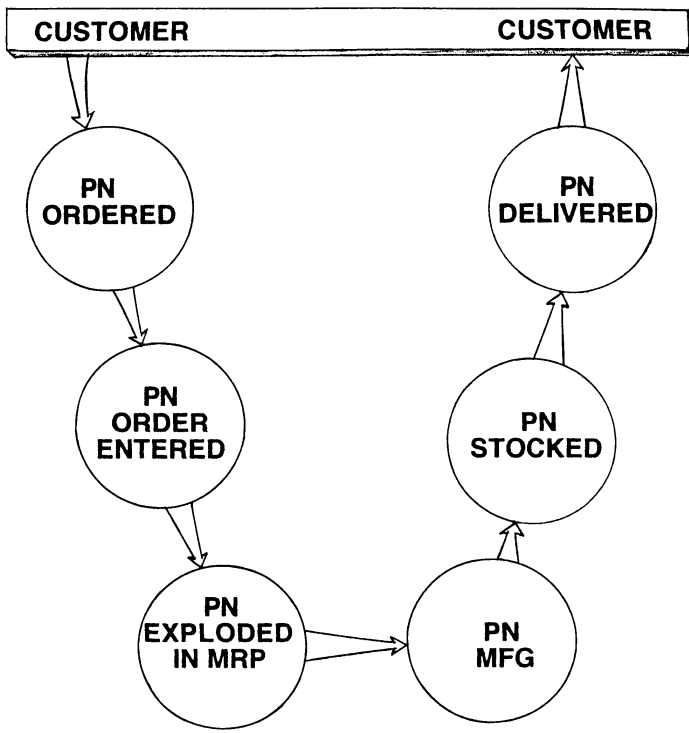


Figure 3.1. The part number cycle.

We need to know if the change is or is not present, but frequent changing of the part number of end items drives the Master Scheduler into orbit. He or she just got done negotiating run quantities and rates between Sales, Materials, and Manufacturing, based on end item part numbers. Does Master Scheduling now have to go back and reschedule old and new part numbers based on the probable effectivity of the change, then reschedule it again because the effectivity plan changes?

Customers will also notice the part number changing and question our companies design stability. When possible, these changes should be transparent to the customer. Will re-approval by UL be required?

This is why many companies do not change the end item part number. They prefer other ways to modify the top level part number. For most companies, it is best not to break the part number chain.

Rule: Do not break the part number chain.

Reason: We want zero unhappy customers and zero product return or replacements. Breaking the part number chain increases the risk of sending the customer something different than was expected.

End Item "Mods"

Process oriented companies generally use a date code which they can change (or record) each time they make a non-interchangeable change. Automobile manufacturers generally use a part of the *VIN* (Vehicle Identification Number) for this identification. Software people use a "Release" number for this purpose. Some manufacturers have an identifier that they call a *Machine Level Control (MLC) Series Code or Mod.* High-end manufacturers (low volume, high product cost), usually choose to trace changes to the serial numbers and not have a modifier (and do not roll the end item part number).

The modifier also allows "batching" or blocking of changes. The software Release modification is typical. This is an economical approach with software because of the extensive testing that is required for each release. Be cautious before using the batching technique with hardware changes, however. The most economical point of incorporation (effectivity) of a hardware change seldom matches the next (or the prior) hardware change.

This modifier discussion raises the question, "If I trace my change effectivity to Serial Number (and don't change the end product part number), why do I need a "modifier?" Answer: if you have a serial number and no modifier, and it works for you, leave it alone. If it ain't broke, don't fix it. In fact, this is a simplistic and, therefore, an excellent method of tracing changes.

Some companies find it more simplistic to be able to identify the version of the hardware as well as the version of the software. If your production operations tend to recycle units and, therefore, mix the units with

and without a non-interchangeable change, the resulting effectivity looks like this:

Example: Change*A*—effectivity: Serial Numbers 122, 125, 126, 129, 131, 132, 135, and up.

The complexity of this condition increases with:

- Earlier assignment of serial numbers
- Higher numbers of non-interchangeable changes
- Higher production rates

Thus, you may want to consider a modifier. In its simplest form, the above units containing change *"A"* might be marked with an *"01"* modifier on the nameplate or in some less obvious location in order to make it more transparent to the customers. The next non-interchangeable change, *"B"* would be *"02,"* and so on. Modifiers can be assigned for units that have change *"A," "B,"* and *"D,"* but lack change *"C."* One company designed an alphabet *scratch sticker*. The non-interchangeable changes were each assigned a letter and the letter was scratched when the change was incorporated.

A	B	C	D	E	F
G	H	J	K	L	M
N	O	P	Q	R	S
T	U	V	W	X	Y

This also made for easy communication between the customer/service/engineer when trouble shooting.

Traceability

The significant CM issue with Product Numbers, end item Part Numbers, Modifiers, and Serial Numbers, is traceability:

- What is the exact content of each product with regard to non-interchangeable changes
- What is the approximate content with regard to interchangeable changes
- Precisely how can it be known that a unit is under warranty

If you can answer these questions your "traceability house" is probably in good order.

Serial Numbers

A serial number is a number assigned to each individual product in order to distinguish that product from all others. They are usually assigned in sequence per product or product family. Manufacturing normally assigns the serial numbers to each product.

As companies grow, they may decide to build products in the same family in more than one plant. At this point the blocks of serials used by each plant must be controlled in order to avoid duplication. CM should control all serial numbers. The best method is to do it with a released document. CM must assure that all necessary parties agree to and are aware of the assignment of the blocks. An alternate method is to have each plant prefix the serial with a letter assigned by CM. This letter should be reflected on a released document. This document could be the nameplate drawing or a separate document referenced on the nameplate drawing.

Serial numbers are typically assigned by Production Control at some point near the end of the production line. The shipment date of each serial number must be captured by manufacturing for warranty purposes. Manufacturing must also track non-interchangeable changes to the Serial Number(s) they actually affect (actual effectivity) or to date, mod, etc.

Rule: If you serialize, make sure you know the date shipped for each serial and the actual effectivity by serial number(s) for non-interchangeable changes.

Reason: This is the essence of Configuration Management traceability (Status Accounting) requirements as well as a warranty control requirement.

The manufacturing organization may have to assign a control number to each product in order to trace non-interchangeable changes to a serial which is assigned later in the production process. There are several trade-offs that CM and manufacturing need to consider and agree upon with regard to when the serial number is assigned—early or late in the manufacturing process. All the factors previously discussed need to be considered as well as other factors, such as correlating test data to an individual unit. Analysis of the best point in the manufacturing process to assign serial numbers may lead to:

1. Early assignment and use of a modifier to overcome the serial number effective “mix” problem.

2. Use of a Manufacturing Control Number with later assignment of the serial number. This method is used with or without a mod.
3. Log the ECO's that are incorporated into a traveler with the unit and capture the SN / ECO relationship when the SN is assigned.

Make to order environments typically trace changes to the order. Thus a non-interchangeable change affects all of an order and all higher order numbers. They sometimes identify the unit with the order number and use the ship date of the order for warranty control.

Part Number

These are the numbers we associate with parts, assemblies, and (generally) the product, in order to precisely identify them. The term "item number" is probably the more expressive term, however, part number is more universal. The terms are generally used interchangeably.

Since the Front End Loader Company is a start up company, the company has a choice, therefore, the part number system will have minimum significance.

Rule: Put as little significance into the part number as possible.

Reason: Because significant numbering systems tend to break down. No matter how good you are at anticipating the number of digits you will set aside for a given characteristic, at some point it won't be enough.

With the advent of low cost computing, it is far better for a start up company to set up a database with those characteristics that might have otherwise been put into a significant part number. The temptation to use a significant part number is high. The significant part number helps us to find similar parts. If we don't have significance in the part number, how do we search to find similar parts? How do we avoid reinventing the wheel? A group technology or class code system is sometimes the answer.

Classification Coding

This technique classifies items by their principal characteristics. There are basically three methods for doing this.

1. Purchase a packaged system. There are several packaged systems on the market that have served some companies well. Requires one or more people to be trained, to code each new item, and to filter out duplicates.
2. Naming convention. Make sure that Descriptions and Name on drawings are done with considerable discipline. Your CAD/PDM probably has the ability to do key word search. The result is a crude but effective classification system.
3. Database fields. Devise your own class code in your database. Set aside a separate field for each element that is a significant item characteristic. This will require report writer programming to make it useful.

The intent of any coding/classification system is the same—to aid the company, especially the Engineers, in four ways:

1. Allows the Design Engineer to avoid reinventing the wheel. That is, to use an already designed item. Without a classification coding system, the engineer may well conclude that it is easier to create a new part than to try to find an existing one.
2. Similarly, it allows the Company to standardize. In other words, to sort through similar items and to designate only certain ones to use in future designs. Other items would probably be phased out of existing designs and made obsolete.
3. Engineers can more easily find similar items for possible substitution. This is very helpful to manufacturing when a critical part shortage arises.
4. Allows the Industrial or Manufacturing Engineer to utilize Group Technology to produce similar items in manufacturing cells. It can also help in the machine loading of molding machines, for example.

A good starter reference on this subject is an article titled *"Group Technology,"* by Frederick Ingram, in the fourth quarter of 1982 Production and Inventory Management (Journal of the American Production and Inventory Control Society, Inc.)

A good place for a young company to start is to write and follow a standard for noun name and descriptions (Naming Convention). Standardizing terminology makes sense anyway. This standard should describe the nomenclature method and give sample document descriptions.

Example: Standard says to always start with the Noun Name, follow with Modifiers, then the Value of the item.

Resistor, Carbon, 20 ohm, 2%
Bucket, Front End, steel, 4 Yard

The trick is to develop a method that will be most helpful for your company. When the first database system is implemented, place all significant characteristics not adequately covered in the naming convention into separate fields. This combination solution may well be the only class coding system you will ever need. A Component Engineer is probably the ideal person to do this.

Preferred and Alternate

Some companies struggle with their parts lists and/or the MRP system to try to inject preferred and alternate part numbers into their Bill Of Material.

Rule: Put the preferred item in the parts list and thus into the BOM. Let your classification coding system find the alternate(s) when needed.

Reason: You normally want the best for your product as a normal condition. When alternates are necessary, there are probably several lesser choices. Engineering intervention is normally advisable in these situations anyway.

A standard may be required to indicate which engineering function can make this decision, whether or not a deviation is required, etc.

Significant vs. Nonsignificant Part Number

Many companies have a significant numbering system at the top level—product level. Some have a significant number for Specification Control Drawings and a nonsignificant system for their own designed items. Many companies have mostly nonsignificant numbers. The pros and cons of each is shown in Fig. 3.2.

SIGNIFICANT	VS	NON SIGNIFICANT
Describes Part	•	No Significance
Is a Class Code	•	May need Separate Class Code
Must Publish Code Book	•	No Code Book (or Code Book in CM)
Misinterpretation Likely	•	Eliminates Interpretation
Security May Be Breached	•	Security Better
Often Variable Length and Alpha Numeric	•	Uniform Length Numeric
Less Compatible with MRP / Info Systems	•	More Compatible with MRP, etc.
Check Digit Use Not Practical	•	Lends Itself to Check Digit
Longer Harder to Memorize	•	Shorter Easier to Memorize
More Error Prone	•	Fewer errors
Probably Separate Document Number	•	Document Number Part of the Part Number
Categories Usually Breakdown - Limited Life	•	No Categories Lasts Longer

Figure 3.2. Significant vs. nonsignificant part number.

The most critical of these issues is that, over time, the significant numbering systems tend to break down. Companies with more simplistic products take longer to breakdown than those with more complex products. Significant numbers, thus, tend to loose their significance. They no longer do the classification coding function intended by their inventors. This is the prime reason for recommending as little significance as possible.

Recommended Part Number

The recommended (minimally significant) part number system is shown in Fig. 3.3.

Notice that this recommended part number has the Document Number built in.

Rule: The document number should always be incorporated into the part number.

Reason: Avoids making and maintaining a cross-reference list. Avoids making repeated reference to the cross-reference for all people for all time to come.

Exception: The top or product level numbering may wisely be a significant number. Especially if that number can become everybody's top number and thus avoid breaking the part number chain.

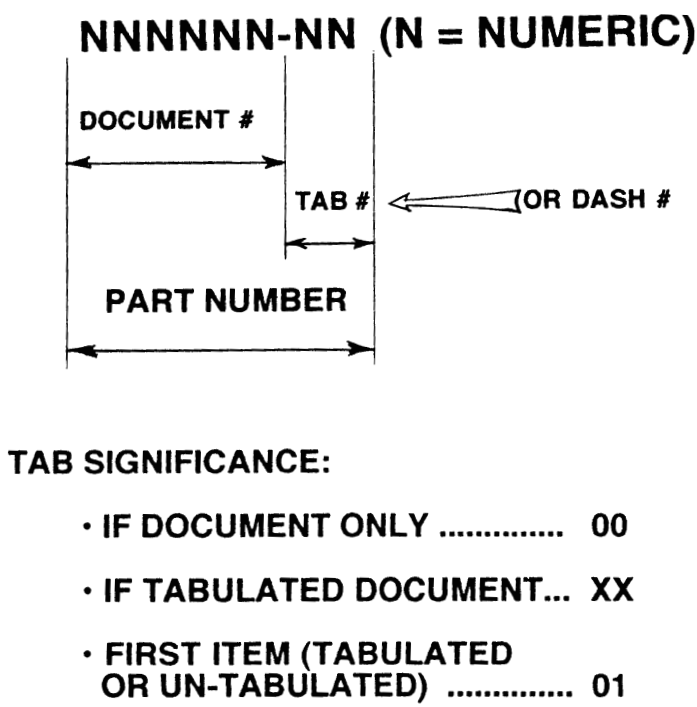


Figure 3.3. Ideal part number (minimum significance, document number embedded, tabulated).

Many CAD, PDM, MRP, ERP, and other automated systems, have a limit on the digits allowed for a part number. Significant numbers tend to be longer than nonsignificant, another drawback.

Companies with significant numbers generally have a separate document number and a cross-reference. Every cross-reference is difficult to produce and maintain. They also waste a little bit of time every time a person has to make a cross-reference—*forever*. They also introduce another possibility for error.

The Tab is a form of significance, but minimal. It is used to delineate similar items on the same document. It saves documenting time during product development. It also makes similar items easier to find (a form of classification coding). If you remember, both of the Front End Loader tires are documented on one tabulated drawing. Similarly, we can tabulate assemblies and end products. This is also the portion of the part number that we will change on non-interchangeable changes. This will save making a new document each time we change part numbers.

Rule: Always tabulate the part number. If you have an existing system that does not include this feature, add it as soon as practical.

Reason: Saves significant amounts of labor to prepare documents and to revise them. Allows change of the tab upon non-interchangeable change and, thus, is friendly to those many people who memorize part numbers.

The "dash" is shown in this book for clarity purposes. It need not and probably should not be used in your part number. Why do an extra keystroke with every data entry of the part number? Over time those keystrokes can be a significant labor expense.

At times it pays to add a couple of digits of prefix to this "ideal part number." They would be digits to identify the document/item "type." PCBs have several related documents (Assembly, Fab Board, Schematic, etc.) which need to be cross-referenced. Thus an addition of a prefix of AY, FB, SC would allow the rest of the document number to be identical. Using such a prefix might also help sell a PN system change.

The further away from this recommended part number companies get the more problems they have/create. A company using a badly structured part number is like you or I walking around with a bone spur on our heal. We don't know what the negative result of the surgery might be and the pain stops whenever we take the weight off the heal. The nagging pain may plague us until we do a significant surgery. With the document number

separate and cross-referenced, no tabulation (resistance to changing part number on non-interchangeable changes), and/or too much significance, the pain will continue. It is probably better that many companies look for an opportunity to do the surgery than to continue the pain

Sketch Number

Many companies use a sketch number to identify parts and documents early in the design cycle. This practice is both unnecessary and counterproductive. Assign a sketch number in the beginning and then create a cross-reference list to tie the design and development records to the released part number record. Why not assign the proper part number to an item when needed?

The system must have the ability to tell what phase of development the item is in. Thus, if the drawing and the system are quite clear that the part number is assigned for design and development purposes, then a sketch number is not needed. Later chapters will indicate at least one method for doing this.

There is a school of belief that part numbers are expensive. It is as though there is a choice. This writer does not buy into that philosophy. Are sketch numbers expensive? Certainly we don't want to assign numbers in blocks if there is a choice. Certainly it costs something to recoup unused numbers. Certainly we don't need some levels of assembly. Certainly there is no need to assign part numbers to desks and chairs, but isn't saying part numbers are expensive somewhat like saying that having a parking lot for employees is expensive?

Part Number Assignment

Design's Engineering Documentation Control/CM function should assign document numbers. Each is tabulated to make part numbers as the document author wishes (within the digit limit and the rules). They should have a document number log and assign the numbers, perhaps in the MRP, but only once regardless of where the log is kept. Numbers should generally be assigned one at a time, capturing on the log:

- Document Number
- Project Number/Product Number (FEL-100)
- Engineer Assigned to

- Date Assigned
- Document Title
- Kind of Document (part, spec, assembly, etc.)

The assignment should not require any signatures. The various functions that need to add information to the MRP database need to be informed that a new part number is assigned. Chapter 7 discusses a method for doing this.

This is an excellent automation application. If your automated database has this ability, use it. A simple PC spread sheet also works well. If your database has a status field, show the status as *PN Issued* or an equivalent code. If it doesn't, add status to your database. You will see how status coding works when we get into the product release process.

It might be more practical to assign document numbers in a "block." This is less desirable, but still manageable. Your assignment log should capture enough information to recover part numbers should you need to in the future. Assign in the smallest blocks possible.

As the document number is assigned, give the engineer your written rules on tabulation; only two digits allowed, 00 = document only, XX in the title block to indicate that the drawing is tabulated, 01 = first part, etc.

Changing the Part Numbering System

Again, least significance is the best method for a start up company. It can also be used when an existing significant numbering system breaks down. This would also be an excellent method for a company that has gone through several acquisitions and needs to consolidate into one numbering method. Some companies design a totally different numbering system for Specification Control Drawings. Since there appears to be no particular advantage in doing this, use the recommended part number universally.

Changing from one numbering method to another is not an easy matter. Considerable planning is required:

- Research the alternates, and plan the number
- Plan the change-over and all its ramifications
  - New items as designed
  - New items and most active products
  - Cold turkey on active items

- Cold turkey on every item
- Combination
- Plant shutdown or long weekend
- Affect on MRP/ERP, PDM, CAD, backup files, warehouse, suppliers, shop floor, assembly floor, standards, etc.

- Look out for documents referenced in the body of drawings and specifications
- Trial run the proposed number in parallel with existing method
- Train necessary people, They will point out problems. Debug, and retrain
- Cut over

Reports indicate that the lack of planning, testing, and training, are the problem areas to be avoided. One company reported that an ill planned numbering system change-over brought the company to its knees. Don't take a part number system change lightly. It is a very serious step and should have top management scrutiny and approval.

Revision Numbers and Letters

The revision letter or number is the change status or level of the document. The revision is for changing the document to reflect *inter-changeable* changes to the item or changes that do not affect the item, only the document.

Rule: The revision is not part of the part number.

Rule: Revision is never marked on the parts.

Rule: Never stock by revision level.

Reason: If your company's system is causing you to do any of the above, it is probably because it does not have clear, crisp, or correct interchangeability rules. If it did, then the part number would change for non-interchangeable conditions. The revisions of a part can therefore be intermingled. This is the only mode of operation that the father of interchangeability, Eli Whitney, would allow, he told the writer so.

Of course, the parts must be identified with part number and revision level in order to be purchased, received, and inspected. As the parts are put into stock for assembly, the revision level should be unimportant from that point in the manufacturing process on. See Fig. 3.4 for the steps in the process wherein revision levels are important and where they shouldn't be important.

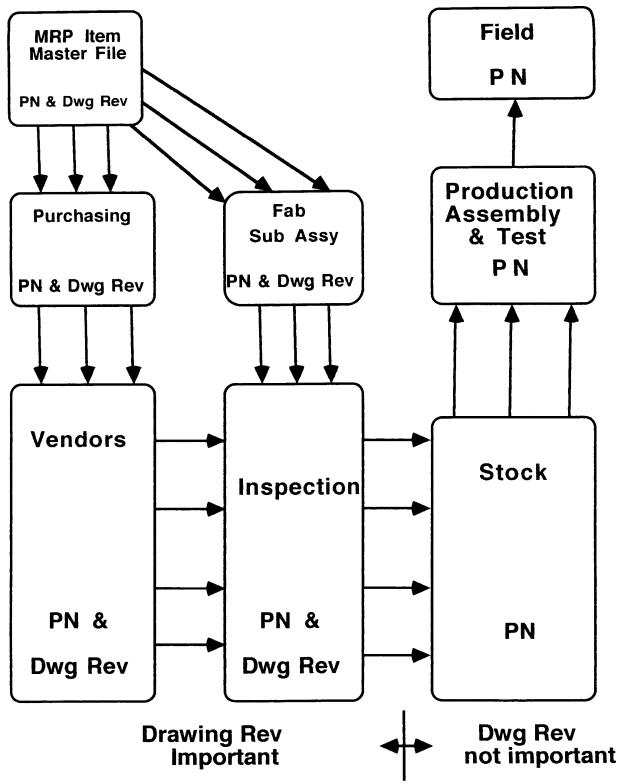


Figure 3.4. Revision level importance.

The revision level of the document should appear in the document revision block and in your database. The revision level of the assembly document would be the only revision shown on the parts list.

Rule: The revision level of the component parts should not appear in the controlled Engineering Parts List document. (See Fig. 2.6, Ch. 2.)

Reason: The revision level relates to the document, not to the parts. The revision level appearance on a parts list implies that it is the latest level. To assure the latest level is shown, one would have to revise every "using assembly" when any document representing a part thereon is revised. Doing this is a waste of energy.

Example: Frame PN 723456-01 used in the FEL-100 (see Fig. 2.6, Ch. 2) may be a frame made from any revision level document. The revision level relates to 723456-00, the document. Any items made from this document must be interchangeable. The fabrication shop or supplier should, of course, be building from the latest effective document, but the stock room may have several different revision levels in stock.

If your company has reached the totally paperless utopia, then the system can update the revision levels on the parts list and all higher assemblies automatically, and rev rolling becomes less of an issue.

Rule: The revision level of parts should not appear in support documents. Parts Catalogs, Maintenance Manuals, etc., should not refer to the revision level of the document depicting the item.

Reason: Items of the same part number must be interchangeable. Showing revision levels would (at least) confuse the issue.

Of all good CM practices, the above rules are the most often violated. The result is a significant contribution to the widening of the gap between engineering and other groups. Sometimes revisions are interchangeable and sometimes they are non-interchangeable. The MRP/ERP system doesn't treat the revision as part of the part number. Manufacturing doesn't want to stock by revision level. Publications job is complicated. The Field Support people order, stock, and think, part numbers. More on interchangeability in most subsequent chapters.

Revision Levels

The question arises, when does the revision level change?

Rule: Every time a change is made to a released document, the revision level must be increased. These may be interchangeable changes to the part represented thereon or document only changes.

Reason: Changes made to documents are important. It is, therefore, necessary for everyone using that document to know that changes have occurred. If the part is affected, the production people or the supplier must be notified to implement the change.

It is also important to have a source for determining the latest revision level of any released document. To satisfy this need the revision level must be kept in your database. This might be a manual file or data processing file, but not both. MRP/ERP systems (part information file) require a revision level. If you have MRP/ERP, keep it there and only there. Many companies have implemented an MRP/ERP system, but CM is still maintaining a card file with the latest revision level for a document number. The card file should be eliminated.

If the CAD/PDM system has the revision level and changes are automatically linked to the MRP/ERP, then this meets the criteria of having only one database to verify the latest revision. Engineering, CM, and Manufacturing, all using the same database (or linked databases) bridges the gap between Engineering and the rest of the world.

Page Revision Levels

When design documents are more than one page long, a decision must be made. Will all the pages of the set be kept at the same revision level or will each page be allowed to remain at its current level if it is unaffected by the change. In the later choice, a matrix must be added to the document (generally on the first or last page) which shows the correct level of each page. Thus, in either system the customers can tell, given the latest revision level, if they have an up to date set.

Both systems work. Some companies use one or the other and some both. Typically, the page matrix method is used for very long documents. This writer prefers to keep every page of the set at the latest revision level.

This costs CM a little extra work, but is significantly easier on their customers.

Change Identification Number

Each change should be identified by a unique number. This is the change number or ECO (Engineering Change Order) Number. This ECO Number should be:

- Assigned by CM
- Sequential numeric
- The number by which the change is filed
- Logged—The log should contain at least the following:
  - ECO Number
  - Date Assigned
  - Primary part number affected
  - CM Technician name

The log is another good automation application. Use your PC spreadsheet if nothing else. The ECO Number is the common thread for change tracking and change traceability. It is the Social Security Number for the change. It appears on:

- Drawing Revision Block
- ECO Form
- Data Base (Item master)
- Configuration Tracking Lists & Reports

As stated before, the ECO Number should be a separate field in the drawing revision block. If your company has multiple divisions, each with design responsibility, the Corporate CM function should assign prefixes (probably a letter) to each business unit. Each division of the company can then assign its own ECO Number.

What Gets a Part Number

Many companies assign part numbers to anything that is movable and some even to fixed objects. If your product is a power plant this may be wise.

A product manufacturing company assigning design part numbers to desks, chairs, and pads of paper, it is at least wasteful. Not only wasteful of the numbers, but of CM time. Time spent to release, file, control, and change the document representing the item can be better used. What should get a design part number then?

Rule: All design documents should be assigned a part number (document number included).

Rule: Support documents which ship to a customer should get a part number.

Rule: Documents which represent items that are not shipped to customers should not get a part number unless they are critical to the field support or maintenance process.

Reason: It takes time to process each part number/document. CM should not spend their resources processing other functions.

Packaging material would be documented with part numbers by this rule. Publications that ship with the product would also be assigned part numbers. Publications that ship with or separately (from the product) to a customer, should, therefore, be assigned a part number. If a tool is critical to the manufacturing or field support process, it should be assigned a part number.

This does not mean that the manufacturing people cannot assign part numbers to fixtures, jigs, and test equipment. The CM manager should work an agreement with manufacturing to use a prefix(s) that identifies the part number as "Not a Design Part Number" or a totally different numbering scheme can be used. If test equipment or a fixture is to be sold or shipped to a customer it should then be released and given a CM part number.

Rule: Just because you have a part number assigned to it, doesn't mean that you need to put it under CM change control.

Reason: Let manufacturing set up its own change control system for Manufacturing Documents; letPublications set up its own system; all under the CM standard requirements. This will free CM time to improve the CM processes.

Does this mean that Manufacturing cannot identify its process and routing documents by the engineering part number? Of course not. They can, and probably should identify by the engineering part number. The same part number can identify more than one document. This is done on a format(s), process sheet, route sheet, etc., that are unique. Thus they need not be under CM change control. Manufacturing must control that document to assure that it reflects the proper process for the effective design of the product. One might require the revision level to be kept by date only in order to avoid confusion with the design document revision.

In companies regulated by the FDA there is a great concern for the process. The necessary concern for the drug/process manufacturing has carried over into the medical hardware. This still doesn't mean that FDA requires CM change control. FDA requires all the same traceability of process changes, but doesn't dictate who does it. They can, therefore, be controlled by the Manufacturing Document Control group.

Every process company needs to be concerned about the traceability of process changes. This is especially true because the formula or mix of the product is sometimes embedded in the manufacturing process. Some process oriented companies have solved this problem by creating Bills of Material for their formula. This makes the mix design controlled by making it a design document. It would be similar to making the iron, molybdenum and carbon for the axle in the Front End Loader into a parts list.

Bottom Line—the fewer things you put a part number on, the fewer you will need to release, change, control, file, etc.

Item Marking and Labels

Some believe that if a part number is assigned to an item that it should be physically marked with that part number. This is a trend that is, at the least, very wasteful.

Rule: Avoid physically marking parts and assemblies when ever possible.

Reason: Part marking is expensive. What does it buy? Won't you have a parts catalog (or illustrated parts catalog) that gives the right part numbers for replaceable items? Might the latest replacement item be a different part number than was in the customers product?

"It only costs a quarter" some say, "doesn't it simplify the spare item replacement?" If you look closely, you will find that you will still need the spares catalog. If an operation could eliminate the spares catalog by marking parts, it might be worth the cost.

The number one reason for rejection of marked parts is "you can't read the marking." Every replaceable item at a quarter apiece, then another quarter for rejection, and another to correct the marking. Would you want it to be your quarters?

What happens when the part design changes non-interchangeably? If the part can be reworked, there will then be a need to rework the part marking. With most kinds of part marking this is no easy task. Now it is a quarter to erase the marking and another quarter to remark. What happens after the product has been in service for a while? Much of the marking can't be read anyway. Then the part number changes and you want the customer or field service people to order the new part number. Will they take the part number from the old part or will they read the parts catalog?

Take a close look at some assemblies and try to figure out which part number refers to which part or assembly. It will cost more than a quarter when the wrong part number is ordered.

While on the subject of marking, let us talk about labels. This is a costly trend in American industry. A friend just bought an outboard motor. He counted no less than fourteen labels on it. "Don't put your fingers here," "don't put your feet there," etc. A lawyer must be running this company. The punch line, however, was that the information needed most frequently, the oil and gas mix, was not on any of the fourteen labels. This "wallpapering" of the product may not be under the direct control of the Configuration Management function, but CM can exert some positive influence.

The Loader Company will put a name plate label on certain major modules, such as the engine and transmission. They will also be serialized for the same configuration and warranty purposes as the final machine. Labeling and part marking will be generally discouraged, however.

The Printed Circuit Board (PCB) is also infamous for being plastered with marking of various kinds. The part number of the assembled board, the part number of the raw board, revision letter of the artwork or silk-screen, the connector part number, and then throw in the board "Type" number. Could this be a bit of overkill? It might make good sense to examine these historical practices. Manufacturing makes some very complex mechanical devices without numerous markings, why not a PCB? As for the argument that, "If it's in the artwork it's free," file that with the "free" lunch. Would

you take a quarter for every board rejected because of bad marking? The PCB real estate is typically very valuable, so why waste real estate with unnecessary marking.

A better alternative to the PCB marking might be to assign a board type or function acronym (reference designator) to each board. For example, the electronic ignition PCB might be an ALTZ board. This reference designator can then be used on the artwork (and thus appear on the board). It would be used on the schematic and in wiring lists. The ALTZ reference designator would also appear in the parts catalog with the proper part number(s). This acronym would not change unless the function of the board changed.

The Loader Company will mark only the final PCB assembly and only with the board reference designator. The part number will be used in the parts catalog, on the box or tag for the board. The PCB reference designator will also be used where appropriate. If a customer or field service person reads the acronym and looks in the parts catalog they will find the proper part number for their unit.

The Loader Company will also have a check in the spares ordering process to assure that the latest interchangeable (new to old) part number is furnished instead of ordering old design boards. Since the revision level refers to the design document, we will not mark revision level on the board. Food for thought.

4

Interchangeability

Eli Whitney developed the Cotton Gin with a new design concept, interchangeable parts. Since the Cotton Gin was invented, customers have come to expect interchange of replaceable parts. If parts are not interchangeable, customers expect fair warning (usually in the parts catalog or a message attached to the spare parts) to tell them which part number to order/use.

If the reader has not read the section in the prior chapter on *Revision Levels* they should do that as an introduction to the interchangeability issue.

Before going too far with this discussion, lets determine the definition of interchangeability.

Interchangeability Defined

Most folks, when asked "What criteria do you use for determining interchangeability?" will say "Form, fit, and function." I recently read in a national trade magazine in which the writer said: "In today's keyed databases, a part number key must be unique, reflecting a part's form, fit, or function. If any of these change, even a little bit, then a different part number must be assigned to maintain integrity." Even a little bit? Use of the word integrity was never explained; nor was it explained why today's databases are any different than yesterdays. Another often used phrase is *compatible*,

as though use of that word adds some magical meaning that wasn't there before. Interchangeability is probably the most misunderstood CM concept. It is also one of the most difficult to discuss. Even the word non-interchangeable is difficult to say let alone type.

If one were to use the form, fit, and function, definition alone, with no further criteria, every change that affects the physical part is non-interchangeable. If we increased the radius of a molded part to make it release from the mold easier, that would be a change of form and, therefore, non-interchangeable. If we open up the tolerance on a part dimension that interchanges with all mating parts before and after the tolerance is opened, it could still be said to affect the fit. Any electrical component change could be said to affect function. This would lead to the conclusion that there are two kinds of changes, document only changes and non-interchangeable changes. Absurd? Yes.

What criteria then if not form, fit, and function? This author would submit that the form, fit, and function, rule is only a start and that criteria for each term needs to be developed. Take a look at the following time proven definition:

Definition: *Interchangeable:* Two or more items are considered interchangeable if, in all applications, they are:

1. Of an acceptable form (appearance) to meet all esthetic requirements per the Product Specification.
2. Of a proper fit (physical) to assemble with other mating items per the drawing dimensions and tolerances.
3. Of a proper function to meet the Product Specifications including performance, safety and reliability requirements.
4. These criteria must be met both ways (old design in the new and vice versa) with no special adjustments, modifications, or alterations, to the item or related items. (Your definition might be different in regard to adjustments, etc.)

So the criteria is established for each term. The Product Specifications are used for form and function. The drawing dimensions and tolerances are used as the criteria for fit. This is a critical distinction to avoid the endless hours of exhausting debate or oversimplified rules like "even a little bit."

Definition: *Non-Interchangeable:* Items which meet some, but not all of the above criteria are not completely interchangeable and are, therefore, considered non-interchangeable.

Thus, any change required to meet the form or functional requirements found in the product specifications is a non-interchangeable change. Any change to exceed those requirements (wherein the product has been meeting the product specification) is an interchangeable change. If the criteria isn't covered in the product specifications, or isn't added as part of the change, then the change is interchangeable. Therefore, some form and function changes can be interchangeable. Also, any change to the parts dimensions and tolerances can be examined in terms of a best case/worst case analysis (a "tolerance stack up"), a purely mathematical determination. Today's CADs do this automatically as an "interference fit" or other function. Thus, some fit issues are interchangeable and some not.

Compatible

The term compatible is very often used in industry and very seldom properly defined. Without proper definition the term is almost meaningless. Webster defines compatible as "Capable of coexisting in harmony: usually followed by *with*. Isn't that a very indefinite term? If it is going to be used as a meaningful CM term we better find a more precise CM definition:

Definition: *Compatible:* The old item is not interchangeable in the new, but the new is interchangeable in the old.

Notice that interchangeable and non-interchangeable must be defined before a meaningful definition of compatible is stated.

Interchangeable—Which Items

Must the rules be applied to all parts? Certainly parts of inseparable assemblies or products need not be included in interchangeability discussions. If an item is made up of inseparable parts (referred to as an inseparable assembly), then its parts cannot be interchanged. Thus, we need not have any concern about fit interchangeability of their parts.

Examples: Weldment, Molded Assembly, Riveted Assembly, Potted Assembly, etc.

Assemblies are a more difficult issue. In the Loader Company the management has made a decision not to guarantee the interchangeability of assemblies which are not on the spare parts list. This means that only their parts will be spared or furnished on special order to a customer.

If the Front End Loader windshield wipers are designated to be replaceable only as an assembly, then all you expect is the assembly to

interchange with the mating part. The company made a conscious decision to spare that assembly while not sparing other assemblies. Thus, interchangeability and part number changing of the non-spared assemblies will not be an issue. Therefore, the Front End Loader Company's concern will be for all parts which are not part of inseparable assemblies plus spared assemblies. We could also say that parts of spared assemblies will not be an interchangeability concern providing they are not spared.

This discussion also explains the inclusion of spare parts in this chapter on interchangeability.

Spare Parts and Assemblies

It is important to most product manufacturing companies to examine the question of "sparing" very carefully. First lets define what a spare is:

Definition: Items that are subject to damage, failure or wear.

This will require our field engineer and our design engineer to put their heads together to determine the initial list of such items. This will allow us to economize on parts catalogs, etc. If your product is an inseparable item, or a disposable product, then you replace the product, not its parts. This spares discussion that is, therefore, meaningless to you.

Rule: Only spared items (part or assembly) will be stocked for quick response to field needs for replacement. These are the only items that will be listed in the field publications.

Reason: Economy. Tremendous cost savings is possible in this area for many companies.

Thus, if we have three thousand items in our FEL-100, probably fewer than 700 of them will be spared. Does this mean that if the customer wants a Front End Loader frame that we won't furnish it unless it is on the list? Of course not, we will furnish any part or assembly to any customer, but it does mean that we will have to give the customer a quote for cost and delivery.

The longer we stay in business and the longer our products remain functional in the field, the more parts that will probably be added to the list.

How should those items be identified? The item master file might be coded for each item, Spared "yes" or "no." In the Front End Loader Company we will also make a special list of those items on a released part list format as in Fig. 2.6, Ch. 2. We will also reference that parts list on the top level assembly parts list as has been done in that same figure.

This allows us to separate spares issues from the manufacturing BOM issues. That is, if an assembly does not appear in the manufacturing BOM structured the way that Field Service wishes, it will be structured as they wish in the Spare Parts List.

Example: The Field Service function wants an ALTZ board without the PROM chip in a special package for storage and shipment and with an instruction for installing/testing.

The CM function can easily structure such a unique assembly and list it on the released spare parts list 62345700 (see Fig. 2.6, Ch. 2). The accounting function can also cost and marketing can price this unique assembly for field replacement.

The benefits of making this spares determination are apparent. We can save tons of inventory carrying costs by sparing only part of the total part numbers. Preparation cost for some of our publications will be about a fourth of what they might have been. Field Services' needs have been met. Our customers will be happier because they understand the ground rules.

The special assembly will also appear when we make "used on" searches, it will show as used on the spare parts list. The assemblies which are spared, whether special or not, will be referred to as Field Replaceable Units or FRUs in the remainder of this discussion.

Used On

Notice that the interchangeability definition refers to all applications. Lets say we have several Front End Loaders, each with a different size bucket. If we made a change that would not allow exchange of the Bucket Arms between any loader/bucket, the Bucket Arms would not be interchangeable. In order to analyze this, however, we need a way to know all applications the Bucket Arms are used on.

Rule: Configuration Management must maintain a manual or computer *Used On* database (Sometimes called "Where Used").

Reason: In order to test interchangeability of parts in all their applications.

Remember, this data is kept in a database not on the face of drawings. Most MRP/ERP systems have a Used On function. The Used On format will show (for the desired part number) the next assembly(s) by part number and, preferably, the next assembly description(s).

Example:

Affected item		Next assembly	
Part Number	*Description*	*Part Number*	*Description*
121456-01	Wheel, small	223456-01	Final assembly

Another kind of Used On format might show the next assemblies and the product Part Number/Product Number in a single look up. If your MRP/ERP has this feature it will save time by avoiding the necessity to step up through the structure one assembly at a time in order to find the Product Used On and, thus, the responsible engineer and or the customers involved.

Also, note that both form and function statements refer to the Product Specification. In other words, the criteria is not what the engineer or anyone else thinks, but rather what the Product Specifications say. Many, many hours are spent debating the form and function interchangeability. The best way to eliminate these debates is to invoke the Product Specifications. More later about product specifications.

Examples to Ponder

Lets take some examples from the FEL-100, referring to the Product Specification in Fig. 2.9, Ch. 2.

Change #1: The outside diameter of the rear tires is increased in order to improve the performance and appear ance of the machine. The machine will still meet the maximum lift height requirement of eight feet.

Discussion: Nothing said about being required to meet product specifications. What if the spec had a requirement that the Loader move at *x* feet per minute in first gear? Might this change be improving performance toward meeting that spec?

Conclusion: The change must be considered interchangeable unless the Engineer is willing to include a product spec change that adds criteria that the change is being made to satisfy.

Discussion: What if the increase in OD of the rear tires caused interference with the fenders?

Conclusion: The change should be rejected.

Discussion: What if one of the old and one of the new tires are put on a Loader? Wouldn't the Loader tilt?

Conclusion: Certainly the customers will replace tires one at a time in the field and the Loader will tilt. If there is an objectionable amount of tilt as shipped from the factory, that requirement should be added to the Product Specification. The drawings would then have to require the old and new tires to be assembled in matched pairs. The change would still be interchangeable however.

Change #2: The frame (previously untreated) is now to be cleaned and painted black.

Discussion: If we again examine the FEL-100 Product Spec, we find no reference to frame paint in the color choices.

Conclusion: Perhaps the product spec needs to be revised to clarify that frames may be untreated or black.

Discussion: We find no reference to corrosion resistance in the Product Specification for the frame or any other part.

Conclusion: The change must be considered interchangeable unless the engineer is willing to add the corrosion reliability requirements into the Product Spec.

Change #3: The tire ID of the front tires is decreased 1/2" and the front wheels are also decreased in OD by 1/2".

Discussion: We don't know the dimensions of the wheels and tires or if we are talking about ten foot tires or three foot tires.

Conclusion: The best case/worst case needs to be analyzed. Agreement will be easy to reach after the analysis.

Change #4: The fuel injection port sizes are increased in order to increase peak engine performance to 4400 RPM from 4390 RPM.

Discussion: Notice that our Product Specification committed 4400 RPM.

Conclusion: This change must be considered non-interchangeable unless we change the Product Spec to change the RPM spec requirement.

Change #5: The fuel lines and fittings have been "beefed-up" in order to prevent breakage when an operator or maintenance person uses them to pull themselves onto the machine.

Discussion: This would seem to fix an obvious safety hazard, both because of a possible fall and possible fire. Examination of our spec reveals that nothing was said about such safety criteria.

Conclusion: If the Engineer is not willing to add the safety requirement to the product spec (and call the change non-interchangeable), take this one up the chain of command for resolution.

Discussion: Beefed up fittings could well mean non-interchangeable.

Conclusion: It may or may not mean that, but we can easily analyze that issue by examining the fitting drawings.

Change #6: The seat material is changed from vinyl to leather in order to improve the functional life and operator comfort.

Discussion: Examination of the product spec reveals no requirement for seats to last for a prescribed period nor that they be leather. Sales Management has heard about this change and wants to advertise the leather seat. Engineering and Manufacturing Man agement don't want to commit to leather in the Product Spec. This change may be a candidate for the "don't do" round file.

Conclusion: If it is to be done, this change must be considered interchangeable. It is up to the Sales Department to take this issue up the chain of command if they feel strongly enough about having leather. If they are successful, the requirement for leather must be added to the product specification. The change would then be non-interchangeable. The Company should also have a policy that Sales can not advertise criteria that are not in the Product Specification.

These examples reveal one very significant rule about the process of determining whether or not a change is interchangeable.

Rule: If criteria is not in the Product Specification then it cannot be used as a reason for form or function (including "safety") non-interchangeability.

Reason: Without a Product Specification, or without using it for this purpose, endless debate results. The responsible design engineer must put form and function (including safety and reliability requirements) into the Product Specification.

As you read these examples, you no doubt made your own analysis. You may have been tempted to reach different conclusions. Read over the examples again and ask yourself on which examples you might disagree with the conclusion. You will probably agree with the fit issues and tend to disagree with form or function issues. Discussion of similar examples in the University seminars yields very few fit interchangeability debates. Most of the form and function issues arise from unwritten or implied specifications. In this case our Product Specifications were very minimal, thus bringing on debate.

Rule: Product specifications must be considered a dynamic document that must be changed or added to as the conditions warrant.

Reason: The alternative is to ignore the specification and have the Engineer, CM or a committee interpretthe change/ specification. This alternative leaves the same issues to be discussed over and over as subsequent changes or product spin-offs use the same Product Specification. Fine tuning the specifications narrows the gap between Design Engineering and the rest of the world.

Make sure that your system requires that the Product Specification be revised simultaneously when the change is said to be non-interchangeable (when the form or function criteria cannot be found in the Product Specification). If the responsible Engineer isn't willing to do this, your policy should make the change interchangeable.

It is interesting to note that the process was held up while settling the safety issue, but not held up for Sales on the leather seat issue. It isn't necessary to hold up the process in either case, but CM Management certainly needs to diligently follow up on safety issues to assure proper resolution.

It is also interesting to note that every parts list change is not, by definition, a non-interchangeable change. We may well change from one tire (or screw, or resistor) to another of a different part number without affecting the form, fit, or function, as defined. The part numbers were different because in all of their applications they may not be interchangeable.

Interchangeability Test

Interchangeable changes are done by a revision level change of the document. Most manufacturing systems (MRP, ERP, etc.) assume that the part number will change on non-interchangeable changes. A very good test to assure interchangeability is to ask: "Can the old and new design parts be intermingled in the same stock bin?" Thus:

> **The Golden Rule:** The blind person working in the stock room (or assembly). The pick list has the part number (no rev) in Braille and the bin is identified only with the part number (no rev) in Braille. That blind person must be able to "read" the picklist and reach into the bin and find interchangeable parts and it shouldn't matter what revision level document the parts were made from.

Notice that "cost" is not a factor in the interchangeability definition or discussion. The DoD has confused this issue by making cost a part of the "Class I" definition. Certainly, if your intent is to increase the price to your customer you should notify them. Cost/Price, however, bears no relationship to interchangeability or non-interchangeability, or to the resulting part number changing issues.

Part Number Change Logic

Notice that up to this point there has been no reference to whether or not the Part Number changed. They are separable issues if done in the correct order. First, decide whether the change is interchangeable or not, then decide whether or not to change Part Number. So, what affect does interchangeability have on part number changing? The general rule to the Loader Company is shown in the logic diagram in Fig. 4.1.

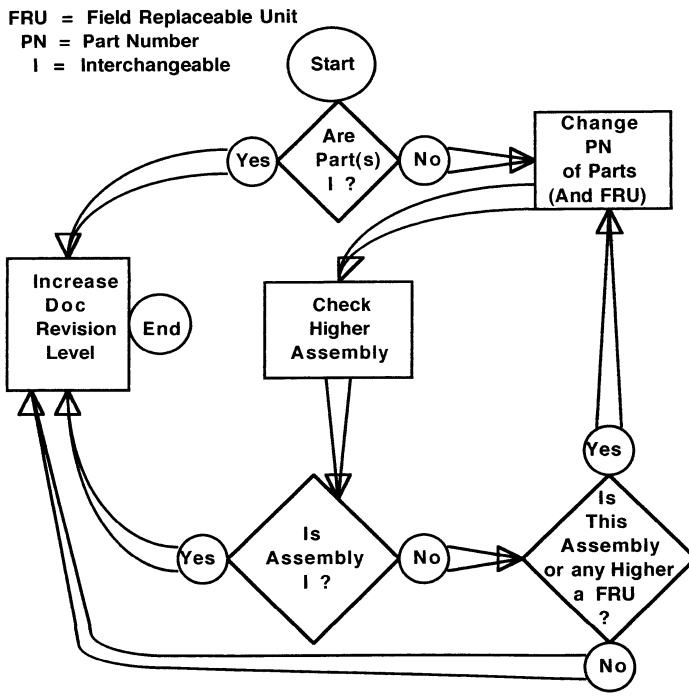


Figure 4.1. Part number change logic.

Use of this diagram in the example of the tire/wheel change wherein the dimension and tolerance stack up indicates the change is non-interchangeable. If we use the diagram for the tire and wheel separately we get the same answers:

- Are the parts (tire or wheel) interchangeable? Answer: NO, therefore, change part numbers of both.
- Check the higher assembly, is the assembly interchangeable? Answer: Yes, therefore, increase the revision level (of its document). (END)
- Result: The part numbers of both the tire and the wheel must change. Since the tire and the wheel were on tabulated documents, all that is necessary is to add tabs to those documents for the new versions. The next higher Assembly would also have to be revised. That revision would be a deletion of the old tire and wheel and addition of the new tire and wheel. Do this parts list change by increasing its revision level. The pictorial drawing would also be revised if it has the same part number and we are keeping it at the same revision level.

The question arises in this and other "fit" non-interchangeable changes:

- "How do I tell by looking at the product/nameplate, that a non interchangeable change has been made?" Answer: you can't since we didn't change higher level assembly part numbers or revision levels. Take the serial number from the nameplate and refer to the serial number records or the parts catalog. The serial number record should tell us if the change was present in any given serial. The catalog should have the old and new parts listed with the effective Serial Number(s). This implies that we have traced the non-interchangeable change to the effective serial(s). If you decide that this is not sufficient, then a Modifier should be considered. In this example, the Mod Level would be increased for those units containing the change. The modifier could be on the nameplate or in a less conspicuous location.

The physical fit criteria are relatively easy conditions to analyze. The dimensions and tolerances on drawings generally answer the interchangeable questions. If they don't, the following rule should apply:

Rule: If physical fit interchangeability is not obvious from analysis of the drawing dimensions and tolerances, added and/or changed dimensions are required.

Reason: Fit criteria must be on the drawings, not in someone's head.

Form and Function

The example change that increased the engine RPM to spec, 4400 rpm, was non-interchangeable. If we apply the part number change logic we would change the part number of the parts involved and we would then examine each assembly to the top level. Each assembly and the top level would all be non-interchangeable since it is the end item Product Specification that we used as our criteria, but should we change each assembly level by level (a practice the author refers to as part number "rolling")? No. Only those levels that are spared (FRU) would be changed. Then we would go to the final assembly and ask if it is interchangeable? Answer: No, because we are talking about the Product Spec, thus, we are also tempted to change the end product part number. This will convey a message to your customers that your design is very volatile and that you may be experimenting on their units. Better to have a company policy that says the end item part number will not be "rolled" unless Marketing wants to sell two products, one with and one without the change.

At the end product level we need to address whether or not to make changes transparent to our customers and/or what our agreements with the customer(s) require. If agreements allow the changes to be transparent then it makes sense not to change the part number or show the Modifier on the nameplate. It also makes sense not to change the end item part number because of UL, FDA, and other agency requirements. They may require recertification if the nameplate data changes.

Affect on the Field Units

This kind of change, form or function to meet specs, raises another issue. "Do I need to revise units that are in the field?" In turn, this question

raises many issues. Are customers who have the old design likely to be unhappy? Do we have contracts that require us to retrofit the field units? Does the form or function issue affect all the customers? How many old design units are there? How expensive will it be to retrofit some or all units? What are the liability issues? etc.

These are all questions that need to be addressed as a part of the ECO process. They need to be addressed in the ECO process because the cost of the change will increase if we plan retrofit. Also, the Field Engineer should be aware of and agree with the decision to retrofit. What better place for this than on the ECO.

As a result of the ECO that calls for retrofit we will initiate a Field Change Order (FCO, described near the end of Ch. 6). The key is not to hold up the change while solving all the related field issues. There is no reason to hold up the change any longer than necessary to get the Field Engineer to agree with a retrofit plan. The details of the FCO can wait. There are several reasons for making the change in manufacturing quickly, not the least of which is to produce fewer units that require retrofit. More on this in the change process.

Notice that the logic diagram and the discussion have assumed that the items that are Field Replaceable Units (FRU) are identified. They should be coded in the database and listed in the spare parts catalog. By doing this we can minimize part number rolling:

Rule: Assemblies that are not field replaceable need not change part numbers in form or function non-interchangeable change.

Reason: Rolling part numbers is expensive, delays the needed change, and is unnecessary. CM, Manufacturing, and Field Service functions are able to handle the "fit" non-interchangeable change without changing higher assembly numbers so they can also handle the form and function non-interchangeable changes without rolling all levels of assembly.

Assemblies which are not field replaceable should not be displayed in the parts catalog.

One more anomaly regarding non interchangeable/part number changing:

Rule: Part numbers need not change on any type of non-interchangeable change if:

- all parts affected are under factory control, or
- if no parts have been made

Reason: Speeds up the change process, saves some work and the old configuration will not exist

This condition typically occurs frequently in new product development and in pilot production. The trick is to make sure that manufacturing people are part of the team reviewing the request/change and that they commit to assuring that all parts affected will be reworked, scrapped, or replaced. CM and manufacturing should agree on the precise definition of "under factory control" and write it into the standards. For example, the definition might be that Production Control decides.

PCB Interchangeability/"Bug Fixes"

There are those who believe that the Printed Circuit Board (PCB) is a special and different case. The argument is—Any change to a PCB is a functional change and, therefore, it is non-interchangeable. This misconception sometimes spills over into any predominately electrical assembly. It is just plain wrong. In the first place, there are mechanical changes to a PCB: connector changes, access holes, solder path spacing, etc. More importantly, the same interchangeability and part number change logic should be applied to the PCB change. Are the functional changes required to meet specs or not? If we have been meeting spec and the change is to improve over and above the Product Specifications, isn't it interchangeable?

The question also arises as to the interchangeability of reworked boards, sometimes referred to as "piggyback, cuts and adds" or "bug on the board." There are two issues involved (assuming the old and the reworked boards are fit interchangeable):

1. The first issue is the form—the cuts, adds, and "piggy backs" make the board look different. Since boards are usually not visible in the finished product, the appearance is generally not considered an item to put in the product specification. Many companies have a limit on the number of cuts and adds that they will tolerate before embedding the changes. This is a quality and workmanship issue, not an interchangeability issue.

2. The second issue is the function of the reworked board. Is the functional change to meet Product Specifications? Yes = non-interchangeable. No = (improvement over product spec) = interchangeable.

Assuming that the board is a FRU, then we need to change its part number if the "bug fix" is required to meet product specifications. It follows then that the part number of the "embed" should be the same as the reworked version. How should the rework be documented? The same as any rework, as part of the ECO which directed it. All these issues should be addressed in the company interchangeability standard.

If multiple bug fixes are done then the embed would have the same number as the last bug fix providing that no new non-interchangeable change was made during embed. The Printed Circuit Board has some unique problems associated with making short term changes as opposed to long term changes (embed of the changes into the artwork). The following may help clarify this issue. It is an e-mail from a client whose product is PCBs, sometimes stand alone, sometimes in an enclosure:

> Frank,
>
> I have a question regarding an ECO scenario that occurs fairly often here. Here's a typical example:
>
> A "bug" is found in a product in production. A change is necessary to meet spec (disconnects, connects, etc.), however, the change is fairly complicated. The designer often finds that the right way to fix it requires a new bare PC board because the change would violate our workmanship standards if done to existing product. However, there is often a "better than nothing" rework that can be done to the existing product without violating workmanship standards. How do we deal with this?
>
> Currently, we write an ECO that describes the better than nothing rework so that manufacturing can start shipping. We update the schematics to agree with the rework, but leave the PC board fab info as is. At some later date, possibly after several more ECOs of this type, manufacturing will decide that they would like the changes embedded. At this point we write a new ECO that performs the changes the right way (our "stitch" ECO), update the PC board fab info and schematics, etc., and release a new BOM that uses the new PC board.

What concerns me is the fact that we update schematics to agree with a change that is only done as a rework, and then later undo those changes and redo them the right way. It seems like we are focusing on the ECO as directing rework to product in production as opposed to changes in design documentation. In effect we are more concerned with documenting the rework than documenting the designer's right way fix. Since the design is incomplete until manufacturing requests that we embed the changes, anyone who wants to derive a new design from the existing one will not get the designer's true intentions if they copy the design that just has the better than nothing fix implemented.

Thanks.

Mike

Frank's reply:

Mike,

It was good to hear from you. Glad to see you up to your ears in the CM processes. The situation that you describe is quite usual in the PCB business. We used to call it the Piggyback, cuts and adds, but the term that I hear more often now is "Bug on the Board" wherein bug has two meanings—bug fix and the fix often looks like a bug.

You have little or no choice, as I see it, but to focus on each rework configuration as a separate ECO. When the bug on the board is done the ECO should indicate the rework configuration and the corresponding schematic changes made (perhaps by mark up). It should also point out, at least in some general way, that when the change is embedded that the permanent fix may be of a different configuration. I would do this only to make life easier for my successor should I get hit by a truck. After all, I would want them to think kindly of me.

The fact that you allow several of these bugs on the board before embedding the changes into the artwork is also not unusual. Some companies predetermine a limit on the total cuts, adds, and piggybacks, that are allowed before embedding. This would be a question of the frequency, customer image, cost of embed, etc.

As I indicated, a mark up of the schematic in the ECO might be sufficient for each bug. Of course, the schematic would also be revised upon embed.

The issue that you didn't raise, which I thought you were leading up to, is that of identification. That gets somewhat harder to discuss. If I assume that the schematic numbering and rev are detached from the board product it would be a little easier for me to relate to. This would imply that upon troubleshooting one must get the ECOs out to examine each for impact.

First we need to decide if each bug fix is interchangeable (improvement over and above specs) or non-interchangeable (made to meet specs). If interchangeable, I don't think any numbering/rev changing is necessary. If non-interchangeable, then we should know exactly which units have the change (and, thus, which ones don't). I would be inclined to change the PN (tab) of the assembled board on each non-interchangeable change.

Upon embed, the unpopulated board would change PN, but the board assembly is probably interchangeable with the last bug fix.

If your board assembly is your top-level product, and you don't want to change PN at that level (it can and should be transparent to the customer) then look at the serial by serial record we talked about. I hope that this will be of some help to you and that adding the identification issue doesn't confuse things. It is, however, necessary to consider it along with the other issues you raised.

Good Logic and Luck,

Frank

When in Doubt

Having and following the prior crisp interchangeability and part number change rules will go a long way toward bridging the gap between Design Engineering and the rest of the world. Even the best rules leave some gray areas, therefore, one last rule:

Rule: When in doubt, change part number

Reason: Better to err on the side of changed part number.

This last rule must not be used as an excuse to throw out any or all earlier rules and logic, however.

It is also necessary to point out that in all the above discussion when it is said to change part number it is presumed that your number has a tab or dash that should change, not the entire number. If you do not have a tab then you will find a tremendous reluctance to changing numbers. Best add, as soon as practical, a tab to your part number.

Some folks say, "We don't have to change this assembly part number because we mark the revision level on the assembly." The author then asks, "What do you do upon retrofit?" The answer is almost always, "Oh, that isn't a problem because we retrofit everything to the latest revision level." This stated retrofit policy is probably OK for the early months of a new product's life. In that early time most changes are to meet spec, however, as the product becomes mature, more and more changes are made to reduce costs and to improve over and above specs. Is it wise or cost effective to incorporate such changes upon retrofit? The author thinks not. That policy is a very expensive policy and should be re-examined.

5

Bill of Material

A database sounds like something only a big company would have, not something needed in a small start up company. Actually it is important to any size company. A Bill of Material database is an essential in almost every product manufacturing company. As we discussed earlier, some companies try to keep too many database elements on the face of their drawings. The Loader Company will keep most elements off the drawings, in the MRP/ERP (Manufacturing/Enterprise Resource Planning) system since this is the first database system we purchased.

Data Responsibility

The product data base is concerned with data that is document or part number related. There are three groups of this kind of data. The groups relate back to our document groups. There are three different functions that should be responsible for this data:

Data		Responsibility
• Design documentation/data	=	Design Engineering & CM
• Support documentation/data	=	Field Service
• Manufacturing documentation/data	=	Manufacturing

In some companies the organizational responsibility may differ from the above. If that works, don't change the reporting responsibility. On the other hand, if there are operational problems relating to the documentation or data, one of the first things to look for is the responsibility.

Example: Who should be most interested in having up to date publications shipped with the product? Answer: Field Service. If the publications aren't up to date, and are produced by Design Engineering, consider moving the responsibility to Field Service. On the other hand, if they are always up to date and ready to ship when the product ships, don't change the reporting chain.

Some companies are too small to even have a Field (or Customer) Service organization. Its functions are done by Design Engineering and/or Engineering Services. That's fine, but still group the data as described above because it is wise to plan for growth. This separation also allows for separate treatment of the data in the release, request for change, and change control processes.

Often the separate organizations will develop multiple databases. The engineering folks buy CAD/PDM, the Field Service organization (Publications) will buy a desktop publisher and the Manufacturing organization usually buys MRP/ERP. This is OK from a CM viewpoint providing that they do not each input and maintain their own Bill Of Material. More on that subject later in this chapter.

Data Dictionary

It is most important that the database be carefully conceived, grouped, and executed. The definition of each element of data, its source, and the function responsible for entering it into the database, must all be addressed. Whether the data relates to the document or to the part also needs to be determined. This basic information related to each element of data is referred to as a *Data Dictionary*.

Example: Data dictionary:

Data Element: Item Weight

Source: Release Document/Drawing

Entry: CM

Character Definition: 5 digits—NNN.N (N = Numeric)

English Definition: The weight of the part in pounds and tenths of pounds. Not required for assemblies. Not required for documents unless they are shipped with the product.

This seems like an unnecessary step in small companies, however, if you are to grow with the least pain, it should be done as soon as practical, avoiding multiple input and maintenance of data. One government site reported that after many years of existence they examined their programs and found that they had twenty seven different definitions for a part number. Configuration Management and Information Systems should get together on the development of this tool.

Item Master File

The typical MRP/ERP system has an Item Master File and this database is the repository for all information related to the part or assembly. The information is divided into several input screens that allow input to be done by the responsible function. Engineering, Production Control, Materials, Accounting, Purchasing, Field Service, etc., may all have the ability to enter and control their own data. This aspect of MRP/ERP systems is a very important feature that should be carefully analyzed prior to purchase of a system. This text will explore only three of the subsets of data, the Design Engineering, Manufacturing in general, and Field Service information.

Next, carefully decide which data elements belong in which group. We will do this with some examples (not meant to be a complete list).

Design Engineering Data

Element	Comment
Part Number	Primary/Key data element
Document Number	00 tab of every part number represents the document
Description	Per Standard—Noun Name, Modifier, Value, etc.
Cognizant Design Engr.	Relates to the document
Type of Document	Per Standard, Assembly, Part, Doc, PL, etc.
Size of Document	Per Standard, A, B, or C
Item Weight	Relates to parts only

Unit of Measure	Only one per PN (the same regardless of Used On)
Assembly(s) Used On	Multiple entries via parts list entry

The last entry above (Used On) is the source of all applications for interchangeability logic. With most MRP/ERP systems, the Item Master File is the primary database. The used on is typically maintained as parts list data of parent—component relationships. That is, each time the same part is included on a parts list (parent component relationship or BOM file) then the part gets another used on in the system. If you have an MRP/ERP system don't create another database as you add other systems.

Example: *Front End Loader:* A partial database for the Loader Company design data might look like this (not intended to be a complete data base):

PN	Description	Engineer	Item	Size	lbs.	U/M	Used On
121456-00	Wheel, Small	P. Rushmore	Doc	B	NA	NA	NA
121456-01	Wheel, Small		Part		14.2	Ea	223456-01 223456-03
123456-00	Product Spec	J. Byers	Doc	A	NA	NA	223456-01
223356-00	Motor Mount	H. Peak	Doc	C	NA	NA	NA
223356-01	Motor Mount		Part		22.8	Ea	223456-01
223456-00	Final Assem	L. Crouse	Doc	A		NA	NA
223456-01	FEL-100		Assem			Ea	Top Level

Most systems have a transparent database. That is, you view screens/reports rather than the database itself, however, the above example (shown as a flat file) is useful for discussion..

Several interesting things are visible from this database. The Small Wheel has two used on assemblies. If we make any changes to the Small Wheel we will have to check the interchangeability in both applications.

Notice that the Responsible Engineer and the Size of Document relate only to the document. If we had included the Revision Level in the database, as we should, then it would also only relate to the Document. Discussion of the Responsible Engineer concept will come later, but for now it is the only person CM will give a request to or accept a change from.

The database can now be used to retrieve information about the Design Engineering/CM business subset. How many assemblies in a

product? How many parts? How many documents? What is the Used On for any part? What size is the document? What is the combined weight of an assembly? What is the weight of the product?

The entry of the drawing size and revision level replaces the need for a manual card file that was often maintained in the print room. This will be our source for the latest revision level and to allow retrieval of a hard copy of the drawing since they are normally filed by size. You can begin to see the power of a database. It is a powerful source of facts about this subset of your business. If you had a Classification (Group Technology) Code, it would be added to the database. The existence of multiple CAD files and the need for engineers to manipulate this data in many various ways has led to the development of PDM systems.

Parent Component Relationship

The parts list shown in Fig. 2.6 will be our released and controlled design document whether on line or in hard copy. This assembly parts list is the parent component relationship. If you have an MRP/ERP data processing system, the Parts List (parent component relationship) would be entered into the Bill Of Material file. That is, for each assembly, at least the following data would be entered into the MRP assembly (parent) file for each item (component) on the parts list:

Data	Comment
Part Number	Of each component called out
Quantity Per	In each specific assembly
In date	Release date or date added by ECO
Out date	Date deleted by ECO
ECO Number	ECO that made any change to the above data

The description and unit of measure are not repeated again since those elements were entered in the part related item master file.

Without an MRP/ERP system, the parts list data (Quantity Per, In Date, Out Date, and ECO #) would be maintained manually on the parts list or in the CAD file. Changes would be maintained in the ECO file. That is, a marked up copy of the parts list must be kept in the ECO package. This will show what changed on the parts list for posterity. The marked up parts

list in the ECO package is a good idea, even if you have an MRP/ERP system.

Marked Up Parts List

Most MRP/ERP systems do not have "red line" ability, thus, the parts list will be marked up manually. This technique can save many hours of ECO writing time as well as reduce BOM errors. An example of this useful method for the Front End Loader product:

Example: In a change discussed earlier, the front (small) tire and wheel changed, thus, making both non-interchangeable. The resulting mark up of a parts list would look like Fig. 5.1 (underlining denotes delete).

DATE REV	REV	REV DESCRIPTION	ECO #	SIGN
1-12-88	01	RELEASE FOR PROTO	1212	FBW

EC3 CORP	DESCR	P/N	SIZE	PG OF
FEL - 100	FINAL ASSEM	223456-01	A	1 1

FIND #	DESCRIPTION	PART NUMBER	QTY	UNIT MEAS	IN/OUT DATE	ECO
1	Motor Mount	223356-01	1	ea		
2	Tire, Large	423456-01	2	ea		
3	Frame	723456-01	1	ea		
4	Tire, Small	423456-02 423456-03	2	ea		
5	Bucket, 4 yard	523456-01	1	ea		
6	Bucket Arm	823456-01	2	ea		
7	PCB, Elect Ignition	923456-08	1	ea		
8	Nameplate	323456-01	1	ea		
9	Axle	103456-01	6	in		
-	Product Spec	123456-00	Ref	Doc		
-	Material Spec	623456-00	Ref	Doc		
10	Wheel Hub, Large	113456-01	2	ea		
11	Wheel Hub, Small	121456-01 121456-03	2	ea		
12	Motor	114456-07	1	ea		
13	Adhesive	115456-01	2	oz		

MARK UP IN RED PEN

Figure 5.1. Marked up parts list.

Notice that this specially programed, double spaced MRP "report" is our official engineering parts list. Also notice that component revision levels are excluded in order to eliminate revision level "rolling."

This marked up parts list gives adequate data for the traceability of interchangeable changes to the effective date. Non-interchangeable changes will also be traced to serial number (or date code, or mod, etc.). The marked up parts list is an ideal tool for input of changes to the BOM database. The deletes and adds are easy to identify.

Configuration Management should also keep an ECO database, which will be discussed as part of change control.

Manufacturing Data

Manufacturing should keep this database. It would have elements, by part number, such as:

- Make/Buy code
- Lead time to buy or build
- MRP codes
- Cognizant Manufacturing Engineer
- Cognizant Industrial Engineer
- Cognizant Test Engineer
- Fixture number
- Hours to produce

If your company has an MRP/ERP system, manufacturing would enter the data on the screens that have manufacturing data elements (Purchasing, Production Control, etc.). If you don't have MRP/ERP, manufacturing should set up a PC database for those elements. Similarly, the Accounting people would enter labor and overhead rates.

It is important that the information contained here be available to Design Engineering, CM, and others. Availability of each database to other groups is necessary to avoid redundancy and to answer their needs. Availability of this data will answer questions such as who are the people Design Engineering should put on a Design Team? Which ME does design get to sign a drawing? What is the cost of an item? Notice that the database and the access to it helps to close the gap between Design Engineering and the rest of the world.

Most MRP/ERP systems contain a code that is critical to the program functions. The code is called by different names in different systems. For this discussion it will be called an MRP Code. An example of MRP coding is shown in Fig. 5.2. A set diagram defining the code is also shown. Notice the similarity to the CM document type code. The MRP code should have the same meaning as CM document type code or, if there are differences, the CM Manager should understand why they are different and reconcile the differences if necessary.

P = PART	V = VENDOR ASSEMBLY
B = BURDEN	N = PHANTOM ASSEMBLY
D = DOCUMENT	A = ASSEMBLY NOT SCHEDULED
T = TOP ASSEMBLY	S = SCHEDULED ASSEMBLY

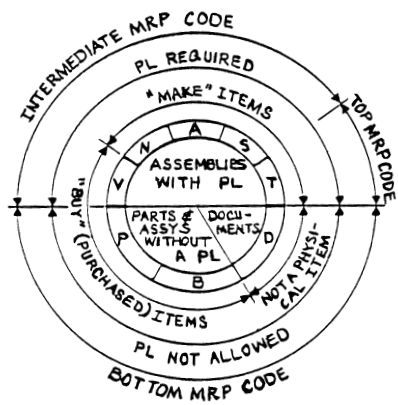


Figure 5.2. MRP Coding (sample).

Field Support Data

Field Support should enter their elements into the database by part number:

- Field Change Order number
- Field SNs affected
- Illustrated Parts Catalog PN
- Maintenance Manual PN

- Cognizant Field Engineer
- Hours to Repair

Note that the field support people must capture the Serial Number of any change installed in the field and feed that information back/make it available to CM. This will complete the traceability of the change.

Data Element Criteria

The data should be established and maintained by some common criteria:

- Notice that no data element is entered more than once. If a data element is to be entered more than once (with the exception of the part number) it is wasteful and probably indicates some confusion about responsibilities.
- The Data Dictionary should be a company standard that all necessary parties agree to.
- Access to enter, add, or delete, elements should be limited (secured) to the functions indicated.
- Make the data available to all who need to know on a read or report basis.
- CM should probably coordinate the establishment of all three databases since they will be responsible for the design data and there is need to avoid redundancy and clarify responsibilities.

Purchasing a System

This topic is a subject of considerable complexity. It is not the purpose of this book to explore all the various systems that are related to CM nor the methodology that might be used in selecting the best one for your environment. Those things that are critical to the CM strategy will be covered once lightly.

If your Company is planning to write its own MRP/ERP/PDM/ Change Management/other system, it needs to be pointed out that there are many systems on the market that are time tested and relatively inexpensive.

That is, inexpensive compared to designing and programming your own system. Your Information Systems Group may want to write the program for a unique system to cover your Company. That isn't surprising because, after all, they are programmers and they like to program. Some support for doing it yourself will come from various quarters because people believe that the company products, organization and methods are unique.

The "we're unique" argument is often used, but is very weak. Take an objective look at what is available on the market. Also look objectively at the real cost of designing, coding, testing, and debugging your own programs. The purchase cost will appear minor alongside a realistic do it yourself estimate. Your product and people are unique, but the basics of efficient manufacturing are very common to all manufacturers.

If your Company is purchasing a new MRP/ERP system, the CM Manager should be part of the team working on that task. If you are the CM Manager and haven't been invited, talk to the chairperson, go to their next meeting and invite yourself in. It is critical to the CM function to be part of that activity. From a CM standpoint the major features you need to look for are:

- Compatibility with your CAD/PDM. That is, can you down load CAD/PDM parts list data into the Bill Of Material module? Is an interface program available? Can a single BOM database be maintained?
- The Bill of Material module is made up of at least two files, part information and assembly information. Is a method of checking transactions to both files available on line or (at least) over night?
- Is the Used On capability included easy to use, does it show next assembly PN, and top level PN without rolling up through the structure?
- Are all the data elements present that CM is responsible for? Are there also expansion fields available to add other new elements?
- Will the system print out a controlled parts list (report like Fig. 2.6) that looks like a design engineering/CM needs or can the MRP/ERP be easily programmed to print the parts list.
- The security of data entry and maintenance is limited by data element or by screen that matches your needs.

Avoid the temptation to buy a system from the marketplace and to tailor it to fit your way of doing business. It is actually much better to change your way of doing business to fit the system and the changes required usually make sense from a business standpoint anyway. Experience has shown that successful MRP/ERP system implementation is done with fewer than a half dozen program modifications. This does not count programming of unique reports. Realize that this advice flies in the face of some major consulting firm's advice. They do business by selling systems to companies that believe they are different and then helping them tailor the system to their unique environment.

Plan to streamline your manual systems which interface with the MRP/ERP/PDM. Probably do this before you implement. For example, the engineering change system should be functioning fast and accurate or else the new system may appear to be malfunctioning.

Don't automate any process unless you are prepared to spend the necessary time and dollars to plan, test, and train, before you implement. Hundreds of companies are changing systems. Many in the same kind of business are trading systems. That is, Company A is throwing out system X for system Y while Company B is throwing out system Y for system X.

The reasons given for throwing out the old systems usually come down to one or more of the following:

- Tailored the system until the vendor wouldn't support it
- Tailored the system until it did exactly what we used to do (didn't improve anything)
- Implemented without planning, testing, and/or training

The implementation of an MRP/ERP system is a huge undertaking and needs to be carefully planned and executed. It is the latter point that seems to be the most prevalent reason for failure. Plan, Test, Train, Replan, Retest, Retrain, etc., etc., etc., then implement.

Part of the planning process must be to plan the relationship between Design Engineering and Manufacturing. Too often Design has its CAD/PDM and Manufacturing has its MRP/ERP and the gap between them widens.

Bills Of Material (BOM)

The Bill Of Material is the heart of most manufacturing organizations. Whether they are MRP/ERP oriented or JIT (Just In Time, also called

Demand Flow Technology) oriented, or a combination of both (American JIT), the BOM is still the heart of the process. In fact, no manufacturing system that man has invented can operate well without an accurate BOM. The parts list may take a hard copy form and/or on line screen.

Definition: The BOM is a compilation of parts lists.

Engineering worries about the CAD/PDM and manufacturing worries about the MRP/ERP. This is the most prevalent negative mind set in American industry. It is wrong. It's a mistake. It widens the gap between Engineering and Manufacturing. It creates major redundancies and waste. The result of this historical monster is two, three, and often more, Bill of Material databases in many companies.

The solutions are fairly easily described, but very difficult to implement, but before getting into solutions, let's lay some groundwork.

Parts List and BOM

The engineering parts list is a single level BOM. All the parts lists for a product entered into a database is a BOM. Other data is added by CM, Manufacturing, and Field Service, as discussed.

From the database (usually an MRP/ERP system), we obtain a multitude of Bill Of Material reports. These reports often contain more than parts list data. Some of these reports are:

- Indented
- Parts Only
- Used On
- Costed
- Lead Time
- Assembly Only
- Official (engineering) Parts List
- Pick List
- Indented By Lead time

The more reports the better, as long as we are talking about availability and not printing out tons of paper. One company had twenty-seven different reports available. Fantastic Reports are not the concern, it is the redundant input and maintenance of the databases (plural) that is the concern.

BOM History

Go back in time prior to computer aided drafting (CAD) days. The assembly pictorial drawing was prepared (drafted) and the parts list for that drawing was placed in the corner of the drawing. MRP systems came about and the parts list on the face of the drawing was used for the input to MRP. Computer aided drafting provided for putting the parts list on the face of the pictorial or on a detached list or both (it wasn't until more recently that down load from CAD to MRP, or vice versa, began). The result is that many companies have ended up with multiple BOM databases. The diagram in Fig. 5.3 pictures the numerous BOM databases that are being kept at many companies.

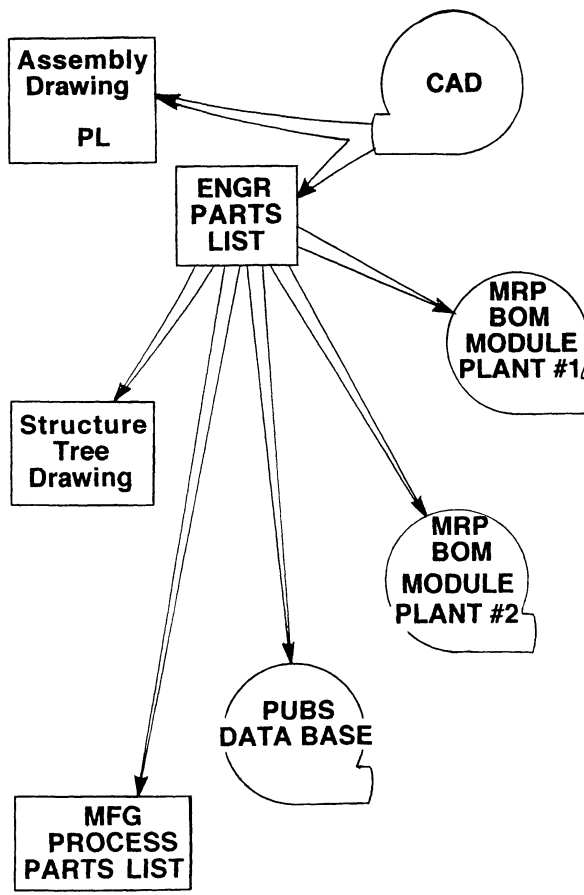


Figure 5.3. Multiple BOM database input.

Go over this diagram and the following list and ask yourself how many BOM databases your company has.

- The CAD is a BOM database if the parts list data is developed or input there.
- The parts list on the face of assembly drawings is another BOM database (unless it got there automatically from the CAD).
- Some folks make and maintain manually prepared hard copy parts lists, another database.
- Some design organizations maintain an Excel parts list database for whatever reason.
- If you make and maintain family tree drawings—another BOM database.
- The MRP/ERP system is still another BOM database.
- Multiple plants building the same product with separate input—more BOM databases.
- Field Service/Publications input again to a desktop publisher—count another.

This author has witnessed as many as eight parts list databases in one company. Could there be waste here? In the University of Wisconsin Seminars this writer tells the story about a Company President who heard that an Industrial Engineer (IE) could save him some money. He decided to hire one and started to interview. An IE came to interview. The President told him he was going to take him down the assembly line and, if he saw any place where he could save some money, to speak up. A little way down the line there was a man sitting and watching the line. The IE asked, "What does he do?" The President checked, came back and said "Nothing." The IE didn't say anything, so they proceeded down the line. Further down the line, there was another man sitting and watching the line. The IE asked, "What does he do?" The President again checked, came back and said, "Nothing." The IE said; *"Ah ha. Redundancy!"*

In American industry (other countries probably have the same problem) the redundancy of databases in general, and Bills of Material specifically, is ludicrous.

One BOM Data Base

More than one Bill of Material data base is redundant, a waste. Worse than redundant, it allows for diverging designs. When manufacturing has a problem, shall they be allowed to create their own fix? This is an easy trap to fall into if manufacturing maintains the MRP/ERP design data. Shall each plant devise their own fix? Which design is the best? How do we get out of this very costly and risky situation? Take it a step at a time.

There are two basic ways to accomplish the CAD/PDM and MRP/ERP duplication besides reconciling the differences forever:

1. Do not input the parts list data to the CAD, only input to the MRP/ERP. The input of the design data should be done by CM. If you have old drawings with the parts list on their face, you will need to make a plan to verify the database and delete that data. If you have an E-CAD system for designing printed circuit boards wherein the input of the schematic/criteria automatically produces the parts list then this solution is not practical.
2. Buy or develop a system that creates an automatic link between CAD and MRP/ERP. Input can be done to one or the other, but not both. CM should control the link. These systems were extremely rare when this book was first published. They are fairly prevalent now although fairly expensive and not completely problem free.

If the parts list is put on the face of the pictorial drawing from the single database, that's OK. The pictorial drawing parts list is like another report. Manufacturing must be included in this planning since they make substantial use of the drawings and parts lists as they are.

If you have MRP/ERP don't make Family Tree Drawings, teach folks how to use the Indented BOM report. If you need family tree drawings in the early design phase, don't release or maintain them. If you don't have MRP/ERP, tree drawings still do not need to be released unless they are your only used on record.

In either choice a released part list, in the format that engineering needs (see Fig. 2.6), is needed. This is for manual mark up for changes. That is, it is needed unless your system will produce a red line parts list for inclusion in the change.

In either choice, the CM function should control the input of the data. They should assure that the release or change has met the necessary criteria and then assign the appropriate revision level. Preferably, place the CAD/PDM Revision Block under security that allows only CM access. Require that any parts list produced from CAD/PDM carry no revision level (date control only). Thus, if copies are printed out, it will be obvious that they are not released documents. CM will assign the proper revision number or letter upon release of the new design or change.

If it is truly cost effective to produce the same product in more than one plant, purchase your next MRP/ERP system with Multi-Plant mode. That is, the same database allows different change effectivity in different plants. This allows for each plant to make the change happen as fast as possible for their conditions (inventory, WIP, lead times, etc.). It may also be necessary to investigate using JIT in all plants so that they each can control their unique processes without BOM structuring changes.

The two methods of achieving a single BOM database are depicted in the diagram shown in Fig. 5.4.

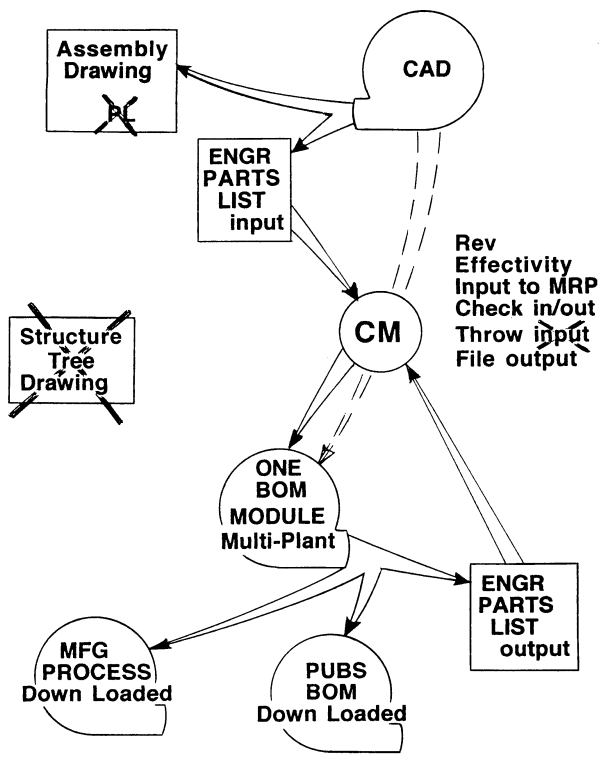


Figure 5.4. One BOM database.

Getting from where your company is now to a single database, is easier to write about than to accomplish, however, the potential rewards are significant. This multiplicity of BOMs is a significant contributor to the gap between Design Engineering and the rest of the world. Getting to one BOM is step one toward Bill of Material accuracy.

100% BOM Accuracy

Now that you have only one BOM database it will be easier to make it accurate. Following the process above will eliminate multiple databases and, thus, many BOM inaccuracies. The other steps are relatively easy:

- Make CM responsible for BOM accuracy. Design data elements only.
- Make CM responsible for all design data input. Check the input (normally by obtaining an output report and comparing the two). If input errors are found, have the error corrected by the person that made it. Design data includes both the parts list input and the engineering parts data file, as previously discussed.
- CM initiates regular audit of the product and the product documentation with the Quality Assurance Group. If QA is not able to help, do it alone. Pick a less complicated product to start with.
    1. Compare the Bill of Material from the database with the pictorial drawings. Note and resolve every discrepancy.
    2. Compare the drawings to a finished product. Resolve every discrepancy.

Resolution of discrepancies must mean that the root cause of the problem has been identified and fixed. Find the root cause and fix that problem. Now tackle your most important product. Keep going through all your active products.

In order to assure that this auditing occurs it must be planned, scheduled, and executed, on a regular basis. Every product should be audited, probably once a year, until the problems with the parts list information has reached zero.

Now that you have attained World Class BOM (singular), what else is there? Before a company can have a World Class BOM process, we need to resolve some nagging issues that are typically ignored.

What Goes Into the BOM

What items should be put into the Parts List and, therefore, into the BOM? Many companies find this to be a significant issue. Does the packaging (box) material go into the BOM? Are fixtures and tools included? How about specifications? Labels? Literature? Burden Items? Raw material? Process consumable? Remember, just because you give a part number to an item doesn't mean it has to go on the BOM. For the purposes of this discussion we need to make a distinction between the database (Item Master File) and the BOM. As discussed earlier, it is desirable to put important data elements into the database. Much of that data is related to the item part number and some to assembly part numbers, however, that doesn't mean that these items must be on a parts list.

Rule: Design Engineering, Manufacturing, and Field Service, should agree on what goes into the BOM (parts list). They should agree on a set of rules that CM should arbitrate and document in a standard. Then every product will be done per the standard.

Reason: This is one of the issues that causes conflict between Design Engineering and other departments.

To help eliminate the "throw it over the wall" syndrome, this issue must be settled.

Why is being consistent from product to product so important? If the BOM on the FEL-100 includes the product packaging, then an FEL-200 is designed and released excluding the packaging, what might happen? The company can complete the build of the FEL-200, have the product on the dock ready to ship and guess what, no package to ship it in. This wouldn't be the first company that this happened to.

A well thought out and agreed upon standard serves to remove one of the significant barriers between Design Engineering and the rest of the world. Instead of debating these issues over and over, people can now spend their energy on making it correct. They can also easily identify cases where exception to the standard should be taken.

It is very difficult to address each issue and to develop a standard for all companies. For example, one company may include burden items (Floor Stock) and the next company might exclude them. Both companies could operate without problems on burden items.

One company, a submarine valve manufacturer, had a system set up for packaging that worked well. They were a contract make to order shop. Each time a contract came in, the Contract Administrator completed a packaging form. They sent the form down to Emanuel who managed the shipping function. Emanuel always had packaging material ready for shipment. He didn't have big inventories, and packaging problems were nonexistent. When Emanuel was on vacation the packaging department still functioned smoothly. Should they be advised to change that system? Of course not. There are some general guidelines that we can develop. They might be treated as rules for many companies:

Guideline: Include any item that is part of the product or defines the product. This would include any item defined on design documentation.

Examples: Burden items, raw material, schematics, specifications, product labels, nameplate, etc.

Reason: These items should show up in the proper assembly Used On. If you have MRP, most systems allow items to be coded as burden. Such coding yields simplistic treatment of the item, such as min-max inventory control. Some of these items may not be properly included in the product cost if they aren't in the BOM. If the definition of burden items means that no cost entry is required (cost part of burden/overhead) then the only reason for inclusion is to assure that manufacturing uses the proper items.

Guideline: Include any item that ships with the product.

Examples: Packaging cardboard, tape, address label, warning labels, publications, literature, etc.

Reason: The company cannot get paid until it ships the product. It is impossible to ship without these items. The damage in shipment is typically a significant problem and packaging costs are often very high. These items should, therefore, be scrutinized the same way the product is.

Many companies haven't fixed the responsibility for the packaging. Sometimes it is done by the design people, sometimes manufacturing engineering, and sometimes by the dock people. If this problem exists fix it now.

Guideline: Include any item that is critical to the support process. Such an item should be referenced on the applicable assembly parts list.

Examples: A unique adjustment tool that is needed in the field replacement of an item, but is not shipped with the product. A specific and unique test device is required in order to assure the product is performing to specifications. A unique cleaning fluid is used that is critical in the manufacture and field service.

Reason: It is critical that the field support people be aware of those requirements. Inclusion on the assembly parts list will help assure this.

Most process consumable items, fixtures, and test equipment used in the manufacture, would not be included or referenced in the BOM. They would be referenced and included in the manufacturing routing or process description. They might well be entered into the part information file of the manufacturing database, but not into the parts list.

Remember that the above are guidelines, not rules. It is an important thing for each company to carefully work out its rules and document them with an agreed upon standard.

Structuring the Bill of Material

Every product is made up of parts structured or grouped into assemblies. The grouping can be, and often is, quite arbitrary. Design Engineering, Manufacturing, Field Service, Accounting, and other people, all have an idea as to what the best combination or grouping is. This is another area that is often a sore point between Design Engineering and the rest of the company. Consider the FEL-100 structured the way that engineering designed it.

Engineering Structure

The design and development people get together early in the project life and decide which engineer, group, or department, will contribute portions of the design. The classic way of doing this is to draw a product tree or family tree drawing. They also visualize assemblies as they make sense to them or are/will be standard to more products.

Use of a family tree early in the development project is encouraged. It helps engineers, CM, and others, to agree on a common structure. Do not release or maintain the family tree, however, as it then becomes a redundant BOM. Use the indented BOM from the MRP/ERP system.

In this case Design Engineering asked manufacturing people how they were going to process the product, but no one seemed to know. In some companies engineering doesn't even ask manufacturing, they merely proceed to structure as it makes sense to them. In this case they did it based on the design responsibilities:

Final Assembly and Project Engineer	Crouse
PCB Programmable Ignition	Kramer
Motor Assembly	Watson
Motor Mount & Frame	Karnick
Bucket Assembly	Radacovich
Wheel Assemblies	Peterson

As this is being done, Crouse draws the tree as in Fig. 5.5.

Each of the engineers can now do their designs without duplicating work and without forgetting any elements of the product. Should any of them have questions about mating, interface, specifications, etc., they know to consult with Crouse. They created a five level structure. It made sense to them. At this stage it would seem to make sense to any casual observer. As development of the product progresses, a new viewpoint arises.

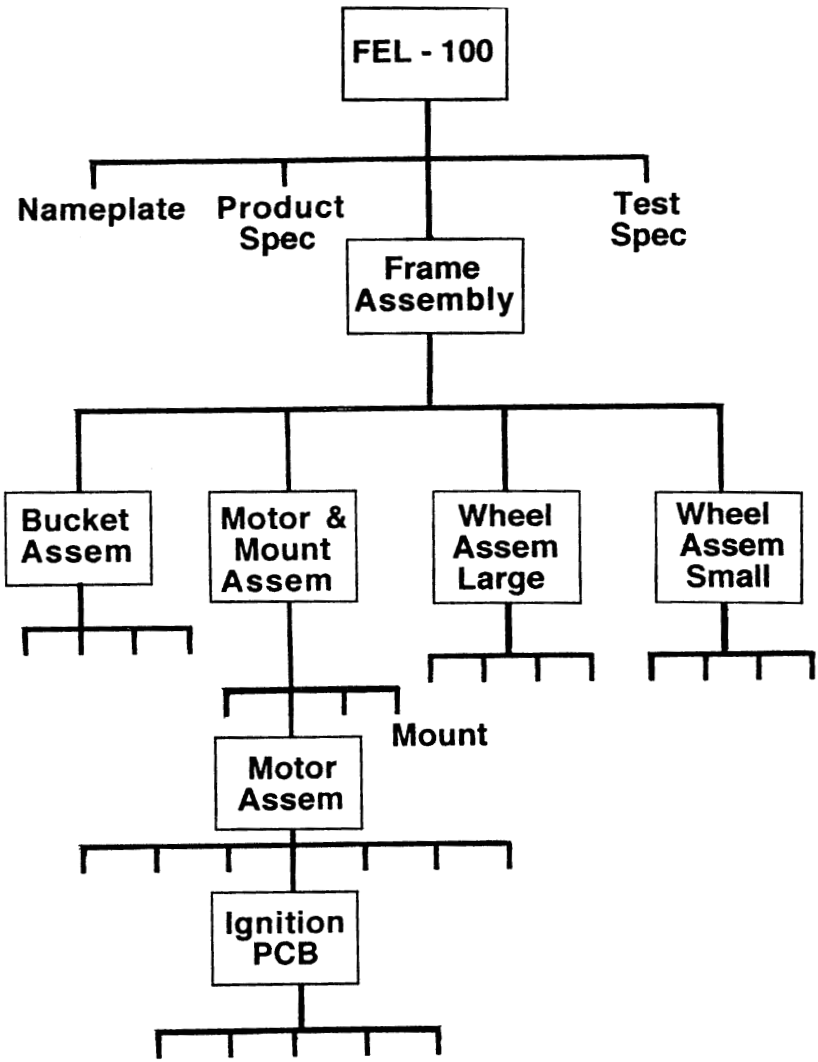


Figure 5.5. BOM Structure/Engineering.

Manufacturing Structure

At some point the manufacturing people get involved. The manufacturing people have their own idea of how to structure the BOM. The Industrial Engineer wants to assemble wheels and axles to the frame and put them onto tracks that will become the main assembly line. They will do the

frame assembly early in the production line, but without the motor. After adding bucket arms and bucket, they will add the motor. The motor however, will be an assembly less the Printed Circuit Board (PCB). They plan to test the motor with a known good PCB. The PCB will then be added near the end of the line. The tires will be put on at the end of the line just before final test and preparation to ship.

As a result of this plan, the Manufacturing people want the structure as in Fig. 5.6.

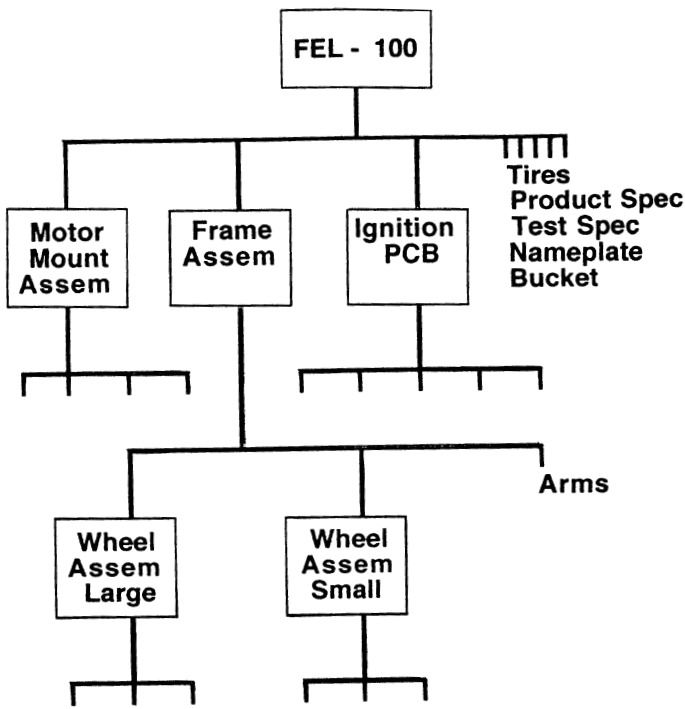


Figure 5.6. BOM Structure/Manufacturing.

The Industrial Engineers may want to use the assembly pictorial drawing as an operator aid in their process. In fact, to obtain simplistic pictorial drawings they may want them prepared for very small groupings of parts. This can mean even more structure levels.

Materials/Accounting Structure

Other departments enter the structuring issue. The materials people want a part number on anything put in stock or shipped between buildings. The buyer often requests restructuring to aid in purchasing an item from more than one supplier. Guess what? They request more levels in the BOM.

The Materials people want more "material drop" points to get the material closer to the point of use. Accounting people have divided the production operations into "cost centers." In fact, it seemed like such a good idea, a cost center is created for each first line manager. Then, in order to get the right parts issued to the right material drop point and to account by cost center, the structure of assemblies needs to match. This may add several more levels of assembly.

Field Support Structure

The Field Engineer enters the picture. The Field Support people want to spare the windshield wiper assembly without the blade, but with a box and instruction. Now Manufacturing and Field Support are at odds because Manufacturing does not want the box and instruction in "their" structure. In fact, Manufacturing makes the wiper assembly in a different building than the final assembly, and they want to move it between buildings as a wiper assembly with blade. Sometimes companies resolve this kind of problem by adding levels to the structure.

MRP/Phantom Solution

The MRP system operates on each level of assembly. That is, the MRP/ERP "explodes" the schedule against the BOM to develop material requirements in lead-time. The system "MRP run" produces purchase orders, shop orders, pick lists, etc. It starts with the top level and progresses down the structure to do this at every level of assembly. Orders and reports are produced. This is a time consuming process, even for high-powered computers.

Most MRP/ERP systems have developed the "phantom" designation in order to minimize this process time problem. The designation of an assembly as a phantom tells the computer to pretend that the assembly isn't there for some of its operations. Thus, the phantom designation is pretense

that the assembly doesn't exist. Every level of assembly that the system can ignore means less process run time. The Manufacturing folks call some assemblies a phantom for this reason.

Some MRP/ERP systems have the same parts allowed in two structures—one for engineering and one for manufacturing. They are facing reality, that engineering and manufacturing don't get together and resolve the structuring issues. Wouldn't it be better if they both related to the same structure?

Common Industry Problem

Industry trends is to treat each of these individual requests as reasonable and to add assemblies to the structure. The growth of BOM structures is a significant and continuing problem in American industry. Many companies develop BOMs that have 6, 8, 10, or more, levels. There is a significant amount of work to create them as well as to maintain them. This author has witnessed twelve levels and heard from a seminar attendee of seventeen levels in their BOM.

The work that results is no surprise to Configuration Management Managers. Much of their time is spent creating, recreating, revising, and changing documents and part numbers in these multiple level BOMs. They do such a good job of it most other functions do not realize the magnitude of the work involved.

Those companies that have MRP/ERP, often see a symptom of the problem—the information systems folks wants to get a more powerful computer. The real need may be for shallower BOMs, not bigger computers.

More levels mean more pictorial drawings from Engineering. More levels mean more part number or revision level rolling for those companies that do this method of tracking. Fewer material drop areas are, in most companies, not a significant cost issue.

Un-Structure the BOM

There are those who say "Structure the BOM however Manufacturing wants it." This is a gross oversimplification of the problem. "Aren't drawings made for manufacturing?" you ask. Yes, part drawings are for the purpose of manufacturing. Structure and assembly drawings are a different

issue, however. They are made for manufacturing only to the extent that the structure is good for the company. It should be obvious by now that the fewer BOM levels the better, but how does a company achieve this goal? Let's examine each request for a new assembly level and seek alternatives.

Field Replaceable Items

Situations like the wiper assembly without blade are common occurrences; especially when the box and instructions are included in the problem. First of all, does the Field Support request seem reasonable? It certainly is something companies face every day. Structuring without the blade, but with box and instructions would allow proper costing of each field replaceable item. Proper costing will lead to proper pricing. OK, it's reasonable. Then structure an assembly for the unique field requirement. For example the FEL-100 Printed Circuit Board assembly for the field might look like Fig. 5.7.

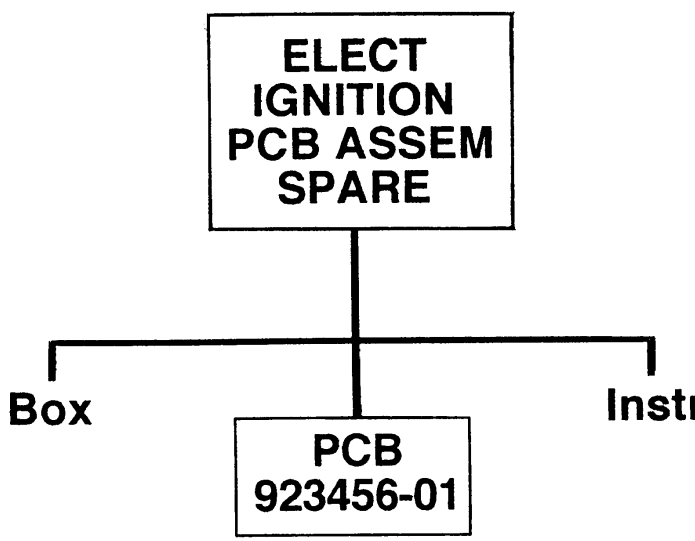


Figure 5.7. Unique spare assembly.

The unique spared assembly is, thus, properly documented. The assembly can now be ordered by field service, manufacturing can build it, and it can be packaged for the field as desired. It can be cost-priced as the unique entity it is. If we enter this item into our database it will be part of our used on relationship. The PCB assembly spare (822334-01) should also be coded in our database as a Field Replaceable Unit (FRU). In this way the interchangeability of the item can be maintained.

This unique assembly should not be put into the design/manufacturing structure, however. Create a separate list for all the FEL-100 field replaceable items and parts subject to wear, damage, or failure, a spares BOM. This BOM will thus contain parts and assemblies designated as spares. Assign a document number (tab 00) to the spares list. Reference the spares list on the parts list for the end product, FEL-100 (refer to Fig. 2.6). This will allow anyone who has the product part number to find the spare items list and for interchangeability of the parts to be maintained in all applications, including the spares/field applications.

Guideline: Structure field needs on a referenced spare parts and FRUs Bill Of Material. Include required field unique assemblies on that list.

Reason: It satisfies the field needs without adding structure to the product BOM.

Design Engineering (author) and Field Engineering (acceptor) should agree on which items are to be field replaceable. The design engineer and the field engineer are the only signatures required on the list and on the unique assemblies. These documents should be released and under CM change control. Now we have satisfied the legitimate needs of the field without adding levels to the product BOM.

Cost Centers

Too many cost centers create more problems than just adding BOM levels. Each cost center begets cost reports, inventory reports, MRP output reports, etc. Piles of paper that no one reads. Errors increase when reporting labor or material usage. Journal entries to correct errors increase. When costs get out of line the accounting solution may be to add Cost Centers. The first line managers, typically, don't have the time to analyze cost reports. This adds to the complexity of doing business and doesn't get at the root cause of the problem(s).

Guideline: Cost centers should correspond to the managment structure. They should normally be at the shop superintendent or the second level production manager.

Reason: Smaller breakdown will add cost, not help reduce costs. If you have an MRP/ERP system, adding cost centers probably means adding BOM/assembly drawing levels.

Pictorial Assembly Drawings

Consider this situation, Design Engineering makes pictorial drawings called assembly drawings. The Manufacturing Engineer or Industrial Engineer make a series of pictorial drawings to accompany the process/routing instructions. The Field Support or Publications Department draft a series of exploded views for parts catalog, maintenance, and repair.

This is a condition that is all too familiar. Is there a pattern of redundancy here? Yes, but each pictorial has a specific purpose in mind. The process pictorials are best in step by step detail, while the ideal Field Support pictorial should focus on the replaceable items. If you have CAD, other departments should be allowed to use the CAD database. The manufacturing and publications people can use the CAD to develop their unique pictorials. If you don't have CAD, you should expect the other groups to cut and paste, trace, or otherwise make use of the design pictorial assembly drawing.

Why shouldn't the process pictorial be the design pictorial? When the production rates are very low and the workstations are fixed this can work effectively. The design pictorial can be very close to the work performed at a single workstation. High end manufacturers typically fall in this category. If the production rate is cut in half or doubled the stations remain the same. It is, therefore, relatively easy to make and maintain engineering assembly drawings that match the fixed station. Lower end manufacturers, however, often have workstations changing with changing production rates. The same pictorial is now used at several stations. It becomes difficult for each operator to pick out that portion of the pictorial that relates to their workstation. This is why the ideal processes have step by step detail with mini-pictorials referring to just that step. Then, as the rate changes up or down, the process (with mini-pictorial) can be broken down into the appropriate number of workstations.

Rule: The determination of assembly structure should not have any relationship to the manufacturing workstation.

Reason: The make up of the workstation is dependent upon the production rate, and is, therefore, far too dynamic to be a structuring criteria. Avoid frequent engineering changes for restructure due to production rate changes.

There are obvious exceptions to this rule. If you are building ships, your rate is probably always going to be low and relatively fixed. In one instance, a locomotive re-builder first identified the workstations and then structured the assembly pictorials to match. If their rates doubled or were cut in half, they doubled or halved their work force and the people moved among the workstations. In this company, the workstations and, thus, the assembly drawing structure were very fixed.

Multiple Plant Build

Some companies have the same product built in more than one plant, because of distribution costs or country tax advantages. When this occurs the structuring problem becomes exacerbated by having more than one method of assembly. Now, engineering has two or more structures requested by different plants. The first inclination is to say that one of their methods must be best and both should use it. Often, however, it is because they use different tooling and neither should retool. This is a situation wherein the plants should each be required to prepare their own mini-pictorials (from the engineering CAD database) for their own process.

Stock an Item

The request frequently is made of CM, "We want to stock this assembly and need to have a part number to do that." If the request is to add the assembly to the field spares list it should come from field support. If the request comes from manufacturing, it must be suspect.

Rule: Requests to add structure to allow in process stocking of an item should normally be refused. A comparison of the costs of alternative fixes to the root cause problem is needed.

Reason: Adding an item to stock will add to inventory quantities and value. Inventory carrying costs are variously estimated from eighteen to forty percent of the inventory value per year. The root cause problem(s) should be identified and fixed.

One of the alternatives considered should be some form of Just In Time (JIT) or Demand Flow Technology (DFT) manufacturing. In these disciplines, the need to stock items approaches zero.

Buy an Item

Are two part numbers required to purchase an item from two suppliers? (Example: Buy an untreated part from supplier A and send it to supplier B for heat treatment.) Sixty-one percent of the seminar companies surveyed said "Yes" while thirty-nine percent said "No." Those buyers who said no were having supplier A drop ship to supplier B. Their Accounting departments were treating A and B as part of the cost of the same part.

The buyer who feels that a level of assembly is needed to buy an item from more than one supplier, must also be challenged. This is not to say that there are not exceptions to the rule, but we should assure that costs are properly identified for all alternatives and that the best one for the company is chosen. Thirty-nine percent of the surveyed companies are blessed with buyers and systems that allow them to generally handle this problem without more part numbers and assembly levels.

Ship Between Buildings/JIT/DFT

Manufacturing has established a production facility in a separate building to build motors. The motor plant makes motors for several Front End Loaders. Shipping between buildings normally requires a part number. JIT/DFT purists believe that they don't need a part number for this item. They will, however, have some means of specifically identifying the unique motor, so it might as well be a part number. If you have JIT/DFT and are getting along without part numbers for these items, don't add them because you read it here. In this case, however, the need for a part number and assembly level seems legitimate to this writer.

The purest JIT/DFT structure is a single level BOM as shown in Fig. 5.8. It is a condition that a few companies have attained and are successful with.

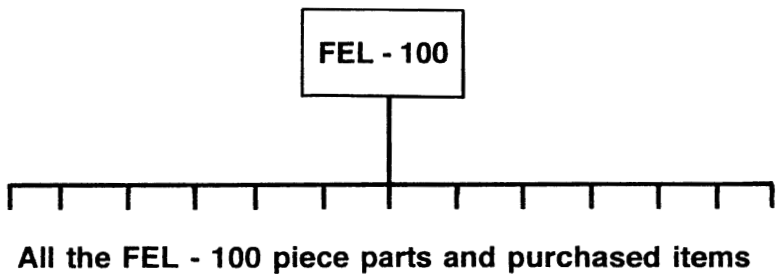
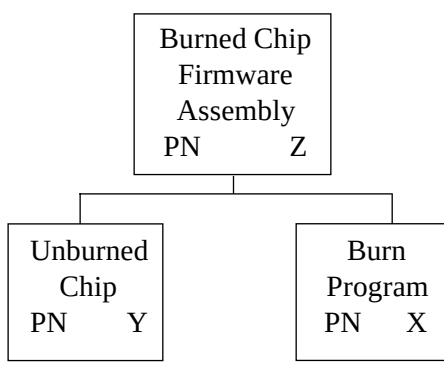


Figure 5.8. One level JIT BOM.

The multitude of assembly pictorials that were previously made in the Design Engineering function must be taken care of in the manufacturing process document. Min-pictorials in the step by step assembly instructions are far superior from an assembly operator viewpoint. The top level of the JIT structure often requires a "book form drawing" which looks much like a specification control drawing. It would contain critical assembly specifications as well as critical assembled dimensions.

Firmware/Application Software

The usual method for structuring firmware is to make an assembly out of the unburned chip and the program. The combination is given a distinct part number as follows:



The Burn Program would be called a Ref-Doc in the Quantity—Unit of measure fields (or whatever MRP/ERP allows). Thus, the system would not drive a program for every unit to be produced.

Is this the only way to handle firmware? No. An alternative that eliminates this assembly is to structure the Burn Program and the assembly with a reference designation similar to that used in any printed circuit board design. For example, let us name this particular chip the QPL function. Then the PCB can include in its parts list a reference to the reference designator (QPL) in the description of the Program and the assembly. For example:

PN	Description	Qty
X	Program for QPL function	Ref
Y	Unburned Chip	1
Z	Burned Chip QPL	Ref

As long as this is a one-for-one relationship it works. The test group (or whoever burns your chips) will understand how to program the chip. If the burned chip, *Z*, is to be spared, it can be placed on the spare parts list. If other chips are to be burned from the same part number, *Y*, this method still works. If, however, the same PCB contains more than one different unburned chip this system then breaks down.

Applications software can be handled similarly by giving the program and the programmed media a reference designator. The same limitations exist.

The Standard Assembly

What if the engineering folks have or are planning to use the Motor Mount Assembly in more than one product? Shouldn't that assembly be documented separately? It would seem entirely logical. Manufacturing would probably make the assembly for both products in one work center to avoid duplicate tooling. Manufacturing should agree to having this assembly separately documented even if the assembly is going to be an in process assembly for both products. This might be an ideal time to use the phantom code in the MRP/ERP system.

One Product Structure

We have now minimized cost centers, separated the spares BOM, and completed all the other steps possible to minimize levels in the BOM, but our original problem is still there. Design Engineering made a structure that was significantly different than Manufacturing now wants.

Look at the design structure and ask why and when it was done. Examine the manufacturing structure and ask why and when it was requested. The two BOMs are not very similar. This situation is not unusual. When the structure related activities are done independently, the choices used are:

- Tell manufacturing to live with what design did
- Restructure (redo assembly pictorials and/or parts lists) to suit manufacturing
- Design some kind of hybrid structure that "kind of" satisfies both

All the options are poor ones. Of course, we should have done it right the first time. Easy to say, but hard to do. At this stage, what is the best choice?

Guideline: If all of the above logic and rules have been applied, then the differences are in the "sequence of assembly." The product should be restructured to suit the sequence of manufacture. This assumes that manufacturing management is committed to the process.

Reason: We should have done it right the first time, but better late than never.

Structure Right the First Time

The root cause problem stems from the failure of Engineering and Manufacturing to get together to agree on the structure. In our case, we could say that Engineering asked Manufacturing what their plan was, but manufacturing wasn't ready to answer the question. In the next case, Engineering might not even ask Manufacturing. In another case, Manufacturing might give some thought to the issue, but change their minds one or more times during the development process.

Yes, there will be changes in the manufacturing plan. Yes, there will be changes in the design, but these facts should not preclude early planning, understanding of each issue, and development of one structure. This too is easily said, but not so easily done. It requires dedicated manufacturing people pre-planning the manufacturing process and intense discussion between all the key parties involved. A little planned procrastination also helps.

BOM Evolution

Engineering folks shouldn't be in too big a hurry to cast their structure into a database. It means that a bit of P^3 should be used—the Principal of Planned Procrastination. They should keep the structure on a flip chart in order to proceed with the design. The first task for Engineering would be to create and release a two item BOM—the top level and the product spec, as in Fig 5.9.

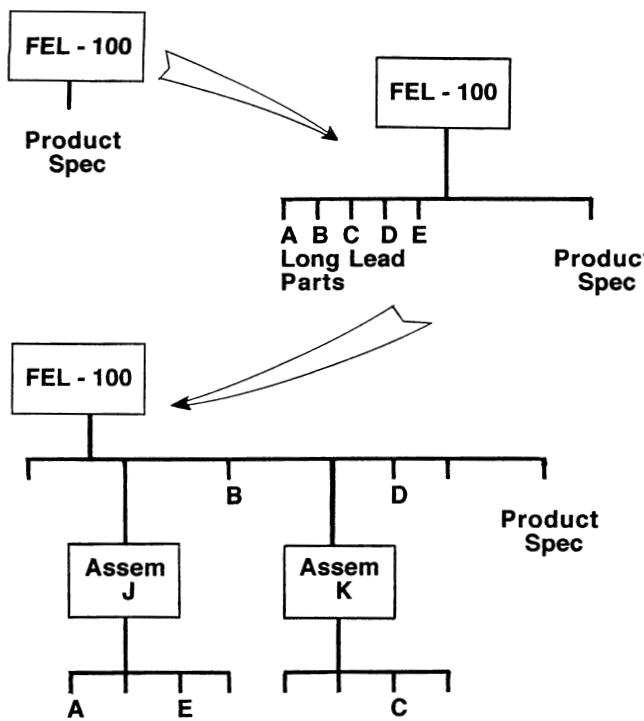


Figure 5.9. BOM evolution.

The Manufacturing folks should get into the team early on. Their first task should be to identify the new design long lead-time items—30 weeks and longer, 25 to 29 weeks, 20 to 24, etc. This is the order of release that best matches the needs of manufacturing, but also the needs of fast new product development. Engineering should concentrate their design efforts to the maximum extent practical on the items in lead-time. When the long lead items are ready for release they should be added to the top-level structure without regard for where they will end up.

This process will buy time for Manufacturing folks to figure out what this new product is like and how they will produce/process it. As the cross-functional team is formed and does its work, they will release more pieces of the BOM. As completed or needed, the new documents are released. Engineering and Manufacturing should then agree on the structure. When they do, the structure can be input to the database by Configuration Management. CM can then put away long lead parts where they belong. See Fig. 5.9. This concept may replace the need for a "planning BOM."

All the parts must be present and accounted for by time of release to pilot production. The final structured BOM probably won't be released until release for full production. Thus, the ideal BOM evolves.

This evolutionary method of release will ease the pain for all involved, meet tight development schedules, and hit the "market window."

If a company has many similar BOMs or many features and options, they should analyze the power of the modular BOM. Whether or not the modular BOM concept is used, however, the BOM and its structure should evolve during the development and pilot production of the product.

Modular Design

All designers are aware of the huge benefits in modular design. Properly done, their designs can be used over and over in similar product designs. For example, if the FEL-100 bucket arm design is done properly it might be very cost effective to use the same arms in the FEL-200, etc., but are all designers and engineers aware of the great advantages in designing for modular build? This concept has to do with planning the design to anticipate features and options, and designing them to be modular.

Definition, Modular Feature and Option Design: To design all parts that are variable with a feature or an option, so that they are in the top of the structure. Thus, they can be assembled on the end of the production

line. Don't bury the feature and option variable parts in the bottom of the structure.

Manufacturing generally assembles from the bottom of the structure up. So when we say in the top of the structure, it is the same as saying on the end of the production line. Examine some examples of feature and option modularity.

Example: The FEL-100 is specified to have either electric or gas starting. That is to say that either a gasoline engine or battery/starter can be ordered for starting the loader motor. If all of the parts unique to either the gas or electric versions are in the top of the structure, then the design is feature and option modular because the feature and option parts can be assembled on the end of the line.

Example: The FEL-100 specification said that the company would paint the loader red, yellow, white, or red and white. If the frame (assembled early on the line) was designed to be painted the option colors, the design would not be modular. If the frame is painted black regardless of color option, then the design would be feature and option modular.

Example: If our motor RPM adjustment feature is a screw on the motor and the screw is covered by the PCB when assembled, this would not be a modular design. If we move the adjustment screw or provide an access hole in the PCB, the design would be feature and option modular.

The idea is simple. Allow manufacture of a maximum portion of the product in an identical process. This also allows a maximum portion of the product to be structured only once. Look at a tree drawing of a modular FEL-100 in Fig. 5.10.

Modular Parts List

The "shopping list" or modular parts list would be a matrix that looks like Fig. 5.11.

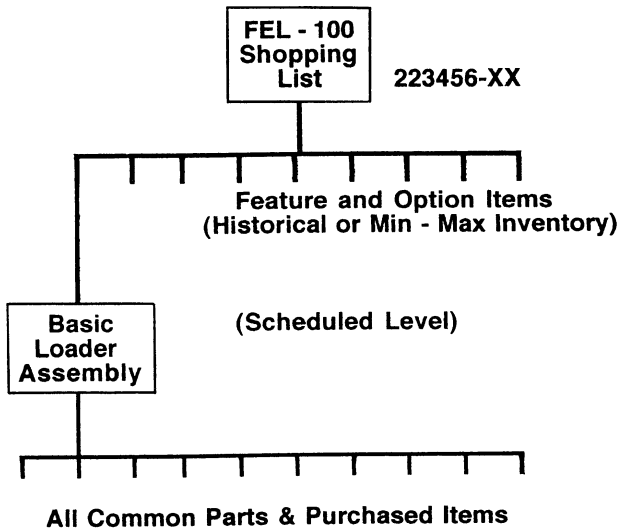


Figure 5.10. Feature and option modular BOM.

FEL - 100 PN 223456-XX

FEATURES & OPTIONS XX →	01	02	03	04
BASIC LOADER	1	1	1	1
GAS START	1	1		1
ELECTRIC START			1	
1/2" WHEEL/TIRE KIT	1	1		
3/4" WHEEL/TIRE KIT			1	1
STD ARMS	2	2	2	
SPECIAL ARMS				2
RED PAINT	1			
YELLOW PAINT				1
WHITE PAINT		1		
RED & WHITE PT			1	
QTY OF LIGHTS *	2	4	2	8

*Lights come in multiple of twos, ten max.

Figure 5.11. Modular shopping list matrix.

Unfortunately, the CAD/PDM and MRP/ERP systems that this author is familiar with do not make matrices. Your PC spreadsheet programs are the next best alternative for preparing and maintaining the matrix.

Notice that the basic loader is used in every variation (tabulation) of the product. The basic loader has all the parts (and assemblies, if necessary) that are common to every product. This assembly is sometimes called the "common" or "vanilla" loader. It may be a kit of parts that doesn't totally hold together.

The feature and option choices are designed and structured in the final assembly. The customer must choose either gas start or electric start. Thus, the 01 tab is a gas start while the 02 is an electric start, etc. The features and options may be parts, assemblies, or they may be kits of parts and assemblies.

Not all features and options need be either/or conditions. For example, the lights feature is the quantity of lights desired. A note appears that says "Multiple of twos, ten maximum." Since our design featured a programmable PCB, the switch settings an/or the programmable chip on the PCB might be options.

Rule: Do not attempt to document all possible combinations. Only list those combinations that are actually ordered, built, and sold.

Reason: The possible combinations tend to boggle the mind while the "real world" combinations are more manageable. Only document the combinations that have been tested, cost-priced, etc.

The most frequent mistake made in modular structures is to build the matrix with all the possible combinations. This makes a matrix of an unreadable/unmanageable size.

Modular BOM Benefits

This document must be precise and void of ifs, ands, or buts. It puts together a specific set of features and options. This document serves several needs.

- Avoids many nearly redundant structures by having only one Basic Loader. Thus, reduces ECO complexity for a significant number of changes that affect only the basic loader.

- Allows the Industrial Engineer/Cost Accounting to more easily cost each specific product. This, in turn, allows marketing people to more easily price each specific product.
- Tells the sales people which specific combinations are available. By omission, it indicates which combinations aren't available. Thus, a special procedure will have to be followed in order to add unavailable combinations. This will give Engineering and Manufacturing the process to examine the Sales requests for reasonableness.
- Provides a tool for the salesman (yes, give the matrix to Sales) to use when closing the deal with the customer. The precise customer needs are now in the form of a unique part number (unbroken part number cycle is now possible).
- Increases the likelihood that what the customer orders is what he gets.
- Allows Sales to forecast the Basic Loader only and to, thus, significantly improve the forecasting accuracy.
- Allows Manufacturing to schedule at the Basic Loader level. This significantly simplifies the master schedule.
- Allows manufacturing to schedule and build the Basic Loader in anticipation of orders. Can significantly reduce the promise to deliver response time.

Modular Scheduling

Most MRP systems do not have the ability to produce this kind of matrix document (except in configurator modules). This is probably fortunate because it tends to discourage the scheduling of each unique product.

Rule: Do not schedule unique end products. Schedule the Basic Assembly. Put all low cost feature and option items under "Min–Max" inventory control. Put high cost feature and option items under separate "recent history driven" schedules.

Reason: Allows the Master Scheduler to keep his or her sanity. Once the feature and option "mix" is handled in the stated fashion, sales forecasting attention is focused on the most significant issue—how many FEL-100s will we sell. This is much more reliable in attempting to forecast each flavor of the product.

Manufacturing can now build the Basic Loader on an identical assembly line. The features and options can be assembled at the end of the line. The time from customer order to delivery can be significantly shortened in this manner. One high tech company cut its time to customize its product significantly by using these modularity concepts. Their delivery time was reduced from about sixty days to twelve days. Another company reduced its promise to deliver time from twenty-six weeks to six weeks.

Modular structuring is another significant way to close the gap between Design Engineering and the rest of the world. This tool is so powerful that it should be considered for existing product lines. Look especially at product lines where the BOMs are numerous, but are known to be the same basic product. A Common Assembly and Shopping List document can be prepared even though the products were not designed to be feature and option modular.

Feature and option modular design and structuring is often a key element in making CM a significant company strategy.

The Perfect BOM

Although the Bill of Material will be different for different industries, and even different companies, there are some attributes that are common. Let us summarize the eleven most significant attributes:

1. Singular—one data base.
2. Must be 100% accurate, at least with regard to Design Engineering data.

3. Contains part and document numbers required by the BOM standard, and no more.
4. Design engineering data is input by CM, manufacturing data by Manufacturing, etc.
5. Is feature and option modular, if the product has features and options.
6. Has at least two levels (if feature and option modular), and no more than three or four total levels.
7. Contains the data base elements (defined in a dictionary) for Design, Manufacturing, Field Service, and Accounting (labor and overhead rates).
8. Has date effectivity ability and historical record ability (discussed more under Change Control).
9. Has ability to produce the used on assembly part number(s) and the corresponding used on product part number(s) and model numbers.
10. Will produce a variety of reports on demand. One of these reports must be a double spaced Engineering Parts List. Various cost reports are necessary.
11. The structure has been jointly developed by Engineering and Manufacturing.

Some of the attributes are a function of the BOM module "design" (8, 9, and 10), and some are a function of our use or management of the BOM Module (1–7). As mentioned before, when purchasing an MRP system, look for capabilities 7 thru 10. The last (11) is a function of an exceptional Configuration Management organization.

These are only the attributes that are most important from a CM standpoint. There are other criteria that Manufacturing, Accounting, or Field Service, would add to the list. The inclusion of cost information is critical to the design management. It is important to them that the cost data is developed from the BOM and done in a disciplined manner.

Referenced Documents

There is a trend to use the BOM for developing reference document lists for other than design specifications. Some people are adding manufacturing referenced documents to the BOM. Some add contract deliverable

documents. Their goal is to develop a Bill of Documents. These unique uses must be carefully analyzed and modeled. Can it be done in your MRP system? Can it be done without cluttering the parts list with non-design documents? Will doing it require more cross reference lists? Can the same results be obtained by numbering manufacturing processes with the design part number? Can the data be added to the database (item master), but not to the parts list?

The biggest question, will the MRP/ERP give you a document used on? If a document used on can be obtained, then the creation of a separate Bill of Documents for each organization would probably be worthwhile. However, caution needs to be exercised when considering addition of other than Design Engineering data to the released engineering parts list.

Configurator Modules

Some companies have many, many, sold combinations of features and options. The viable combinations of their product offering isn't in the dozens, it's in the hundreds or even thousands. Their desire is to take orders for the particular configuration that the customer wants and to fill it quickly, "Mass Customization" it is called. If you make a shopping list matrix as suggested above, you will find that there is a limit to human capability to add to the combinations while avoiding duplication/to find a combination that already exists. The notes on the matrix will also make the use of the matrix complicated. The matrix can and should be sequenced into the best make sense progressive grouping possible, but still, there is a limit on the human's ability to use and manage it. This writer's experience says that if the matrix gets over four or five dozen sold combinations (columns) it is very difficult to find what you are looking for and to maintain it. When this occurs, a Configurator Module should be considered. In essence, they (at least) perform the matrix function in program code.

Before that conclusion is reached, however, the product line should be carefully examined for unprofitable product offerings. It should also be examined for unsold product offerings. Other avenues should be explored, perhaps some of the FEL-100 options could be a dealer add-on, the lights, for example. This process is referred to as Product Line Rationalization. The matrix should also be limited to sold configurations. If, in the real world, sold configurations still exceed a few dozen, then look at Configurator Modules, usually referred to as *Configurators*.

Configurators are rapidly developing products that are sometimes stand-alone products or sometimes they are part of other systems. These

modules come with a variety of functionality. Some are rules or knowledge based and some not. Some are Sales Department oriented and some are MRP/ERP oriented. Some front end, some back end. Some bridge the gap between Sales/Marketing and the rest of the company and some don't. The Configurator business is currently very volatile. There are several dozen systems available and more coming. Be very cautious—at this writing you should seek expert help, and by someone who isn't selling one of the modules, before proceeding.

6

Potpourri

Before launching into the heart of EDC/CM—release, request and change control—it is necessary to discuss several related preparatory issues.

Cross Functional Teams

It was already mentioned that getting Manufacturing & Engineering to agree on the BOM structure is extremely important. In order to have the most efficient release and change processes, the use of Cross Functional Teams is a necessity. Cross Functional Teams are sometimes called DesignTeams, Concurrent or Simultaneous Engineering Teams. This author will refer to them as simply *teams.* Teams must be established very early in a development project and, thus, be functioning early in the release processes.

Rule: Institute Teams at the beginning of the project, coupled with regular management reviews.

Reason: The team approach should improve both the documentation and product. as well as reducing the number of design changes required later. The team concept is difficult to get started, but the alternative is to continue some form of adversarial relations.

How early to start in a new program development? Planning for the team (a management function) should start the day after the program is approved. The first team meetings might come a week to a month into the program. Design Engineering must be encouraged to concentrate on functional layouts and specification development in the early development. This leaves assembly structure and other manufacturing issues until a little later in the project, when the team is fully functioning.

Management must make sure that appropriate manpower is dedicated to the project. It is especially important that Manufacturing commits manpower to the development project early on.

Note: The word "committed" is used as opposed to the word "involved." There is a difference. We want commitment as in ham and eggs. The chicken was involved and the pig was committed.

Regular meetings are required both for the team itself and for the entire team with management. Configuration Management acts as a design quality assurance function during the team process. They make sure that management is aware of any shortcomings in the team process. Are meetings held as required? Has a leader been established? Are the right people present? Is management doing its part? Etc.

Team Make Up

Teams must be broad based and well led. Representatives from other engineering functions should be on the team;

Manufacturing Engineering

Industrial Engineering

Test Engineering

Field Service Engineering

Sales Engineer

Other functions should also be on the team;

Configuration Management

Production Control

Purchasing

Quality Assurance

Publications

Marketing

The make up of a team at any particular company might vary from the above. The key element is that they be broad based and should, preferably, be physically located together. This will help create the trust and teamwork that is required. It also makes communications easier. Any representative that is halftime or more and dedicated to the project should be physically located with the team. It's the "garage shop" development atmosphere.

Do broad based teams work? R. D. Garwood, in a white paper titled *"New Product Development"* states: "Broad Based Teams surface problems early in the process. A widely quoted study points out that a change could cost up to:

$ 1,000 in the design phase
$ 10,000 in pilot testing
$ 100,000 in process planning
$ 1,000,000 in production test
$ 10,000,000 in production/field."

This is often referred to as "the rule of tens." Finding or fixing a problem one stage later than it might be is ten times more expensive to fix and also reinforces the need for concurrent engineering. For example, if the process planning is done during the design and pilot phases, how much cost would be avoided?

Team Responsibility

The team must not be a "committee design" team. The members are there to offer alternatives, analyze trade-offs, cost alternatives, and to listen to others' positions. The final responsibility for the design, however, must be with one person.

Rule: The Project Engineer must be responsible for the design of the product.

Reason: Committee designs are almost never on target.

All members of the team must be made aware of their responsibilities. A standard may be in order. They must also be aware that the final responsibility for the design of the product lies with the project engineer.

If a team does not do "team design," what do they do? They consider alternatives in areas such as:

- Customer Specifications, Reliability, Safety, Performance, Form; etc.
- Design specification
- Testability; test specification
- Manufacturability
- Maintainability
- Minimum assembly structure
- Time to market
- Product cost
- Project cost

Notice that there must be emphasis on cost, this is why the Industrial Engineer is involved. The Industrial Engineer (or Cost Accountant) should calculate the costs of alternatives as requested by the chairperson. The roll of the Configuration Manager in the team can be pictorialized as shown in Fig. 6.1.

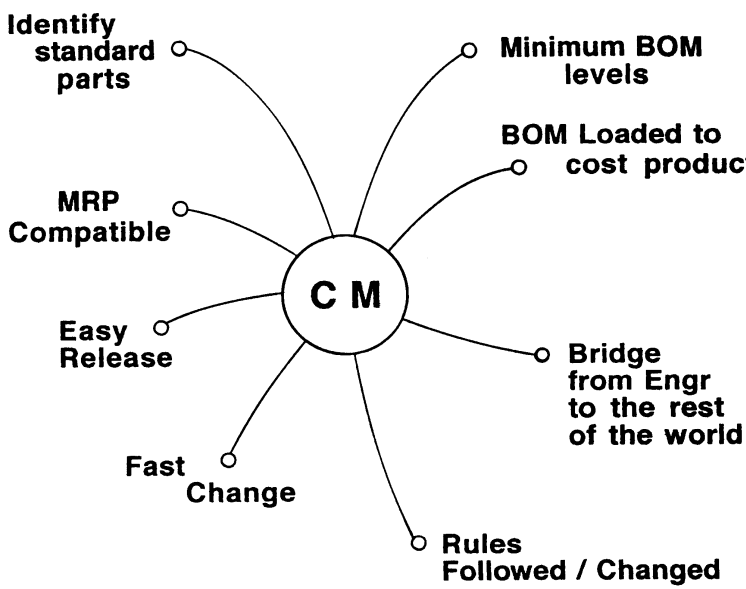


Figure 6.1. CM's roll in the design team.

Team Meetings

The effective team should function throughout the definition, development, pilot, and production phases. For released products, meetings might be shorter, but they should still be held. This is one way of curbing ongoing changes to a mature product. One of the most frequent problems with company strategy is abandonment of teams after pre-release or release of the product.

Rule:	Teams must continue from the design phase into pilot and production phases.
Reason:	All of the same needs exist, regardless what phase the product is in.
Rule:	Meetings must be short to be effective.
Reason:	Long meetings bore participants, they will show up late, leave frequently, and not pay attention.

One seminar attendee relayed a technique used at their company, a high table with no chairs. She related how fast the meetings tend to go. It is also important not to try to solve issues or try to design processes in these meetings. Assign action items to someone to work on outside the meeting.

Notice that these meetings do not constitute a Change Control Board (CCB). They are, however, a prerequisite to elimination of the CCB. Discussion of all technical aspects of each product under development and of many requests/changes to a product should occur in team meetings. This is the time (up front in the process) for technical and cost exchange.

The team should not try to set the effectivity of changes. More on this issue in the Change Control chapter. They should definitely be used for the review of and for the acceptor to sign off of any new or marked up design documents. They might be used for minimal signatures on the Engineering Change Order.

The Project Engineer might chair this kind of meeting. The Design Manager or the CM manager might act as chairperson. Group dynamics might reveal a natural leader. If the leader is not the Project Engineer, then the leader must be careful not to usurp the design responsibility. Training for team leaders and members is advisable. Figure 6.2 shows the kinds of functions represented and the frequency of the meetings (or the number of changes discussed) diminishing through time.

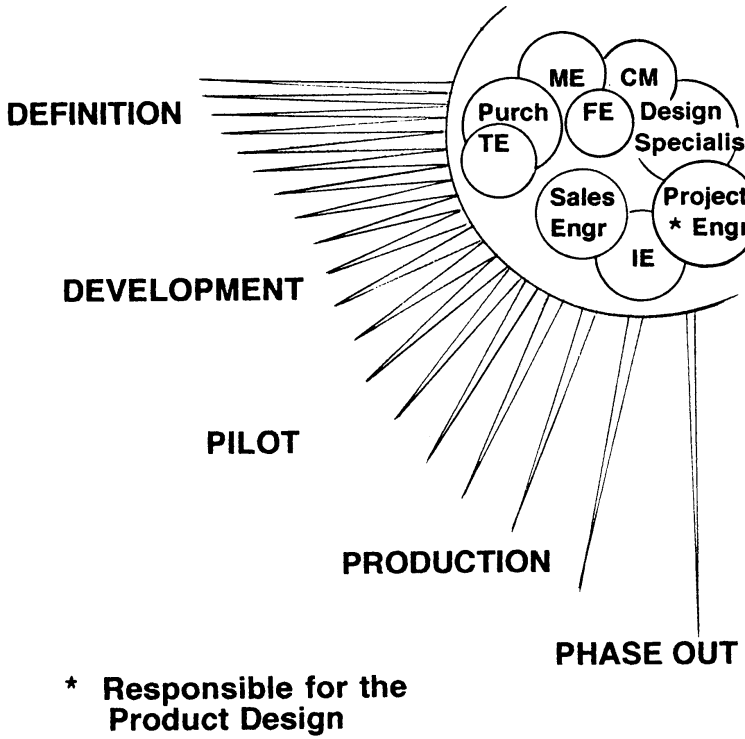


Figure 6.2. The team at work.

Meetings should be held regularly at a set time and place, however, they need not be in a conference room every time—the layout table, the lab, over the prototype unit, at/with a supplier, in front of a CAD terminal, are all effective places to meet.

Team Action List

Team meetings are a necessity for new product development in any except the garage shop environments. Team use in the request/change process will be discussed later. Minutes should not be kept. Who said what to whom is not critical. Action item lists should be kept. What are the technical concerns, who will resolve them, by when, and what was the resolution? The following format works for keeping action items:

Headings for Action Items List

- Concern number (never repeat a number)
  - Concern (brief description of the problem or concern)
    - Action required (brief) (reference change request number, if applicable)
      - Person assigned to take that action
        - Committed completion date
          - Number of times the commitment changed
            - Actual completion date
              - Resolution

The CM representative might well keep the action items list. This is a very good way to help in the process. All the members need not be at every meeting. The people who have action items due, however, must be at that meeting if the project is to progress as fast as possible.

Rule: The action items list should be hand carried or e-mailed to each team member no later than the day after a meeting.

Reason: Reduce the time to market by demonstrating a sense of urgency and resolving problems on the critical path.

The Project Engineer, the Manufacturing Engineer, and anyone signing, should be at every meeting. The agenda is the action items list. Items that have actions due at the present meeting should be covered. Review the list crisply and see if there are new items to be added to the list.

Team Success

Management or the team itself needs to make it clear that the team will be measured for success. The criteria should be established and it should be the same for every team. Some criteria for measuring success:

- Fast development (lapsed time to get the product released, piloted and produced)
- The shallowest BOM (fewest levels)

- Meet targeted product cost
- Decrease design change activity and cost
- First units meet product specifications
- Reduce changes required to meet specs

The first criteria is the primary reason most teams are established. The goal is to speed up the process of development and release in order to beat the competition to the market. Shallow BOMs keep the structure simple and, therefore, help speed the process. To be sure that the product cost is on target, the team should develop a costed BOM.

Management should be looking for the advantages that the team can produce by *concurrent engineering.* In effect, the various engineering functions are working in parallel, rather than Design Engineering getting the documentation done and "throwing it over the wall" to Manufacturing.

Team Measurement

Each of these criteria is measurable. Perhaps CM should be given the responsibility to measure the results (except for cost) and to report to top management. After all, measurement in and of itself, tends to improve performance. Besides, without measurement how can anyone know if conditions have improved.

The measurements (except cost) can be presented in a simple chart. First pick a product recently put into production without a team. We will call that our Base Line Product. Measure what happened on the FEL-100 development, and add what is happening on the FEL-200 development. (See Fig. 6.3.)

If all criteria are not improving on like projects then the teams are not functioning as well as they should. Top management needs to review these criteria frequently.

Each team will develop a character of its own. This is a natural process. The successful team will have a "documented garage shop development attitude." They will all be pulling in the same direction because they are all part of and aware of the whole picture.

	Baseline	FEL-100	FEL-200
From project start to all docs released to pilot	4.1 mo	3.5 mo	3.0 mo
From pilot release to pilot units completed	4.3 mo	3.1 mo	2.2 mo
From pilot units completed to production release	5.0 mo	2.3 mo	
From production release to first production unit	3.5 mo	2.0 mo	
Structure levels	7	5	4
Design Changes/week	14	8	

Figure 6.3. Measuring the team.

Design Responsibility

There are Project Engineers, Component Engineers, Power Supply Engineers, Manufacturing Engineers, Industrial Engineers, Agency Coordination Engineers, Test Engineers, Quality Engineers, Software Engineers, and Systems Engineers. Oh yes, Mechanical Engineers, Electrical Engineers, Chemical Engineers, etc.

Who is responsible for the design? Who should CM accept a release from? Who is a request for change given to? Who is invited to the Team Meeting? Who is responsible for the changes? These are all legitimate questions. Surprising how confusing the issue is in many companies. CM people are wandering the hallways trying to find out who is responsible for a particular assembly or part. Some organizations solve the issue by having the Project Engineer or Design Manager be the responsible engineer. As often as not, the Project Engineer or Manager becomes a bottleneck in every process. Even if all he or she is doing is delegating the work to the correct engineer, the bottleneck remains.

Another often used policy is to accept changes from any engineer. Wow! In any but the smallest company, that sounds pretty risky to this author. Talk about committee design! Won't we want a horse and get a camel?

As companies grow, the problem becomes more and more apparent. The printed circuit board change may affect the Component Engineer, Software Engineer/Programmer, and Agency Coordinator. Shall we have CM carry the change to each of them and get their approvals? Some companies do this. The CM Technician walks the change between and among the various engineers. When one asks a question that another must answer, the CM Technician goes from one to the other relating who said what to whom. This is another bad solution.

Have teams, let the Engineers talk there and sign off there; but do we need each of these engineers at every meeting? How about the concern that looks too important to wait for the meeting? If we wait for the meeting that is now held once a week, it will add a week to the process time whenever there is a problem. There has to be a better way, and there is.

Cognizant Engineer List

Develop a list that depicts the name (and perhaps the phone number and e-mail address) of the responsible or cognizant engineers. The Project Engineer is still responsible for the overall design. If the Cognizant Engineer has questions or doubts, he must consult with the Project Engineer or other engineers as needed. This places the burden for technical communication where it belongs.

The Cognizant Engineer will consult with the Component Engineer, Software Engineer/Programmer, Agency Coordinator, etc., in order to optimize the design decision. Now the process has the Cognizant Engineer talking to other engineers without a middle man. The responsibility is clear. The Cognizant Engineer need not get signatures of other engineers in order to make a release, reject a request, or make a change. The standard that covers the Cognizant Engineer list must make that clear.

Rule:	The Cognizant Engineer is designated only by the Project Engineer or the Design Management.
Reason:	Since Design Engineering is responsible for the design, only they can delegate that responsibility.
Rule:	Configuration Management should prepare and maintain the Cognizant Engineer list. This is done per the Project Engineer or Management direction.

Reason: CM will be the principal user of the list and, therefore, has a vested interest in seeing it prepared, maintained, and distributed.

The list can be prepared in various kinds of detail. It might be simplistic or in part number detail. The important criteria is to remove all doubt possible as to who is responsible for the design. The list for the FEL-100 started out looking like this:

Final Assembly and Project Engineer	Crouse
PCB Programmable Ignition	Lawrence
Motor Assembly	Watson
Motor Mount & Frame	Karnick
Bucket Assembly	Radacovich
Wheel Assemblies	Peterson

For small companies, that may be all that is needed. As the company grows, it will be necessary to add more detail. A Component or Specification Control Drawing (SCD) Engineer may be added to the staff. At some point the Project Engineer may choose to add the Component Engineer to the list:

Components or SCD Documents	Maday

Some companies put the Cognizant Engineer's name in the database for every part number. As companies grow the tendency might be in this direction. Certainly the small company should allow for this possibility when they design their database.

Other Function Engineers

Who is responsible to sign a drawing for Manufacturing? Who signs the spares list for Field Service? Who is the release package sent to? Who will approve changes? As the company grows the issue becomes more troublesome. It may even become unclear as to which CM Technician is responsible for a product/part of a product. The simplest solution is to expand the list:

Cog Engineer	Design	ME/IE	Field Engr	CM
Project Engineer	Crouse	F. Peterson	Cross	Pierson
Final Assembly	Mathews	"	"	"
PCB	Lawrence	Shumar	"	"
Programmable Ignition	Black	"	Son	"
Motor Assembly	Watson	"	"	"
Motor Mount & Frame	Karnick	Ford	Jacobs	"
Bucket Assembly	Radacovich	Sjhig	Hankins	Martin
Wheel Assemblies	J. Peterson	Ford	Jacobs	"
Spec Control Drawings	Maday	"	"	"

This is certainly a simple enough concept. It requires some work on the part of the CM Manager, however, the preparation and maintenance effort will be saved many times over. CM people are often found chasing engineers, being middlemen, etc. The act of making the list often leads to a reduction in the required signatures.

Responsibility

The Cognizant Engineer Standard should spell out responsibility and perhaps what each engineer signs. Chances are people may be signing things and not even know why. An example of a signature standard:

- *Design Engineer*—Responsible for the design of the product and its documentation. Signs the design documents, all release forms, all request forms, and all change forms. Must consult, as necessary, with all other design function engineers and the design manager prior to signing.
- *Manufacturing Engineer*—Responsible for the manufacturability of the product and the process. Signs the design documents and mark ups as acceptor. Must consult with all other manufacturing technical people and supplier technical people, as necessary, prior to signing.

- *Field Engineer*—Responsibility for the maintainability of the product. Signs the spare parts list. Signs change forms that are to be installed in the field or upon repair. Must consult with all other field service people, as necessary, prior to signing.

Notice that the responsible engineers are the hub of technical people in their organization. The responsibility statements for any company should be just as short, clear, and crisp, as the above. If the responsibilities aren't clear, confusion will exist or the team will try to take joint responsibility or, worse yet, no responsibility.

Delegated Design

The Project Engineer often delegates portions of the product design responsibility to other design engineers. Some companies delegate the entire product design responsibility to a *Continuation Engineering* or to a *Sustaining Engineering* function after some period of successful production. Some delegate portions of the design to Manufacturing Engineering.

Sometimes Design Engineering delegates responsibility to other organizations. The writer first ran into this concept as a young engineer doing pilot processing on the first "single sideband" airborne radio. The Quality and Workmanship manual was very clear about wiring service loops and connections. The actual length of a wire could, however, vary depending upon the operator routing technique and the room temperature. The production people were constantly asking for wire length changes in the wire harnesses. I, in turn, would ask the design people to change the wire lengths. One day the Design Engineer added a note to the wire lists which said that all wire lengths could be determined by Industrial Engineering. From that point on I was able to control the lengths by the process instructions. The number of change requests and change orders declined and we were able to shift our efforts to other more important matters.

This delegated design concept is often used by the Design Engineer for quantities in the assembly parts lists. The "convention" is to enter AR (As Required) when the designer knows the requirement is not critical. This is OK when the item is in the burden category (cost is part of the material overhead rate); if not, it leaves a part of the product cost in limbo. If need be, the manufacturing engineer can convert "AR" to the needed quantity. The responsibility should be delegated by note, standard, and/or the Cognizant Engineer List.

Another application of delegated design is to design a "weldment" as a completed part. Delegate to the Manufacturing Engineer the design of the pieces to be welded into the part. In this way the ME can design the pieces based on the fixture, shrink, tools, etc.

Rule: Allow for and encourage the concept of delegated design.

Reason: It is the most cost effective way of achieving quality product design in many cases. It also can reduce the number of changes that the system must deal with.

When a company has a meaningful Quality and Workmanship Manual, this concept becomes easier to do. The Design Engineer will relinquish the responsibility more easily if the criteria that manufacturing will use is clear.

Since many design changes are for cost reduction purposes, logic favors making manufacturing responsible for significant portions of the product design on mature product. This concept is one that the design management and the manufacturing management need to foster.

The effect of delegation from the CM perspective, besides reducing the number of change requests, is simply to place the Manufacturing Engineer's name in the design column on the Cognizant Engineer List. The ME now has the responsibility to discuss the proposed change with any other affected engineer.

Change Control Boards

The Change Control Board (CCB) is an outgrowth of Military and DoD specifications. Those specifications recognize the need for releases, change proposals, and changes, to be reviewed by the affected parties for technical issues, impact, etc. This need is exactly the same as the needs discussed in the Design Team/Concurrent Engineering topic. However, the typical CCB meeting is, however, held after that point in the process where the design engineer effectively says to Document Control/CM, "Here is the change, I'm done." This is often a basket in the document control area. The CM group then puts the change on the next meeting agenda. The proper point in time for such discussions is, however, "up front" in the process. The design changes should be discussed very early in the process at design team meetings.

Rule: CCBs are typically held too late in the change process. They should be held up front, before the development of a fix for a problem, right after the problem is identified.

Reason: The team needs to discuss technical and other aspects of the problem and the potential alternative fixes prior to development of the solution.

The typical CCB is held after the Engineering folks think they are done with the change. It is often the first time that many on the board have seen the change. Why do most companies use teams in new product processes, but drop the idea in favor of CCBs when in production?

Properly implement the team concept eliminates part of the need for CCBs. If culturally necessary, name your team meeting that deals with changes the CCB, but bring requests and problems to the meeting, not engineering completed fixes. The engineer should bring some changes to the team after the design change is designed. Thus, after the team has done the discussions, analysis, cost estimate, etc., there will be no further need for meetings after the engineer submits the change to CM.

"But CCBs do more than that;" you say. Yes, they often do several other functions:

1. A rare CCB calculates the cost of the change.
2. Set effectivity/disposition parts.
3. The place where signatures are or aren't obtained.
4. Talk about implementing the change.
5. Add emotion to the process.
6. Substitute for a process.

The usual CCB is a large room full of people, some of whom do not even know why they are there. Typically several manufacturing people, several design engineering people, and several others, are present. Most have not analyzed the change before coming to the meeting. Many have not even read it even though it was distributed to them a couple of days before the meeting. The design engineer that developed the fix thought he or she was done with that problem. They don't even want to come to the meeting since they have moved on to another problem. Really dumb questions are asked, then some good question is asked about the proposed fix. Someone has a better way to fix the problem. The engineer doesn't want to change the change. Emotions

run high. Someone that needs the change wants to get it signed right now. Verbal battles result, name calling, swearing, even worse.

Some of the people involved feel comfortable with the group signing. There is safety in numbers people think. "They can't fire all of us." If something does go wrong, the stock answer is; "Gosh, I thought someone else worried about that."

Rule: Have precise placement of authority and responsibility. CCBs are typically a substitute for a process. Better to have a process that limits signatures by establishing precise responsibilities and assuring communications within a functional area through a single person.

Reason: All the reasons CCBs are started are bandaids. The CCB got started because teams didn't exist, it is easier to start than a process, the Department Of Defense (DoD) and most three letter agencies encourage them.

This is an area where the DoD influence should be resisted. Examine the functions that CCBs perform. Look at each objectively and ask what is the best method to fulfill that need. Move the CCB up front into a team format then look at the four other useful functions earlier identified:

1. **Cost of the Change—**Few companies formally estimate the cost of changes. This is potentially one of the most fruitful areas for eliminating undesirable changes. Most Design Engineers have an idea of the development cost and some feeling for the product unit costs. Few engineers have a feel for all of the one time implementation costs other than their own. The key issue with regard to CCBs is the timing. The cost should be estimated up front in the process. The team should have a person, probably an Industrial Engineer, who is responsible for estimating the cost. When a cost estimate is needed, the industrial engineer can work with the planner/buyer to project the effectivity of the change and estimate the implementation cost accordingly. Some design functions hold the Cognizant Engineer responsible for the cost estimate. Regardless of who does it, the time to do a cost estimate is very early in the process. Perhaps the solution that first comes to mind is not the most cost effective. Perhaps the change shouldn't be made. Thus, the estimate should be done

as part of the team action items. The team, in time, might decide to proceed with some or most changes while the cost is being estimated. At least the so-called cost reductions should be estimated. More on cost later.

2. **Set Effectivity of the Change**—Someone in the CCB has typically taken it upon him/herself to set the effectivity and disposition of old design parts. Everyone else usually accepts this. It is never quite clear, however, as to who on the committee will follow up on the change to make it happen or to change the effectivity plan when necessary. This is left up to the computer or the group. The effectivity is sometimes dictated by the customer. When not dictated by the customer, several factors are at work. Among the effectivity impacts are:

   - Lead times of make parts, buy items, assembly, test, etc.
   - Work in process, at the supplier, in transit, etc.
   - Time to rework, scrap, etc.
   - Lead time for tools, test equipment, inspection devices, etc.
   - Lead time for process documentation, programs, etc.
   - Schedules, schedule changes, etc.

Certainly no one person can be all knowing with regard to which item has the longest lead-time, or which costs are the greatest, etc. However, far better than having a committee (CCB) performing this task, look to a single manufacturing representative to be responsible for coordinating the activity, a function that is already deeply involved with many of the effectivity impacts.

Rule: In most companies, Production Control is the most logical function to coordinate the analysis of the change impact and effectivity analysis.

Reason: Most design changes are driven by schedule and material factors.

Of course, a committee can do the function. When a CCB is used, however, one other thing happens, the typical meeting is held once a week. The typical change, thus, waits two-and-a-half days before CCB. Then someone finds a problem with that change or raises an issue that needs

investigation. The result, delay the change a week to see it again at the next CCB. Then another issue is raised. Another week. The process is so slow that someone invents a way to make fast changes—another method to make changes—sometimes two or more methods to make fast changes.

Rule: CCBs tend to become a way to let the documentation catch up to the real world or to use when there is no hurry.

Reason: The process with a CCB is so slow that other method(s) of making quick changes are devised.

A few CCBs do function adequately, particularly in small companies where very good communications happen outside the meeting. Small companies have a tradition of growing, however. It is for this reason that even the small company needs to find a better method.

3. Obtaining Signatures—If the team has done its job, the Design Engineer and the Manufacturing Engineer sign the marked or new drawings at the team meeting. The Field Engineer, if affected, should sign the ECO at the team meetings. These are the "engineer to engineer" signatures. That is, the cognizant design engineer should be responsible for obtaining other technical signatures. They should talk face to face without "middle men." These signatures should be obtained before the cognizant engineer is complete/submits the change to CM. Thus, the team needs to consider the problem/change very early in the process.

Rule: Technical signatures should be obtained by the cognizant engineer prior to bringing the change to CM/prior to purporting the change to be complete. Such signatures should be obtained engineer to engineer without middle men.

Reason: The discussion of the technical aspects of the change should occur very early, in the request process or early in the change process so as to get alternatives, suggestions, etc., before the engineer puts fingers to keyboard orpencil to paper. This will speed up the process and yield better changes.

Use the index to find other discussions of signatures.

4. **Implementing the Change**—Every function affected by the change needs to take proper implementation action. Their planning should start with the first team meeting discussing the request or problem and progress from there. The significant element is that conditions frequently change. As a result of changing conditions, the effectivity plan often changes. Production Control must be the focal point for this responsibility as well.

It has been said that a committee set out to design a horse, and a camel resulted. As constituted in most companies, CCBs are committees. They are, therefore, usually a symptom of a failure to develop better processes and to address the gut issues involved. The CCB is typically held after the engineer completes the fix and submits the change package to CM. If the team has discussed the request/problem/suggestion prior to the engineer placing fingers to keyboard/pencil to paper, the engineer is much more open to suggestions and alternatives. The team discussion should take place on each problem/change much earlier in the process than the CCB. Check the request and change processes for further development of this concept.

Process Documentation

Process requirements are found in either design documentation or in the manufacturing documentation. When the Design Engineer feels the need to specify a particular process, he or she typically does that with a Process Specification either on a separate document or on the face of a part or assembly drawing. That specification should be treated as design documentation. All other process documentation should be typically "owned by" manufacturing.

The manufacturing process documentation is made up of many different documents. Tool drawings, test equipment drawings, inspection procedures, floor layouts, assembly instructions, fabrication instructions, and routing, are some of these. These documents are called by different names at different companies. To process a part in a fabrication environment, *fab instruction, route sheet*, or *process routing* is common terminology. An assembly shop may refer to assembly procedures or assembly instructions. These are all process documentation.

Process docs are produced as a result of a new product release. They should be produced in parallel with the design documents because manufacturing engineers are part of the team, however, the product release is not

held up if process documents are not complete. Process docs often cannot be completed until the related design docs are completed. Nor will the changes be held up waiting for the process documents to be marked up or revised. The process engineers can begin planning their effort at the team meeting that first discusses a problem/fix. The Process Engineer cannot reasonably begin to execute changes to the process docs until the design is complete. The completion of the process docs is not required until the docs are required in the change implementation.

Fabricated Part Processing

Processing of parts generally require the use of fabrication instructions/routing documents. Almost all companies or their suppliers produce fabrication docs. They are essential to processing parts. A typical fabricated part process is the part drawing accompanied by a document as shown in Fig 6.4.

They are written and maintained by a process engineer, usually working in manufacturing. Computer Aided Manufacturing (CAM) software applications take the place of fab instructions at aa automated machine.

Area	Description	Mach / Tool	Feed / Speed
720	Spot Weld 6x	ABX 1027	1.2 sec @ set G
430	Grind Surface A	MBQ 823	4 ipm / 6200 rpm
800	Drill 6 holes	7752 AX	Hand / 3100 rpm

Figure 6.4. Fabrication instruction (attached to the part drawing).

Assembly Instructions

The assembly instructions are another matter. The start up company tends to use the engineering assembly drawings instead of having assembly procedures. Large "high end" companies (like a ship builder or locomotive manufacturer) do the same thing. The "low end"/very high production companies tend to use robotics which don't require assembly drawings (the assembly instructions are software applications for the robot).

Many other companies tend to try to use assembly drawings as their process docs with a very poor result. Most of those companies should have someone in the manufacturing group producing assembly process instructions. This "someone" is usually a Production Engineer, Industrial Engineer, or Manufacturing Engineer. They should be doing the assembly instructions with mini-pictorials alongside the step by step instructions. (See Fig. 6.5.)

Step	Description	PN	Qty	Tool	Sketch
1	Base plate to fix	123450	1	Fixture#389	#2
2	Bkt to Base Plate	432672	1		
3	Screw four places	00202	4	Air Driver 12 psi	#4
4	Remove from fix	-	-		

Figure 6.5. Assembly instruction.

Ideally the step by step instructions will be produced using Design Engineering's CAD file. That CAD file probably already contains layouts, three-dimensional, and part drawings. Manufacturing should be allowed to access CAD to down load what is best for fabrication and assembly—tiny steps and tiny pictorials to go with each step or a few steps.

This step/sequence detail is the most efficient way for the production operator to learn a new task. The process sheet also allows the time standard to be properly engineered. This results in improved product labor costs. When changes are made in the process or to the design, the change of process docs is the most effective way to implement the change to the operator's method.

Many customers are rightfully concerned about process control. The FDA is acutely concerned about process control. Process companies are keenly concerned about process control. Manufacturing Engineering can and should control the process docs under the CM overall system.

Process Document Control

The control of the manufacturing process documentation is a challenge similar to design documentation. International Standards Organization/QS/AS 9000 recognize this fact. So do the FDA and others. However, this is still not reason to place it under the control of the CM Department nor to "bundle" them in the ECO.

Rule:	Manufacturing should be responsible for doing release and change control of process documentation.
Reason:	Keep the responsibility and authority together and in the department (Manufacturing) that is responsible for producing that documentation.
Rule:	The CM function should control the overall processes.
Reason:	Distributed document control needs to be under an umbrella function to make sure minimum reasonable requirements and regulator's requirements are met.

In start up companies the control might all be in the same function. As the company grows, however, the control should be distributed to the function that needs and authors them. Manufacturing might control the unique part numbers that may be required for tools, fixtures, production equipment, test equipment, etc. They might even assign unique document numbers to process instructions, but that practice is often wasteful.

Rule:	Identify fabrication and assembly process instructions with the corresponding design document part number.
Reason:	If unique numbers are used, cross-reference lists are then required. Upkeep of cross-reference lists and referencing these lists (forever) is wasteful.

Rule: Manufacturing would maintain each process sheet with its own revision control. They must record the relation of each revision, if applicable, to the design release or change.

Reason: Changes can occur to process sheets for many reasons other than the change of design documents.

Why do ECOs (Engineering Change Order) for those process changes? Perhaps the best way to understand this concept is to take some examples:

1. **Receiving Inspection Process Sheet—**The process sheet would explain which dimensions to inspect, sample sizes, process control charts, etc. It might be noted on a print or accompanying the print. The inspection process for an item is normally identified by the part number because that is what the supplier is building and shipping to receiving. The inspection process and drawing would normally be filed by the design part number. Changes would occur to the process sheet for a variety of reasons—change in sampling technique, for example. The revision level of the inspection process sheet must, therefore, be related to, but not necessarily the same as the CM assigned document revision. Date revision control is often used to accomplish this. When applicable, the corresponding ECO number is referenced in the description of change column of the process sheet revision log. The proper revision level (not necessarily the latest revision level) drawing is in the folder. When the next revision level is to be effective the print must be replaced in the package and the old one destroyed.

2. **Test Process Sheet—**The Test Engineer (TE) could identify the test process sheet with the design part number of the assembly to be tested. The TE could maintain a separate revision assignment and log. Revision numbers might be used that are related to the assembly drawing (with the proper CM revision level, not necessarily the latest) only through the log. This allows the TE to make process changes without a corresponding change order.

3. **Fixture Drawing—**This drawing might be assigned a manufacturing Tool Number. It would have a revision block just like a design document, but need not be revised by ECO. The

description of change in the revision block would spell out the details necessary to trace the change to its cause. If an ECO did cause the fixture change, the ECO number would be referenced.

Process Control Summary

Other manufacturing process documents can be treated as described above. Require the level of control (to the entire process documentation set) as is necessary in your kind of business. Are you FDA regulated? Is Lot Control in order? Do any of your parts have a shelf life requirement?

In the extreme (FDA requirements), the manufacturing process control can be as stringent on process documents as CM controls are on design documents. A separate MCO *(Manufacturing Change Order)* may be required. Companies that are FDA regulated and have separate document control functions, usually control the process documentation in this manner.

In smaller companies the process document control may be made a CM responsibility. This is a most critical time. The CM person/manager must take all possible steps to keep it separated from the design documentation. Release or change the process documentation as a result of design document releases and changes. Release and change the design documents first. Don't hold up the design documents while the process documents are being marked up/changed. As the company grows, this will make it easier to spin off the responsibility and give it to manufacturing. Also, see Fig. 10.3 under *Change Control.*

Publications

Service publications can and should be treated much like manufacturing process docs. Service docs are installation manual, maintenance manual, spare parts manual, etc. Many changes will be made to these docs that are not the result of a design change. If affected by an ECO they should not hold up the ECO to the design. They should be a second step in the CM process. The publications must be completed prior to closing the box/shipping the product. The service function should control these docs.

Rule: Service should be responsible for doing release and change control of publications documentation.

Reason:	Keep the responsibility and authority together and in the department that is responsible for producing that documentation.
Rule:	The CM function should control the overall processes.
Reason:	Distributed document control needs to be under the CM umbrella function to make sure minimum reasonable requirements and regulator's requirements are met.

A change form is typically not required to manage the changes. A change log should be kept for each document that captures the reason for change, etc. If the change was caused by an ECO, that fact would be logged to provide "traceability." Also see Fig. 10.3 under *Change Control.*

On Time Publications

Many companies suffer from, "We're ready to ship the product, but the publications aren't ready." The same thing happens with the revised product. Why can manufacturing order parts, make parts, buy parts, assemble product, test product, while revised sheets of paper cannot be done in the same time? In this case, there is probably a management problem, not a CM system problem.

The Management must be made aware of the condition and take appropriate action to fix the problem(s). This condition existed at one high tech computer company—the publications were never ready to ship with a new or revised product. A deviation was placed with each product shipped indicating that the publications weren't up to date/ready. After asking a few questions, it was clear that the responsibility for their publication was with another division, across the city. This other division built another product line. You can guess whose products had up-to-date publications. The responsibility was transferred to the producing division and it was surprising how fast the problem cleared up. The management must assure that the publications function is organized by product and located with the producing plant.

CM managers are often burdened with a management edict: "Don't release another change until the publications have been revised." This is a bad decision. Hold up the fix for a problem while waiting for publications?

Build more scrap or rework while waiting to update the publications? Hold up a cost reduction while waiting for publications?

Address the root cause of the problem. The publications people probably aren't brought into the process early enough. Usually the publications people are the last to find out that a new product is being developed or that a change is being made. Get them into both processes early. They should be part of the team in both the new product release process and the change process.

Publications people can also do many things that will assure the publications are ready to ship when the product is. Some of the actions are:

1. Say it once with as few words as possible. Most manufacturers have gone from little or no support literature to far too much. When the pile of paper accompanying your PC is higher than your PC, something is wrong.
2. Don't try to cover all possible combinations of features and options. Cover those that have been sold, and add others as sold.
3. Don't try to cover all possible failure modes. Cover a few expected major hitters and add failure information as other frequent failures become apparent.
4. Don't hard bind the manuals. Use three ring or equivalent. This is especially effective when changes are to be incorporated. Thus, replace only the affected pages when a change occurs.
5. Use word conservation.
6. If the country of destination is known, make a separate manual for each language. The customers might well look at a product that is covered only in their language as a user friendly product.

The most significant thing that the management can do is to expect/demand that the publications be ready when the product is. They must never use the release or change processes to "fix" the problem by "bundling" the publications into the change package.

Lot Control

Lot control is the tracing of the content of a product by an identifier. Certain materials, parts, assemblies, are specified to require lot control. They are specified in customer contracts, agency standards, or company standards. Why is lot control important? This is typically required because of the critical nature of the item to the function of the product. Since processes for you and your suppliers have some tolerance they work within and since the process control may not be precise, lot identification and tracking is sometimes required to troubleshoot problems. This may be true whether the item is produced in batches or continuous flow.

Several methods of identifying lots are used in industry. Date coding or lot numbering are typical identifiers. The date code or lot number must be changed whenever a significant change is made to the process. The date code or lot number must then be tracked through subsequent process (mix) or assembly. This is done by attaching the code or number to each subsequent mix or assembly until the final product is completed. The lot or date code(s) in the product are recorded. The end product serial number (or mod or date code) is, thus, traceable to the exact lot for each required item.

The items that require lot control must be carefully sorted out and noted. Probably the best way to identify them is with a code in the database.

Rule: If Design Engineering is involved in the decision as to which items are lot controlled, CM should maintain the data base or place a note on the drawing. If not, manufacturing/quality assurance should maintain the database.

Reason: Keep the responsibility and authority together.

The responsibility for lot tracking should be a manufacturing responsibility. Answering customer lot control questions, hosting agency audits, etc., should be a joint CM and Manufacturing responsibility. CM might coordinate the customer or agency visit, but manufacturing should answer lot control questions.

The manufacturing control number previously mentioned and a serial number are a lot number for a lot size of one. Manufacturing must also be responsible for the tracking of this number to the customer.

Shelf Life

The longer you live, the shorter your life. We may not like it, but it makes sense. The same sense applies to some of the items in our products. A prime example is O-rings. You or your customer may require that no O-ring be assembled with an effective life of less than two years. Your vendors identify and ship you O-rings that have an effective life of three years or more. The problem, then, is to identify the rings as to their effective life and to trace the product content of O-rings.

Typical shelf life identification is handled like the grocery store. The supplier is requested to identify the expiration date. Identification would usually be by the *bag and tag* method.

As manufacturing assembles the rings, the process sheets should instruct the operators to tag the product with the expiration date. Manufacturing must design a tag(s) which allow traceability of the O-ring content to specific locations in the product. The tag would have the serial number added and a copy of it stored in either Quality Assurance or CM. The customer should be made aware of this information as the contract requires.

Down Level Drawings

The appearance of an improper revision level drawing on the production floor should be of serious concern to any manufacturing person. The product must not be built from down level prints after the effective date. The QA, management, and regulating agencies, are all rightfully critical of any CM process that allows this to happen. The best cure is an ounce of prevention. Don't allow design drawings to get onto the manufacturing fabrication or assembly floor in the first place.

Rule: Every point of use for a design document should have a designated technical support function. Those technical support functions should be sent the action paper, release notice and/or ECO. They should read the ECO and obtain the correct revi sion level print for the production floor at the right point in time (effectivity).

Reason: These people are probably already part of the team, already have reviewed the ECO, and under stand the change.

Who should the technical support functions be? Make your own standard using the Loader Company as a guide:

Point of Use	Technical Support Function
Supplier	Buyer
Receiving Inspection	QA Engineer
Fabrication Shop	Industrial Engineer
Assembly Shop	Industrial Engineer
Test Floor	Test Engineer

If the assembly floor has assembly instructions instead of assembly drawings then the Industrial Engineer would revise the process and place a new revision date process on the assembly floor on the correct date. If drawings are used or do accompany the process sheet, the old revision level is removed on that day by the technical support function. The technical support function would be responsible for destroying the old revision level documents.

The make to order company often solves this problem in the assembly area by the technical support function putting the proper revision level assembly print into the order package which accompanies the order through the process.

By this method, CM has a limited number of functions to distribute changes to. The control of old revision level prints is then done by the people closest to the production operations. This method compliments the *pull, not push,* system.

Push/Pull Document Distribution

The typical process calls for distributing seventeen copies of the release document, seventeen copies of each document released, seventeen copies of a weekly list of released documents, seventeen copies of each change package, seventeen copies of each changed document, and seventeen copies of a monthly list of released changes. This is a *push* process. Some folks have limited the distribution by creating a few controlled document satellite centers. This is still a *push* process. The centers are seldom maintained and still contain many kinds of documents that aren't used in that area. This "wallpaper the plant" mentality is gradually disappearing. This is truly an archaic practice.

Rule: Eliminate the *push* system in favor of a *pull* system. Distribute the cover sheet of the release document/ECO (preferably on line) to those who need to know (seventeen, if necessary). Expect the recipients to read the ECO and to determine which documents they need. They then go to the "vault" to *pull* those documents they need when they need them.

Reason: Forces the reading of the ECO cover sheet to see the effectivity plan and to determine/verify what action and when that action is required. Save untold dollars in distribution and center maintenance costs.

The author tells clients who are talking about becoming paperless that the place to start is to eliminate push in favor of pull. If this cannot be accomplished, the company culture is not ready for paperless. Better start working on the culture.

Nonconforming Material

CM is not normally involved in the nonconforming material process, however, since that process can produce design changes, it should be briefly discussed. Usually a company has a discrepant material form. All items that do not conform to the drawing/specification is tagged and a form completed. A Material Review Board (MRB) is formed of a Design Engineer, Quality Engineer and a Process Engineer.

All nonconforming material is reviewed daily and disposed of—return to supplier, rework, scrap, etc. They must treat each problem as importantly as the next. They identify the root cause of the problem and address the proper fix for the problem. Sometimes a change in design is called for. Usually this is because of a repeated problem with a disposition of "use as is." The above is a condensed version of the normal MRB process.

One company added a wrinkle that is worth considering. A copy of the discrepant material report was sent to CM whenever the decision was made to change design. This allowed CM to assure that the clock started on that change when the report was dated.

The critical thing about this process from a CM perspective is that it should not be used as a method for making a quick change. This issue will be discussed further in the chapter on changes.

Field Support

The continued trouble shooting, repair, and maintenance, of a product is one of the most difficult and high customer visibility tasks in the manufacturing business. Whether it is done by dealers, your service people, or the customer, this is the *Customer Satisfaction Test.*

The field service is embodied in:

1. The people who perform the task.
2. The training they receive and give.
3. The publications (Maintenance Manual, Parts Catalog, Spare Parts List, etc.).
4. Field change orders and kits.
5. Traceability (Status Accounting) Reports.

The last three are of significance to CM. The field people have aservice adage which states *"All serious problems occur when the factory is closed."*

Service dependence upon the publications, field change, and traceability reports, is critical. The field change order and kit is of special significance to CM.

Field Change Order and Kit

Field Change Orders (FCO) should almost always be a result of a design change to fix a safety problem or to meet product specifications. The FCO is a separate document and is originated because an ECO so directed. Again, the ECO should not be held up waiting for the FCO. Here are some other rules about the FCO that are food for thought:

- Only a non-interchangeable change should be a candidate to result in an FCO.
- Not all non-interchangeable changes need to become an FCO. One company saved over one-hundred-thousand dollars (in 1973 dollars) a year in field change cost by eliminating a rule that said: *"if the change is class I, an FCO is required."*

- The Field Support group should sign all ECOs which "direct" an FCO. That is, they should agree or disagree with the cognizant engineer's position on changing the field.
- The Field Support function should write all FCOs. People who have done field repair are in the best position to write them. Detailed instructions for incorporation of the kit and subsequent testing are needed. They should probably be approved (accepted) by the Cognizant Engineer.
- The Field Support group should originate a kit of parts (BOM Parts List) for each FCO.
- The FCO should reference the kit part number. The FCO document should be assigned a part number and that number should be referenced on the kit parts list. The FCO document should, thus, be included in the kit.
- The Service organization or the CM group should furnish standard marking/sticker/label for the kit if identification changes are required.
- Unless the field is on line with the factory, the CM group should furnish (in the kit) a simple, self-addressed post card for feedback of the unit serial number (mod or code) affected.
- All FCOs should be modeled and tested by a person other than the writer. They should get a production kit and install it into a production unit, then install and test per the instructions. That person should identify the unit per the instructions and fill out the postcard. A complete "modeling" of the field change is the best way to assure the field people of a quality field change. If this is not done, modeling will take place in the field and every problem with the kit or instruction will be discovered by several field people and will be ten times more expensive to correct.

Many companies do not have a field change problem. Those that do, have many problems in this area that might be solved by taking some or all of the above steps.

A separate form is generally needed to make the change in the field. The ECO doesn't cover disassembly, covers versions of the product not changing in the field, doesn't cover retesting, etc. A suggested form is shown in Fig. 6.6.

Field Change Order	**EC3 Corp**	**FCO #**
Choose One: Now ☐ On Failure ☐ At Regular Maintenance ☐		
Product Numbers Affected:		
Mfg Eff: Ref ECO #	**SNs**	
FCO Kit PN:	**Estimated Man Hours / Unit**	

FCO must contain the following subjects in order:
1. **Reason for change.**
2. **Publications affected.**
3. **Description of change.**
4. **Change Installation step by step procedure.**
5. **Special tools required and availability.**
6. **Removed part(s) disposition and field warehouse disposition.**
7. **Test / checkout procedure.**
8. **List of attached & referenced documents.**

Authored By:	**Accepted By:**		
Date:	**Page of Pages**	**FCO PN**	**Rev**

Figure 6.6. Field Change Form.

Normally this author would expect a form instruction to accompany each form. The FCO form shown in Fig. 6.6 is fairly self-explanatory. Some more comments about the form, however, are in order.

- Your FCO "types" should be specified—Immediate, On Failure, At Regular Maintenance, Recall, etc.
- Product numbers affected should not be left to the field service engineer, they should be from the ECO.
- State the manufacturing effectivity so that the field service person doesn't have to look at units that already contain the change.
- One author and one acceptor should be all the signatures required.

A quality job on this document and the kit will allow the field people to function when the factory is closed.

ISO/QS/AS 9000

The International Standards Organization has done an outstanding job of writing make sense, minimum logical requirements for a quality operation. The automotive (QS) and aeronautical (AS) industries have modified and added requirements in their specifications. An excellent overview, analysis and perspective of ISO 9000 can be found in the Reference and Reading List.

It is significant to note that the vast majority of this series of standards are Engineering Documentation Control/Configuration Management kinds of requirements. Seminar attendees report that a majority of the "gigs" received upon ISO audit are for documentation control issues. In fact, the paragraph on "*Document and Data Control*" has the highest deviation from standard, nearly twice that of any other paragraph, and that is only one of many CM related requirements. This is effectively international recognition of the significance of Configuration Management. International Standards Organization 10007 (Guideline for CM—not a standard) also recognizes the significance of CM.

This author often hears, *"ISO requires"* followed by a highly questionable statement. Best to get a copy of those standards and read them for yourselves. Do not rely on the interpretation placed on the standards by your certifier any more than you have to.

Since most of ISO 9000 requirements are nothing more nor less than make sense engineering documentation control, those requirements will not be repeated again here. A few highlights are in order, however. For example, ISO rightfully places high emphasis on the product specification. The key nature of product specifications is discussed throughout this text.

The last revision to the standard changed the terminology about down level prints to the proper revision level. This is recognition that the latest revision level of a document may not yet be effective. They are also very concerned about down level drawing proliferation. This issue was covered earlier in this chapter.

The International Standards Organization also says, *"The supplier shall establish and maintain procedures to control and verify the design of the product in order to ensure that the specified requirements are met."* Since the ISO requirements, and many product specifications, are very general, a company can choose to do the minimum or choose to do something more. In that process, a significant issue remains. What is currently being done in any given company may be ill conceived, slow, wasteful, inefficient, and counter productive. As long as the requirements in the procedures are met ISO doesn't care about such issues. Thus, there are three ways that ISO certification can be approached:

1. Document minimum requirements without making improvement and then seek certification.
2. Document minimum requirements, seek certification and pursue improvement afterwards.
3. Pursue improvements as or before the documenting is done, then seek certification.

Each company launching into this venture, needs to make a conscious decision as to which course they will follow.

It is also true that just because a company or division has achieved ISO certification it doesn't mean that they have arrived. Documenting the system and following that documentation is barely the beginning. Consider the CM ladder (that is included here again) in Fig. 6.7.

This is not to say that obtaining ISO certification isn't important. It is a critical first step toward exceptional Configuration Management. It sets the stage for improvement.

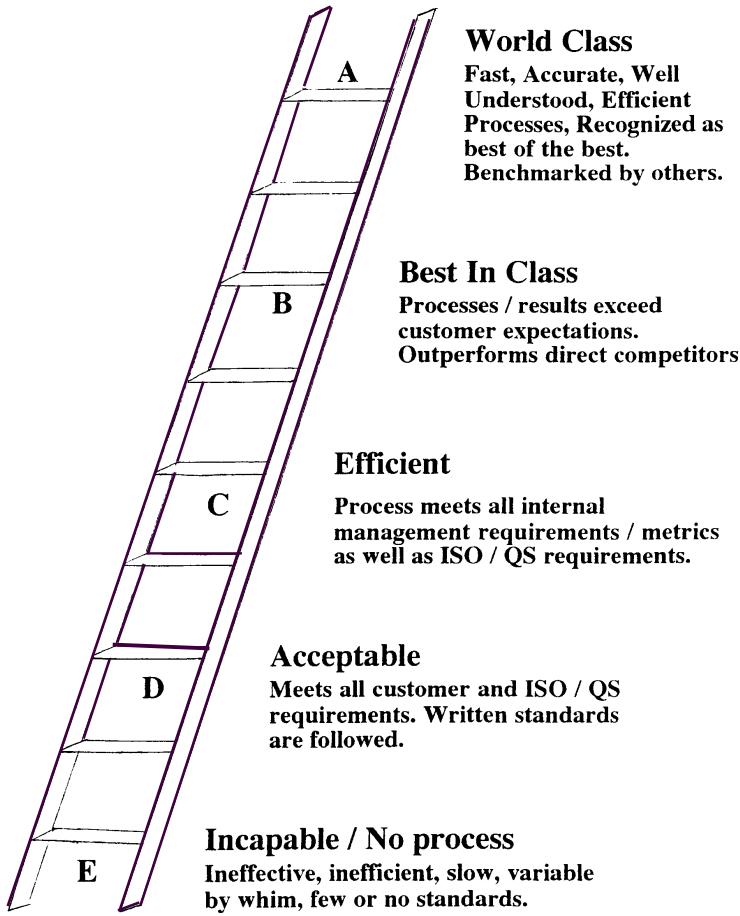


Figure 6.7. CM ladder. (Adapted from an article *"How to Stay Flexible and Elude Fads,"* by Irving De Toro and Thomas McCabe in *"Quality Progress,"* March 1997.)

7

Product and Document Release

The release of the product and its documentation should be an evolutionary process (see Fig. 5.9). Very shortly after the design and development begins, the service support planning and manufacturing process development should start. Design Engineering is developing the product, Manufacturing is developing the production process, and Field Support is developing the service and maintenance plans and process. Each is communicating its needs and plans to the others through the team. Each is presenting its needs for the drawing, specification and BOM. The team is costing the alternatives, and settling individual issues as they occur. They meet with the management to review progress on a regular basis.

Manufacturing needs the release of part documents first—in lead-time to produce. Engineering should accommodate that need to the maximum extent possible. Thus, documents should be released one or a few at a time—in lead-time. When a single drawing is agreed upon, it can be released. This is evolution of the product and its documentation. It is the fastest approach to new product release.

Life Cycle Phases

As this process takes place, the management (or your customer) will impose certain major milestones to pass. These milestones (or baselines as they are more frequently called) divide the project into phases. These phases

are called by different names at different companies. Our Loader Company will use the D2 - P3 terminology pictured in Fig. 7.1.

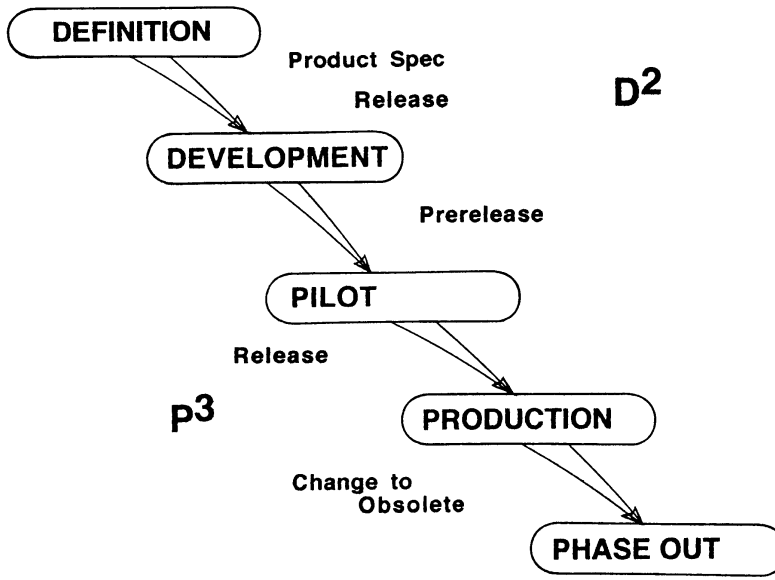


Figure 7.1. Product documentation release phases.

Some companies choose to have more or fewer than five phases. Make to print companies typically have two or three phases - contract / PO, sample/ qualification unit, and production. On repeat orders, samples may not be required. Some companies have a field operation phase. Some don't treat obsolesce as a separate phase. The "the line" between phases are baselines. In DoD terminology they are - Functional, Allocated and Product. You can give them your own names or refer to them as "development to pilot" baseline. The baselines are crossed in the Loader Company by release done on a blanket ECO. The distinguishing "event" (Product Spec Release, Prerelease, Release & Obsolete Change) between phases, is also shown in Fig. 7.1.

Rule: The phases and baselines to be used at your company need to be defined and agreed upon.

Reason: This is a matter of defining communications and management expectations. The people in a given enterprise came from different experiences and tend to use different terminology. However, they may or may not mean the same thing. Communication barriers start to come down with the definition of common terms.

Terminology varies in different industries and in different parts of the country. Regulators influence the terminology. What the Loader Company calls Definition might be "Contract" or "Bid" or "Product Spec." in another company.

Different parts of the company tend to look at the "correct" phases in terms of their own functions. Engineering will often define the phases and introduce phases that Sales or Manufacturing do not relate to.

Rule: The phases should be limited to the fewest practical for the total company.

Reason: Phases are defined for the total company - for the cross-functional team - not for any single function. They, therefore, need to be for the business unit, not for one function.

Rule: The phases should be established for the new product - not the "spin off" product.

Reason: This is the "worst case," the team can then make a decision to skip a particular phase that may not be applicable for a "spin off" product or a repeat order.

This question of company phases is critical and needs to be determined at the highest management levels of the operation. They should not be dictated by corporate headquarters to be identical in all business units.

Documents Tied To Release Phase

These are product and document life cycle phases. Since the product is defined by its documentation it is necessary to tie these phases to the documentation. Since the development of the product should be evolutionary it is necessary to be able to look at any single document and tell which phase it "represents." This is sometimes done by stamping the document. For example: "OK for Pilot Build." A simpler process is to use the revision block

to indicate the applicable phase. The diagram in Fig. 7.2 indicates how the product and its documentation are "tied together" by use of the document revision level.

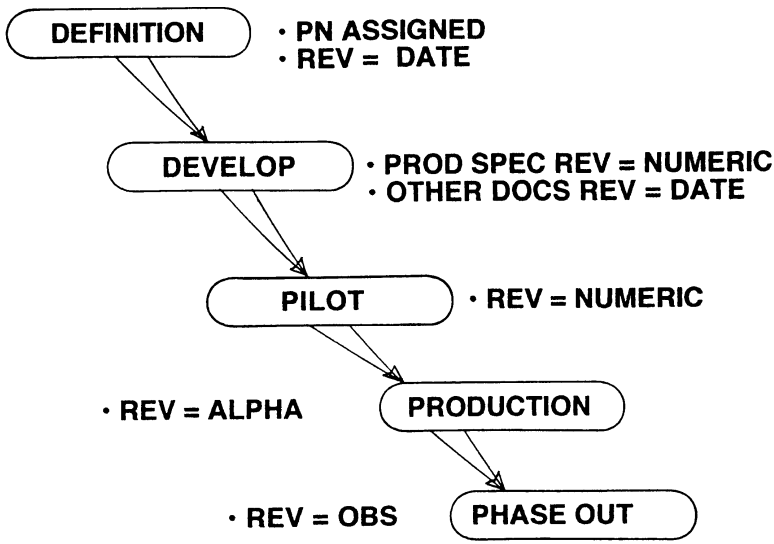


Figure 7.2. Release phases and revision levels.

In this case a blank or dash in the revision field indicates that the document is in the "definition" phase. This means that the designer will need to use the "date" field to keep track of the changes. In the "development" phase, also use a blank or dash revision. This choice is made purposely—to reserve the revision field only for CM use.

The Product Specification is an exception because it was pre-released (revision number control) the day after the project was started. In the pilot phase the documents will be a numerical revision. In the "production" phase, use the alpha revision. When it is determined that an item will no longer be produced, place a notation of "obs" in the revision field.

Rule: A standard is needed for a company that defines how to relate the revision block to the development phases.

Reason: It should be apparent by looking at a document, which phase it may be used in or is good for.

It must be kept in mind that the above refers to documents developed uniquely for this program. The program will use other items already released. Those items remain in a released condition. Sometimes companies reverse the roll of the alpha and numeric. That is OK providing they are consistent. In no case should a drawing or specification (that is under the engineer's control) be done by revision letters or numbers—the engineer controlled drawing should always use date control.

Having the ability to look at the document and know what phase it is "good for" is very important. It will avoid buyers or fabricators placing orders for production units when the part is only approved for pilot.

The Revision Block

As a result of these rules, the revision block on a particular document would, over time, look like Fig. 7.3. The phase history is, therefore, visible on the document.

REV	DATE	DESCRIPTION	ECO	SIGN
_	3-21-94	drafted	_	engr
_	3-29-94	redraw	_	engr
1 *	4-12-94	Released to Pilot	248	CM
2	4-17-94	Changed orientation	283	CM
3	4-20-94	Finish note added	280	CM
A **	4-27-94	Tested & Release to Prod	302	CM
B	5-11-94	Changed front tire O D	324	CM
C	5-30-94	See ECO	352	CM
D	4-20 95	Changes material	589	CM
OBS	8-04-02	Not used for new designs	2040	CM

* Move Master Document from Engineering to Master File and Start Informal Change Control

** Start Formal Change Control

Figure 7.3. Document revision block.

Life Cycle Phase Issues

It is also necessary to resolve many other issues in respect to the development phases. Just a few of those issues are:

- Location of and control over the "master" drawing.
- Whether or not the drawing will be microfilmed, digitized, etc. in each phase.
- Formality of the change control process.
- Associated MRP codes.
- Names to call the units built during that phase.
- Budget responsibility for the units built in that phase
- Kind of test that will be required to progress to the next phase.
- Kind of management and/or customer review required.
- Management and / or customer approvals required to proceed.

It is important to make a matrix of the agreed upon phases verses the "issues" as arise in your company.

Baseline - Phase Relationships

These phases need to be company/business unit decisions. That is, each product/project within the business unit should not make independent decisions. Allowing each program to develop its own rules invites chaos. The best way to develop these "release rules" is to write a standard that includes a relationship chart such as that in Fig. 7.4.

Rule: Every business unit should have a standard on "Product and Documentation Release" which includes a chart that crisply defines these relation ships. The chart must be void of lines/arrows crossing baselines. The standard and the chart must also be free of "ifs," "ands," or "buts."

Reason: The terminology and the tie between the product and its documentation must be clear. It represents the manner in which the evolutionary design process is to be monitored. Communications are much clearer.

A blanket release document would be used to indicate that the team has agreed that a particular item / document is "released" to the next phase. The document revision level would be changed by Document Control.

PHASE	UNIT NAME	CHANGE CONTROL	REV	DWG
DEFINITION (Concept)	Breadboard or Development	Engr	Date	Engr
PRODUCT SPEC BASELINE / PRELIMINARY DESIGN REVIEW				
DEVELOP-MENT	Prototype or Development	Engr	Date	Engr
DESIGN BASELINE / CRITICAL DESIGN REVIEW				
PILOT	Pilot Prepro Qual	Informal	Number	CM
PRODUCTION BASELINE / QUALIFICATION TEST REVIEW				
PRODUC-TION	Production	Formal	Letter	CM
PHASE OUT (Obsolete)	NA	No Longer "used on" any application	OBS	M'Film

Figure 7.4. Phase chart.

CM and The Release Process

The following may help to clarify the release process requirements. It is a reprint of an article by the author for the *Midrange ERP* magazine:

In previous articles, the proposition was put forth that a gap or wall often develops between Design Engineering and the rest of the company and that bridging that gap or tearing down that wall is the most important task of a

Configuration Management (CM) function. It was also proposed that CM tends to be whatever the management wants it to be. Where it all starts is in the CM release process—the process that a product manufacturing enterprise follows in the release of new products and their documentation.

The use of cross-functional teams is typically touted as the most important aspect of fast and successful new product introduction. These teams are, of course very important. In very small/start up companies or in "garage shop" development environments the team approach tend to happen naturally. All the functions represented in the garage are constantly communicating about the process that is and will be followed. But as the operation grows, difficulties set in. New people with a variety of backgrounds and experiences enter the picture. Even the meaning put on key words tends to be different. What a pre-production unit is to one, is a pilot unit to another, is a prototype to another. A meeting develops into disagreement or disarray and the cause isn't apparent. The answer is sometimes simply because words and terms have not been carefully defined.

Within your enterprise take a poll among key people in several departments and ask; "How many phases are there in your new product release process and what do you call them?" The results are eye opening! Ask "How do you know when you have progressed from one phase to the next?" Do you get questioning looks? Also ask "How can I tell by looking at a drawing or the database which phase a part number is approved for?" Has your company ended up with a quarter million dollars of useless parts in stock or on the dock because someone made/bought parts for production from a drawing that wasn't ready for production? These are all symptoms of a problem—confusion in the release process. Cross functional teams can help, but they need to know what the operations normal process expectation is.

First, determine the number of phases normally required on a new product development and what the enterprise will call them. Some possible phases (in the writer's terminology since there is no industry standard) are:

Definition / Bid / Contract / Specification Phase

Design / Development Phase

Pilot / Pre-production Phase / Qualification Phase

Production Phase

Phase Out / Obsolescence

Although five phases are listed, this is not to imply that they should all be used in any given enterprise. Some operations might require two and some

seven. A make to print company would have different phases than an aerospace company on a DoD contract. This decision must be carefully analyzed in order to arrive at the fewest necessary phases required for the operation. Engineering or Manufacturing or others may have sub-phases in their operations but the enterprise wide phase plan is most important to define. A different set of phases might be required for "spin-off" products as opposed to "new" product. Remember this is the normal expectation, the release policy should state how exceptions can be taken.

Example: "The team can skip or add phases for a particular product by noting in the team meeting action items list what is being done and why!"

Once the phases have been quantified and named, the next step is to prepare a chart to define numerous associated "issues." Let's take a generic company that normally needs three phases and decided to call them Development, Pilot and Production. The chart would address issues by phase:

	Phase		
Item	Develop	Pilot	Production
Name of Units	Prototype	Pre-Pro	Production
Number of Units to be built	3 to 6	20 to 30	Per Schedule
Build by	Engr	Pilot Mfg	Manufacturing
Serialized	No	under 100	over 100
Testing	Engr Lab	QA Reliability	Prod Test
Ship to Customers	No	After Upgrade	Yes
Location of Master	Engr	CM	CM
Signatures on Doc	None	Engr	Engr & ME
Revision Level	Date	Numeric	Alpha
MRP Status Code	D	T	P
ECO to Release	NA	Yes	Yes
Change Control	Engineer	Informal ECO	Formal ECO
ECO Signatures	NA	Engr & ME	Add Field & PC
Who Changes Master Docs	Engr	CM	CM
Signatures on Changed Master	Engr	CM	CM
ECO Distribution	NA	A list	B list
Interchangeability/PN chg rules	No	Yes	Yes

Add to and tailor the chart for your enterprise. Notice that there are no "ifs," "ands," or "buts" in the chart. Each line item or "issue" needs to be carefully analyzed in terms of minimizing control while also minimizing risks. The chart needs to be placed into a standard and published. An associated policy statement should be prepared to answer a number of questions about the release process that are still unanswered. Examples: How will the team authorize the release from one phase to the next? Will new documents be distributed or should those who need a new document be required to "pull" when needed. Can assembly documents be released to Pilot or Production before all its parts have been released?

Keep in mind that the entire product/all new documentation does not need to progress through the phases in a "bunch"—don't wait for release until all new documents are ready. The release can and should take place a document or group of documents at a time. Manufacturing needs the release of parts in lead-time to build. Engineering should release parts (documents) in their lead time sequence—30 week and longer items first, then 25 to 30, etc. Recognition of this simple concept causes many good things to happen, not the least of which is a step function improvement in release time.

This chart and the associated standard(s) are absolutely essential in clarifying the release process. Without it, a certain amount of chaos in inevitable. With this chart, cross-functional teams, the associated standards and the required training you can attain fast, accurate and well understood release of new product. Try it, you'll like it.

Product Definition Phase

In the Loader Company, the standard that describes the Definition Phase will address:

> The kind of testing that the breadboard model will be subjected to.
>
> That change control is in the hands of the responsible designer.
>
> That revision control will be only by date.
>
> The master drawing will be under the Cognizant Engineer's control.
>
> Pre-release of the Product Specification immediately after the project is approved.

A meeting(s) of the team with the top management (Preliminary Design Review) to examine the;

1. Latest product specification.
2. Test results and the breadboard model.
3. Product cost estimates, pricing, contracts, etc.

When the management (and the customer if applicable) approve, the Product specification will be "pre-released" (rev "1" & under formal CM change control).

Note that progress from the Definition Phase to the Development Phase is marked by two measurable milestones—completion of the Preliminary Design Review and of the Product Specification at revision #1. Successful passing of these two milestones constitutes passing the Product Specification Baseline.

Rule: When the management (and customer if applicable) determine that the preliminary design and Product Specification are acceptable, the Product Specification must be pre-released.

Reason: To document the fact that the Product Specification is agreed to and the date the agreement was accomplished. Track specification changes that might be made at the same time.

Notice that the Product Specifications is one phase ahead of all other design documents. This puts the document under informal change control and assures that the team is involved in any further changes.

Product Development Phase

The Loader Company standard for the Development Phase will describe that phase by addressing the following issues:

The kind of tests that are required for the prototype unit(s).

That change control will still be with the responsible designer (except the Product Specification).

Revision control will continue to be done by date only (except Product Specification).

The drawings remain in the designer's hands (except the Product Specification).

The designer and the field support person will make a pre-released spares item list.

A meeting of the Design Team and the top management to examine;

1. The latest Product Specification.
2. The Prototype Unit and the test results.
3. The evolving BOM, cost roll up, pricing issues, etc.

If management (& customer if applicable) approves, the remaining drawings and specifications must now be pre-released.

The Product Specification must be revised (Rev A) because; "critical design review is complete and the team has agreed that the product is ready for Pilot Production." This should be done whether or not there are changes to the specification.

Item by item prerelease by lead-time is encouraged. At prerelease the revision changes to numeric (Rev 1 description of change = "pilot prerelease"). The drawing is now under informal change control. The master drawing goes to CM "vault" control.

Note that progress from the Development Phase to the Pilot Phase is marked by three measurable milestones: completion of the Critical Design Review, pre-release of the remainder of the drawings and specifications, and revision of the Product Specification. This constitutes passing of the Design Baseline.

Rule: When approved to pass the Design Baseline, all the master drawings and specifications must be in CM. Informal change control will now be administered by CM. (Except the Product Specification which is under formal change control)

Reason: To document the completion of the Critical Design Review and the date it was accomplished. Tracking of progress is visible on the documents. Minimize risk.

Just as the Product Specification can and should be released prior to the Preliminary Design Review, so should some of the drawings be pre-released prior to the Critical Design Review. After all, this process should be an evolution—not revolution. The long lead items should be pre-released to allow purchase of the pilot parts. Parts or assemblies used from existing designs would have been previously released. Evolutionary pre-release must be encouraged to avoid bunching the work and the resulting delays.

Product Pilot Phase

In the Pilot Phase, the Loader Company will address the following in it's standard:

The kind of tests that are required for the pilot unit(s).

That informal change control will be with CM.

Revision control will be numeric.

The master drawings must now all be under CM's control.

Formal release on an item by item basis by lead-time will be encouraged.

Engineering and field support will review the spares item list for release.

A meeting of the team and the top management to examine;

1. The latest Product Specification.
2. The Pilot Unit(s) and the test results.
3. The latest costed BOM, pricing issues, etc.

If management (& customer if applicable) approve, the remaining drawings and specifications must be alpha released.

The Product Specification will be revised (To the next alpha revision), whether or not changes are made.

Progress from the Pilot Phase to the Production Phase is marked by three measurable milestones: completion of the Qualification Test Review, all drawings alpha released, and the Product Specification revised (next alpha character). This constitutes passing of the Production Baseline.

Rule: The product must be approved and listed by any and all certifying agencies prior to formal (alpha) release. The end product document (top level) shall not be alpha released until such approval and listing has been obtained.

Reason: Product liability risk too high to do otherwise.

Rule: All critical components must be qualified (tested) before formal release. Design Engineering, Manufacturing and Field Support must agree on which components are critical.

Reason: Assures the repeatable quality of the component and assures that there is an agreeable method of testing it.

Rule: No assembly may be formally released (alpha rev) until all its part drawings, assembly documents, specifications and referenced documents have been formally released.

Reason: Minimize the risk. Keeps people from being misled by the revision status on the documents or in the MRP system.

The production of the product entails significant dollar expenditures. It should be done only if confidence in the design is high enough to formally release. The product cost is now very quantifiable. The BOM is in place and cost can be accurately "rolled up." Notice that the product cost is a subject for constant review as the product design, the drawings, and the BOM evolve.

The design and development budget authorization should also be a subject of constant review. This helps to assure cost within goals. It also aids the evolutionary release progress by authorizing spending for portions of the next phase—long lead items, tooling, etc.

Product Production Phase

The drawings and specification masters are under CM control. The letter revision is used. Formal (but fast) change control will be used. If the

Design Team has done its job well, fewer changes will result. The product will be manufactured according to the master schedule/orders. The Loader Company will now prosper from the profits on this product.

Product Phase Out

Lastly, when the product is no longer to be produced, the Loader Company will:

Check the Used On for every item.

Those items unique to the obsolete product, will be revised by ECO to indicate "Not used in current production" in the reason for change block and enter "OBS" in the revision block. We will also refer to the part (if there is one) that replaced the obsolete one.

Should a use for the part arise in the future the document will be revised to reverse that process for the using program.

Several other issues arise in this phase that are highly individual company dependent:

The definition of "obsolete," "superseded," "cancelled," "redrawn," etc.

What if an item is still on a spare item list but is not in production?

Is the replacement part new to old interchangeable?

What do applicable regulating agency specifications require?

What are the company support life requirements?

What are the liability issues?

All of the related factors must be analyzed and definitions written accordingly. The manufacturing and service functions need to agree with engineering on these definitions. They both have possible stock purges to accomplish. Service may have manuals to revise, etc. The significance of this "phase" is dependent upon the complexity of these and other issues. The action required is usually to make a document change (by the normal change process) in order to implement the necessary terminology into the database, on the face of the drawing, and/or in the revision block.

Rule: Look for obsolesce (not used in current production) of each deleted part on each design change. If A deleted part has no used on, obsolete it as part of that change.

Reason: This is a key to making "phase out" a practical day to day event.

Management of the Release Process

Written approved standards allow the company to proceed with the development in an orderly fashion. It is not a reason to expect every product to be done identically, however. The management and the team can use the standard to manage by exception.

Example: Since the FEL-200 is a "spin off" of the FEL-100, management may choose to bypass the Definition Phase by starting the project with a "dictated" product specification.

Example: The management may have high confidence in receiving Underwriters Laboratory approval, and may therefore decide to alpha release and to risk building deliverable units expecting agency approval prior to shipment

Example: The team might determine to build fewer than normal pilot units because fewer units are needed for reliability testing.

Companies may and do make many exceptions. But this should not be a reason to do without a standard. On the contrary, a standard will yield understanding as to what is to occur if there are no management or team exceptions. Give all involved the normal condition against which to consider exceptions. **The standard therefore is the basis for "management by exception."**

Many companies may decide to proceed even if all the rules have not been met. This should typically be done by a written and approved Deviation.

Any company without a phase chart and standards will tend to have a totally different method used on each product it develops. The confusion

will tend to lengthen the development process. It has been demonstrated to this writer's satisfaction that it is better to have a documented method and to be flexible about its application than to have the "variable by whim" method.

MRP Status Codes

Most BOM systems have the ability to identify part numbers with a "Status" code. This code is usually in the item master file (database). It will typically print out on key reports, such as the Purchasing Decision Reports.

Different codes/acronyms are used in different systems. In one case, the MRP/ERP system has three codes - NIS, PRE, and REL. Include in the release standard, a definition of each. The definition must be compatible with the document release revision status. Example:

NIS = Part Number Assigned but not pre-released.

PRE = Numeric Revision, is pre-released.

REL = Alpha Revision, is released.

This allows the status of the part (in MRP/ERP) and the status of the document (Rev) to be compatible. This is very important since some people typically refer to the MRP/ERP while others typically refer to the documents. The coding in the database is for everyone to see and it is another necessity to "bridging the gap." (Also see Ch. 5, Fig. 5.2)

Release Form and Signatures

Some companies design a special form to accomplish the release of a drawing, spec, etc. The information that must be captured for any release is:

Product and/or project number.

Reason for release. (Production Release, Phase out, etc.)

Revision level (numeric or alpha).

Approval (s)—might only be on the documents being released.

Document or part number(s) released.

Test record per the applicable baseline.

Dates of release. (Dates on the documents may be days earlier than the actual time of release)

Management/Team meeting that gave authority to pass the baseline. (optional)

Number (control or form sequence number for tracking back to the above).

When parts are released, they need not have a "home"—such as long lead items released prior to structuring. The top level can be a temporary "home." The formal Used On relationship will come when a parts list is released.

Almost every element above must already be on the design change form (ECO). Because of this overlap, the same form is often used for release and change. This issue is very much a matter of a personal preference. Thus, if your company has a separate form or uses the same form, and it works, don't change it.

If you prefer a separate form, layout the above information and you will have a sound release form. The release form is also a very good automation application. Put it on line for distribution. A consistently formatted email message serves this purpose well. Since signature(s) should be on the documents being released, there should be no need for signatures on the release document. The CM technician's name should appear on the form/email to indicate responsibility for the accuracy of the release list and that the rules (Check List) have been followed (or that exceptions have been noted).

This is a very good application for a "blanket" (ECO) release form. This is the practice that the Loader company will use. A pre-formatted ECO will have a "log" to allow recording of each release as it occurs. The same ECO document will be used to release all the items required for the FEL-200. Items will be released one or more at a time and added to the blanket ECO "log" and redistributed once a week.

Some believe that no form at all is required to release. Items 1 through 4 above can (and probably should) be handled on the released documents. The team meeting reference (#8) is optional. That still leaves a need to find out when the actual documents passed to CM (since the dates on the masters may, and often are, "old"). Having no form begs the questions: How do those who need to know find out that the release occurred? How do we track what happened some time later? If data entry to a particular data processing

system produces a record of these things that is available for all that need to know, than that record is a release form.

The proper "acceptors" signature must either be on the released document or on the release form. One "acceptor" from manufacturing should sign either the document or the release form. All too often engineering "releases" an item that manufacturing cannot verify at receiving inspection (test) for example.

Release Checklist

In order for any release to be accepted into CM, it should pass a check—accept/reject point. The checklist will be different for each baseline. The list can be prepared from the baseline standard. Put the checklist into the Release Standard, and have it approved by the appropriate top management. This checklist should have a series of crisp yes or no questions. A partial checklist for formal release follows:

Have all drawings been properly signed?

Are all drawings / documents in accordance with the applicable standard(s)?

Are marked up drawings (for "same as except" conditions) in accordance with the mark up standard?

Are all the design reference documents included or previously released?

Have standard parts and assemblies been used where possible?

Before an assembly is alpha released, have all its parts been formally released?

Before the product is alpha released;

Has everything in the structure been alpha released?

Has the management approved baseline requirements?

Has applicable agency approval been obtained?

Have all the document numbers assigned to the project been accounted for? (need not hold up product release)

Check lists are thus a summary of the requirements in the standards that you judge to be significant enough for a CM check.

Rule: Every company should have a set of agreed upon release criteria put into a standard in the form of a checklist.

Reason: To attain a release by release auditing of standard (normal expectations) release requirements.

Rule: Before an item can be formally released, it must pass the checklist standard. If it fails any part of that checklist it cannot be released. CM assures this.

Reason: The agreed upon requirements must be met.

Application of a well thought out and agreed upon checklist will aid in management by exception.

Closing the Gap in Pilot

The team can help close the gap between Design Engineering and the rest of the Company. The tendency is to dissolve the team when the Pilot Production Phase starts. "We're done with that design, now let us move on to the next challenge." This is the worst possible thing that can happen. If fact, the team should not only stay essentially in tact during pilot, but:

Rule: The team should move physically into the pilot production area. Perhaps not every design engineer but certainly the Project Engineer and all the non engineering representatives should move lock, stock, and desk into the pilot area. This includes the CM representative if he or she is dedicated half time or better to the project. They should continue to meet regularly.

Reason: The team spirit that has developed must be held together until the design is built and tested by production workers. Problems will arise and the communications are much faster and more accurate when these people are together.

If the team has functioned well to this point, the volume of problems/changes resulting is relatively low. However, problems will still occur. The

design change process is administered by CM during the pilot phase. It should be informal (under numeric revision control). This might mean that only the Design Engineer and CM are required to sign the change. At the very most, one Manufacturing representative may be added to the sign off. Notice the assumption that pilot units are built by production personnel. This is essential to prove that the design is manufacturable and to train key production personnel.

When released to production, the Manufacturing Engineer and the production personnel should rotate into production. The team, although diminished in numbers, should move to their normal area but still meet frequently—probably for shorter meetings. This is critical to good communications and training of the new people involved.

In this author's view, one of the most significant mistakes company's make in the release process is to try to get along without a recognized pilot phase. Engineering will often build more units that are required for design purposes and do reliability testing on them. Unless the products are very simplistic it is much better to recognize the phase, have engineering build fewer "prototypes," have manufacturing build the pilot units and test them.

Catch 22

As time progresses, prerelease or production release occurs and the change control process must begin. If the release or change processes are slow and cumbersome, the engineers will be reluctant to release the documents. They will tend to hold them and release them in "bunches" only when absolutely required (forced). If this is done, there will be times when little is occurring and times when batches of documents are released together.

This batch method slows the process. In turn, the engineers view the slow release and change progress as reason to hold documents under their control as long as possible. If the change process is cumbersome, it amplifies the batch affect. Usually the company finds a way around the slow release process by, for example, using a deviation to release long lead items. Again we have two methods for releasing when one would do—if the single method is easy and fast. It is therefore critical that CM design and implement fast release and change processes. Much more will be said about the fast change process later.

The Release Process

As previously discussed, the release process must be evolutionary. It must be in parallel with the design and a team process. The document release process must handle a single drawing, assembly documentation, a group of parts, documents or a combination of these.

The checklist will vary but the process can be the same for any phase. One systematic way of quickly releasing documents is needed. First, examine the tasks that need to be performed during this release system.

Release Process Tasks

For the Loader Company, the release process will use the change form with only the minimum release blocks completed. On this form (or on the documents to be released), will be indicators about the following activities:

Start Project – The allocation of funds for a design and development project, completion of design and development constitutes start of pilot, etc.

Review Design Concept – Early on in the project the team should review the design concept. This might first occur when the product specification is "pre-released." It will occur again on release to pilot or production.

Release Product Spec – As previously mentioned the product spec is to precede all other documentation by one phase.

New Document(s) Complete – Preparation of one or more drawings, specifications, etc. according to the company drafting standards and on the CM approved format(s). Done by Design Drafting under the engineer's responsibility.

Modeling and Testing Complete – Engineer indicates that the testing required by the applicable baseline has been satisfactorily completed. The testing might be for a component, assembly or the entire product - whatever level is being released.

Blanket Release Form – CM cuts a blanket ECO for each baseline phase release. Document by document release will be "posted" to that ECO. The "required information" is minimally the part numbers being released and the date of release (may be some

time after document signatures are dated). The "form" might be an on line record in PDM or MRP / ERP.

Review Model, Tests & Documents – The team review the applicable items for the part, assembly or product being released.

Documents Signed – The signature of the Design Engineer who created the document in the title block. By policy, that engineer is required to sign after the team has reviewed the document. This gives an opportunity to incorporate ideas from the rest of the team without the "attitude of ownership" that comes with signature. An acceptor, usually the Manufacturing Engineer must also sign the document.

Check, & Technical Release – CM immediately reviews the package against the checklist. This is a "go"—"no go" point. If all items are acceptable, CM will proceed. If any item(s) are not acceptable, the specific requirements are noted and the item release is rejected.

Rule: Once passing this check, the release will not be stopped, revised, put on hold, etc. The release has passed a point of no return.

Reason: Discourages frivolous release actions.

If all items are checked and correct, the CM Technician immediately assigns the applicable revision number or letter and posts the part number(s) and date of release. This is an indication that the release is technically acceptable and has passed the necessary check.

The documents being released will not be reproduced and distributed. Rather the release notice should be the user's notice to pull the required documents as needed, when needed. This is using a "pull" system as opposed to a "push" system. This saves time, cost and trees.

Support & Process Documents – The applicable support documents (catalog, maintenance manual) and process documents (fabrication instruction, routing, assembly instruction, tool drawing, etc.) are created as a result of the release—a next step. They were not previously part of the release package. When the support documents are complete, a notification of that event is announced by the Publications/Service Doc Control function to all who need to know. When the process documents are complete the

Manufacturing Doc Control function will notify all who need to know. Again, email is an ideal tool for such notification.

Input To MRP / ERP – All design item data and assembly data must be input to the database. CM will compare output report to the input parts list in order to assure the accuracy of the data. CM will do this for all design elements. They do not hold entry while waiting for manufacturing data entry or support data entry. Those activities occur as a result of the release—a next step.

Back Up File & / or Microfilm Complete – CM assures that all items to be microfilmed, imaged, digitized or are otherwise preserved.

Close the Loop – The various functions noted above have notified CM of the completion of their tasks. As each notification is received, CM notes the date. When all are received, CM closes the release.

The above list constitutes the elements of the Loader Company release process. Most engineering functions believe that when the drawings are available for users, they are done with the release. This is a myopic view. The job is not done until other tasks are completed, at least the input to MRP/ERP.

This list of tasks implies some procedural steps, but are not complete from a process standpoint. The temptation is strong to merely put this list into a written procedure (standard) and sit back and relax. After all, they are the tasks that need to be performed to release aren't they?

Release Procedure / Flow Diagram

If we numbered these activities, one through thirteen, we could then boast that we have a procedure. Indeed we would. It would be a string of thirteen tasks in series and would probably be performed in that same sequence. Performed in number order, it would be the longest possible path for release—a series process.

This would not constitute an efficient system, however. To create an efficient system one question needs to be asked. "What is the arrangement of these tasks to produce the shortest possible path from start to finish?" Or stated another way, "What tasks can be done in parallel?"

To create a fast system, the relationship between each task must be carefully examined. What task(s) is required to be completed before this task can be completed? What other task is dependent upon completion of this task? For example, the team must review the new documents before they

are signed. Add "responsibility" to each task and put circles around each activity/responsibility. Next, take every task involved and carefully examine each relationship. This systematic approach will put tasks together into a process. It is a picture worth a thousand words. See Fig. 7.5.

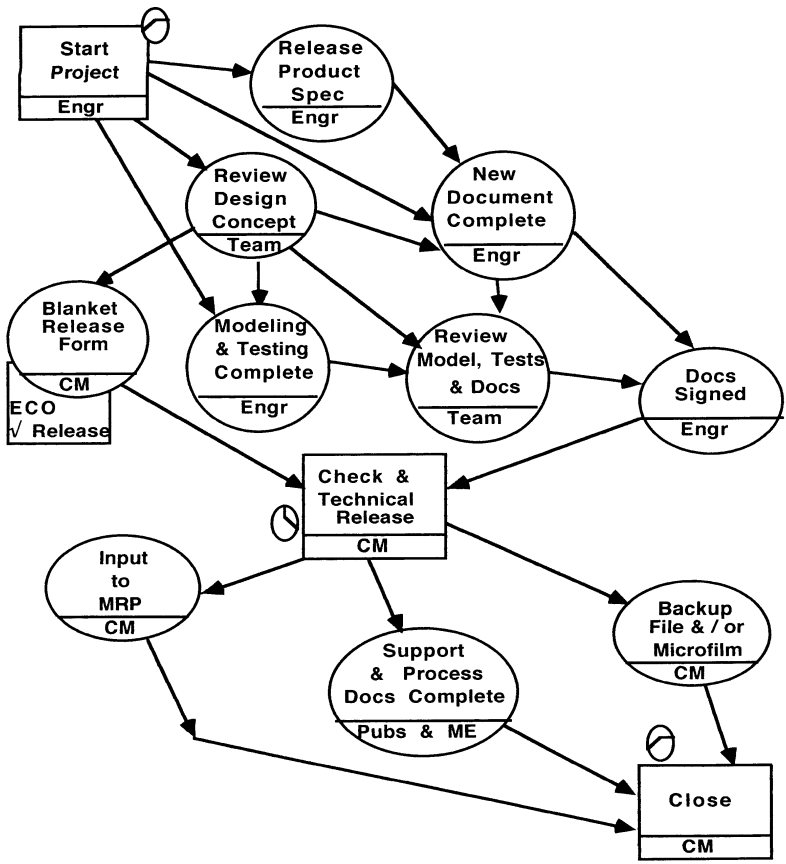


Figure 7.5. Release process flow.

Notice that responsibility is always singular. The Cognizant Engineer can't do the team review, but he or she is responsible to assure that it occurs. CM might be chartered to call the team meetings, to keep action items, etc., but this doesn't take away the responsibility of the Cognizant Engineer.

The point of origination of the release form is noted. To clarify, a few notes may be added. Too many notes, however, is an indication that standards are needed. The titles of the task are traceable to the task list. We could have numbered the tasks and shown the numbers on the flow diagram.

Rule: Do not write procedures to describe a system. Make a work flow diagram and put the flow diagram and task list into a standard.

Reason: Although it can be done, the description of relationships is difficult and confusing when in Description form. Parallel relationships are particularly hard to describe. The work flow "picture" is also a better training tool.

This is now a releaseprocess. All of the required tasks are in their proper relationship and documented into a standard(s).

The tiny "clocks" on the rectangular activities are those events that we will measure process time between.

Measure the Process Time

Measurement, in and of itself, tends to improve performance. Don't try to measure every point in the process. This is a common mistake. It yields so much data that it is difficult to pick out what is important.

Rule: Measure the Release Process time in meaningful pieces, and report the results to the top management.

Reason: The project goal was to beat the competition to the market. Tracking release time will allow future projects to learn even better ways to handle the release. This will yield a constant improvement program.

The key points in this process are flagged with a small "clock." There are three clocks dividing the process into two parts. Each measured point in the process needs to be described in the task list or in the standard.

Visibility

Measurement of the release process time will be most effective if the results are made very visible. Report cards do tend to improve kids performance. Sending the report card home to Mom is putting visibility on the results.

All the dates can be kept in a log. A more visible method is to log all the dates on each release form. Put the log into a PC spread sheet. Each week or month a chart or graph can be prepared to show project management and top management how long the major portions take.

For example:

March Releases – Qty 6

Average Work Days

	Project Start to Tech Release	Tech Release to Close
FEL-100	38	4
FEL-200	29	3

Comparisons can be made against historical averages for that type of product. Benchmark the performance with other companies in your kind of business. Post the results and goals in prominent locations. Send them to the top management. Review them with your people. Make CM the source of reliable release reporting.

This writer is not alone in believing that the process time is very important. R. D. Garwood stated in a white paper—"The single Most Important Factor in Determining a Products Profitability is Time To Market!" The fast release process is such an important company strategy that:

Golden Rule: The Time To Release Is Critical To Profitability.

8

Change Requests

If the teamwork is properly done during release, the number of design changes required should decrease. It is, however, unrealistic to believe that the need to change can be eliminated. Humans do not do everything right the first time. And, we engineers are human. Besides, what is thought to be "right" when the design was released, can change as well. Compression of the new product design and release "window" also results in changes. Customer's needs change. If a mind-set of constant improvement is taught and followed, changes will result.

This is not to encourage changes solely to exceed the Product Specification without a plan. This is also not to encourage cost reductions that aren't. It is to encourage changes which are real cost reductions, to meet the specification (including safety standards and failure rate specifications) and to improve those products where the market demands.

Some needs are identified by customers as they use the product. Some needs are recognized by the Field Engineer while maintaining the product. Some are identified by production people as they assemble or fabricate the product. Some while testing the product.

The question is not whether or not changes will become necessary, but rather, how quickly do we recognize the need to change, and respond to that need and how do we sort out the counterproductive requests.

Field Failures

Listen to your customers. React to their questions, complaints, reports, feelings, and suggestions. Every communication from a customer should be logged and followed to conclusion. Every communication should be divided into its parts and every part followed to a conclusion (closed loop). Every portion of a customer communication that pertains to the product, should be sent to the responsible engineer for evaluation. Every customer letter should be copied for each responsible engineer who might be affected. The management must train people to do this, demand that it be done, and do it themselves.

Rule: Have a simplistic form/email that captures the date, customer name, person's name, and comment about any design or function related issue. Positive comment, negative comment or questions must be fed back to the cognizant engineer. Require its use.

Reason: Doing so will allow a competitive edge. It is too easy for a sales person, field person, or manager to "write off" a problem because it is the first time they have heard about it.

By these methods, the information indicating potential problems are in the hands of the person responsible to fix them—the Cognizant Engineer. Let the engineer respond to the customer and copy the sales person or who ever received the communication. In this manner, and only in this manner, will the engineers be able to make the quantitative and qualitative judgments which should be his or hers to make.

Larger companies may have a Field Service organization that takes all customer problems. This works very effectively when they are well trained. They respond to problems which they are confident about, and refer others to the Project Engineer or Cognizant Engineer.

Keep track of the lapsed time from receipt to response. This should probably be done by CM as a part of tracking all requests. Report the turn around time to top management.

Keep track of the data in a systematic way and also send the data / reports to the Project Engineer and Design Management. Do not let the report be the first time the engineer hears about a problem, however. No matter how meaningful and timely the failure reports are, they do not have the impact that one at a time communications do.

Reliability and Other Test Data

This data is normally fed back to the responsible Engineers in a report form. This is satisfactory providing the report is timely. On line data is ideal. Again, a response to each item of significance should be expected on a timely basis. All such problems should be on a problem list and tracked by CM.

Material Review Boards (MRB)

What do we do with parts or assemblies that do not meet their specification? Usually the nonconforming material is segregated and reviewed by a mini team of the Cognizant Design Engineer, Quality Engineer and Manufacturing Engineer. They disposition that material to use as is, rework, return to supplier, or scrap. This activity often highlights the need for a design change. The nonconforming material report can be used as a change request. See also the section on Non-Conforming Material and Change Control for further discussion.

Production Problems

When the machinist or assembly operator believe that they have a design problem or wish to request a change, there needs to be a simple method of communicating to the Cognizant Engineer. This could be a simple form to fill out. This form may be called a Request for Change, Engineering Action Request, etc. An email containing the required information is effective. Have the requests sent to CM. The change form should generally not be used for reasons that will be discussed.

Rule: All the production people should be given a brief training session by CM or their own management as to the method for identifying problems / requesting changes.

Reason: This helps to assure action on production problems.

Have CM train the production management and they, in turn, train their people. Coordinate the training with the Manufacturing Engineering Department so that distinctions can be made between design and process documentation/changes. The information required on the request for change

should be limited. Keep it simple. Prepare a form and form instruction that indicates those blocks that must be completed by the requester.

Can Anyone Originate a Change?

Political correctness has crept into the CM processes. It has become very popular to make the statement in the standards that "anyone can originate a change." Many company's procedures say; "anyone can originate an ECO." Yet when the standards are examined there is no explanation as to how that is done. This statement is often pure fantasy. Many people cannot originate an ECO because they have no idea how to do that. They haven't received any training and don't have a form instruction. Which blocks are required to do that? How do they describe the change properly? What if they have no solution, only a problem? Far better to design a very simplistic form and process which separates the Request from the Change.

Request for Change

Getting feedback to the designer from anyone inside the company can be done with a very simple form (and the associated training). The information required by the Cognizant Engineer is:

- Originators name and phone number
- Origination date
- Description of the problem / justification for changing/ reason for change
- Some idea of the urgency of the problem
- Description of fix/solution (if known)
- Document/Part Number(s)/Product Numbers having the "challenge"
- Control number
- Then the engineer needs to indicate the disposition of the request
- Cognizant Engineer's decision - accept/reject
- Reason for acceptance/rejection

The form is therefore very simple. (See Fig. 8.1.)

Engineering Change Request	**EC3 Corp**	ECR # 1
Description of Problem / Reason for Request	**Urgency** _____	2
3		
Problem is with: ¤ Product ¤ Process ¤ Pubs ¤ Other		4
Part Numbers / Document Numbers / Product Numbers (As Known)		
5		
Proposed Solution (If you know one) (Attach Mark Ups if Possible)		
6		

Requesters Name 7	Phone # 8	Page of Pgs 1 9	Date 10

Cognizant Engineer 11	EDC Techs Name 12	Date to Engr 13

Problem ¤ Accepted ¤ Rejected ¤ Next Product by Cog Engr 14
Reason For Acceptance / Rejection
15
Acceptance condition(s) 16

Title of ECR 17	Cog Engr Sign 18	Date 19

Form Date: If you have talked to the responsible engineer and can fully delineate the change, do not fill out the ECR, go directly to the ECO.

Figure 8.1. Request form.

If you have a Request Form and process must it always be used—No! See the note on the bottom of the ECR form. Certainly if the chief engineer asks for a particular change there is no reason to cut an ECR. Some companies force a change request to proceed every change order. This seems like "make work" to this writer. Merely make sure that every problem is put on the request list.

Request Form Instruction

Every use of a form should have a form instruction. The instruction should state "what" is required in each block and "who" should normally fill it out. The form instruction for the Front End Loader Company is shown below. The Find Number (FN) refers to the form box "numbers" in Fig. 8.1.

Requester (Neatly hand letter)

1. Leave blank. (Doc Control will send a copy to you that will be completed through box # 12 including the ECR number.)
2. Describe the urgency of the problem—"line down," etc.
3. Describe your problem, suggestion or challenge.
4. Check if the problem is with the product, the manufacturing process, the publications or other (describe).
5. Enter those part numbers, etc., that you believe to be associated with the problem if you know them—optional.
6. Describe the solution to the problem if known—optional.
7. Your name.
8. Your phone number.
9. Enter the total pages in the set. If you have attached prints or specs, enter the total number of pages in the set and number all pages accordingly. If no attachments enter "1."
10. Enter the current date: Month - day - year. Forward the form to Document Control.

Doc Control (Neatly hand Letter)

11. Sort out process changes and pubs changes and send to those departments. Consult the Cognizant Engineer list for the responsible design engineer, manufacturing engineer or publications person. Enter that name here. Note that only

requests for change in the design will be followed-up by Doc Control. Enter design change requests to the Request List.

12. Your name here and copy the form twice.
13. The date you forwarded one copy to the Cognizant Engineer and the other copy to the Requester. File the master for follow-up and reporting.

Cog Engineer (Neatly hand Letter)

14. Analyze the problem/challenge. Call or see the requester as necessary. Present the problem to the team as/if required and respond to the requester accordingly—accept, reject or next product (will be addressed in the next product development).
15. Give reasons for acceptance or rejection.
16. State any conditions on acceptance. Example: "Accepted subject to finding a solution to the problem that isn't worse than the problem."
17. Give a "name" to accepted problems—use as few words as are practical. (This is the name Doc Control will use when reporting on the ECR status.)
18. Sign the ECR.
19. Enter the date signed. Return a copy of the ECR to Doc Control.

Doc Control

20. Log the date, make a copy and send it to the Requester whether accepted or rejected. Log status in the Request List.

The ideal situation would be to have the form, form instruction, work flow, and required reports on line. The team would review the requests and the engineer could "disposition" them on line.

Avoid Temptation

Avoid the temptation to add more information than is shown. The more information added, the higher the likelihood that you are trying to "preprocess" an actual change. This is a mistake that many companies make. They

include or use the ECO form in order to include; disposition of materials, effectivity, impacts, stock status, approvals, etc., etc. There seems to be an irresistible urge to start processing the request as a change sometimes even before the cognizant engineer has even heard about the problem.

One large computer company had a 120 day total process time. Upon examination it was obvious that the same information was on the request form as was on the change form. In fact, the request was going through a process that was very similar to the change. The information and decisions made during the request process were near identical. The difference was that the request cycle was on the basis of "what if we made this change," while the change process was on the basis of "we will make this change." The result was that all the information and decisions made during request had to be revisited during the change process. Many times the information changed because of the lapsed time between the request and the change. The Cognizant Engineer was also left out of the request part of the process. It was his/her decision to accept the request, reject it or address the problem when designing a different fix or satisfying the request in a spin off product. Examination showed that the first pass (during request) was essentially wasted. They took forty-two days out of the process by "boiling down" the information required at request and getting unneeded people out of the process.

Rule: Do not try to "preprocess" a request as a "what if we change."

Reason: It will be a waste of time and energy even if the redesign remains as requested, the time lapse will require review of all prior work. The Cognizant Engineer is also likely to design a different fix.

Rule: The request for change should contain just enough information to allow the Cognizant Engineer to make a decision as to whether or not there is a problem that needs fixing, i.e., to take ownership of the problem.

Reason: The Cognizant Engineer needs to recognize the problem and take ownership before doing any thing else. The question of ownership must be clear or piles of unowned requests will exist.

Realize that we are dealing with the design of the product. Therefore, there is no reason for the Production Supervisor, Manufacturing Engineer, Production Engineer, Industrial Engineer, or any one else (except CM) to get between the requester and the Cognizant Engineer. These people can submit a request of their own if they wish. If they are in the process they will delay, edit, modify or change the original request.

Request Process Design

Above all, these "other parties" should not delay the request. The easiest way to avoid this is not to allow them in the request process. All of these people should be on, or represented on, the design team. The single exception is to have the CM organization in the process to log each request to assure timely response. CM might also be used to sort out process or manual changes and forward those to manufacturing or service functions.

One way of designing this process is with a multiple copy form (snap set). The requester can keep a copy while another copy is returned with the Engineer's decision as to change or not to change (request rejected). An email to CM can also be used to place the problem on a list for the team to address.

All problems might well be brought to the team for discussion before engineering accepts, rejects, etc. The team members will often help in terms of solutions, rejection of the problem, cost of the problem, etc. The team discussion of the problem/suggestion is an invaluable tool in avoiding later problems resulting from lack of involvement. This is also an ideal stage for the management to get involved in the process. Management can often make some hard decisions about rejection for lack of resources, cost pay back, opportunity cost, etc.

The Request Flow

Assuming that the CM Department is in the flow, the flow diagram for change requests would appear as shown in Fig. 8.2.

The CM Department is also in the flow to add the "Used On." This is done so that the team and Cognizant Engineer knows all the applications affected. They must also assure a timely response—either positive or negative—to the requester. Does the responsible engineer accept the problem as a legitimate one, or not? Conditions on taking ownership of the

problem may be in order. A category of acceptance might be included that says the problem/suggestion will be incorporated into the next "spin off product" design or the next time a particular assembly is redesigned.

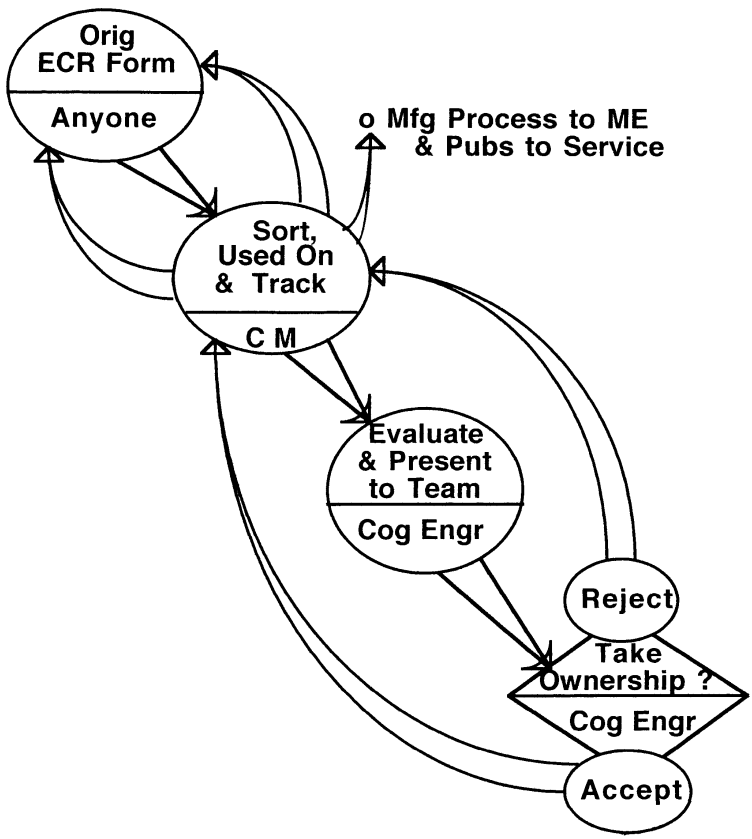


Figure 8.2. Request process flow.

Just because engineering takes ownership of a problem doesn't mean that it won't be rejected later. Sometimes the design engineer may not be able to develop a solution to the problem. Sometimes the solution may be more expensive than living with the problem.

Often times the engineering folks are so burdened with requests that they just don't have enough time to fix all the known problems—even in the next year. In some companies the problem is so severe that engineers don't want to walk out into production areas because they will be accosted about the requests. The management must set some rules to avoid manufacturing people thinking that engineering people have ownership when they really don't. Letting requests pile up in engineering is not building a bridge, it is digging the gap wider or putting more bricks on the wall. A few companies set a six or ten month limit. If the engineers cannot work on the problem in that timeframe, they must reject it.

Request Process Measurement

Configuration Management should also measure the volume accepted, rejected, etc., and the throughput time. CM should report on the results. Again the average throughput time should be reported to the top management in engineering, manufacturing, and service. The management should set a goal for the average throughput time expected. The Loader Company will allow six work days average to process the paper through CM and for the team and the design engineer to accept or reject the problem. This might allow two days to process the paper (one on either "end") and four work days for the engineer and the team to analyze the problem and accept or reject.

Remember, this process is not closed until the "disposition" is returned to the requester. This point in the process is also the start of the change process as will be covered later.

Just because you have a request process in place doesn't mean that it must be used for every problem. Some requesters understand the change process and are capable of completing a change form. Those people should be encouraged to talk with the engineer and if agreement on the solution is obtained, they should go directly to the ECO process. Notice that a note to that affect is on the bottom of the Loader Company's ECR form.

Request List

Probably the most important element of a request process is the creation of a request list. Whether the process is on line, hard copy, email based, or whatever, a list of problems must be "made and worked." The list should be similar to the team action list mentioned in ch. 6 for new development.

Headings for Action Items List

- ECR Number
  - Origination date
    - Request title (brief description of the problem or concern)
      - Action Required (brief)
        - Person assigned to take that action
          - Accept / Reject / Next Product / Etc.
            - Date of accept / reject / etc.

This list can be used for the change request process as well as the change control process. It must be very clear however as to whether or not engineering has "taken ownership" of the problem. The requester must be notified by some method that the request is now the responsibility of engineering. The team should be involved in the request/list preferably before engineering accepts or rejects a request. The team can often offer very constructive advice that will sort out unproductive requests.

All forms of requests (other than the ECR) should probably also be placed on this problems/challenges list. This gives design engineering a complete "things to do list" on existing product.

Summary

If this chapter seems short to you, it is purposely so. The request process begs for simplicity. It begs for separation from the change process. When the change form is used there is usually confusion as to where the engineering organization takes ownership of the problem. A list must be made and followed to conclusion. Care must be taken to avoid the "compulsive urge" to treat every request as though it were a change.

9

Change Cost

Bad habits can develop in start up environments. Typically the cost of a change is not an issue because all changes are being made to meet the product specification. It isn't for a year or more that cost reductions and improvements begin. The start up company has, however, formed a bad habit—not to calculate the cost of any changes.

How much do changes cost? A college professor once decided to find out how much changes cost and gave up because few companies calculate the cost, and those that do include different cost elements.

When the writer asks that question in seminars or while consulting the answer is typically a dollar figure between $500 and $2,500. Are these numbers meaningful? Is that the criteria that should be used to evaluate a change? Using this logic, if our company has a $1,500 per change cost, should we merely ask if the change seems worth $1,500 or more?

Those numbers were developed by adding up the budget for the Configuration Management and some other functions and divide that number by the number of changes in the same period. The result is not the cost of a change—it is the **administrative cost per change**. It is not an average cost of a change! This is not a bad number to have, however, if you benchmark other similar companies and compare functions and this administrative cost per change. This might be a good number to use to roughly estimate the cost of a "document only" change. The cost of a product change is usually more significant than just administrative costs.

Costing a Change

Pressure to change comes from many directions. Many needs are legitimate, some aren't. Sorting out which needs are legitimate and which aren't is a significant challenge. Proper costing of changes is a missing element and a missing science. Costs are usually tracked judiciously during new product development. After the product is in production the cost of changes is universally ignored. Cost estimates are, when done, usually of a very gross nature.

Most companies do not cost the change before it is released. Fewer than ten percent cost any portion of their changes in a detailed fashion based on informal polls in the author's seminars.

Design and Development Cost

The time to analyze, design, model, test, and communicate the design change is usually a significant cost. This is a cost that the engineer normally mentally evaluates before launching any significant change. It is especially crucial to estimate this cost when a change is intended to reduce manufacturing or field service costs. The design and development costs must be weighed against the product, manufacturing and field related cost savings.

Manufacturing and Field Costs

Generally, the most significant (and most ignored) of all change costs is the manufacturing and field support related costs. These costs are not necessarily apparent to the engineer making the change. Every impacted function will have associated costs. The supplier, purchasing, quality assurance, manufacturing engineering, production, materials, etc., etc., all will have start up costs. The field change labor, kit cost, repair, retrofit related costs must all be considered. Tools, fixtures, software, process / routing, test equipment, etc., may be impacted.

Materials and Parts Costs

Most engineers are attentive to the affect of the change on the product unit cost. They may not have a good idea of what the parts and materials will

cost under expected actual production conditions and quantities however. Although some companies make the design engineers responsible for knowing the related manufacturing, materials, parts, and field related costs, this author believes that this is an unrealistic expectation in all but the smallest companies. This will probably "take a back seat" to design work and or not get done in a quantitative manner.

Who Should Estimate Change Cost

The affect of the change on the supplier, fixtures, test equipment, etc., are costs that one shouldn't expect the Cognizant Engineer to analyze and estimate. You can also call in the Accounting Department and expect them to estimate the change cost. Better to place the responsibility where most of the cost is—in Manufacturing.

Rule: Estimation of change cost should be done by manufacturing—probably Industrial Engineering.

Reason: Most of the cost elements are likely to be manufacturing costs. Manufacturing also has more reason to do the task quickly since they have the most scrap, rework, etc., at risk.

Everyone impacted can each contribute their own costs. But someone needs to apply the proper labor rates, overhead rates, assure all impacted are included and to summarize the cost. A benefit of cross-functional teams is that the cost estimating can take place easily in well-constituted and well-led teams. The Industrial Engineer (IE) can pull together the design, manufacturing and field related costs even before extensive development time is invested. Such "value engineering" analysis is an invaluable cost avoidance measure. It might be grossly estimated before the request for change is accepted or rejected and refined right after the probable fix is designed. The IE would estimate (or ask PC to estimate) the effectivity of the change, the disposition of the old design parts, etc., in order to prepare a cost estimate. The cost might be "fairly obvious" or "not an issue." The decision might be made by the team/team leader.

Costing changes is a complex task. This probably explains why the vast majority of companies do not make a quantitative estimate.

Cost Policy

Many issues arise when discussing change costs. Shall we cost all or only some changes? What costs shall be included? Will costs that are normally part of overhead be included? Who will calculate the costs? Who will furnish labor and overhead rates? Who will approve the expenditure? Product unit costs should be annualized using what build schedule? The fact that there are so many perplexing questions probably deters estimation of costs. However, it is imperative that all the associated questions be answered.

Rule: A standard or policy is required to determine the company attitude toward change costs.

Reason: Avoid creeping elegance. Failing to estimate costs is probably the single most significant CM related reason for erosion of profit margins.

Any change being done to "reduce time," "ease of," or "reduce cost" should probably be cost calculated. Changes that "improve (over and above specifications)" should probably be included. Certainly, if the engineer has two methods of fixing a problem they should have the ability to obtain a cost comparison.

Cost Pay Back

If a change saves $5 per unit should it be done? How about $100 per unit? The obvious questions to ask are how many units are produced in a year. What if we can save $100 per unit and we produce 500 per year. This will seemingly save $50,000—but what are the one time or "start up" costs? If they total $25,000 (pay back in 6 months) we would probably make that change. If the one time costs totaled $150,000 (pay back in 3 years) we would probably reject that so called "product cost reduction."

Rule: A pay back time period should be established by the top management.

Reason: Assures best utilization of limited resources.

One computer equipment company had eleven "Sustaining Engineers." They were working on mature products. That company's policy was to move the design responsibility from the new design to the sustaining design group after the product had been production released for one year. They had many

mature products. They had many changes to "improve manufacturability," "save test time," "save assembly time," "ease of assembly," "ease of maintenance," etc. Upon careful examination of the change by change cost, they found that almost 40% of their **so-called cost reductions weren't!** They put one of those engineers to work calculating costs and three others were freed to return to new product design—a task they were much happier doing and much needed for.

Which Changes to Cost

Certainly "document only" changes would not require a cost estimate. As discussed earlier, their cost can be roughly estimated by adding appropriate budgets, and/or parts of budgets, and dividing by the number of changes in the same period. Costs can be "contained" by queuing document only changes and by simplifying the process/approval.

Your policy in this area should be tailored to your enterprise. There is one category of change that should always be cost estimated by any company with products in production for a year or two.

Rule: Cost any change that is said to be a "cost reduction."

Reason: Avoid degradation of profit margins.

A few companies follow this rule and require all cost reductions to be estimated. A standard policy is then set for the "payback period." Thus if the savings pays back the cost in say one year or less (or whatever the cost policy states) the change would be released. You might well consider any change required "to meet specifications or safety standards" as changes that "must be done" and therefore, do not need to be cost estimated.

Change Cost From

Figure 9.1 shows a precise form for calculating the cost of a change. If this form seems as complex as an IRS form to you and a little scary—that's because it is! The form has been developed for an ABC (Activity Based Costing) method. It precisely quantifies the first years cost savings (or increase) and compares that to the start up costs. The pay back of start up cost is figured for a cost reduction. Provision has been made for comparing company pay back policy to the change pay back.

Request / Change Cost Estimate **EC3 Corp** © Pg 1 of 2

General:

☐ Request ECR# _____ ☐ Change Order ECO# _____ ☐ Other #____

Change type / class _____

Key Estimator Name _____ Date __-__-____

Title of Request / Change _____

Initial / Rev Date __-__-____ Reason for Revision _____

Unit Part Cost

Old Part:

Part Number	Std $	Qty Per Unit	$ Per Unit	Scrap Qty	Scrap $	Rework $ Per Part	Qty to Rework	$ of Rework
_____	____	____	____	____	_____	____	____	_____
_____	____	____	____	____	_____	____	____	_____
_____	____	____	____	____	_____	____	____	_____

V **Old Part $ / Unit** _____

Total Scrap $_____ Total Rework $ _____

New Part:

Part Number	Std $	Qty Per Unit	$ Per Unit	Qty in Field Kit	Field Kit $	Supplier Tool $	Company Tool $
_____	____	____	____	____	_____	_____	_____
_____	____	____	____	____	_____	_____	_____
_____	____	____	____	____	_____	_____	_____

V **New Part $ / Unit** _____

Total Field Kit $ _____

Total Supplier Tool $_____

Total Company Tool $ _____

Difference between Old and New Part Cost x Mat'l Overhead ___% = **Material $ Diff / Unit** _____

(parenthesis if old is less than new)

Unit Labor

Direct Assembly Labor Difference:

_____ Hrs x Labor Rate ____.__ $/Hr x Overhead ___% = Assembly $ Diff / Unit _____

(if old is less than new)

Direct Test Labor Difference:

_____ Hrs x Labor Rate ____.__ $/Hr x Overhead ___% = Test $ Diff / Unit _____

(if old is less than new)

Other _____ **Labor:**

_____ Hrs x Labor Rate ____.__ $/Hr x Overhead ___% = Other $ Diff / Unit _____

V

(if old is less than new)

Figure 9.1. Change cost form.

Request / Change Cost Estimate **EC3 Corp** © Pg 2 of 2

Annualizing Unit Costs

Product Per Unit Savings / (Cost Increase): from above = $ _____

Annual Schedule Quantity = _____

Annual Product Unit Savings / (Cost Increase): = $ _____

Implementation ("one time" or "start up") Costs

Materials:

Scrap $ _____ + Rework $ _____ + Other $ _____ = $ _____

Suppliers Charges:

Rework $ Scrap $ $ Tool Cancel/ Prem $ Returns Cr $

_____ + _____ + _____ + _____ - _____ = $ _____

Manufacturing:

Tool $ Test Equip $ Facility $ Other $

_____ + _____ + _____ + _____ = $ _____

Engineering:

Engr _____ Hrs x $ / Hr _____ = $ _____

CAD Design / Drafting:

Des Dftg _____ Hrs x $ / Hr _____ = $ _____

V

Total Design & Development = $ _____

Field / Repair:

Kit $ Labor _____ Hrs x $/Hr _____ Rewk $ Scrap $ Returns Credit

_____ + _____ + _____ + _____ - _____ = $ _____

Configuration Management:

CM _____ Hrs x $ / Hr _____ = $ _____

Quality Assurance:

QA _____ Hrs x $ / Hr _____ = $ _____

V

Total Implementation Costs = $ _____

Pay Back / Opportunity Cost Analysis **(Company pay Back Policy = _._ Years)**

This Request / Change Pay Back in Years (cost increase in parenthesis) = $ _._

Opportunity Cost (what other project might limited resources be better invested in): _____

Conclusion:

Cost analysis indicates: ☐ **do change** ☐ **don't do change** ☐ **Other**

Estimators Comment: _____

_____

Figure 9.1. *(Cont'd.)*

Here is how it works:

General:

- Self-explanatory information about the request or change.

Unit Part Cost:

- The old (deleted) item cost is calculated. The old parts are listed, The standard cost and the quantity per unit are multiplied together and totaled. The scrap and rework are calculated and totaled for later use.
- The new item cost is similarly calculated. The field kit, supplier tool and company tool costs are calculated and totaled for later use.
- The total material difference between the old and new item cost—savings or cost increase—is calculated with the appropriate material burden/overhead rate.

Unit Labor:

- The direct assembly labor difference (between old and new designs) is calculated as is the direct test labor and any other labor difference.

Annualizing Unit Costs:

- The product unit cost or savings is the totaled and multiplied times the next years schedule quantity to attain the annual product unit cost or savings.

Implementation (one time or start up) Costs:

- Enter the material scrap, rework and other costs from above.
- Find the supplier related "one time" cost of rework, scrap and tooling. Add the supplier premiums and or cancellation charges and subtract the returned parts (credit).
- Add the company tool dollars from above to the test equipment costs, facility costs and other manufacturing one time costs.
- Calculate the engineering, CAD Design and other applicable costs by estimating the hours required and entering the proper labor rates from Accounting. Total the Design and Development costs.
- Calculate and add field related "one time" costs.

- Similarly figure the CM, Quality Assurance and other labor required and total the Implementation Costs.

Pay Back / Opportunity Cost Analysis:

- Compare the Annual Product Unit Savings to the Total Implementation Cost to calculate the request or change Pay Back.
- State what other projects the request or change is competing with for the limited company funds.

Conclusion:

- The estimator should make a recommendation for doing or not doing the request/change for the team to consider. The company pay back policy will preclude many improvements and "so called" cost reductions from being done.

Keep in mind that your Accounting Department may not necessarily include the elements into "direct" or "burden" categories as this form does. The Industrial Engineer assigned to do the costing of changes needs to examine and revise this form with a cost accountant. This cost estimating / calculating process is an ideal on line application (see the reference and reading list or the authors web site).

Dollar Approvals

The other part of your cost policy is to determine who is authorized to approve the cost. Many Accounting Departments already have a "delegation of authority." This may be all that is needed. Often that existing policy can be used for design changes. In this writer's opinion, however, it is better to set the payback policy and empower the team to review the cost and approve changes that meet the policy and to reject those that don't.

Charge Back of Costs

The onetime costs resulting from a design change can be charged back to the "benefiting" or "causing" department. A few companies choose to do this under the assumption that the changes may be more carefully considered if this is done. This might mean that if the customer asks for the change or dictates the effectivity of the change then charge the cost back to Sales who would presumably charge the customer. If Design Engineering

initiates the change then charge the cost back to Design Engineering. If Manufacturing requests the change, then charge the cost back to Manufacturing. Limited experience with charge back indicates no conclusive evidence as to its resulting in lower cost per change or reduced volume of changes. Limited experience with charge back would indicate the following:

- If cost charge back is done, it should be per the numbers on the design change cost estimate. This will probably assure better estimates.
- Charge back of onetime costs is fairly easily accomplished.
- Charge back of product unit cost differentials is very impractical to do.
- Charge back of costs is a labor intensive task.
- Charge back of costs often results in considerable finger pointing.

Dollars Without Delay

It is often asked; "but won't estimating the cost hold up the process?" Of course it can, but it need not.

Rule: The change process must not be delayed by estimating and approving the change costs unless the team wants to hold the change until costs are available.

Reason: It would be counter productive to hold up the process and thus create more "bad" parts.

This can be achieved by following five steps:

1. The company policy (the changes to be cost estimated, the form to be used, the cost elements to be included, etc.) must be clear and approved at a high enough level to assure compatibility with company goals.
2. The person responsible for the change estimating / summing must be identified.
3. Limit the changes for which costs will be estimated.

4. The estimating process must start with the team discussion of the change. If each function is to furnish their own costs, they would do that at a team meeting.
5. The cost must be pre-approved (the team empowered based on the pay back rules) or approval obtained by CM before release to manufacturing.

More about how the costing ties into the total change flow process later. Costing of changes must be included in best in class or world class CM strategy. Without a policy, procedure, form, and form instruction in this critical area, a company is open to "creeping elegance." The need to change must be factored by the cost of change in order to avoid profit erosion.

Golden Rule:

Need To Change + Cost of the Change = Continued Product Profitability

10

Change Control

Change control is often thought to be the beginning, middle and the end of Engineering Documentation Control/Configuration Management. Of course it is not the whole subject, but it is the single most important process in the entire system.

The mere thought of "control" strikes fear in the hearts of we engineers. Managers, service and manufacturing people are constantly complaining that there are too many changes—except for the ones they request. Executives have sometimes pounded the table and declared that "We have to cut down on the number of changes!" People respond by putting more than one change into one ECO—actually making the process more complicated and slower.

Most companies have a significant number of changes—an average of 22 per week according to the author's benchmarking survey. One of the greatest challenges is to find logical ways to sort out unwise changes. We need to learn to do it right the first time! There is some antidotal evidence that properly used teams in the new design process do reduce the number of changes. Even then, knowledge of what the customer needs and wants changes. Technology changes. Goals change. Many things happen which logically require design changes.

The change process is often undocumented, slow, confusing, variable by whim, and the source of considerable finger pointing. In most companies, it grew by chance as the company grew. Then ISO 9000 requirements caused many companies to document what they do. This has generally been

a worthwhile first step, but a long way from efficient, exceptional or world class. Most companies need a considerable amount of analysis and redesign of the change process whether or not they realize it.

To analyze the change process properly, it is necessary to examine all its facets, one at a time. First of all, what is a change?

Definition: A modification that affects only the documentation or a modification to a product(s) that is necessary to make that product:

- Meet the product specification including reliability and maintenance requirements.
- Meet the product safety standards or specifications.
- Manufactured at a reduced cost.
- Maintained at a reduced cost.
- Exceed its product specification (usually called "product improvements").

This assumes that the product specifications are well thought out and complete. It assumes that MTBF (Mean Time Between Failure) and MTTR (Mean Time To Repair) requirements are in the spec. Notice the specific inclusion of safety requirements. This is a necessity for product liability protection and keeping the customer first.

Rule: Safety specifications should be included or referenced in the product specification. Official company standards might constitute the safety specification. In this case the standard should be referenced in the product spec.

Reason: Safety requirements are a critical part of the design criteria and should be written for all to see.

This writer is not an attorney but it would seem to make sense in terms of avoiding litigation and/or presenting a better image to the court if litigation does occur.

Why Change?

The last category in the definition—change exceeds (improvements over and above) specification—is one area where changes can be avoided/

rejected. Unless your company has a plan with a goal of purposely making such improvements, this type of change isn't necessary. They shouldn't be done! Call this category "**Creeping Elegance**!"

But doesn't this fly in the face of continuous improvement? Of course it does. Continuous improvement is for processes—not necessarily for the product design. But some products need to be continuously improved because the competition requires it. Certainly a new product usually needs to be changed to meet the product specification.

Rule: The company's products should be divided into two groups—those that need to be improved over and above specification (group A) and those which don't (group B).

Reason: Avoids erosion of profit margins. The market demands and the next product developments need to be considered when making this decision. This decision should be documented in a standard and revisited every six months.

Rule: Changes solely to exceed product specification on group B products should not be done.

Reason: They erode profit margins and result in "lost opportunities."

Doing one change that isn't cost effective or isn't necessary has a double-barreled affect. It does something that isn't in the best interest of the company while not doing something that is—lost opportunity.

This is the first place to look if you feel you have too many design changes. Chances are high that there are engineers assigned to mature products who feel it's their duty to improve the product. Reassign them to new products. The computer equipment company mentioned in the Change Cost Chapter found that this policy freed-up another two of their sustaining engineers to work in new product development. Almost 20% of their changes were to the B group products.

As previously discussed another area for potential reduction in change volume is the "cost reduction." Questions need to be asked. "Why is the change needed?" "What is the benefit from the change?" "What is the justification for changing?" Ask these questions on the ECO (Engineering Change Order) form instead of asking for the "reason" for change.

Type of Change

Ask the engineer to check one or more items on the ECO form (from the definition of change) as follows:

1. **Document only change.**
2. **Meet the product specification including reliability, maintainability and safety standards.**
3. **Reduce manufacturing cost or maintenance cost.**
4. **Exceed product specification (improvements)**

This author would submit that all changes fit into these type categories. Try it on your own changes. When this assertion is made at seminars there is one type that is often mentioned. There are sometimes circumstances wherein a supplier will no longer furnish what you have been using. This is an extreme case of a cost reduction because not making the change would mean that the product could no longer be produced.

Checking one or more of the above, gives definite indicators for further treatment of the change. For example the required signatures can be two (engineer and Doc Control) on a document only change. If number two is checked then the change is (by definition) non-interchangeable and part number change should be assessed. If number three is checked then the cost must be calculated.

Deviations, Waivers, Off Specs, Etc.

Before discussing the correct method to use to make a change to the product or its documentation, there is a need to understand what methods should <u>not</u> be used to make a change.

Rule: A Deviation should not be used to change the design or its documentation.

Reason: A Deviation is a temporary departure from design document requirements. After a specific timeframe or a specific number of items, the intent is to return to the specified design. Thus, no design change is needed. One fast and accurate method of changing the design is all that is needed. It's not a Deviation.

Rule: The Quality Assurance people should sign all deviations.

Reason: To make sure, among other things, that they are not used to change the design.

Deviations must not be allowed to continue beyond the agreed upon number of units or timeframe. The number of units or timeframe should be specified in the deviation. It is most important that the root cause problem is fixed. Thus:

Rule: A specific individual must be designated to "clear" the Deviation. This is the person who is closest to having the total responsibility for the actions that must be taken to assure that no more units will have the problem.

Reason: The alternative is to write another Deviation because the problem continued or occurred again, and again, and again.

If Deviations are written and approved more than once for the same dimension or specification, then the requirement should be reviewed for possible design change—probably a decision that should have been made prior to the first Deviation. A sample Deviation form is shown in Fig. 10.1.

Another name used for a Deviation is "Off Spec." The same rules should apply to Off Specs as with a Deviation.

Some companies use Waivers as well as Deviations. The Waiver tends to be used as a "before the fact deviation." That is, the supplier sees a problem producing the part per the drawing. The supplier may request a Waiver. The same rules should apply to the Waiver—it should not be a method for changing the design or its documentation. If the Waiver highlights a condition wherein the design should change (supplier cannot meet the tolerance on a given dimension and it is determined that Engineering can live with what the supplier can do), then don't approve the Waiver. Write and ECO immediately to permanently solve the problem. Send the ECO to the supplier referencing the Waiver.

Urgency

Often companies invent a "quick change," "floor change," "temporary change," "emergency change," "red line change," etc. This is often done in addition to the normal ECO form/process, that is, followed by the formal ECO process.

Deviation Authorization	EC^3 Corp ©	DA#
Originator Name	Dept	Date
Reason For Deviation		
Specific Timeframe or Serials to be Deviated		
Product(s) Affected		
P N Affected Documented Condition Deviated Condition		
Name and Organization Responsible for Clearing This Deviation		
Has This Condition Been Deviated Before ? Yes ☐ No ☐ If So: DA # Date Timeframe Or Units		
QA Name	Sign	Date
Mfg Name	Sign	Date
Cog Engr Name	Sign	Date
Doc Control Name	Date Filed	

If a design change is required, go directly to the ECO, do not write a Deviation.

Figure 10.1. Deviation form.

Rule: A company should have one fast, accurate and well understood method of changing the design and its documentation.

Reason: One method is the lowest cost, least confusing and the simplest to use, operate, maintain, improve, etc.

Oliver Wight states in his book on MRP II that *"When one system doesn't work, companies develop several other systems to try to do the same job."* The author's experience shows that it is not unusual to find two,

three, or even four ways of making a design change. The multiple product manufacturing benchmark survey indicated and average of 2.4 methods of doing a change.

The existence of two or more systems is a symptom of a problem—the "normal" system is no doubt too slow. Somewhere along the line this was recognized, but the solution was to create another process instead of making the "normal" way fast and accurate.

Every company should develop one fast and accurate ECO (Engineering Change Order) form and process. There should be only two kinds of ECOs.

Rule: Two kinds of ECOs will be processed by our fast, accurate and well-understood system. One is*Fast*, and the other is *Hand Carried*.

Reason: Some changes are more urgent than others.

Rule: The "hand carry" will not be done by CM but rather by the person who says that this change is so important that it must be hand carried.

Reason: Avoids having most changes called "hand carries." If someone else (CM) has to do the extra work, it is easy to overstate the urgency.

When the hand carry ability is coupled with a normally fast system, the quantity of changes that are hand carried are few indeed. Experience shows that less than 5% will be deemed so important as to require hand carry treatment. If a company has a second and/or third shift, it will often be necessary to have a "design person" on that shift. That person must have the authority and knowledge to hand carry a change. If CM is chartered and manned to hand carry changes, then the result will be that, almost all changes are hand carried.

It is imperative that the change order precedes the product change. To prevent getting the cart (hardware) before the horse (change document), the change process must be fast. As you will see later, it is very reasonable to expect a fast system to process changes through CM in three to five work days (average time). The "hand carry" through the same process should happen in one half day.

One electronics company was faced with an occasional need to make changes in less than a half day. They had been doing quick changes on the floor by the engineer and manufacturing engineer signing a redline. The changes were supposed to be followed by a formal ECO immediately. They

weren't. The pressure was off when the fix was implemented on the floor and the ECO was sometimes even forgotten. Sometimes the ECO when processed, did the fix differently than the redline. The redline fix wasn't documented. Six people signed the formal change. Sound familiar? This company asked themselves and the writer if there wasn't a way to create a single formal process for this type of change. We created a superfast process as is represented in Fig. 10.2.

Purpose:

- To describe the only acceptable method for doing emergency "line down" changes.

Applicability:

- All emergency / line down changes to be processed by this Doc Control function. The only method to be allowed for emergency / line down changes.

Policy / Practice:

- The **Cognizant Engineer** or an engineering representative shall be **available to the production operations** whenever the production line is scheduled.
- A **Manufacturing Engineer** shall be **available to the production operations** whenever the production line is scheduled.
- The Doc Control process for expediting changes through the normal process in **one half day** is in place. (If this is in place, many companies will not require a "Line Down" process)(If this is not in place, too many changes will become "Line Down".)
- The engineering representative and the manufacturing representative must **agree on the need** to process the change in less than one half day.

Procedure:

1.	Production	Calls Cognizant Manufacturing Engineer.
2.	ME	Calls the Cognizant Design Engineer.
3.	Cog Engr	Reviews conditions, if in agreement with urgency, makes two sets of marked up documentation and signs both.
4.	ME	Signs both mark ups.
5.	Cog Engr	Calls Doc Control for change number and notes "line down" in the Reason for Change box. Posts change number to both sets of marked prints. Gives one set of marked prints to production.
6.	Production	Incorporates change.
7.	Cog Engr	Completes change form and delivers the other copy of marked prints to Doc Control within one hour of obtaining the change form number.
8.	Doc Control	If mark ups and change form are not received within one hour of number assignment, notify the VP of Engineering and VP of Operations. (they in turn must let the engineer know that more than one hour is **unacceptable and it should not occur again**)
9.	Doc Control	"Skips" all other signature boxes and incorporates the change (marked "line down") exactly according to marked prints. If there is a problem with the change, another change will be required and that occurrence will be reported to the VPs of Engineering and Operations.

Primary Responsibility:

The Director of Engineering Services is responsible for keeping this standard current.

Figure 10.2. Line-down change process.

They did not follow this change with a "formal ECO." This is their formal process. The management agreed that this process could only work if they backed CM on the one-hour rule. New engineers tended to miss one deadline but it never happened again. This puts the cart so slightly in front of the horse that it doesn't matter.

Having a fast process and these two kinds of changes also eliminates the need for classifying changes as to their urgency. In one situation, an electronic company determined whether each change was Routine, Urgent, or Emergency. I asked if the throughput time was measured. The answer was "no!" They started measuring the lapsed time. They measured time through CM (from engineer complete to release to manufacturing). What they found was:

Urgency	Calendar Days Average
Routine	38
Urgent	76
Emergency	103

Yes, you read it right! The emergency changes took almost three times as long as the routines. There were many problems with the process, the result was that it took more time to debate about the urgency classification than it should have taken to process the change.

Rule: Do not classify changes by urgency. (Except "Hand Carry") unless it can be done in five man minutes or less.

Reason: It takes more time than it is worth. All changes that meet our requirements are important and all should be processed quickly and accurately.

It is not uncommon to find urgency classifications such as "emergency," "line down," "site down," "routine," "normal," etc. Seldom are process differences apparent, however. Use of the word "mandatory" is common. Does that mean that other changes are not mandatory? With urgency classes of "normally fast" and "hand carried" the process will be the same, but the hand carried change will be specially treated. The people in the process will have standing instructions to drop what they are doing and to process the hand carry first.

Class of Change

Companies sometimes classify changes based on the interchangeability definitions.

Class I	=	Non Interchangeable changes
Class II	=	Interchangeable
Class III	=	No affect on the parts (Records Only)

This is done for the ease of expression. It is easier to say Class I than it is to say "Non Interchangeable." This class also ties to the change of part number (class I) or revision level (class II). The military/DoD folks use the class I and II in somewhat the same way.

Rule: Interchangeability should always be one method used to classify changes.

Reason: Significant differences in the process can and should result.

Class II will be a revision level change. Class I will be examined for part number changes. Steps in the process can be skipped according to the class. For example: A class III (Records Only) change doesn't need to go to team meetings. Nor does it require look up of the "used on." As discussed, the cost treatment might be different depending on the class. Other examples will be apparent later.

Take care not to use the DoD definition, however, as you will find "cost" to be a factor that makes the change a class I. Cost is unassociated with interchangeability according to this writer.

What Makes Up A Change

The question is often asked, "How many problems can I fix with one ECO?" The answer should be "ONE."

Rule: One problem, one fix, one ECO, one effectivity and one set of drawings revised.

Reason: It is easier to understand the problem and the fix when they are "stand alone." More importantly, each hardware fix tends to have a most logical / economical point of incorporation for each product affected.

Two or more problem / fixes in the same change would cause "splitting" the effectivity (making the change very hard to understand) or to compromise the effectivity of one or both changes. Two or more fixes makes quantification of change volume difficult to compare from project to project or company to company.

Exceptions to the Rule:

1. If the conditions merit a "short term" and a "long term" fix, and it is not economical to wait for the long term fix, two ECOs are acceptable.
2. Several class III changes to the same document.
3. Several class II changes to the same item providing they can be economically effective at the same date.
4. Blanket ECOs.
5. Software changes

A few companies make one change to one document with one ECO. Thus, when one problem results in a change to more than one document, they have multiple ECOs to document that change. The usual practice is to cross-reference the ECOs to each other or each to a designated "mother." This is a method that is used successfully, however, since it is cumbersome, better to use the one problem, one fix, one ECO rule. We will count the number of documents affected as a separate metric.

Universal or global problems are often fixed with a "blanket" ECO. The concept is to pre-approve the fix and have EDC/CM for any purpose or whenever they have "available time."

Software Changes

Problems with or changes to the code are normally identified by some kind of Change Request process. The "forms" are identified with various unique names. The software engineers decide which are valid and which aren't with or without team interaction. The code changes are made in bunches called a "Release." Because of the intricate interrelationship between many software code changes, they are typically tested as a group (Software Release). The individual code changes and the testing of the batch are controlled by the software engineer since that is the design and development phase.

The release is then done by an ECO. The software "Release" is thus "blocking" of changes to the code. This is true at most companies. This allows the company to do the best product assurance and to limit the media distributions to customers, dealers, Manufacturing, etc.

Often companies devise a unique form for making software changes. Careful preparation of the ECO form and form instruction will allow the same form to make software changes, firmware changes and hardware changes. If a change affects both hardware and software they should be described on the same ECO. The important aspect is that a minimum level of control is present, not what the form is called or if a different form is used.

Software changes typically need not precisely describe the changes. Usually the software engineers have files established that can be compared when necessary to precisely define the changes. The best practice is to describe in the ECO what requests have been satisfied with the ECO release and to make sure that this list matches the request status list. Sometimes the software engineer finds the ECO release a good vehicle to list the remaining requests that have not been solved in the current release, a very good practice.

Otherwise the same principles that are required for hardware or specification changes apply to software and firmware changes. The CM organization should control the part numbers, revision levels, maintaina file representing the latest code as well as down level (earlier releases) code files and/or ECO files.

What Goes Into the ECO Package

What does or doesn't go into the ECO package is a critical decision. The more documents required to be in the package, the longer the process time. The required content of the ECO package is simply stated.

Definition: The ECO must contain all the documentation required to precisely define the change to the design documents that represent the item(s) being changed.

Rule: Only those pages of the design documents that are affected need be included.

Reason: The unchanged pages are costly to include and inclusion lengthens the process time. If several pages in the set need to be renumbered as a result of the change, the ECO can note that fact.

Rule: Manufacturing and support documents will not be included in the design change.

Reason: Inclusion of manufacturing and support documents will delay the process unnecessarily.

This is a very difficult concept to understand for some companies. It isn't that the manufacturing/support document changes cannot or should not, be controlled and precisely described. It isn't that they shouldn't be added to the change package or a separate cross-referenced package later. It is a question of timing. If I am a Manufacturing Engineer or Technical Writer I simply cannot begin to execute changes to my documents until the design document changes are defined and technically released (past thepoint of no return). This is the crucial fact that favors unbundling the change package.

Unfortunately some companies have developed a rule that says that all the technical documents (Manufacturing and Publications / Service, etc.) affected by a change must be in the design change package. This often occurred because the revised publications weren't ready to ship with the revised product or the revised assembly instruction was not ready when the change was to be incorporated. Instead of fixing the root cause problems they have used the ECO process as a crutch. The result is most often a very slow and divisive process. Very often the CCB (Change Control Board) is waiting for the non-design document changes. When they arrive, the design fix has been modified. Now the non-design document changes must be reevaluated. The process is taking so long that someone piggybacks another change into the package because it affects documents in the earlier package. Go around again!

In some companies the design, manufacturing process and publications are all the responsibility of the same engineers (they must get awful tired of changing hats). It must be asked if one person is normally good at doing all those jobs. As your company/operation grows look at opportunities to hire a manufacturing/industrial engineer to be responsible for the manufacturing process. A service engineer to be responsible for publications and field service.

Often folks interpret ISO 9000 and FDA specs to require the bundling of these documents. This is simply not true. FDA is very concerned about process changes and essentially the same control must be present as with design changes—but they need not be bundled together. Get out those requirements and read them for yourself.

The package must, of course, include all new design documents required to define the change. It must also include a precise description of the changes required to existing design documents. The manufacturing and support documents will change as a result of the design change. Their completion will be addressed in the implementation phase of the change.

In the Front End Loader Company we will develop a complete and detailed process which will assure that each document is ready when the dependant event needs it. The design change will be done first, followed by the changes to the support or manufacturing documents. See the block diagram in Fig. 10.3.

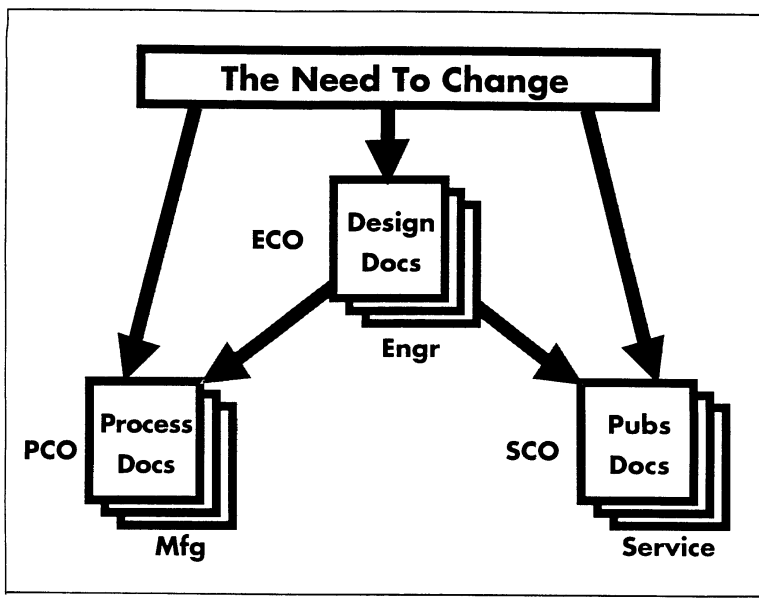


Figure 10.3. Unbundle Manufacturing and Services Docs.

Using the policy depicted in this block diagram, the changes to the manufacturing process don't require an ECO if no change to the design documents is required. Nor does it require the same document control function that controls the design documents. Likewise for the support documents (service publications). The block diagram might imply that a separate change form must be used by manufacturing and service. They can use a separate form or no form at all. A "log/revision block" on the documents might do in most environments. FDA will look for a form to control the manufacturing process changes.

Distribution of the ECO

In many companies a careful reexamination of the distribution practices is also needed. Many times, a copy of the ECO form (cover sheet) itself is an adequate substitute for the entire package. As previously mentioned, only the revised pages of a document need be in the package (when required on a "push" basis). The combined affect of these savings methods can be substantial. One large electronics company cut the ECO package size and costs as shown in Fig. 10.4.

And this savings only reflects the paper and reproduction costs. The handling, reading, filing, etc., probably tripled that figure.

Old System		New System
27	Pages per ECO	17
x40	Copies per ECO	x25
1080	Total sheets per ECO	425
x90	ECOs per month	x90
97,200	Sheets per month	38,250
1,166,400	Sheets per year	459,000
	Reduction in sheets per year = 707,400 @ $ 0.10 per sheet	
	Savings per year	$70,740

Figure 10.4. Copy cost savings.

Depiction of Adds and Deletes

Why must the changes be precisely described in the ECO? Put your self in the document customer's shoes. Given a revision D drawing and a revision E drawing isn't your first question going to be "what is different?" The several users of the documents are going to get neck sprain comparing the documents. Your suppliers will often have a light table to overlay both hard copies in order to identify the differences. The document customers will spend a lot more time if changes aren't precisely described (and make errors) which will come back in the form of higher prices. The time spentby your customers will far exceed the time required to precisely describe the changes.

Two methods are generally used in a change order to depict the change, marked print and the "descriptive" methods. The most prevalent method is the use of "from - to" drafting. This is called by many names— "was - now," "was - is," etc. The essence of this method is to describe all the changes in terms of what is the current configuration is and what the new configuration will be. In this method the steps usually followed are as follows:

1. The engineer (or aid) marks up a set of documents to depict the change. Messy mark ups are allowed (no mark up standard).
2. The CM person studies the mark ups, goes to see or calls the engineer as required to interpret the mark ups. This may require several iterations since the engineer is not always available.
3. The CM person "drafts" neat and legible "From (old) - To (new)" descriptions.
4. CM has the engineer review and / or sign the "From - to" drafting.
5. When the ECO is approved, the "From - to" is used to update the master documents.

Did you ever wonder what Lincoln's Gettysburg Address would have been like if someone else had to interpret those notes on the back of an envelope? What happens if CM assumes they understand the mark ups? Errors result! The CM person makes some assumptions about the mark ups or the engineer doesn't review the "from - to" closely. This method induces many errors.

The other method employed is to use the mark ups (hand, CAD redline/overlay, etc.) directly in the ECO package. The process now looks like this:

1. The Engineer neatly marks up the documents per the company standard.
2. Eliminated
3. Eliminated
4. Eliminated
5. The marked documents are used to update the master documents.

Most CADs have "redline" or "overlay" ability. Many companies simply do not use it or do not own that module. If you are in a paper world,

when dealing with larger size documents sometimes the changed area on the drawing is only "A" size. If this is the case, cut and paste the mark up in CM to reduce it to "A" size. Study a sampling of your past changes. The result is usually such that:

Rule: Use of marked documents is almost always faster, lower cost, and more accurate than use of "From - To" descriptions.

Reason: The fewer steps in a process the less opportunity for error, the fewer hands-on minutes and the least lapsed time results.

The key here is to develop a standard for mark up and enforce its use. In order to use the technique on parts lists, the parts list must be double-spaced. If CAD or MRP system is your official parts list, it might have to be reprogrammed to have a double-spaced, no component revs, option. Make this parts list your official Engineering Controlled Document.

This method also requires the master documents to be very high quality—capable of two or three iterations of reproduction and still be highly readable. Thus:

First generation	– The engineer asks for a "latest revision quality print for mark up"
Second generation	– The marked prints are reproduced as part of the ECO
Third generation	– The ECO is microfilmed (if applicable)

It might be that Drafting, CM or a technician helps the engineer "up front" in the process. In that case they would probably do the mark up for the engineer. In any case the mark up standard is a key.

Flag Notes

Some companies have "flag notes" on the documents. These are small symbols (sometimes a flag) that contain the new revision level. They are placed on the document near the point/points where the change were made. The customers of the document can now compare the two revision levels and identify (if they are careful) what changes occurred. The problem with this method is that it is not precise—bring on the light table. Thus this writers conclusion is that they aren't adequate used alone.

Use of flag notes is helpful if used in conjunction with a precise ECO. They should never be used instead of a precise from-to description or a marked print. The best convention would be to only keep the latest revision flag notes on the master.

Mark Up Standard

The company standard for mark up of design documents would include requirements as follows:

- The CM Department must maintain document masters of quality to allow two (or three) generations of reproduction while being highly readable.
- Requires the use of mark ups by all engineers unless the change can be completely described in the space allowed on the ECO form.
- Mark up shall be done via CAD or in red pen. Specify size and type of pen if required.
- Neatly hand letter mark ups in a script slightly different than the original hand drawn.
- CAD overlays or redlines are encouraged.
- Circle (or underline) deletes—do not obliterate.
- Write adds along side or immediately below the original.

Figure 10.5 shows a method for marking up a parts list. Most MRP/ERP systems do not have a "redline" ability. For this reason we developed a special Engineering Parts List (screen/report) that is double spaced for ease of mark up. Note that the deleted item is underlined, not obliterated. The added item is written in immediately below the delete. Also notice that the item now changing was changed previously. ECO 2204 made the previous change. The current mark up will now result in the CM function adding the ECO and Production Control adding the effectivity week for this change (WK 50 - ECO 2844).

Most MRP systems do not have the ability to show the ECO number that made the line item change. They generally only show the last ECO number affecting the parts list in the header.

Figure 10.6 depicts one method for marking up a pictorial drawing. The "delete" is circled and the "add" is written in below the "delete." Other conventions may work as well as long as the old spec is not obliterated. The critical thing here is to specify a simplistic method that is best for your company.

3-02-95	REV C	ASSEMBLY PARTS LIST				223456-01
FRONT END LOADER - FEL-100		PG 1 OF 1			AUTHOR FBW	
FIND #	DESCRIPTION	PART NUMBER	QTY	U/M	IN/OUT DATE	ECO #
1	Motor Mount					
2	Tire, Large					
3	Frame					
4	Tire, Small					
5	Bucket, 4 Yard	523456-01	1	ea	wk 42	2204
5	Bucket, 4 Yard	523456-03	1	ea	wk 43	2204
6	Bucket Arm	523456-04	1	ea	WK 50	2844
7	PCB Elect Ign					
8	Nameplate					

Figure 10.5. Marked-up parts list.

Rev	Date	Rev Description	ECO #	Sign
–	8-24-94	New Item	–	FJ
01	10-1-94	Pilot Release	802	CM
A	11-4-94	Qual Test Compl - Rel	831	CM

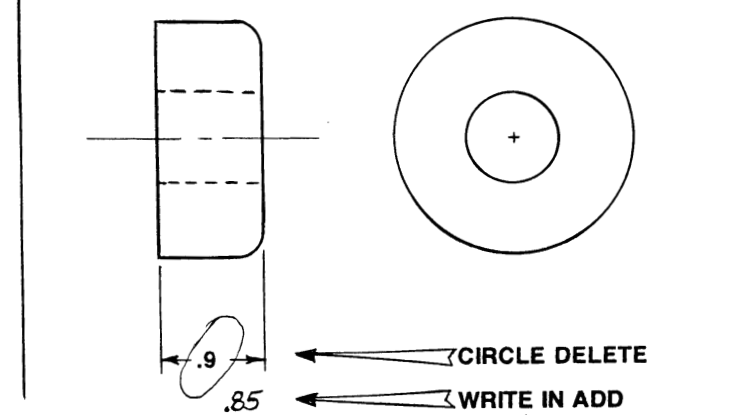


Figure 10.6. Markup of a pictorial.

Similar conventions can and should be developed for specifications and other textural documents. Most word processing systems have methods for distinguishing deletes and adds. In the simplest form, italics or highlighting can be used to show additions and underlining to show deletions. Some systems display a marginal line to show the new text. The same rules should apply to text documents—a precise description of before and after so that your customers are not required to compare.

Same As Except

When a new item is required by a design change, the new specification, drawing, parts list, etc., must be included in the ECO package. If the new item is nearly the same as an existing item, the "same as except - marked document" technique may be used. This means that the Cognizant Engineer need not have a new drawing prepared to accompany the change. Rather a mark up of the similar item drawing can be made. The red marked document will be used to produce a new master and then assign it the next available part number. This is a tool that was used before CAD tools simplified the drawing tasks. It is still a good tool to use with CAD because the reviewers, buyers and suppliers can readily see the similar item and relate to problems, processes, sources, etc., for the new item based on the old one.

Revision Drafting and Daisy Chaining

Incorporation or revision drafting typically does all changes to masters (CAD included). This function should be a part of the CM responsibilities. The people doing this function should be part of the CM organization. The reasons that it should be part of the Configuration Management are:

1. The responsiveness or "sense of urgency" is not typically present when the function is part of a drafting or design group that also works on new products. The new product documentation will typically take precedence. A slower change process results.
2. The CM organization is much more likely to update the master documents on a change by change basis instead of "queuing" several changes before the master is updated.

3. When in CM there is less temptation to change the change after it has been approved.

When changes are allowed to queue, negative things happen. First of all, the latest revision print is not available to those who need it. If one asks for a print, they must be given the last update of the master and all the "attached" changes. This is an insensitive attitude toward the CM customer. If the item is purchased the buyer and supplier are burdened with the update problem.

The latest print is not available to mark up for the next change. We can hope that the next change wasn't "dependent upon" the earlier or spend extra time checking to make sure.

The issue of "urgency" is raised. The resulting time spent to prioritize the Incorporation Drafting effort can exceed the time to incorporate the change into the masters.

Since several documents may be affected by one change or several changes affect the same document, the resulting entanglement creates a significant amount of debate and "make work." It occurs so frequently in American industry that it is given a name—"daisy chaining!" The term tends to mean different things to different companies, but it is usually a direct outgrowth of queuing changes to documents.

The time that Drafting or CAD departments spend incorporating changes (and doing "same as except") can be quantified. The resulting number of people should be shifted to the CM organization. One CM manager reported that this idea was implemented in their company and that "they had given her their poorest performers!" Some months later an update showed that "they were all good people and some were just over their heads!"

One medical company established a policy that all new hires would enter through the CM group and do incorporation drafting. They reported that it was an ideal way to train new people as they saw all the products, formats, standards and mistakes. When a new hire was approved a CM drafter moved up to the new design group.

The drawback that is sometimes reported is in companies that have several CAD systems and the training on those systems is time consuming.

Queuing Changes

Interchangeable changes to a single part or document may be queued and made as a group. This is typically logically done if the changes can be

made at the same point in time (effectivity is the same). The responsible engineer should do the queuing so that CM gets into the habit of processing all changes immediately upon receipt. This includes revising the master drawing. Doing this means that the revision level increases with each change. This also places the responsibility for determining what is or isn't critical where it belongs—with the Cognizant Engineer.

ADCN

The Advanced Document Change Notice (ADCN) is an often-used method to make changes without revising the master documents. A limit of the number of ADCNs that can be "accumulated" against any single document is set. The DoD sanctions this method. Most government agencies sanction this method. The Drawing Room Manual (DRM) sanctions this method. A copy of the ADCN is placed with or noted on the master. If someone asks for a print, they are given the print plus a copy of each accumulated ADCN. A limit is usually arbitrarily set at five—when the master must be updated.

The effect of the practice is very negative. It places a burden on the CM customer to "integrate" the changes before use of the drawing. It tends to force the changes that accumulate to be made effective together—usually when the master is updated. In the meantime is production and/or the supplier building parts that will need to be scrapped or reworked? It costs time to copy and attach the ADCN to the print master. It cost time for each customer to "incorporate the changes" so they can use the document. It tends to preclude the use of marked prints for changes since one cannot obtain the latest revision print to mark up. All these negatives and what positive? The time to incorporate each change is the same. It saves pulling and re-filing the master drawing! It saves distribution of the documents affected if you have a "push" system. We need to get out of the push system into a pull system anyway.

There is nothing "advanced" about the practice. It makes the CM customer suffer for very little, if any, savings in CM. The practice should be abandoned in favor of a fast change process wherein the master is updated with each change—and promptly. Think of the ADCN as an RDCN—**Retarded** Design Change Notice.

Who Signs

The most debated issue in the change control system is the signature requirements. Everyone wants to sign. As a comedian used to say, "Everybody wants to get into the act!" This is one of the most significant contributors to long throughput time. We need to have a team involved in the request and change process but they do not all need to sign the change. First of all, let's examine the minimum signatures on a production-released item, what they should sign and their responsibilities:

- Cognizant Engineer signs: new design docs
  (responsible for: the design marked up docs
  of the product) ECO
- CM signs (optional): ECO
  (responsible for: the BOM & ECO system)
- Manufacturing Engineering signs: new design docs
  (responsible for: design of the marked up docs
  manufacturing process)
- Manufacturing Production Control: ECO
  (responsible for: effectivity and implementation)
- Field Service: ECO
  (only if retrofit is proposed or the spares list is affected)
  (responsible for: the product after shipment)

CM is noted to be optional because the culture varies from company to company. Can CM assure that they do their tasks on a change and that the proper process is followed without signing the ECO? Will the management accept that this has occurred without CM signing?

If a change is a class III (records only) then no manufacturing or field signatures are required—only notification. If the change occurs during the Pilot Phase, have an "informal" change process that requires only the Engineer and one Manufacturing signature. For example require only Manufacturing Engineering signature on the pilot phase change (marked-up documents). This is done on the basis that the changes will affect all the pilot units and therefore there is no "effectivity setting" to be done.

Notice that the ME (Manufacturing Engineer) is signing the design documents—not the ECO. All manufacturability issues are on the design documents, not on the ECO unless done by "from - to." The ME should sign the design drawings and the marked drawings "up front" in the design phase

of the process. Also notice that the Field Service representative need only sign the ECO since that is where the retrofit plan will be.

Two people always need to sign the ECO form – the Cognizant Engineer and the manufacturing representative that is setting the effectivity. This same representative should be responsible for implementation of the change. The person manufacturing assigned to sign the ECO should set the effectivity only after consultation with and analysis by all other affected functions. Some companies have an implementation team for some or all changes. Having one person responsible for coordinating the implementation makes better sense to this writer.

If any of your customers have change approval authority, then add:

- Customer sign: ECP

The term ECP (Engineering Change Proposal) is most generally used when the customer has approval authority. The term ECN (Engineering Change Notice) is sometimes used when the customer has review authority. These forms are simplified versions of the ECO, telling the customer what they need to know.

Rule: No other signatures than shown above are needed for accurate processing.

Reason: More signatures will slow the process and compromise the accuracy.

Where is QA you ask? Quality Assurance should monitor the process, sit in the team meetings, and audit the processes. Signing one hundred percent of the changes is like trying to inspect quality into the parts by inspecting all the parts in a lot. QA has a more important task, to audit the process and to report to management when things go astray.

Where is Sales, Marketing, etc.? How about other manufacturing or field service departments? They should receive a copy (hard copy or on line) of the ECO cover sheet at standard distribution points. They can come to CM or Production Control to look at the entire change if necessary. They can all take exception to any change by use of the chain of command. This is "process management by exception."

Empower the Team

All those who can be affected by changes should be on the team. They need not all be signers. Each can be empowered, however.

A medium sized company with a complex electromechanical product developed an "empowerment" signature process. They have minimum signatures much as is outlined above but they allow anyone on the team to stop any change by writing an email to the responsible engineer and copying CM. CM has the responsibility to follow up on the issue to resolution. In the beginning the authority was used fairly frequently but as time went on (and the processes were improved) the authority was seldom used.

The responsibilities of each person/function in the process must be crystal clear. This is where your standards again come into play. The Policy, Procedure (Flow Diagram), standards, form, and form instructions are critical to this clarity. They must state each person's responsibility very clearly. Those not signing should receive an ECO cover sheet. They should have the responsibility to contact their representative if necessary.

There are many functions potentially affected by the change. It is totally impractical to have all of them sign. It is equally impractical to expect CM to coordinate all those signatures. Thus, make a signature standard for your company or division and limit the number of people directly in the signature act. Point out to folks that think they need to sign each change that they could be liable or end up in court and sometimes their attitude changes.

Change Impacts

Most change forms ask the engineer to state whether or not the change will impact certain areas of the company. If your form doesn't it should! Does the change impact publications? Tooling? Test Equipment? Software? UL approvals? Inspection Procedures? Assembly Instructions? Supplier tooling? Will the field be retrofitted? Etc? This is all worthwhile information to know. It is, however, somewhat unrealistic in most companies to expect the Cognizant Engineer to know the correct answer to all the questions for every change.

Who should better know whether or not publications are affected than the Publications Department? Tooling than the Manufacturing Engineering Department?

The cognizant engineer needs to think about the impact of the change. It is wise to ask the engineer to give an opinion as to the impact of the change. The engineer may consider the change more carefully realizing the total impacts / areas affected. But what if the engineer is wrong? Specify, in a standard, which department is responsible for reviewing and changing (if necessary) the engineers' initial thought. That department should feed

impact "changes" back to CM so that the cover sheet can be changed. The worst case impacted list should be on the ECO from. Each should be accompanied with a "yes" or "no" box—a positive / negative approach. You will see this on the Loader Company form.

Mark Ups in Production

Take care that the mark ups do not normally get to the production floor. Most auditors are very concerned if they see marked prints on the production floor. Once marked prints are allowed to be on the floor, what stops any person from changing the design by merely marking up a print? Again the Manufacturing Engineer (ME) and the process / routing is the key. As previously discussed, the ME should use the ECO and its mark ups to revise the manufacturing process. This keeps the prints and the mark ups off the floor. See Fig. 10.7.

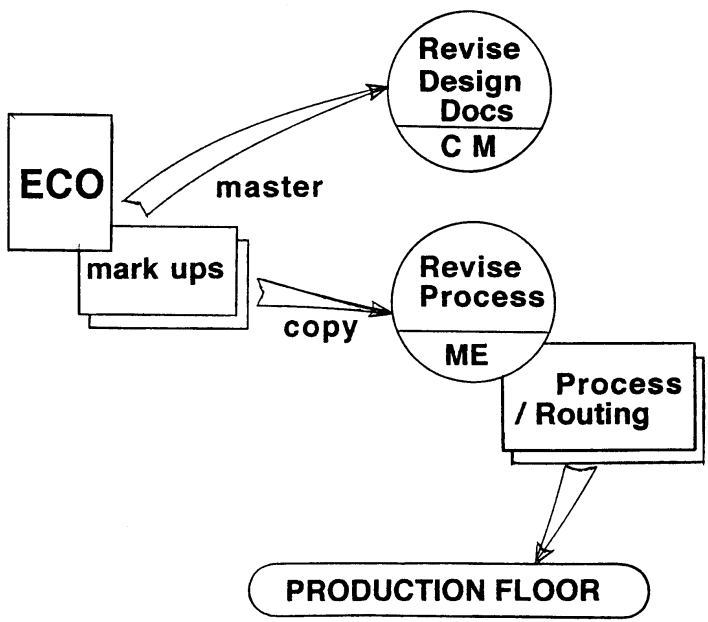


Figure 10.7. Control of mark ups.

If prints are used in the production process then this process must assure that the proper technical support function (ME) removes the down level print and replaces it with the proper revision level print at the proper point in time.

Customer Review and Approval

In the majority of product purchases, the customers or OEMs have no review or approval right what so ever. It is expected that good interchangeability rules will be followed. The product specification and warranty are the buyer's expectation. If the product doesn't perform as promised, then the problem must be fixed. It is not expected (also not desirable) that change review or approvals occur.

There is an alarming trend for companies to require approval of the supplier changes. Time is added to the process without much value added. It is certainly not cost effective for the company or its customer to go through such processes. Often it is used as a crutch in place of agreeing on the product specification and interchangeability rules for the purchased item. This is why the Product Specification, Test Specification, and Specification Control Drawings (for the supplier) become so important in Configuration Management. This is why make sense interchangeability and part number change rules are so important.

Rule: Try not to give customers change review or approval authority.

Rule: If negotiations make it necessary, give the customer review authority.

Rule: If necessary, give review or approval authority only on the following basis:

- Written contract agreement.
- Class I changes (non-interchangeable) only.
- Increase the price for the ECN / ECP processing.
- Reserve the right to increase the product cost if the customer requests the change or if approval delays cause costs to increase.

Rule: Give approval authority only if the customer agrees to be bound by a specific approval time.

Reason: To keep the product cost down and to compete in the world market.

The customer approval, if absolutely necessary, should be subject to a contractual "default clause," such as; "If approval/disapproval is not received within 10 working days the change shall be approved by default."

Companies have obtained contracts with this default clause because it is good business for both parties. Most customers know that the longer the wait the higher your costs go. The higher your costs the higher their price. About ten to fifteen percent of the companies in our university seminars are currently contracting in this fashion. Even the DoD product folks are starting to make this process work.

There are those that say ten days is not enough time. In most businesses there is seldom a design change that cannot be analyzed by a competent engineer in less than four working hours! So it is a matter of taking the queue time out of the process.

Working the customer contract requires a fair amount of work on the part of the CM Manager or Engineering Services Director. The work done in the contract phase will be more than returned in the execution of the contract, however. The Contract Administration people may not be anxious to change the contracting policies. They will also usually come around when they realize the benefits. The customer's representatives at contract time are usually aware of the need for speed because they want the product sooner, not later. Sometimes day for day delay in product delivery is added to the contract.

Effectivity

There are essentially four forces at work to impact the optimum point/time to incorporate the change in the product.

T1 = When does the customer want it? If the customer requested or requires the change, they may desire to see the change quickly. If the customer is paying for the change or added feature, they may wish to "cut it in" at the lowest cost point.

T2 = When does the design engineer want it? The responsible engineer will often have an opinion as to when the change should be effective.

T3 = When does minimum cost indicate? The estimation or calculation of the associated costs will tend to point to a time in the future.

T4 = When are parts or tools available? The longest lead-time part or tool will be a major factor in the incorporation time for the change. This point in time may be different than any of the above! It is also typically a time in the future.

How do we consider all these forces? Lets take an example from the Loader Company:

Example:

The customers are having a problem with the steering wheel cracking. They want the problem fixed yesterday.

The engineer responsible has a fix for the problem—new resin to mold the steering wheel. No change in the mold is necessary. There is no difference in the material cost—old to new resin. The engineer wants the change this week.

Material Control says we have enough of the current resin to last five weeks. The old resin is a special blend that cannot be returned. Both old and new resin will cost about $8,000 per day at current production rates.

Purchasing says that without a special $15,000 expediting charge, they cannot get the new resin for three weeks.

When should this change be made effective? Effective week: 1 2 3 4 or 5

Discussion:

The example is one used in the University EDC / CM seminars. Answers range from week one to week five. Considerable debate results. The situation is not unlike many debates witnessed in CCB (Change Control Board) meetings.

Which week you chose depends upon what assumption you made about the severity of the problem. We know that more than one customer had the steering wheel crack. We do not know several things:

- How many steering wheels cracked?
- How many customers have experienced the problem?
- What was the age of the wheels that cracked?
- Has the new resin wheel been adequately tested?
- What is the total field population of identical steering wheels?
- Does the crack present any current or future safety problem?
- Has the engineer, field support and management made a decision to retrofit the field?

Our ECO form instructions for the engineer should require quantitative information about the problem. In this case we should expect the engineer to pass along at least the number of units that have failed, the total number of units in the field, and probably the estimated Mean Time Between Failure (MTBF). It is also critical to know if there is an operator safety issue involved.

Will the cracked steering wheels be retrofit? Our ECO form should indicate whether or not the engineer is expecting the field units to be changed. The effectivity decision would be much easier to make given this information.

Rule: Assure that pertinent and quantitative information about the problem is included in the ECO package.

Reason: Intelligent decisions about the proper effective point cannot be made without them.

What will happen in this example if all the facts are known? Examine the effective point issue given all the facts:

Conclusion: (Assuming safety is a real issue)

- The change should be effective in week one or two to minimize liability issues. Field retrofit of failed wheels should be part of the plan.

Conclusion: (Assuming no real safety issue is present)

- The critical issue to settle first is whether or not failed units will be retrofit.
- If field retrofit is not planned, week five would seem like the logical effectivity. This minimizes cost.
- If retrofit is planned (say on a failed unit basis), then minimizing total (field and factory) cost at week three might be the optimum point. The cost of retrofit in the field must be compared to the manufacturing costs, however to be sure.
- The lessons that are fairly obvious as this example is discussed are:
  1. It is natural to have engineering want to see the problem fixed as soon as possible. It is natural for manufacturing to want to minimize the cost. The CM organization must bridge this gap.
  2. It is very difficult to get a team to agree on the effectivity plan. It is probably better to vest the responsibility with a single department.
  3. Agreement on whether or not we will retrofit is a precondition for a make sense plan.
  4. More information than is typically seen on changes is needed to make a good effectivity and retrofit decision.

Charge back of costs (price change) to the customer should be considered. If the change was requested by the customer (and it is not required to meet specifications) the customer should probably pay for the change. It is surprising how many changes are made because the customer required it, but the change process doesn't allow for an increase of price. Most companies need to develop a policy for charge back to the customer. It is too often left to "someone else" to decide. Why not use the team?

Effectivity Responsibility

The customer's requirements and wishes are important and must be stated on the ECO. The Engineer's wishes and quantitative information are important and should be stated on the ECO. It is important to know if the

change is required to meet specifications, etc. Input from other people is important.

Rule: The final responsibility for determining the effective point of the change should lie with manufacturing. If customers are dictating the effective point, that information must be stated on the ECO and manufacturing must comply with the customer dictates.

Reason: Most changes are manufacturing impact lead-time "driven."

In many manufacturing companies, the material cost is two thirds or more of the product cost. In most operations the material lead-time is most often the pacing item and the material status is a very dynamic picture. Sample your changes and see if this typical condition isn't true for your changes.

If it isn't true for you, then figure out what is "driving" the effective point and place the responsibility accordingly. There are companies who do not fit this "norm." Casting or molding companies might have the mold revision time as the typical "driver" of the effectivity. In this situation, the mold design or build group might be the best place to set effectivity.

If you fit the norm, place the responsibility in manufacturing, probably in Production Control. If you are one of the growing group of companies who buy all the components and parts for the product Purchasing might be the logical function. Many operations have moved to the "buyer/planner" combined responsibility. If you are in this category the Planner/Buyer is probably the natural place for setting effectivity.

Rule: Production Control or the Planner/Buyer will be responsible for setting the effectivity plan, tracking that plan, revising it as conditions change, and capturing the actual effectivity after implementation.

Reason: In most companies, the Planner/Buyer function is in the best position to analyze all the material related factors on a continuing basis.

The current stock, in process, on order, in MRB (Material Review Board), etc must all be considered. Supplier deliveries over or under the order quantity affect the plan. The lead-time changes, cancellation charges, schedule changes, etc., are all part of many change effectivity decisions.

Rule: The same function that sets effectivity should be responsible for implementing changes and tracking the change to determine the actual effectivity.

Reason: In order to track the change to its effective date or unit the same elements must be tracked as are needed to properly set effectivity of the change.

It seems to this writer that it is a natural fit. Most companies "let the change happen." When the team is asked "Who is responsible for implementation?" no hands are raised. The engineering document control function releases the change and the revised documents and they close the change (file it away). Each affected function makes their portion of the change "ad hoc." Tracking the change often doesn't happen. When problems occur, the troubleshooting effort is extremely difficult and spare part replacement becomes a "pick and try" process.

The Effectivity Pipeline

Most changes are not dictates from the customer or real safety issues. However, the engineer still wishes to indicate when he or she thinks the change should be "cut in." When a date is used many folks don't understand what that date "means." If a date of 1 August is set on a purchased item is that the date the buyer will place a revised PO? Is it the date that the supplier will cut in the change? The date the revised item is to be shipped? Received? Dates alone are not very specific.

A very good method for this communication is by the use of the Effectivity Pipeline on the ECO form. A "check" on the pipeline would indicate that the change would be cut in at that point and in all earlier units/points in the pipeline. An example for the Loader Company would look like this:

X - Next customer order
X - Next Purchase Order
X – At Receiving Inspection
X – Issue From the Warehouse
PC ✓ X - In Assembly
E ✓ X - In Test
X - In Run In
X - In Finished Good Stock
X - In the Field

In this case the engineer put an "E" at the point expected that the change should be cut in. The further down the pipeline, the higher the implication of urgency. Some companies try to get at this issue by classifying changes as mandatory, routine, etc. Examination of the pipeline method of communication will show it to be much more precise. Production Control has indicated the point of effectivity chosen with a "PC." This gives a running record as to differences between the engineer's expectation and PC's plan. The engineer should be on the ECO cover sheet distribution and can take exception (if necessary) to what manufacturing is planning. CM should resolve any such issues raised by the engineer.

Any parts list change would be effective upon issue from the warehouse because that is how most MRP/ERP systems are designed. Each kind of change can be described in an effectivity date planning standard. Then the pipeline is not needed on the ECO. The pipeline information is, of course, somewhat meaningless without the effectivity date plan and the disposition of old design parts.

Disposition Old Design Parts

Each old designed part should be dealt with on the ECO form. Companies that do not make a conscious decision on each old design part are unconsciously increasing their excess and obsolete part inventory. It is therefore, critical that the disposition plan be shown on the ECO form. Those companies that do not address this issue change by change generally have a "bone pile" of down level material they "will someday figure out what to do with!"

The engineer also needs to indicate what he/she wants to happen to the old design parts. The typical way of doing this is to indicate for each old design part:

- Scrap
- Rework-able
- Use as is
- Return To Supplier

At many companies, the engineer is not in the proper position to decide whether or not to rework. This decision is probably better left to manufacturing based upon the economics of rework, how urgently the part is needed and other costs that might cause them to rework even if that is more expensive than a new part which won't be available for some time.

Rule: Have the engineer indicate whether or not the parts are rework-able. Let manufacturing determine whether or not to rework.

Reason: The resulting costs will probably reside in manufacturing and they would be in a better position to determine the economics of rework.

Thus the indication on the ECO form should be:

- Scrap
- Use as is
- Return to Supplier
- Rework-able
- Manufacturing To Rework

The Manufacturing Engineer or Industrial Engineer would inform Production Control as to whether or not they choose to rework. The "Return to Supplier" category is often not included as a disposition choice. It is assumed that if a purchased part is involved then someone will take care of the old designed items. You all know how assume is spelled! Have the engineer and the team address this issue change by change.

The same person who is responsible for the effectivity setting should be responsible for determining how to dispose of the old design parts. Some companies indicate on the ECO form the specific quantities to be scrapped, reworked, etc.

Effectivity Planning

Plan the effectivity of all product changes (class I or II) generally by date. The planned date should be entered on the ECO form when it is first processed. Subsequent changes to the plan (as conditions change) should also be noted on the ECO form. If a specific effectivity is required by the customer (and properly negotiated) then this effectivity should be specified (by engineering) on the ECO.

In order to establish which units have the change (Traceability or "Status Accounting") the change must be tracked to implementation in the product.

Rule: When the change has been implemented Production Control will notify CM of the actual effectivity.

Reason: CM must know when all product changes are effective and must notify all others who need to know.

Whether you are on line or in hard copy made, the best way for this communication to take place is probably by copy of the ECO cover sheet.

An email would be acceptable if all who need to know are on line. The actual effectivity needs to be precise on class I changes but can be approximate on class II changes:

- Class I (not interchangeable) must be traced to serial number, order number, lot number or other "Mod" identifier which is "unit exclusive." That is, one must be able to look at a unit and see from its serial number, order number, etc., whether or not the change is present.
- Class II (interchangeable) need only be traced to the date they were implemented on the production floor or received from a supplier. Should it become necessary in the future to more closely identify which changes do or do not have the change, this can be done with this date.

The cost of tracking each change to every specific unit is expensive. In most companies, the majority of changes are class II. Sometimes 70 to 90 percent are class II. By exactly tracing class I and approximately tracing class II, the wheat is sorted from the chaff and tracking cost is minimized. Keep in mind that these rules change significantly when Agency "critical items" are involved. Any changes to those critical items must be treated as class I.

The date that every unit ships, regardless of its change content, needs to be known in most companies.

Rule: The date that each serial number (or other code) is shipped needs to be known for warrantee purposes. Manufacturing is responsible for capturing this data and making it available to all who need to know.

Reason: The company needs to know the date the warrantee starts.

Knowing the class II effective date and the date each unit was shipped allows traceability to approximate serial number should it become necessary. Since class II changes are interchangeable, and our methods for determining interchangeability are sound, this will seldom be necessary.

Typically the Shipping Department would be responsible for capturing the date each unit is shipped. They would make a list (or input to the database) the date each serial number (or code) is shipped. This database

might also be expanded to show the ECO numbers, Mod, lot #, etc., in order to make the traceability (Status Accounting) data most available.

Effectivity and the Parts List

In your MRP/ERP system, the BOM module probably has fields for effectivity of parts list changes. These changes may either class I or class II. Just because there are part numbers added, deleted or changed doesn't mean that the change is non-interchangeable. The typical Engineering Parts List should look somewhat like the one for the FEL - 100 in Ch. 2.

Remember the "IN" and "OUT" date columns? These would typically be used for the date of effectivity. Most MRP systems are programmed for this to be the material issue date. Thus the old designed part would cease to be issued from stock on the effective date (shown in this text as week numbers for simplicity) and the new designed part would begin to be issued on that date. The ECO number which made the change should be shown as a reference (common thread, if your MRP/ERP system allows). The original release date of the item also shows in some systems. Thus, if we take a look at these columns in the current week (say week 48) we see:

FN	Description	Part Number	Qty	UM	In Date	Out Date	ECO #
4	Tire, Small	42345602	2	ea	wk12	wk43	256
4	Tire, Small	42345604	2	ea	wk43	wk51	281
4	Tire, Small	42345605	2	ea	wk51		

The original tire called out in this parts list was the -02 part number. It was initially released on week 12. ECO #256 made a change to delete the -02 in favor of the -04 part number. That change was actually effective on week 43. The next change is designed/planned (remember we are in week 48) to be effective in week 51. That change is being made by ECO # 281. It will change the small tire to the -05 part number.

The BOM/Parts List effectivity dates thus becomes key in knowing the "as designed" (or "as planned") configuration as well as the "as built" configuration with regard to all parts list changes. If your company doesn't have an MRP/BOM system, then another method needs to be devised to track the design/plan, and actual effectivity of all parts list changes.

Effectivity / Make to Order

In make to order environments, another method used for setting effectivity is by order number. That is, a decision is made to have any given order with or with out the change. This typically works fairly well. The MRP/ERP system should be able to "attach" a BOM to a specific order. An "order related BOM capability" is desirable if that method is used. In the same sense the effectivity of non parts list changes can be traced to the order by logging the ECO Number in the folder that typically accompanies each order.

Use of this method doesn't take one important condition into account, however. The material on hand and/or on order doesn't always match the order quantity. For a variety of reasons, the material status reality may call for effectivity within an order. Probably planned by date. Make to order companies need to address this issue during their change process planning. A method for tracing class I changes to the exact unit will also be required. More later on methods to do that.

Effectivity / Batch Manufacturing

Some companies are very batch or lot oriented. Planning is then done on a lot number basis. If the MRP/ERP system has "lot number control," the timing of the lot (and all the related parts) can be managed via the system. When the material planning doesn't match the lot, the lot may be split into two parts so the effectivity can be traced to complete lots.

Sequencing Changes

The question always arises, "Does the order in which changes are incorporated have to match the order of revision level change of the document?" The answer is, quite simply—no! Many companies force it to match, however.

In the above Small Tire parts list change analyze the following scenario:

> If another change (ECO 290) to the same parts list is made the next day to a different find number, and is truly independent of the tire change, it could be effective earlier than week 51 (say week 49). So the independent changes can be effectivity sequenced by use of the effectivity date in MRP/ERP. The revision level of the assembly for ECO 281 might be rev J while the later ECO, effective earlier, is rev K.

This is a concept that those people and companies who are "rev fixated" will have a difficult time understanding. They believe that changes should always occur in revision sequence because that is normally what happens. They typically want to change the revision level in effectivity sequence and often "roll the revision levels" up through the structure to the top level and even expect to be able to identify the top level by a part number and revision. They would typically want Document Control to re-sequence the revision level changes to be "progressive" in time. This is a form of insanity. It assumes that all parts list changes are non-interchangeable and thus need to be tracked to the specific end unit. Certainly in the changes made to Find Number 4, Small Tire, some or all might be interchangeable. We can, and will, explore better ways to trace changes later.

The following approach, presumes that good interchangeability rules have been followed and that all revision level changes represent interchangeable changes. It also presumes that the changes are truly independent. If the changes are dependent—ECO #2 must be present before ECO #4 can be installed—then the dependency must be noted in the later ECO and the effectivity and revision levels must be in sequence.

Lets take a look at a set of independent and interchangeable changes to the same part. For example, the changes to the loader bucket (52345601) might be done as follows:

ECO #	Revision	Description	Effectivity
228	A	Release for Production	Not Applicable
220	B	Side Plates Thicker	Week 27
301	C	Cleaning Spec Change	Week 12
280	D	Tooth Profile CNC Change	Week 20

The ECO numbers were assigned as requested and the changes were approved and incorporated in the master document as reflected in the Revision sequence. Thus the ECO number order is not in the Revision

sequence. Notice that the ECO number order also bears no significance to the order that the changes are to be made effective. Nor is the order in which the drawing is revised the same order the changes will be effective in. The fact that this conditionsometimes occurs is further reason for saying that the revision level refers to the document—not the parts. It is also further reason for not marking parts with the revision level.

Rule: The order in which the Engineer thinks up the changes; the order in which the changes are incorporated into the master drawings; and the order the changes are made effective; need not be the same.

Reason: Attempting to make them the same, creates unnecessary constraints on the process and on the documentation.

This condition is managed successfully in some companies who follow good interchangeability/part number changing rules. The order of incorporation is managed by dates on the ECO, not by drawing revision level. The production process sheets, the supplier/purchase orders, etc., all "speak to" ECO effectivity. All drawing changes are separable by examining the revision block of the drawing and the ECO. They are therefore separable in time.

Since the sequencing issue is not typical but unusual, many companies merely write/revise the ECOs as necessary to make the revision levels match the effectivity sequence. Some use a "deviation" to flag/allow the sequence to be out of order. A few companies merely state in their change standard that out of sequence is allowable as long as the ECOs properly state the sequence. In the above scenario, the ECO must be sent to the supplier so they will understand the sequence in which they are to incorporate the changes. ECO's should be sent to the suppliers affected in any event.

Tracking the Change

In the above example Production Control (PC) must monitor the schedule, availability of the -05 tire as well as the stock status of the -04 tire. They must be aware of the customer's wishes as expressed on the ECO. If the plan date must change, they will notify CM who, in turn, will change the week 51 date to the latest plan in MRP/ERP and on the ECO. CM should also make sure that the date change doesn't violate the intent of the customer. When the change actually becomes effective, PC should place the actual date or serial number on the ECO (on line) or transmit the actual

date or serial number to CM for placement on the ECO. This is "closing" the ECO. If a database is maintained that would tell us the effectivity by ECO number, then it wouldn't be necessary to place the effectivity on the ECO itself providing the database is readily accessible.

Production Control should also follow class II changes that do not affect the parts list. The date to be used must be defined. The definition of the date might vary depending upon whether the change affects a supplier, the fabrication department or the assembly department. The actual date effectivity should be "sent" by Production Control to Configuration Management or to a database. CM would enter this date on the ECO and redistribute it if necessary.

Production Control should also follow class I changes through production until the actual Serial Number(s) affected are known. Depending upon where the serials are assigned, manufacturing may have to attach tags (identified by the ECO number) to the changed units in order to trace to the specific units that have the class I change. This would be done until manufacturing was confident that all the old design units have been "flushed" from the floor.

Another method used is to change the product date code or suffix on the day that the change is actually effective. Another is to affix a "Mod Letter." These "Mod Letters" are assigned to class I changes. The convention might be to add the letter when the change is present or to "scratch" theletter from a preprinted label. Each non-interchangeable change is assigned a letter. A "scratch ticked" is attached to the product. When a change is incorporated into a unit the appropriate letter is scratched. Mod scratch ticket:

A B C D E F
G H J K L M
N O P Q R S
T U V W X Y

The advantage of the scratch ticket method is that changes do not need to be forced to occur in sequence—all units have change B before change C is installed, etc.

The tracking method used is not important, providing it works for your company. All methods have issues, pros and cons associated with them. The method chosen needs to be carefully thought out and documented in a company standard. CM and Quality Assurance must monitor this process to make sure that it works—all the time.

Status Accounting (Traceability)

Simply put, "Status Accounting" is to know what is in the product. During design and production we discussed how the "as designed" and "as built" configurations can be determined. Given an ECO number, the effectivity was tracked to the date or serial. Sometimes a customer problem is immediately and directly related by the engineer or service person to a specific ECO. Thus the actual effectivity should be on the ECO.

Usually people have "problems," however, not "ECO numbers." Thus, the need arises at most companies to have access to this data by other than the ECO number. Given an assembly part number, product SN, date code, mod code, date of manufacture, or a failure symptom, how do I know what is in the product, at least with respect to class I changes? The reports generated to fulfill this need are called Configuration Traceability Reports.

One of the most common configuration traceability reports is the Illustrated Parts Catalog (IPC). In this publication the parts and assemblies which are spared/field replaceable have been pictorialized and listed. All changes to those field replaceable items part numbers are shown by part number with the corresponding effectivity. Thus, the data is retrievable from the standpoint of a "person with a problem" using the IPC. Over time, the maintenance manuals also become a configuration traceability report based on failure mode.

Companies that are SN tracking often need a change database/report by SN. Thus when a customer has a problem with a specific unit, the class I change content is at the fingertips.

Many times, companies develop special "traceability" reports for special purposes. These reports are far too numerous and unique to discuss here. There are, however, four significant questions that need to be asked before such a report is devised:

1. Is this report needed because the Illustrated Parts Catalog or Maintenance Manual is not timely or up to date or is prepared by "someone else?"
2. What changes will be included in the report? Class I, class II, all part number changes?
3. Will the report be done for the product only "as shipped" or will field change incorporations be fed back and included?

4. If field changes are not to be included, is there another report and a redundant database that tracks changes made to field units?

Thus, Status Accounting is simply defined as: Knowing what is in and planned to be in each product by ECO Number, date, serial number, lot number, "mod" or other code to the extent necessary for your kind of business and your kind or product.

Change Modeling and Testing

Most companies produce a prototype model of every new product. Many, pilot produce several units of each new product. When it comes to design changes, however, this practice is often not required or assumed to be part of the design task. As a result, many changes get modeled and tested for the first time on the production floor or in the field. The results are often disastrous. Almost every company has horror stories to tell about such changes. Some companies aren't even clear about modeling new product options and features. Yes, the modern CADs do three-dimensional modeling on line but is that enough on all changes?

Certainly most class I changes should be physically modeled and tested. New features and options should probably all be modeled in hardware. Perhaps class II changes at some companies should also be modeled in the lab. Each company needs to address their policy in this critical area.

If practical, a production unit should be used to model and test changes. This will avoid problems resulting from differences between engineering's lab unit and the latest production unit. The pertinent questions about the tryout of the change should be noted on the ECO form. What serial number was modeled? What date was it tested? What was the report number or page in the engineers note book where the results were recorded? Who performed the test?

This information should be required on the ECO form prior to technical release of the change to CM. That is, prior to the "engineer complete" point in the change process the testing required must be completed. This places the responsibility and the process time where it belongs —in the design phase.

A concern always exists that the change time will merely shift from the CM and implementation phases back to the design phase. That the total change process time will go up. The only measured process changes of this

sort, that this writer has witnessed, showed improvement all around. The parts and the whole of the process time decreased when modeling and testing requirements were inserted into the design phase.

Cover Sheet Revisions

The cover sheet, by standard, will change due to changes in the effectivity planning and due to corrections in the change impact. Such changes need to be tracked in some manner. A cover sheet revision date is necessary. The choice of a date as opposed to a number or letter is to avoid confusion with the drawing revision.

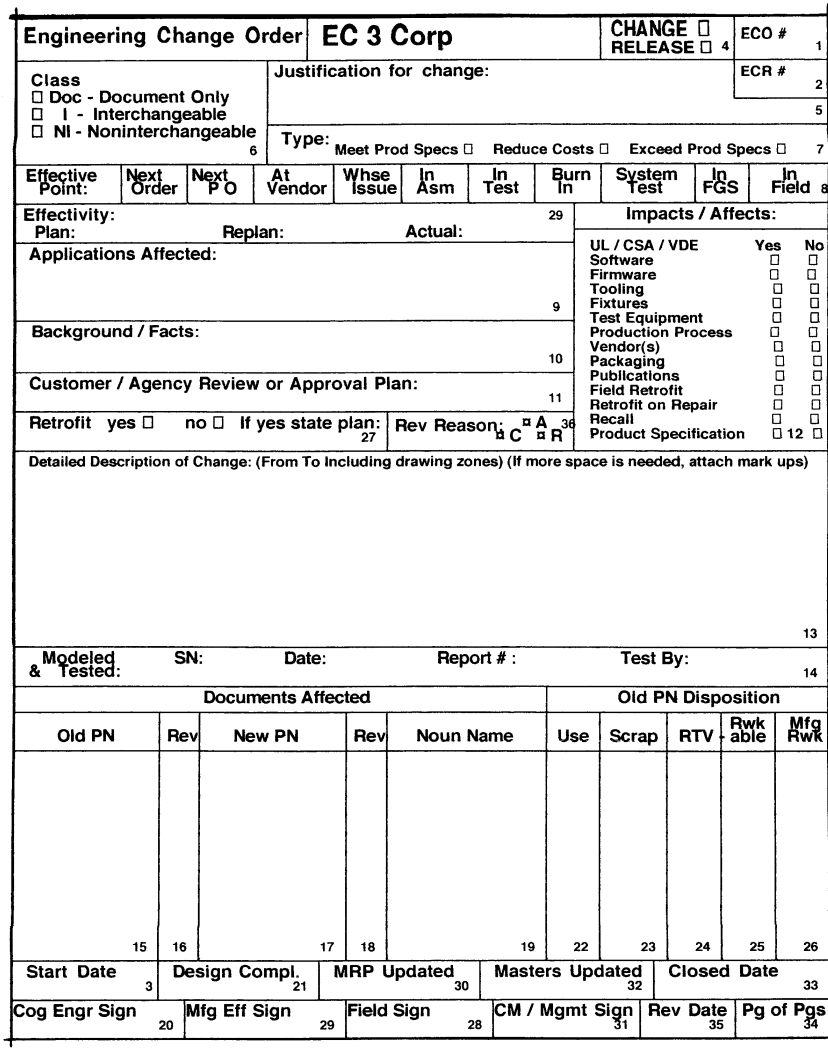
Notice that this is not intended to allow changes in the technical design of the change to the product. "Changes to the change" are, as you will see later, to be avoided and will be measured separately.

Change Forms

The Request for Change forms have already been shown and discussed in the chapter on change requests. As previously discussed, combination of the request form with the change form can contribute to a compulsion to process a request as if it were a change. For that reason, keep them separate. Combining the release and change forms, however, seems logical. This is because many of the "questions" asked for each form are common. It is also logical to combine them because many changes include the release of a new item/document.

The form designed for the Loader Company is dual-purpose and looks like Fig. 10.8. This form combines all the good features that the writer has witnessed in any ECO form. Some of the features may not be applicable to your company.

Notice that this ECO form has all the blocks necessary to make it applicable as a release form as well as a change form. All of the features discussed under change control are present. A release or change involving more than a few line items would require a continuation sheet. Such a continuation sheet would have the same headings as the "documents affected/Old PN Disposition" section of this form.



Engineering Change Order | EC 3 Corp | CHANGE ☐ RELEASE ☐ 4 | ECO # 1

Class
☐ Doc - Document Only
☐ I - Interchangeable
☐ NI - Noninterchangeable 6

Justification for change: | ECR # 2 | 5

Type: Meet Prod Specs ☐ Reduce Costs ☐ Exceed Prod Specs ☐ 7

Effective Point:	Next Order	Next P O	At Vendor	Whse Issue	In Asm	In Test	Burn In	System Test	In FGS	In Field 8

Effectivity: 29
Plan: Replan: Actual:

Applications Affected: 9

Background / Facts: 10

Customer / Agency Review or Approval Plan: 11

Retrofit yes ☐ no ☐ If yes state plan: 27 | Rev Reason: ☐ C ☐ A ☐ R 36

Impacts / Affects:

UL / CSA / VDE	Yes	No
Software	☐	☐
Firmware	☐	☐
Tooling	☐	☐
Fixtures	☐	☐
Test Equipment	☐	☐
Production Process	☐	☐
Vendor(s)	☐	☐
Packaging	☐	☐
Publications	☐	☐
Field Retrofit	☐	☐
Retrofit on Repair	☐	☐
Recall	☐	☐
Product Specification	☐ 12	☐

Detailed Description of Change: (From To Including drawing zones) (If more space is needed, attach mark ups) 13

Modeled & Tested: SN: Date: Report # : Test By: 14

Documents Affected | Old PN Disposition

Old PN	Rev	New PN	Rev	Noun Name	Use	Scrap	RTV	Rwk able	Mfg Rwk
15	16	17	18	19	22	23	24	25	26

Start Date 3	Design Compl. 21	MRP Updated 30	Masters Updated 32	Closed Date 33

Cog Engr Sign 20	Mfg Eff Sign 29	Field Sign 28	CM / Mgmt Sign 31	Rev Date 35	Pg of Pgs 34

Figure 10.8. Change form

Form Instruction - ECO

The next step is to develop a form instruction for the change use of the ECO. Notice that the ECO form has tiny numbers in each block. Those reference numbers will facilitate a form instruction. The Loader Company's form instruction would appear as follows:

PURPOSE

To define the information required to successfully complete the ECO cover sheet. To define the functions responsible for completion of each form block. **The form instruction is <u>not</u> intended to show the sequence of process steps—see process flow diagram for sequence.**

POLICY / PRACTICE

- The form is designed to accommodate the "One problem, One fix, One ECO" policy.
- All engineering changes must have an ECO form as the cover sheet.
- This form must be completed on line or with a black pencil.
- It must be accompanied by the applicable marked prints, specifications, new drawings, "make from drawings," etc which completely define the change to the product and its design documentation.
- CM may cut and paste marked prints to smaller than actual size as long as the Part Number and current revision are identified.
- The change may be described with "from - to" detailed descriptions if that can be completely done in the Description Of Change field of the form. If not, then the marked up print technique must be used.
- Reference Numbers (#) may not be in the sequence completed. For proper sequencing, see the Flow Diagram.
- People other than the Cognizant Engineer may initiate or help complete the form but the responsibility for the accuracy of those blocks called "engineer" remains with the Cognizant Engineer.

PROCEDURE

Responsibility **Instruction**

Cog Engineer

1. Leave blank. Doc Control will assign an ECO number after receipt/check.
2. If there was an ECR that preceded the ECO, enter its number here.
3. Enter the date that you first realized that the problem beingfixed was significant enough to warrant change. (If an ECR preceded the change, enter the date the ECR was accepted.)
4. Check Release if document(s) are being released (see standards). Check Change if document(s) are being changed. Check both if the change includes release of document(s). If the ECO is a "pure release" then boxes 2, 6, 7, 10, 11, 13, 14, 15, 16, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32 & 36 may be left blank.
5. Justify, in the space provided, why the change is necessary.
6. Check the correct class. One check allowed. See interchangeabilitystandard.
   a. If the change is a "Doc Only" then boxes 7, 8, 12, 13, 17, 18, 22, 23, 24, 25, 26, 27, 28, 29, 32, 33 & 36 may be left blank.
   b. If the Change is "interchangeable" then boxes 14, 27 & 28 may be left blank.
7. Check the type of change. More than one check is acceptable.
9. Enter the product or model number(s) that are to be changed. It is acceptable to say "All used on as of report attached/dated _____"
10. Give facts/background about the number of units that have failed, field population, customers affected, etc., Safety issues. Time/costs tobe saved. Attach relevant documentation.

11. Is customer/agency approval required? Review? Not applicable? If approval is required has it been obtained? If not obtained should the change proceed or be held for approval? If review is required has a description of the change been sent?
12. Review the impacts list and check each line, either *yes* or *no*.
13. If space provided is adequate for complete From – To description of the change do a detailed description here. Include drawing zone for each document change.

    Example: In zone C - 2 length dimension changes from 14.000 in to s tolerance from + or - .006 to .003. 100.

    If space provided is not adequate, attach neatly marked up prints or specs. Mark up of a released Engineering Parts List is allowed and encouraged. (See marked print standard). Any combination of "From – To" or marked prints is allowed.

    The Cognizant Engineer must obtain the Manufacturing Engineers signature on the "From – To" in block #13 &/ or on the marked prints attached to the ECO.
14. For those changes which must be physically modeled and tested (see ECO policy), indicate the SN modeled, the date it was tested, the report number/notebook page(s) that the results are shown in and who performed the test.
15. List each document being affected by the change. If a marked parts list is attached enter "Marked PL attach." (Document Control will either enter boxes 15, 16, 17, 18 and 19; or will attach an "Old PN Disposition" to the parts list; or allow Production Control to add the part disposition to the PL markup.)
16. Show the current revision level of each part number/ document affected by the change.
17. If parts/documents are being released, show their numbers here. If a part number is changed, show the new part number opposite the old number.

18. Show the revision level of each new part number (rev numeric for pilot release, rev alpha for production release).
19. Enter only the noun name of the item being revised or released.
25. Indicate whether the old PN can physically be reworked into the new PN.
27. The Field Service Engineer and the Design Engineer agree on the retrofit plan (on repair, on failure, at next maintenance or recall, etc.)
28. Obtain the Field Service Engineer's signature on the form. (If retrofit is proposed.)
34. Complete according to the total pages in the set. Number each page accordingly.
20. Sign the form.

Cog Engr/Doc Control

21 The date you give the form to Document Control. (Doc Control is authorized to up date this box to the actual date received).

Document Control

1. Check the form and attachments according to the check list standard and all other applicable standards. If OK, assign ECO #. If not OK return to the Cognizant Engineer with specific deficiency notations. Distribute the cover sheet to all potentially impacted/affected (whether checked *yes* or *no*).

All Impacted

12. All on the list, whether the engineer checked yes or no, must take ownership of the check accuracy. If the check is not correct, contact Doc Control to correct the check. One day will be allowed by standard. If affected "yes" notify Production Control of the lead-time in work days to perform the work required—one additional day will be allowed by standard.

Production Control

22. The quantity of the old design part to be "used up/used as is."
23. The quantity of the old design part to be scrapped.
24. The quantity of the old design part to be Returned To Vendor (RTV).
26. The quantity of the old design part to be actually re-worked.
8. Circle the point in the manufacturing process at which the change will be made effective.
29. Plan the effectivity date for the change. Also responsible for following-up on that plan, changing the plan as required by entering a "re-plan" date, and capturing the actual date (class II) or unit Serial number (class I) on which the change was incorporated into the product. Sign the ECO after all the responsible boxes have been completed.

Document Control

30. Input all the required changes and additions to the MRP Item Master file and BOM file **for design data elements only—including the effective date.** (Screens A & B in the MRP.) Enter the date complete.
31. Sign the ECO and distribute the cover sheet to all affected (checked "Yes" in box # 12).
32. Update all the master documents/files affected by the change, checked by a different person than did the change incorporation. Enter the date completed here.

Document Control

30 Enter the actual effective date in the MRP from the master ECO box # 29. Enter the date that this action is completed.

35. Change the Rev Date each time the effectivity or any other element of the form changes. Redistribute the ECO (cover sheet only) to anyone who needs to about the revisions.

36. Categorize each new ECO and each revision to an ECO as follows.

    C = This ECO is a Correction of the design (From - To or mark ups) in an earlier ECO.

    A = An Administrative change to effectivity plan, impact yes—no checks, etc., after box # 31 distribution.

    R = A Redesign of the fix (From - To or mark ups) after completion of box # 21. Redistribute the cover sheet to all affected—"Yes."

33. Assure completion of the actual effectivity and any other activity required to close the ECO. Enter the date closed here. File the master package by the ECO #.

Notice that the form is complementary to the "closed loop process." That is, the feedback to CM of the actual effectivity (and other activities) and the distribution of that actual effectivity is closing the loop with all who need to know.

It is useful to have a colored blowup of the form instruction for training purposes. The colors would correspond to the functions responsible for completing the block(s).

Every form must have a form instruction and the ECO form is no exception. Writing a form instruction will reveal problems with the change process and/or the form itself. The form and its instruction are a keystone in the change process.

Facts Data Base

An important element in making good decisions about the engineering change form or process is to have hard facts available. Decisions to improve the process will be easier to make and more productive with the "facts in a bank." What percent of your changes affect the BOM? How many affect parts that you purchase? How many changes were checked class II? What portion of the changes affected the parts list? How many line items are typically affected in a parts list change? How many documents are affected by the average ECO?

CM people tend to believe that they are so close to the changes that they intuitively know the answers to these kinds of questions. Many are quite

surprised to find that their intuition wasn't as accurate as they believed. Better to get the facts, especially since it is not a huge task.

List all the questions that you or others would like to know about your changes. Sample your ECO forms and packages from the last six months or year. Ask your Quality Assurance folks what size sample you need to be "representative." A ten percent sample will probably do. Take care to pull the changes at random. Make a matrix on your PC. Review each change and answer all the questions listed. As you do the first few, you will think of other questions that can easily be asked and answered. Summarize the results. Publish the results. You will become the resident expert on changes.

This "facts bank" will be used frequently as you or your team to constantly improve your system. Launching "improvements" without the ECO database is a risky process

Cultural Change

Without a doubt, the hardest change of all is the cultural change. Most companies understand that even the best new product development processes do not eliminate the need for changes. Most companies also have processes that assume that all changes are worthwhile. This mind set develops early in the company's/product's life, when almost all changes are necessary. The attitude is that change is necessary and that, therefore, all changes are necessary. Later in the company or product life, however, many changes are not necessary. The top-level management and all the teams must come to realize this fact.

11

Fast Change

Almost all companies have some kind of a change form. Some have a documented process. ISO 9000 requires a documented process and that you follow that process. ISO and other standards don't care about the speed or the efficiency of the process. DoD and some other agencies seem to find ways to slow the process. Witness that the change approval time for DoD is measured in months. When asked "Why is process speed important?" The answers are much too vague. People obviously haven't thought about the question!

Why Process Speed is Important

How can the process speed be important? These processes are "just paper pushing," how can speed matter? Other than saying "time is money," what specifically in fast processes contribute to improved profits?

Perhaps the best way to answer these questions is to ask some more questions. It is a good idea to have 20 minute meetings with the people involved in the process and ask them to brainstorm why speed is important! The questions to ask:

- How fast / slow is the current process? Perhaps 40 days?
- Is there more than a few hours of "hands on time" to process a change?
- How fast might the process be? Perhaps 5 days?

- What happens during the 35 unnecessary days?
- What are suppliers doing? Building items that will have to be returned, reworked or scrapped?
- What is the shop doing? Building items that will have to be reworked or scrapped?
- What is assembly and test doing? Working on items that will have to be reworked or scrapped?
- Is the line or part of the line "down"? Do we want to keep it that way for 35 extra days?
- Will the change be retrofit? Will we ship 35 more days worth of product to be retrofit in the field or factory returned?
- What if the change is a real cost reduction? Should we ship 35 days worth of product at the higher cost?
- Did the customer request the fix or feature? Should we make the customer wait 35 unnecessary days to get it?
- Is the site down? Would you like to be the field service person taking the heat during 35 extra days?
- What is 35 days of customer good will worth?

Few companies (military or nonmilitary) have a fast process. Yet, this is where the rubber meets the road. This is where much of the economy is in change processing. This is the most significant strategy in the Configuration Management business. Let's review some of the reasons why speed is important in the change process:

- Customers see the change or feature they requested much earlier.
- Fix customer identified problems earlier.
- Reduce the amount of Manufacturing and Supplier rework and scrap costs.
- When retrofitting a change, speed reduces the number of units that Field Service will have to find, disassemble and fix. Fixing in the field is much more expensive than fixing in the factory.
- Incorporate real cost reductions earlier.
- Satisfy that frustrated production employee much quicker.

- Prevents the creation of a substitute process(s) and thus doing the change once "fast" and again "formally."

These are powerful needs! The dollars involved are staggering. What if the process is currently forty days long and we could magically implement a five day process. The customer sees the fix, feature or option 35 days sooner. Thirty-five fewer days of producing scrap or rework. Thirty-five fewer days worth of units that will have to be retrofit in the field or recalled. If we are truly saving $50 a unit after the pay back period multiply fifty times the units produced in thirty-five days. How much does it cost to run the change twice—once by the informal system and then again by the formal system. The savings would be enormous, and we might stagger the competition from the shock. And it is an attainable goal! Small, medium and large companies have attained three to five work-day CM process time, and while also shortening the Engineering and Implementation portions of the process.

The author has yet to visit a company that had significant change control problems that did not also have "bone piles" of down level material in Manufacturing. Material that was affected by changes. Material that needed to be reworked and put back into the process or scrapped.

Rule: The longer the change throughput time the bigger the "bone pile."

Reason: Every day, every hour, every minute that manu facturing waits for a change, the more units that are likely to be produced which have to be reworked or scrapped.

The typical production operation is oriented to producing new products. Thus, when the design change calls for rework, the tendency is to set them aside to; "rework when we're not so busy." Another change comes along that affects the same assembly. The change is implemented as quickly as possible and the units to be reworked are added to the pile. After a while it becomes a major project to sort out what work needs to be done to each unit. The inventory carrying cost of the "bone pile" is substantial.

If the part disposition turns out to be "scrap," how many units are built per day that will be scrapped? Would it be less costly to shut down part of the production line? Then what will the idle people cost the company?

How many Field Service Engineers or dealers take the heat from customers who are waiting (not too patiently) for a product fix? Is

manufacturing building more units to be field retrofitted, risking more unhappy customers? What is one unhappy customer worth?

If we have a true cost reduction, why build any more units than necessary at the higher cost? What is the cost of creating and maintaining one or more substitute systems? One to make a change fast and another to do it over again "by the formal system?" What is done then, if there are some differences between the fast fix and the formal fix? How shall we document the different configurations? Why don't we just do the change fast and right, the first and only time?

Based on informal polls, about five percent of those companies represented in our University Seminars have attained five work day CM throughput time. This gives them an enormous advantage over their competition. Attaining a single, fast, accurate and well understood process is easier said than done. There are, however some proven methods that will simplify and speed the process.

Measure the Process Time

The first step is to recognize the problem! If it is not known how long it takes to process a design change, then it is not known whether or not there is a problem. Nor is it known how serious a problem we have. Without measurement how can one tell if "improvements" in the process are working? Fewer than fifteen percent of the companies attending the University seminars (informal polls) even measure the process time change by change! The first step is to measure the process time:

Rule: Measure the process throughput time change by change.

Reason: It is necessary to know the throughput time in order to know whether or not there is a problem and the extent of the problem.

Many companies assume that the process time is reasonably fast. They are shocked to learn that the measured time if ten fold what they thought they had or would like to have.

Sometimes the documentation manager has measured the system and has a drawer full of data. That manager is often frustrated because no one else seems to be concerned with the slow process.

Publish the Results

An old Industrial Engineering axiom says, "measurement in and of itself tends to improve performance." Add to that axiom, "if the results are published!"

An example of a time and volume measurement report chart is shown in Fig. 11.1.

Rule: Publish the results.

Reason: Measurement, in and of itself, tends to improve performance if the performance is broadcast to those who need to know.

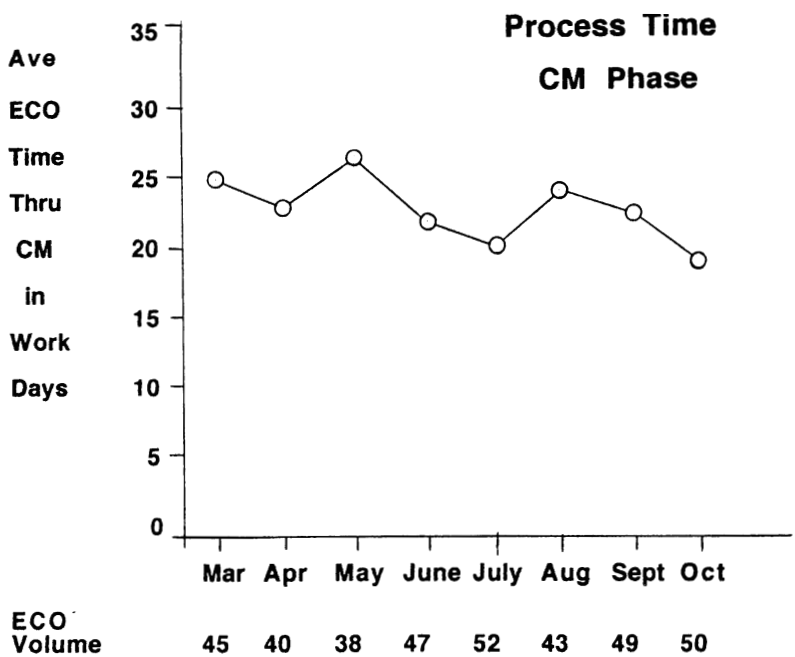


Figure 11.1. Typical process time graph chart.

This is team and process measurement, not an individual performance measurement. Therefore, it should not be embarrassing to publish the results. Measurement without publishing the results will probably not achieve much improvement. The throughput time should be graphed on a very large chart. A size of two feet by three feet might assure it is seen and considered important. Make several copies. Put one in the CM area, one in the cafeteria, and one outside the "corner office"—in small companies this would be the Presidents office; in larger companies this would be the Division VP or Plant Manager. You should include the VP of Operations and VP of Engineering. This also makes them part of the improvement process. Since this is a group measurement, not an individual measurement, properly introduced, it will become a team challenge to reduce the process time.

Rule: Educate those people who need to know why speed is important.

Reason: Understanding will lead to individual and collective ownership and action.

One Configuration Management manager measured the process, took some of this material and prepared a fifteen minute presentation. She gave it to all those involved in the change process and their management. She included higher level managers. The people responded by coming up with ideas of their own as to how to save time. Modest throughput time improvement was experienced without making any process changes. When she suggested a small process improvement team, the idea was welcomed.

Points to Measure

There are five significant points in the process to measure. Begin by measuring these most significant points. A few more points can be added later. Take care not to measure too many activities. The five most important points are shown in the basic flow diagram, Fig. 11.2.

The measurement of too many points tends to dilute the importance of the data and to confuse the issue. Too much data tends to increase the possibility that no one will read it. A CM manager with the "drawer full of data" extracted these five points from the data and published the summary information as described above. Eight work-days were taken off the CM and overall time as if by magic. That was their first step toward a best in class process.

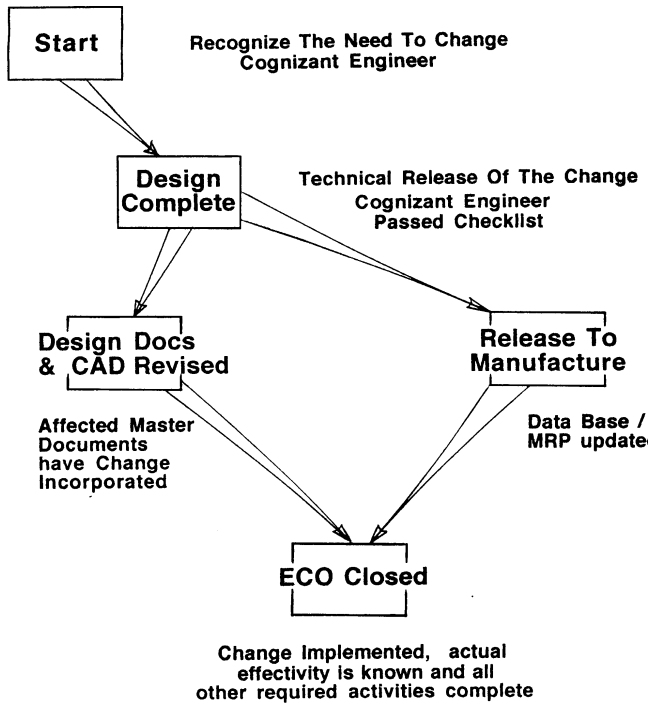


Figure 11.2. Five most significant points.

Your company may not have clearly defined points exactly as shown in this basic flow diagram. For the time being use the "closest" points in the existing process. The points are defined and discussed below:

START. Identify the time when the problem is first identified and accepted as a problem. This would be the change request "engineer accepts ownership date." That is the date the engineer agreed that there is a problem and agreed to task ownership of that problem. The first field failure or customer complaint might not be recognized as the start point. Ask when was the problem recognized? If no document exists, ask the engineer (on the ECO form) to indicate when the problem was first recognized.

DESIGN COMPLETE. This is the point in the process when the Engineer turns in the change into CM. Then CM completes the checklist that verifies it to be complete. (Was the change modeled and tested? Are mark ups per standard? Etc.) Put this date on the ECO.

This point can also be called "Technical Release." because it should be a point of no return (more discussed later). That is, the only changes after this point that will be made to the ECO package will be to administrative

issues—such as changes to the effectivity plan. After this point, the only way for the engineer to do the fix differently should be to process another change. This causes "deliberation" early in the process (where it should be) and results in more changes done right the first time.

You may not be able to sell this event as a point of no return in the beginning. Let that be a later step in your improvement process.

MRP/ERP UDATED. That point in the process wherein Manufacturing is released to buy parts, etc. This point is normally identified by the fact that the sign off is complete and CM input to the MRP / ERP is complete and verified to be correct. If we also have data to be down loaded to a CNC machine or other forms of CAM, this could be the date that transaction was completed (or whichever is done later). Put this date on the ECO.

DESIGN DOCUMENTS UPDATED. This is the date that all the master design documents affected by the change have had the change incorporated. This point should be done in parallel with the MRP / ERP update as a result of the change. Both that update and the design documents update must be completed prior to completing the CM portion of the process. Put this date on the ECO.

IMPLEMENTED/ CLOSE. The change is actually incorporated in the product. This point was captured on the ECO when Production Control advised CM of the actual effectivity. For "document only" changes this would be the date when CM completed incorporation of the change into the master prints. There may be other events that you would want completed prior to closing the change—revision of the Publications, writing of the Field Change Order, etc. When the last one is complete, close the change. Put this date on the ECO.

Don't wait! Measure the throughput time for these major events now! This step is a must, and it should be done prior to taking any other step. This is done in order to know if other improvements achieve the expected throughput time reduction.

Change Phases

Use of such events divides the primary responsibility for the process into logical parts:

- **Engineering Phase:** From Start to Design Complete
- **CM Phase:** From Design Complete until the MRP / ERP / CAM and Master Documents / CAD / PDM (whichever happens later) have been updated.

- **Manufacturing Phase:** From The later of the above to close of the ECO. This can also be called the Implementation Phase.

Although CM should be responsible for the process covering all of these phases, the management and the people should feel responsible for the execution of the change by change process. The throughput time reports can be distributed accordingly.

Revision of Masters

The best point in time to incorporate the change into the master drawings and specifications is a much debated issue. It is done by various companies in all three of the change phases! The following is a discussion about doing it in any given phase:

- **Engineering Phase:** Tends to be done by Design Engineering driven companies. Tends to make the "Engineer Complete" milestone a definite point of no return. This writer views this as an acceptable approach, providing;
  1. The team gets at least one review of the change prior to incorporation in the masters and another review if the team deems it necessary and
  2. If Design Engineering obtains other technical signatures before incorporation in the masters and
  3. The ECO precisely describes the differences between the old and new and
  4. Providing CM assigns the revision levels or has equivalent release phase control.

  Since the above is difficult to assure, the best process would make redlines by CAD or by hand in this part of the process and leave the incorporation of the change to the CM part of the process.

- **CM Phase:** Probably the most common approach. Tends to be required by companies using the part or assembly drawing on the production floor. Often the incorporation step takes so long to get done, many complaints are received from manufacturing. An edict by management result. "Do it before the MRP / ERP is updated" is the edict. This writer views that as a poor way to fix the problem. The incorporation drafting / CAD process took too long so the solution was to hold up the change until it is done. The solution should have been to find out why the incorporation was so slow and to fix that problem. The ideal process would have CAD redlines incorporated in the master (a few keystrokes) in this part of the process in parallel with MRP update. If old hand drawn documents are still in use, transfer the needed manpower to CM. They will give it the immediate attention it deserves.
- **Implementation Phase:** Some companies say that the CM phase is complete and implementation can begin when the MRP is updated. They generally require the MRP to be updated before the master documents. Is typically done by companies that have manufacturing process instructions used on the production floor and marked prints are sent to the supplier. They accept the "mark up" as an acceptable tool to update the process instructions. This writer views this as an acceptable (although not ideal) approach providing update of the master docs happens fast.

In fact, no matter where in the process the incorporation effort is done, the key is to assure that it happens fast. That is why it must be separately measured and reported. Two to three work days is a reasonable expectation. This function is often a trouble spot when it is not a CM function, it usually takes a back seat to new design effort.

Set Goals

The first part of the process—from "Start" to "Design Complete"—is very hard to generalize about. The writer has observed throughput times

from less than one week to ten weeks. People in our seminars have reported design time up to twenty weeks. If a DoD product involves an engineering change proposal with customer approval it would typically take several months by itself. This is not to say that this is a reasonable period of time, only that it is typical. Don't accept past history as a reasonable time for customer approval. For your company and your product however, identify a goal for this part of the process. Make a separate graph for this portion. Label the graph as Engineering Department responsibility.

In the middle part of the process, the activities must be thought of and treated together—from "Design Complete" to "Update MRP/ERP/CAM" or "Update Drawings/CAD/PDM," which ever comes later. Three to five work-days is an obtainable goal. The ability to hand carry in one half work-day is also important. Label this graph as Configuration Management responsibility.

Measure the revision drafting time separately. A reasonable goal in most companies is two or three work-days. Many companies have achieved this time whether they have hand drafted or CAD or both. Label this graph with the department responsible (preferably CM).

The last segment—from "Release" to "closed"—is also difficult to generalize about. This is paced by the "effectivity" of the change. Time (effectivity) can vary from "today" to many weeks. Thus a benchmark of implementation time is dependent upon your product and especially the materials lead-time. Even here, however, goals can and should be set. This measurement will present a benchmark for future improvement. Label this graph Manufacturing responsibility.

Measure Volume/Reduce Backlog

Next, measure the volume of changes. Measure not just the average rate, but several attributes:

- New problems (changes) per week (at "start")
- Count backlog in Engineering
- ECOs into CM per week (pass check point)
- Count backlog in CM
- ECOs released per week
- Count backlog in Manufacturing
- ECOs closed per week

These volume measurements can be obtained by keeping a "log" in your PC and counting the ECOs in process. Measure these volume figures for several weeks running to make sure that the numbers are representative. Then examine the incoming rate as compared to the outgoing rate.

Example: Lets say that the Loader Company has rates into and out of CM as follows:

- Into CM (pass check point) = 25 ECOs / week
- Out of CM (Released) = 21 ECOs / week

Conclusion: If this pattern persists over several weeks, we can conclude that CM needs long term help. Without help the backlog (and throughput time) will grow by 4 ECOs per week. The "help" can be, either to find a way to cut down on the CM workload or get more manpower into the function.

Reducing the CM workload can be done by adopting some or all of the ideas that have been previously presented, or ideas that are yet to be presented. Reviewing some of the ideas already presented:

- Eliminate excessive signatures
- Pull vs push distribution
- Cross train the process people
- Don't hold up the design change to include changes to manufacturing documents
- Don't hold up the design change to include changes to service documents/publications
- Queue changes only by the Cognizant Engineer
- Lack of a standard written process
- Making the same change by a fast process, then again by the formal process
- CM department lacks revision drafting responsibility
- Process time not measured
- Measurement not published
- Hold brief training sessions as to why speed (and accuracy) are important
- Separate the request from the change process clearly and crisply

- One function responsible for effectivity and implementation
- Require actual product modeling and testing of certain changes
- Limit customer approvals

Now examine the backlog and compare the results to the throughput time measured previously.

Example: During the same period of time, the backlog was about 125 ECOs and the incoming / outgoing rates were both at about 25 changes per week.

Conclusion: Five weeks worth of backlog should equate to five weeks of throughput time for CM. Check the throughput time measurement and make sure the throughput time is about five weeks through CM.

Conclusion: If the incoming and outgoing rates are about the same, the throughput time can be reduced by working off the backlog.

At one company, outside temporary help was used to reduce the backlog. The more effective method is to enlist other department people to work it off. Engineers, draftsmen, and technicians from all affected areas of the company are asked to come into CM and do a few ECOs apiece.

At another company the Vice President of Design was a volunteer working side by side with the other people asked to help. This was very effective, as it showed the other helpers and CM people how important the VP thought it was to have fast ECO throughput time. If the incoming rate exceeds the outgoing rate, however, reducing the backlog is a very temporary measure.

In many cases measurement of the time and volume (with the appropriate action to reduce the backlog) is all that is needed to reach the throughput time goals. A small medical device manufacturer cut its process time by one sixth, by reducing the backlog. In their case, measurement, reporting, setting goals, and backlog reduction was all they needed to achieve four work day average time through CM.

Often, however, these steps aren't enough to reach the goal. If prior steps have still not reduced the time to acceptable levels, then change the system.

Change the System

Before launching into any system change, especially if significant changes are contemplated, form an "Improvement Team." The CM Manager may feel and be competent for the task. Continuous improvement can often be brought about by the sole effort of the CM manager. Many times the improvements are met with objections from others involved in the process. The manager probably is capable of designing a fast system. This is not the issue. The issue will be to get key other functions to "buy into" the new system.

Rule: Before starting any system improvement program, get Manufacturing, Field Service, and Design Engineering to join CM in an "Improvement Team."

Reason: You want ownership in the new system by key functions. The team may be formally recognized or an "ad hoc" group.

Rule: Keep process improvement teams to no more than three or four people

Reason: Larger groups don't get thing done because they talk too much and present too many apparently diverse opinions. It takes too long to reach a consensus.

You might want Quality Assurance to join this effort. If they are not under the manufacturing wing, they should probably be added. You may not have a significant "service" issue with your products. One key person from each major function—no more. Too many cooks can spoil the broth! If CM is under the Design Engineering management, have CM represent the design group. This makes a working and workable size process improvement team. Each member is required to review standards with all the key people in their area of responsibility—personally, not by email or notes.

You may also want a Management Steering Committee. This group might represent some functions—finance, contracts, etc.,—not on the Improvement Team. If this group gets large it isn't necessarily bad—more buy-in. The Steering Committee should be chaired by a "Top Gun"—the President, VP, or GM. The Improvement team should report, about monthly, to the Steering Committee on progress and plans. Get the Steering Committee to buy into your goals. Keep the goal(s) fairly simplistic.

Example: Improvement Team Goal: Design one system which will be the only way to make changes to the product or its design documentation. Attain a seven work-day process time through CM in the next twelve months. Improve quality of changes and do this without increasing Design or Manufacturing time. Do this with the existing CM work force.

If you have a current committee of a dozen people/functions, turn it into a steering committee.

Missionary Leader

The leader of the design team must be a person with a high desire to improve the system. The zeal of a missionary is needed. Luke warm interest will assure failure. The CM manager may be the correct person to lead the Improvement Team. If the CM manager does not have a high desire for improvement, another person must be found. It would be best to have a management "champion" with the same missionary drive. The champion should be on the Steering Committee and probably chair that committee. Between them, they must have the aggressive desire to assure success.

Nine Steps To Success

The Improvement team should follow nine (not so easy) steps:

1. Define the current system
    - Gather any and all existing standards about the current system.
    - Gather all current forms and form instructions.
    - Assure that time and volume measurements and reporting are in place.
    - Analyze the current ECOs. Build a "facts bank" (database).
    - Make a flow diagram of the current system. This need not be "pretty," but it must be done. It will, educate the team, start the teamwork going and eliminate arguments later. Many a CM person has commented to me "I thought I knew my own system, but flow diagramming it opened my eyes!"

2. Flow diagram the proposed system

   - List all the legitimate inter-departmental operations that need to be performed. Break them down into their smallest parts. Don't put them into any order.
   - Identify required dependencies. Example: Can't get technical approvals until modeling and testing is complete.
   - Start each operation as early as possible.
   - Complete each operation when required by the dependent event. (Don't force completion of an operation any sooner than necessary.)
   - Do all possible operations in parallel.
   - Use all the "Rules" from this text that apply to your operation.
   - Last - place one "best responsible department" on each operation.

3. Define the proposed system in Policy, Standards, Form, and Form Instructions.

   Keep each to a single subject—should be three pages or less. See the next chapter for a discussion of best of the best standards writing practices.

4. The team must pre-sell the system.

   Have each team member review the proposed system with key people and management in their area of responsibility. Expect / invite constructive criticism. Iron out the rough spots. Re-sell as necessary.

5. Trial run system

   Using the Improvement Team, run a representative set of changes in parallel with the existing system. Debug the process and standards. Run another trial if necessary.

6. Get Steering Committee approval to try the system

   The steering committee and the "top gun" need to be cautious about over managing the team. Give the team leader the authority to proceed when the team appears to have reached a consensus and all major points of contention seem to be adequately resolved. The standards can be signed by the team leader for the pilot and later signed by the responsible Director or VP.

7. Pilot & train

   Use the Improvement Team to train key people. Have them pilot run a representative set (a few of each type) of changes by the new process. Don't stop training until all the people in the process have had an adequate exposure to the new system. Nothing can defeat a new system faster than people who haven't been properly trained. Expect criticism, and debug when it is constructive.

8. Implement

   Get Steering Committee agreement when the time has come to cut over to the new system. Pick a day and start all new changes by the new system. Let the old system changes "flush out." Don't expect immediate improvement. It will take 75 to 150 changes to see peak performance.

9. Follow up

   Assure that all the old methods of making changes have been "extracted," "killed" and "burned." Keep the Improvement Team and the Steering Committee functional until this has occurred and until you have met the goal.

Don't forget to have a party. It's a great accomplishment. The improvement team or the CM manager may continue to continuously improve the processes. Each step is critical. None can be skipped. Whether you make three or thirty-three changes to your system, the only way to assure success is to do all nine steps.

Bootstrap or Reinvent

The question often arises, "should I make small changes, big changes or reinvent the system?" A thorough analysis of a company's current processes, documentation and process time is required to answer that question. A rough guideline might be based on the CM process time:

Under ten work days	Improve the process in small steps
Ten to thirty work days	Look for logical batches of improvements that can be implemented together
Over thirty work days	Design a new process

This guideline is, of course, directed only at the change process. It presumes that a reasonable semblance of order exists in the Release, Request, and BOM processes. What priority is in order if two or more of the major CM processes are in need of improvement? That issue becomes very unique to particular company conditions. If the request process is long and intertwined with the change process, it may not be possible to address them separately. The BOM process is, of course, affected by the release and change processes. Attacking them all together is not the answer, however. Find a way to divide and conquer. Remember, you can and should come back to any part of any process again, to make continuous improvement.

The Improvement Team must keep the scope of their first project as small as possible. The management may feel that the entire system needs immediate help. The Improvement Team must take the smallest bite possible for its first step. This may be the request process, the change form, or an interchangeability standard. If there is to be an error made in this decision, better to err on the side of small improvement steps. Take small issues that are more easily agreed upon/sold first. Then move to the more difficult ones.

The most significant step to short process time, is to make the Flow Diagram. The flow can then be improved in small bites or in a whole. Before the new or changed process flow diagram is addressed, remember that many of the standards must be in place. Better to have the building blocks on site before starting the structure.

Fast Change Work Flow

If the Improvement Team has done its job, a complete and crisp flow diagram will result. The diagram will have one responsible function for each operation. It will show where key forms are originated. It will have a method for indicating where time measurement points are. (In the examples to follow, a miniature "clock" will be used.)

Join the operations with arrows. The tail of the arrow indicates the earliest point at which the operation can be started. The arrowhead into an operation indicates "dependency." The circle indicates the completion of the stated operation.

The flow diagram must normally be "backed up" by policy, standards, forms, and form instructions. That is, if the flow diagram has an operation that states; "New and Marked-up Design Documents" the back up might be:

- A standard which defines those documents that are Design Documents, Support / Service Documents, Manufacturing Documents, etc.
- New Document standard that defines how documents are to be prepared.
- Mark-up standard which defines the criteria for mark up.

In this fashion, few, if any, notes will be required on the diagram and no written "procedure" is needed.

Rule: Flow diagrams with supporting policy, standards, forms and form instructions are better than written procedures.

Reason: A picture is worth a thousand words.

This is critical! If there are many notes on a flow diagram, then one of two things are needed:

1. Subjects need to be standardized or the standards are not complete.
2. More operations need to be flow diagramed in order to depict the process.

Several iterations of flow diagram may be necessary to meet each process time goal. Each time a flow diagram is made, ask some hard questions:

- Can the operation be done in parallel with another operation that is now in series?
- When is the earliest point that the operation can be started?
- When is the latest point the operation can be completed/ what operation is dependent upon it's completion?
- Is there a single function responsible for the operation?
- Is the correct function responsible for the operation? This may not be the department that is currently doing the operation!
- Have provisions for skipping operations depending upon the class or type of change. Note that the Loader Company ECO form instruction (see Fig. 10.8) listed steps to be skipped in certain circumstances.
- Specify the standard process time expected on all the significant steps in the process. Get the management of the responsible function to agree with the lapsed time standard. Lapsed time allowed is generally greater than the actual time to perform the task. For example, inputting a change to MRP might, on the average, be an eight minute job, but you might allow three hours of lapsed time.

Work Flow Diagram

There is no more a "typical flow" than there is a typical company. A "make to print" company would have a different flow than a "make to stock" or "make to order" company. If your company is a combination of these types of businesses, you might have a unique flow with a more complex "skip steps" chart. Many features of the change system flow will be similar, however. In order to simplify the flow diagram discussion we will again use The Loader Company as an example. Remember that the Loader Company has no "three letter agencies" governing its business. It adheres to industry standards such as UL and ISO.

Engineering Flow

The "up front" portion of the process is the general responsibility of Engineering. It begins with recognition of the need to change, and ends with the Design Complete operation. The Loader Company flow in engineering is shown in Fig. 11.3.

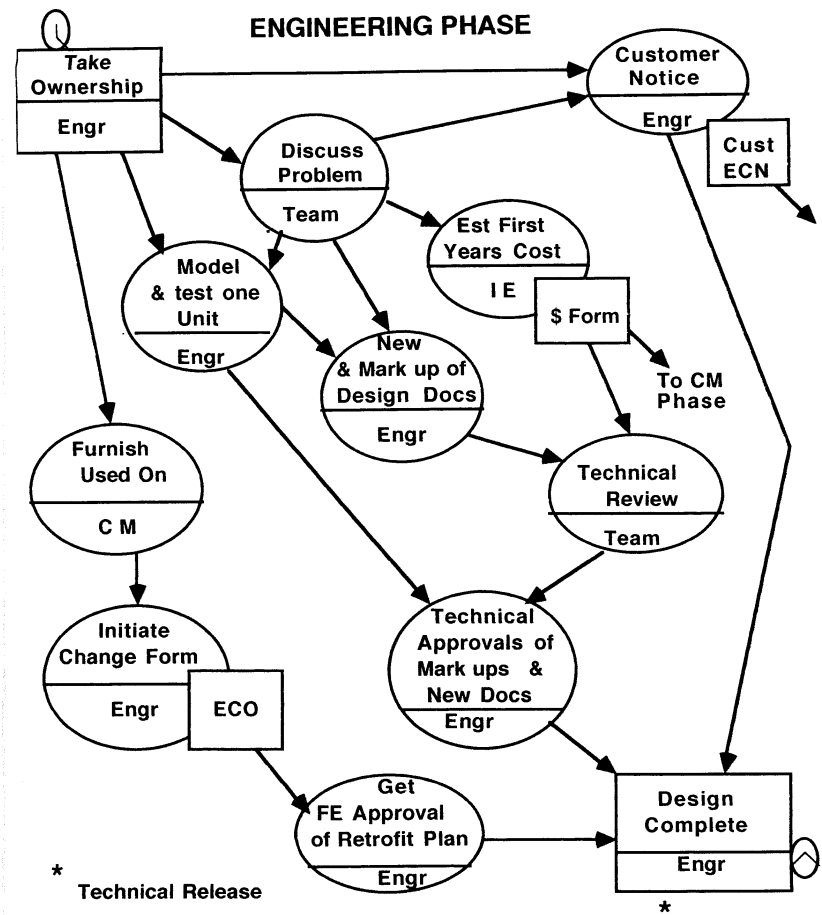


Figure 11.3. Engineering flow.

Notice that several operations are done in "parallel." This contributes to quicker throughput time. When the Cognizant Engineer first recognizes the problem, four operations can begin before or at the next team meeting:

1. CM looks up the Used On and gives the engineer a list.
2. The engineer begins modeling and testing as required.
3. The engineer presents the team with the problem / challenge. If there was an ECR and this was done in the Request Process it can be skipped.
4. The Customer is notified of the impending change. If UL reviews were required they are likewise initiated. (If the agency or customer has contractual approval rights, the point at which the package is sent might be later in the process).

The diagram further indicates how the signed and reviewed documents come together when the design effort is complete. It is important to note that Lab Technicians, CAD/Drafts–person, and CM Technician may aid the engineer during this process but that the engineer is still responsible. The clock "stops" when the engineer gives the package to CM and it passes the critical items check.

It is important to realize that the entire Design Team is aware of the pending change. This happens because each change (excepting class III) has been discussed at least once at a team meeting. Each member can begin preparations for their implementation operations. For example, the publications writer can probably identify the manuals affected, the man-hours required to change the publications and to schedule the effort.

Also notice that the Cognizant Engineer is responsible for obtaining the technical signatures—the Manufacturing Engineer on the new and marked up documents (where the manufacturability issues are) and the Field Engineer on the ECO (where the retrofit plan is).

Rule: The responsible Engineer should obtain technical people's signatures.

Reason: This puts technical people talking to technical people thus keeping CM or others out of the "middle."

Rule: Technical signatures must be obtained before the design is complete. This can be done at a team meeting at the Loader Company since that meeting is held early in the process.

Reason: How can one say the design is complete without having the required technical people agree? It forces the technical discussions to occur earlier in the process when the design engineer is more flexible.

Hopefully the change was discussed first during the request process and again, if necessary during the redesign phase. Most companies hold the CCB (Change Control Board) meeting after the change is brought to CM presuming that the design is complete! This is too late in the process.

If a change requires hand carrying; either the team is called together on an "on call" basis, or the change is hand carried among the team. One telecommunications product company reported that some hand carries occurred on the night shift. If the responsible Manufacturing Engineering had to implement that change that night, the ME was responsible to hand carry the change completely through the system the next morning. Few changes were implemented in that fashion because of the extra effort required doing the hand carrying.

Point of No Return

Most companies have a point of no return. They hold a CCB, obtain the required signatures and then refuse to change the change (point of no return) - another ECO will normally be required to correct that problem. This is too late in the process. It encourages engineers to launch a "straw horse" without having done their homework. Engineers make frequent trips into Document Control to have them "give me that ECO back because I have to . . . . .!" Much finger pointing occurs during the CM part of the process as a result.

The point of no return is so significant it is shown separately to assure proper emphasis. If the engineer's package passes the check, CM will proceed. If the package is deficient, it will be returned (hand delivered) to the Engineer. Each problem will be carefully noted for the engineer's attention. (See Fig. 11.4.)

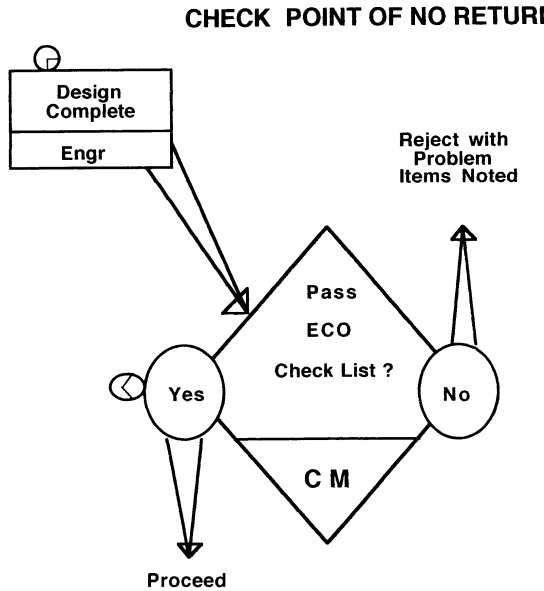


Figure 11.4. Check point in the flow.

The lapsed time required to do this check will be charged to CM if it passes. If not, the time will be charged to the engineer. CM should set a standard to do this operation in one hour.

Having the process be irreversible tends to, prevent false starts, prevent "holds," discourage the engineer from entering "lightly" into the process. The ECR number was used until the change passed the checklist at "engineer complete." This is done purposely—in order to have ECO numbers associated only to changes that are in a "go" or "one way" mode.

Rule: Policy will indicate that this is a point beyond which the engineer will not be allowed to hold, add, delete or change the ECO package. If changes are required a new ECO must be initiated.

Reason: All design work must be completed during the redesign phase and policy and practice must encourage this.

Should CM proceed with a change knowing that it contains an error? Of course not. The error should be corrected, noted in the ECO and this should be done without resigning the ECO. Obviously there may be some

question about "what an error is?" The answer—it is CM's call not the engineers call.

CM might correct errors found and notify the engineer, but the engineer will be unable to make changes. One company that is using this policy refers to this point as "Technical Release." That term is very expressive of the author's intent for this point of no return. After this point, administrative changes may occur on the cover sheet but not in the "from—to," the new or marked prints, specifications and other design matter attached.

Configuration Management Flow

The CM function is responsible for the next part of the process—From Design Complete through Release to Manufacturing and Update of Drawings and CAD. Note these operations in Fig. 11.5.

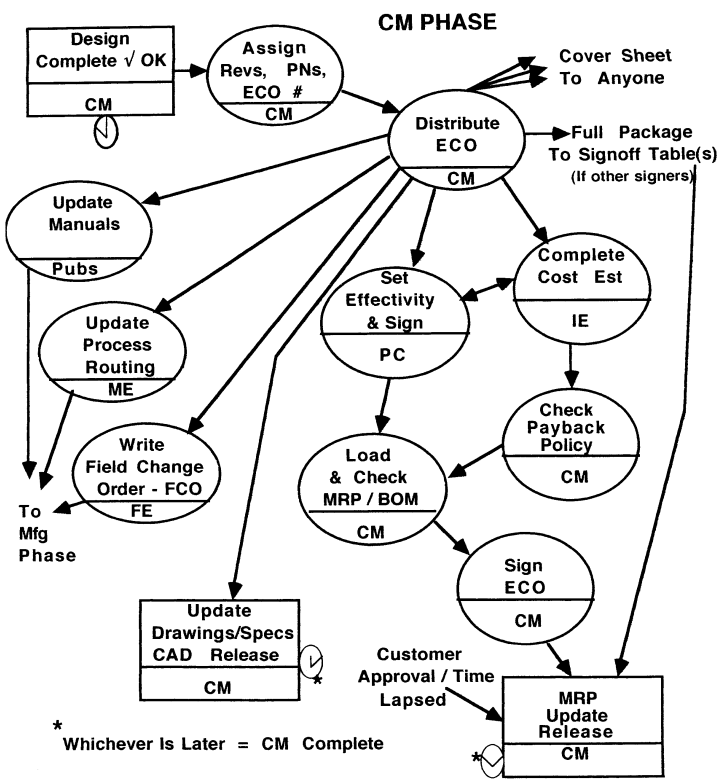


Figure 11.5. CM flow.

CM immediately assigns the necessary part numbers, the next revision level, and distributes the change. The cover sheet is distributed to anyone who needs to know (preferably "on line"). The entire package is distributed only to key locations (assuming no "on line" capability for the entire package).

In a small company occupying one building, only one complete package should be required. It would be placed on a "sign off table" in CM. In larger companies a package might have to be reproduced for the manufacturing people—probably put on a table in Production Control. Any recipient of the cover sheet can then go to the sign off table to review the entire set. In still larger companies, a copy of the entire package might have to go to each building or to the Publications, Field Support, and ME functions. Production Control now coordinates the determination of the effectivity of the change and notifies all who need to know the effectivity including the Industrial Engineer (if costs are being estimated).

The Industrial Engineer is now able to finalize the cost and give the cost sheet to CM. CM obtains the required management approvals based on the cost.

As soon as customer approval (if applicable) and the signed cover sheet(s) are in hand, CM can load the change information into the MRP/BOM system, and check the output.

It is very important to note those things that are not required by this point in time:

- Update of the publications is not required here.
- The field change form(s), if required, are not needed here.
- Production process / routing changes are not required here.

Waiting for any one, or all, of those operations to be completed is unnecessary and wasteful. Waiting would cause a delay in ordering the parts required to implement the change. One day, hour, or even a minute, can produce more scrap, rework, or an unhappy customer. Thus, these operations go to "Close" or to "Production Floor Implementation."

Can the Manufacturing Engineer, Technical Writer or Field Engineer begin to execute the changes to their documentation? Yes—with very high confidence since we have passed the check point/technical release.

Notice that the Update of Drawings and CAD is required to occur before the clock stops on the CM time. It must happen quickly. "Release to Production" is therefore an indication that the MRP has been successfully

loaded (thus the ordering of parts will proceed) and that the revised documents are available for those orders.

There is no need to obtain the engineer's signature on the updated drawing. The incorporation of the mark up correctly is solely the responsibility of CM. The entire CM portion of the process will happen in three to five work-days average.

Notice that several subjects—such as "Manuals"—are actually depicted by three points in the process. They can start their planning at the team meeting, they can start execution when the design is complete (and they are notified) and they must complete their activity when the dependent activity requires it. In this case it is the closing of the box/shipment as you will see in the next phase.

Manufacturing / Implementation Flow

The flow from Release to Manufacturing to ECO Closed is a Manufacturing responsibility. (See Fig. 11.6.)

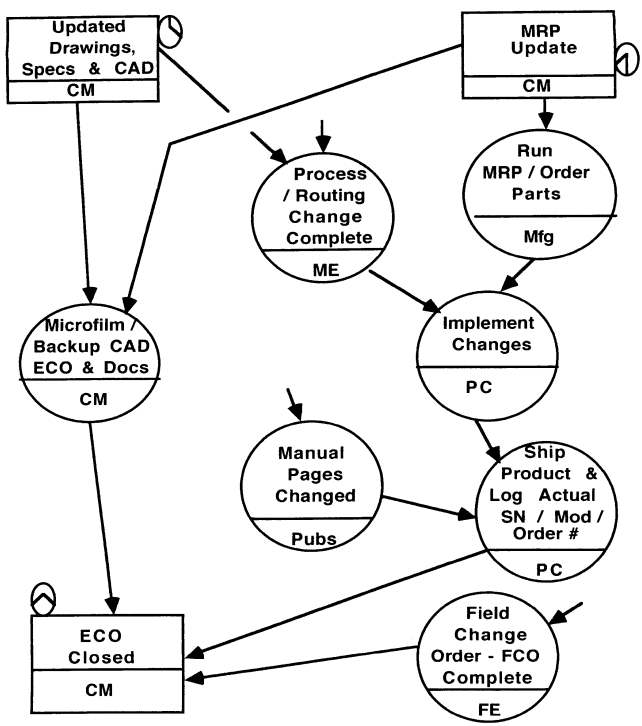


Figure 11.6. Implementation-phase ECO flow.

When the parts are available and the assembly instructions / part routing are available, manufacturing can implement the change on the production floor. Any changes to the effectivity plan are given to CM and the cover sheet is redistributed to all who need to know.

Thus in order to "Close" the ECO, manufacturing (Production Control) must notify CM of **the actual effectivity**. The other operations that must be completed in order to close the change need to be defined. In the case of The Loader Company the other requirements to close are:

- All revised master documents / drawings are backed-up and microfilmed.
- The ECO is microfilmed.
- The MRP must have been run to "drive" parts to the production floor. The process / routing must have been updated. These things must have occurred in order to implement the change on the production floor. The evidence of this occurring is the actual effectivity feedback.
- Company policy says that manuals that ship with the product must be revised and present before the package is closed or the product cannot ship. Production Control will notify CM of the actual effectivity.
- The Field Change Order, if applicable, is completed. A copy of the FCO is sent to CM as evidence that this activity is complete.

Quality Assurance should verify that all these activities occur by auditing the processes. They should report to management as to any discrepancies found.

After all the listed operations have been complete, CM can close the change. The clock then "stops" on that change. This section is referred to as the "manufacturing phase," but it is obviously implementation on the part of several functions. They must all be tracked to satisfactory completion. One good way of notifying CM of each completion is by "copy" of the ECO cover sheet—preferably on line.

The flow diagram is a picture of the process as we design it/improve it, train/communicate it, and measure it. The flow diagram is the most powerful tool available to the CM Manager or Systems Analyst. Using the flow diagram as a training tool tends to bridge the gap between Engineering and the rest of the world.

The system must also be managed, just as the people involved must be managed.

Quality Factor

How can better quality speed up the process? The concept is simple—do it right the first time and time will not have to be spent doing it over correctly while the change is in process or after it is released. The engineer should have the design of the change technically complete when turned over to CM. The completion of a checklist will verify that it is complete. After this point, the form can be revised only for specified reasons. Changing of the effectivity plan being the principal reason. Administrative changes to the cover sheet generally being allowed. Changes of the design of the change are not allowed in the Loader Company but most companies allow changes to the change (fixes to the fix). Separate the administrative changes from the design changes to the ECOs. Count the changes to the design after the change is brought to CM and develop a change process quality measure.

$$\text{Quality Factor \%} = \frac{\text{number of "fixes to the fix"}}{\text{total number of changes}} \times 100$$

Thus "fixes to the fix" of any change in a weeks time, whether it is an ECO to correct an earlier ECO (no matter when the original was done) or a revision to an ECO in the CM part of the process. that total is divided by the total number of changes done in that week.

Example: Seven ECOs had design problems found while in the CM part of the process. Three ECOs were processed which corrected design problems on earlier ECOs. Fifty total ECOs were processed in that week.

Thus:

$$\text{Q F \%} = \frac{7+3}{50} \times 100 = 20\% \text{ Quality Factor}$$

This means that about 20% of the time folks spent in change processing is wasted. It also means that the changes probably could have been processed 20% faster if they had been "done right the first time."

This is the only meaningful quality measurement of the change process that this author has ever found. Companies that measure this criteria are surprised to find the quality factor at 14%, 18%, and in one case 28%. It is an indication of a poor process—or if at 2 to 3% (normal human error level) its an indication of a quality process.

Management for Fast Change

The management at the highest levels should be motivated to achieve a fast, accurate change system. They should form an improvement team, participate in the steering committee, expect goals to be set and follow up on the entire project. Once the time is measured, the volume is measured, the backlog is reduced, and the new or revised system is in place, the management task passes to the CM Manager. Lacking management involvement, the CM Manager can still improve the processes although probably not as quickly or to the same degree as with a management champion.

Some of the things that the CM Manager can do in order to assure the speed and accuracy of the system are:

- Be dedicated to continuous improvement with or without an improvement team, management champion, etc.
- Establish one ECO "basket" (Just In Time "Kanban") for each work station. Do not have and "in" and "out" basket. The Single basket will be a "JIT in basket" for work in process. The baskets can be numbered and the flow diagram noted with the same number.
- One ECO at a time can be worked on at each work station—others must remain in the basket.
- Do not allow ECOs to be put into files or desk drawers. The manager needs to be able to walk around and see the total ECOs in process at each work station.
- Require each person to hand deliver a completed ECO to the next workstation. If the next station is very far away, examine the alternatives. Another basket for hand carrying by anyone who is making a trip may be practical. A special mail arrangement may be necessary. The manager may carry them. An on-line system may be required.

- CM does not hand carry changes except to the next station. The person who "thinks hand carry is required" does the hand carrying.
- Each CM technician must be instructed to drop what they are doing to do "hand carries" ahead of all other changes. If the person doing the hand carry is not familiar with the process, show him or her to the next work station.
- Train all Cognizant Engineers and others directly involved in the change process.
- Establish a limit on the number of changes that will be allowed to accumulate in each basket (Kanban) before help will be obtained. The limit may be fairly high in the beginning, then reduced over time to very few changes. Do the queuing to achieve the desired time.

  Example: The average volume of changes is 18 per week. The current goal is fifteen days (three weeks) turn around time. There are six work stations in the process.

  Conclusion: No more than nine ECOs can be in any one work station. After the fifteen work-day goal is met, a ten work day goal can be set. This would translate into six ECOs per work station. Then set a five work day goal which would be three ECOs per work station.
- Manage by walking around. Find the overloaded Kanban. Look for help from other workstations where the Kanban is low. The manager may have to step in to help a work station when needed. Temporary help may be in order. Help must come quickly or the people will sense that speed isn't that important. Once the CM people have been trained to help each other, they will generally begin to do this on their own.

- Cross train the people. The ideal is to have all people trained in every work station. This would allow organizing the people by product or customer or mirror the engineering organization. A quantum leap in communications is possible. Cross training is needed to fill the sick or absent persons work station. Remember: If you think training is expensive—Try Ignorance !
- Larger CM departments should consider a subgroup breakdown. Pair a "beginner" with a "fully learned" or a "teacher."
- The manager should hold an informal "continuous improvement / department meeting" for ten minutes at the same time each day. The manager and the CM Technicians would explore ways to improve the system, its accuracy and its speed. Don't be negative about any idea. Merely sort out the best ones for implementation. Invite other involved or affected people on occasion.
- When a mistake is made on a change, make sure that it is corrected by the person who made the mistake. If someone else corrects the mistake, chances are that the mistake will be repeated. Do on the spot training to assure that the person knows how to do it right.
- Train all the involved and impacted people on the workings of the change process. They will come up with improvements too.

Continuous improvement needs to become a habit. The flow diagram will be the primary tool for discussion of ideas and for implementing process changes.

A Case Study

Picture a fast growing corporation in the computer products business. Fast reaction is a necessity for survival. The companies largest division processed about one hundred changes each month. Their OEM contracts routinely required customer approval.

That division was experiencing many of the symptoms of an engineering documentation control problem. Fixes took too long. Customers were impatient. Sometimes the paper got lost! The division Executive Vice President recognized the challenge.

We started our analysis by properly defining the problem. The people involved measured the actual throughput time. It soon became apparent that the 100 changes per month were taking an average of 120 work-days. The time broke down into roughly equal parts:

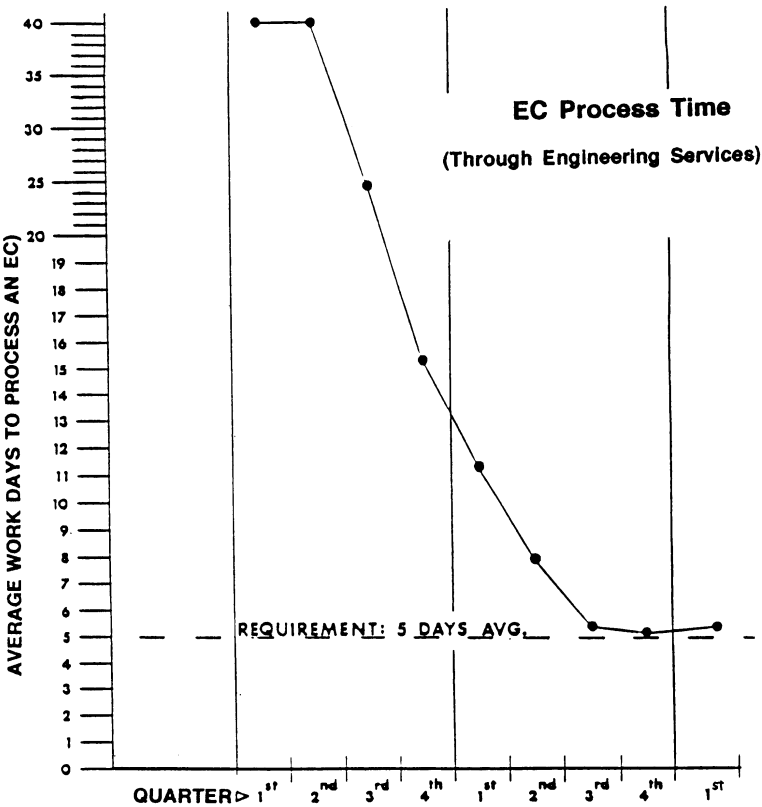
- About 40 work-days to request, design and develop the changes.
- About 40 work-days to process the paper work, update the master documents and the BOM / MRP.
- About 40 work-days to implement the change in production.

It was determined to attack the middle forty part of the process first. We set a five work-day goal. We assigned one person from Engineering, Materials, and Manufacturing (Materials did not answer to Manufacturing) to a "task force." A steering committee was formed. The division Executive VP chaired that group. The task force started by making a plan:

- Analyze the current process
- Brainstorm and document changes to (or reinvent) the process
- Document the process
- Trial run
- Approval of the process
- Train
- Implement

Analysis of the current system included:

- Continuing measurement and large graph reporting (see Fig. 11.7).
- Sampling of over one hundred changes from the prior year. A data bank was developed with over 10,000 bits of information about their changes.
- Flow diagramed the current process.
- Gathered all the current system forms, policies, and procedures.



Number of EC	280	243	248	294	304	288	307	369	75
Actual Avg Days	40	40	24.6	15.3	11.3	8.0	5.4	5.2	5.4
6MO MOVING AVG (WEIGHTED)				19.6	14.7	11.0	7.1	5.8	5.3

Figure 11.7. Case study process-time graph.

The result was filled with surprises, even for those who considered themselves very knowledgeable about the process. The middle forty work-days included the following events:

- Translate a messy engineer's mark up into "was - now" drafted ECO.
- Set effectivity.
- Rarely estimate costs.
- Revise all drawings, specifications, and field support document master.

- Obtain an engineer's signature on each updated master.
- Stop, hold, change, or reverse the process at the engineer's whim.
- Make copies totaling over one million sheets of paper per year.

We divided the entire process into small subjects and wrote standards about each. One to five pages per standard/subject. The task force then brainstormed improvements. It was determined to reinvent the process.

Brief sessions were held to explain the project and to explain why speed was important. Large throughput time charts were posted. The task force and the steering committee were ever present. The people involved realized, for the first time, that process time was important. The CM process time had been reduced to thirty-two work-days. They took the first eight work-days out by individual action. The task team wasn't sure how it happened! It was the result of visibility on the metrics and holding "what are we doing and why speed is important" meetings with all involved in the process.

Design, testing, training, and implementation of the new process took hold. The process time continued downward. (See Fig. 11.7.) In about twelve months, training was complete the new process in place, debugged, and the team reached the goal—five work day average.

This reinvention took over three man-years of total effort. That company considered it worth every hour. The surprises continued:

- It was done without any change in the number of people involved in the process. Two fewer people in CM were offset by two "new" people: an IE to estimate the cost of all class I and II changes, and carry over of one team member to facilitate continuous improvement.
- The design and development time went down a few days. This happened even in the face of requiring modeling, testing and design team meetings in the Engineering Phase. Why? The only explanation seemed to be that measurement and reporting, in and of itself, made it happen.
- The Manufacturing / Implementation phase time also went down a few days. Same apparent explanation!

- The teamwork in the CM area visibly increased.
- They obtained a one work day average hand carry time. Only four percent of their changes were hand carried.

They had no good way to measure the reductions in rework, scrap, "bone pile" effort, field support savings, earlier implementation of cost reductions, or customer happiness. Judgments were that all of these factors had, likewise, improved.

Significance of Speed

We have already discussed the benefits of having a fast, accurate and well understood change process. We did this on the basis of identifiable results—reduce rework, etc. Note that speed is important as a strategy. Consider the following quote from the Harvard Business Review in an article titled; Time—The Next Source Of Competitive Advantage. In this article, author George Stalk Jr. states *"As a strategic weapon, time is the equivalent of money, productivity, quality, even innovation."*

This is why the change process must have the:

Golden Rule:

The speed with which you process design changes is critical to profitability.

12

Process Standards and Audits

The two subjects—Process Standards and Audit are discussed in the same chapter simply because without standards there can be no meaningful audit. This is the same reason why the ISO and copycat standards require written documentation on your processes. This is also why folks say they require you to "document what you do and do what you document." In other words, specify the process and audit against that specification.

CM process specifications are referred to by many different names. Some call them policy and procedure. Sometimes the word "documentation" is used. The word "procedures" is a frequently used term, much like this writer uses the word "standards." The term procedure would imply step by step instructions and might tend to exclude forms, form instructions, policy or the use of flow diagrams to depict the processes. SOP—Standard Operating Procedure has the same drawback. This writer, therefore, prefers the term "standards."

Why Are Standards Needed? Regardless of what they are called, every company needs to develop a set of standards for their CM processes. It isn't adequate to say that ISO requires them or that management requires them:

Rule: The CM system must be documented in written standards.

Reason: Standards are necessary because they:

- Make it easy to train new people.

- Provide a tool for training people in process changes.
- Give people a uniform method to follow yields more consistent results with less "debate" time.
- The repeatable process is more accurate.
- Yields repetition efficiencies.
- Gives a foundation on which to improve.
- Give people and management the baseline from which to take exceptions.
- Give management, customer or regulating agency something to audit "against."
- Reduces dependency on the "expert."

For all of these reasons, the standards are a significant part of the CM task. As our policy statement points out, it is the CM Manager's responsibility to see that they are created and kept up to date. The CM manager may enlist some help in developing the standards. The "Improvement Team" can, and should, take some of the burden for their development. "Subject matter experts" should develop some. A CM department "teacher" should develop some. No matter who does the development, they must be done if the CM processes are to be carried out in some form of "sanity." Up-dating of the standards is sometimes ignored.

No one should be embarrassed if the standards need to be changed. In fact, just the opposite should be true. If the standards are to be useful, they will be constantly corrected and improved. Kaoru Ishikawa in his *"What Is Total Quality Control? The Japanese Way"* writes: " . . . if newly established standards and regulations are not revised in six months, it is proof that no one is seriously using them." The principals of "Kaisan" and "Continuous Improvement" require continuous changes to the standards.

Rule: Each standard should state who in the organization is responsible for keeping it up to date.

Reason: If this isn't done, the "book will eventually ignored."

If you are ISO certified, there will be a "project" required each six months to update or risk loosing your certification. Better to update when and as the need arises.

CM Policy

The first standard written should be a policy statement. It must be brief but precise enough to define the CM "turf." A good example of a CM policy is shown in Fig. 12.1.

The CM Policy should be signed by a high company officer. In small companies, the president should sign. In a larger company, the Chief Engineer or Executive Vise President should sign.

PURPOSE:
- To assure the lowest total product life cycle cost as well as **fast and accurate well understood** Product & Documentation Release, Change Request, Design Change, and Bill of Material processes.
- To assure systematic identifying, controlling, status accounting (traceability), **and reporting** of a products configuration throughout its life.
- For the benefits noted elsewhere including meeting **ISO / QS / AS 9000 requirements**.

APPLICABILITY:
- Applies to all design, manufacturing, quality and service functions served by this Document Control function.

POLICY / PRACTICE:
- To have an organized, fast, accurate and consistent process for controlling the configuration of hardware and software products.
- To document the practices and to assure that the documentation is followed.
- To consist of planning, control, identification, traceability, and reporting.
- To consist of Release, Change Request, Change Control and Bill of Material **processes**.

PROCEDURE:
- Not applicable

PRIMARY RESPONSIBILITY:
Doc Control Manager:
- **Design and documentation of the CM Processes** by Flow Diagram, Form, Form Instruction, Standards, and further Policy as required.
- To manage the processes and to **report to senior staff** as to the volume, speed, and accuracy.
- To **educate and train** those involved on the EDC standards.

V P ENGINEERING:
- To assure that the C M function has the necessary resources and authority to perform its functions.

AUTHORIZATION: President / GM _____

Figure 12.1. CM policy standard.

Writing and Formatting Standards

Important decisions need to be made to develop the most functional standards. For example, shall we include inter-departmental operations and/or intra-department operations? Since we are talking about standards to

beaudited (by CM, Internal Audit or ISO) the best decision is to cover inter-departmental steps but to exclude the intra-department steps. Each department might have their own "work instructions" which should generally be left out of the CM "manual" and left out of audits. This is a very important point to cover with an audit organization before seeking certification because it can reduce the costs involved significantly.

Should they be numbered by the military method or cross-referenced to the ISO standards? The following "standard on writing standards" tries to answer those questions. The "header" and "footer" have been deleted for simplicity.

Purpose:

- Briefly state the purpose of the standard. "To meet ISO 9000 requirements" is one reason for writing standards. Better reasons for writing standards are:

  1. Provide consistency in the day to day process operation.
  2. Furnish a basis for training people.
  3. Provide a basis for improvement.
  4. Standardize the usual or normal expectations (not exceptions).
  5. Specify who may take exception to the normal expectation.

Applicability:

- State the limiting aspects of the scope of the standard, example: "Engineering Change Request and closely related matters."
- Include elements of the processes which are cross-departmental / functional. Do not include department instructions since they are / should be subject to rapid change and aren't cross- department business.
- The standard shall not contain a separate section for cross-references to other related or associated standards. This practice creates a "web" that is very difficult to originate and

to keep up to date. The related standards can be referred to by title in the text where important.

Policy / Practice:

- One subject / topic should be included in one standard. Use of the word "and" in the title may indicate that separate standards should be written.
- Do not try to cover all the situations that have ever occurred. Leave exceptional circumstances to be handled by exception. This will normally keep the length of most standards to one to three pages. This makes them easier to read, understand and to train the affected people.
- List the statements about the subject that are important and value added to the company. Do not try to address infrequently occurring conditions. Leave those anomalies to be handled by exceptions to the standard.
- Include elements of the processes that are critical to the interdepartmental function of those processes.
- All EDC standards will be written in the form and format herein described. Each shall contain the header, footer and subtitles: Title, Number, Date, Page Of Pages, Purpose, Applicability, Policy / Practice, Procedure, Primary Responsibility, and Authorization. When not applicable, enter "NA."
- Keep sentences short. Use "bullets" as opposed to paragraph numbering. (2.4.4.3) Informal polls have indicated that this method is considered friendlier than paragraph numbering. Do not use the ISO paragraph numbers since those are not within your control and are subject to change.
- All standard numbers and form numbers shall be assigned by Document Control. All standard and form version dates shall be assigned by Document Control, unless that standard states otherwise.
- A new version date will be assigned when the changes to a standard are made. Changes are highlighted. All pages of that standard will be updated to the latest version date.

- Each form shall have a form instruction standard. The instruction will be "find numbered" in order to associate the instruction to the form. All forms shall have a unique date in the lower left corner. The date is the latest version of the form. An on line form and form instruction is an acceptable standard.

Procedure:

- Procedure shall describe the process method required to describe interfaces between departments. Internal department practices shall be left up to each department manager to delineate in department instructions as necessary.

- Flow diagrams shall be the preferred method of describing the procedure. Flow diagrams shall be in the format used elsewhere in this book. The responsible department is shown in the lower part of the event symbol. The responsible department shall normally be a single department ("team" events would be one exception). The origination of an arrow will indicate the earliest event wherein the next activity / event can begin. The arrowhead shall point at the dependent event. Flow diagrams shall always be used for processes with one or more "parallel" events.

- A procedure may be described in "play script" format <u>if it is properly a "series" process</u>. An example of a "play-script" procedure:

Customer	1. Gives print order to the vault.
Vault	2. Pulls the microfilm card.
	3. Runs required copies.
	4. Notifies customer that copies are ready.
Customer	5. Picks up prints.
Clerk	6. Enters print order in spreadsheet and discards print order.
	7. Prepares monthly report of print volume.

- "Dwells" or "holds" or "queues" should normally be avoided for the fastest procedure. When necessary, they should be included with a time "sunset" limit.

Primary Responsibility:

- List the department that shall be responsible for keeping the standard up to date. This is the department that initiates draft improvements, circulates them, calls a task team together if necessary, pilots the change, obtains authorization as required, trains key people and implement the change.
- This standard shall be the responsibility of the Manager of Document Control.
- List the person or persons that are authorized to take exception to the standard. This allows management by exception. That is; the content of the standard is the normal condition and the person(s) specified will take exception as appropriate. The way that they do this should be specified. Example: "The Document Control Manager shall be authorized to take exception to this standard by briefly stating in the standard why exception was appropriate."
- Do not repeat the policy, practice, procedure or flow diagram responsibilities.

Authorization:

- The signature of the manager in authority over this process or standard. This might be the chief engineer or chief operating officer for example. It may be a lower level manager if that level has ownership of that portion of the standard or process. Normally avoid several signatures.
- Any management or key people affected by the standard should be given an opportunity to review and comment, but they need not sign.

Authorization Doc Control Manager

Typical Standard

The standards must be short. They should cover only one subject. The typical standard should be one to three pages in length. If a standard is much longer than that, it probably covers more than one subject. It probably also won't be read. The goal is to divide the total subject of Engineering Documentation Control into its logical processes and then to develop standards on each subject in that logical process. The logical processes, as defined by the author, you will recall, are:

- Product and Documentation Release
- Bill Of Material
- Request for Change
- Change

There must also be a general category to cover such subjects as part numbering, interchangeability, etc. Some important subjects such as Cost Estimating Changes or Field changes might deserve a separate category. The standards will take the form of:

- Forms
- Form Instructions
- Policy Statement
- Flow Diagrams
- Standard Definitions
- Standard Methods

The "Standard Definitions and Methods" allow the flow diagrams to be clear and crisp. As previously discussed they keep the words on a flow diagram to an absolute minimum. While preparing a flow diagram, if lengthy operation statements or notes are needed, chances are that a separate standard is called for.

Subjects to Standardize

The particular subjects that would be candidates for a standard will vary from company to company. Some guidance can be given, however. By process, subjects (probably a "worst case list") to consider are:

General

- Policy, EDC / CM
- Writing EDC Standards
- EDC Requirements for Drafting Standards
- Document Groups
- Teams for All EDC Processes
- Cognizant Engineers
- Part Numbers
- Approved Manufacturers List
- Deviations
- Spare Parts
- Prints / Points of Use / Paper-less
- Signatures
- Class Coding / Naming Conventions / Group Technology

Release Process Standards:

- Release Policy
- Teams in The Release Process
- Phase Release
- Release Notification / Form

Request Process Standards:

- Change Request Policy
- Team in The Request Process
- The Request Form
- Request Flow Diagram

Bill Of Material Process Standards:

- Quantity and Units of Measure
- BOM Content
- BOM Structuring
- Engineering Parts List

- Parts List Input and Verification
- MRP Codes
- Modular BOM and Shopping List Drawing

Change Control Process Standards:

- Change Control Policy
- Team In Change Process
- The Change Form
- Change Form Instruction
- Interchangeability
- Part Number Change Logic
- Part Number & Revision Level Changes
- Change Classification
- Mark-up of Design Documents
- Effectivity Point
- Effectivity Setting
- Disposition of Old Design Parts
- Impacted / Affected By A Change
- Design Complete
- Tracking Actual Effectivity
- Line-Down Change
- Closing a Change
- Change Process Flow Diagram

Field Change Standards:

- Field Changes
- Field Change Form
- Field Change Form Instruction
- Field Change Flow Diagram

Change Cost Standards:

- Costing Design Changes
- Change Cost Form
- Change Cost Form Instruction

Some of these subjects probably don't apply to your company. Those that do apply will be very short documents. This brevity will make them easier to develop, review, agree upon and approve. Divide and conquer!

Example Standard

The easiest way to look at this method of brevity / divide and conquer is to look at a sample standard. An example of a one page standard for the Approved Manufacturers List is shown in Fig. 12.2.

Procedures and Work Flow Diagrams

Folks often write a procedure as they would describe the process to a friend. Witness the following procedure written in a "Descriptive" method. Don't worry about whether or not you agree with the method, only try to understand what the method is:

Descriptive:

Technical approvals are obtained on the ECO or mark ups. After the change has been technically approved, the change may be incorporated into the master documents by EDC without waiting for the effectivity to be "finalized" or the parts list changed (if applicable) to be entered into the MRP system by EDC. The entry of a parts list change into the MRP, checking that entry and EDC signing the ECO must be done only after the effectivity plan is set and PC has signed the ECO. Entry of the parts list change to the MRP need not wait for the master documents to be updated. Which ever of these events (update of the master documents or input to the MRP) takes place later, will constitute completion of the EDC phase of the ECO process.

PURPOSE:

- To specify the method of controlling the acceptable manufacturer(s) for each purchased item. (Often called AVL - Approved Vendor List or QVL - Qualified Vendor List.)

APPLICABILITY:

- All new items released by this Doc Control function.
- All changes to the AML for released items.

POLICY / PRATICE:

- Engineering shall furnish the first acceptable manufacturer for each new design item to be purchased
- Purchasing, Engineering and Quality Assurance must agree on the addition of manufacturers as acceptable sources
- The control of the source shall be by an Approved Manufacturers List (AML).
- This list will be maintained by part number in the MRP Item Master file.
- It will contain the manufacturer name, not wholesalers or other suppliers names.
- The Specification Control Drawings (SCD) will not normally show the approved manufacturer(s). This is not done because the SCD will be sent to the supplier and it is not desirable to have the supplier(s) know the competition or that the part has a "sole source".
- The AML input and maintenance will be the responsibility of Quality Assurance. They will not use the change form as a method for control. That AML form will not be used for design / document changes.
- Quality Assurance will obtain Design Engineering and Purchasing agreement with all changes to the AML.

PROCEDURE:

- Engineering shall furnish the first acceptable manufacturer for each new design item to be purchased. The Buyers are available to assist in this effort. The first manufacturer will be named on the form releasing that item.
- The CM function will input the first manufacturer to the AML.
- Anyone wishing a Manufacturer to be added to or deleted from the AML shall notify the responsible QA engineer.
- The QA engineer will ask via email the cognizant design engineer and the buyer if they agree with the change.
- If both the Buyer and the engineer respond positively the QA engineer will update the MRP Item Master file.
- If either or both respond negatively the QA engineer is responsible for resolving the issue.

PRIMARY RESPONSIBILITY:

- Quality Assurance function will maintain this standard in a current condition.
- Quality Assurance may take exception to this standard by outlining the reason in the AML control form.

AUTHORIZATION:

_____

VP Quality Assurance

Figure 12.2. Sample standard.

Now lets take the identical process and describe it in "play-script" format:

Play Script:

Function	No.	Procedure Description
Cog. Engr.	1	Approves and obtains other technical approval on the marked up drawings, specifications.
	2	Approves and obtains other technical approvals on the ECO.
EDC	3	Updates master drawings and specifications. This step need not wait on subsequent steps.
PC	4	Set effectivity of the change and sign the ECO. This step need not wait for step number 2.
EDC	5	Input the change to MRP, check the input and sign the ECO. This step need not wait on step 2 but must wait on step 3.

Note: Whichever of steps 2 and 4 are completed later shall constitute the completion of the EDC phase.

The play-script is certainly an improvement over the descriptive method. It is much easier to understand than the descriptive method. The parallel activities are still very hard to explain and understand.

Now lets take the same exact process and describe it by flow diagram (see Fig. 12.3).

Which do you think is easier to read and understand? Isn't a picture worth a thousand words?

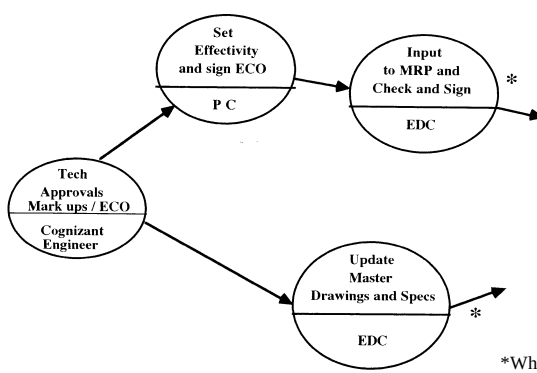


Figure 12.3. Procedure in the flow diagram.

*Whichever is done later constitutes the completion of the EDC phase.

Standards Manual

The standards should be placed in a book or in a computer file/program. They may be under the CM manager's control, in a company manual, or in the quality manual. Given a choice, opt for a CM manual under CM's control. If they are in a separate manual, the company manual or quality manual should reference the CM manual. One good way to do this would be to place an overall policy statement into the company manual. In the policy statement, place a reference to the CM manual.

Each standard should be given a number and be revision/date controlled. They should not be given an engineering part or document number. Doing so might lead one to believe that they are under the CM process control. The forms should be numbered from a log or contents page. The form number should be on the form—typically in the lower left-hand corner.

Larger operations may choose to put engineering part numbers on their forms and to stock them in the warehouse. If that is a consideration, it is probably an ideal time to put the most used forms "on line" to save the paper cost and improve communications.

Training

The necessity for training has been pointed out several times. It cannot be over emphasized. Train before implementing. Train before "finalizing" a standard. Train before implementing any continuous improvement. It is a "pay me now, or pay me later" situation. The investment in training will pay back many times in the future.

Keep in mind what Mark Twain said about training —"My land, the power of training! Of influence! Of education! It can bring a body up to believe anything."

The process of continuous improvement must mean continuous training. Even well conceived and documented processes can fail for lack of training. Don't just call a group of people into a room and tell them what is happening. Use a real world company assembly to develop your training tools. Document that assembly, release it, structure the parts list/BOM, request a change to it, and change it. Develop the new form(s) for that company assembly. Walk people through the process.

Different levels of training may be appropriate. A good place to start is with generic CM training for the team(s) and related people. A "system overview" training session might be good for the general population. Specific training for the Design Engineers, Manufacturing Engineers, Production Control/Materials, CM, or the production floor management. You may want to develop a specific class for your customers or suppliers.

Just as the standards develop with continuous improvement, your training will develop over time. Training will be the key to bridging the gap between Engineering and the rest of the world. And as stated before**; if you think training is expensive—try ignorance!**

Auditing the CM Processes

If the CM discipline is to bridge the gap between Engineering and the rest of the world, it must be subject to audit. Outside audit, internal audit, self-audit, or all of the above. Rather than looking at the concept of audit with fear, the CM manager must view audit as an opportunity. In fact, start with a self-audit in order to find out how useful they can be. Perform one or more of the "sanity tests" described at the end of this chapter. You will be surprised that all parts of the process aren't working as planned.

Outside Auditors View

It is only human to look for standardized methods of doing business. Auditors are only human. Lack of standards gives the impression of chaos. Whether your customer or governing agency require it or not, having standards is a real necessity to world class CM, some institutions require them. Series ISO 9000 states: "The supplier shall establish and maintain procedures to control and verify the design of the product in order to ensure that the specified requirements are met" Engineering Documentation Control (CM) is at the heart of "verify the design" and "specified requirements." In this writer's judgment, CM is the heart of a vast majority of ISO 9000 requirements. CM is also the heart of many other agency requirements. And, after all, having standards is just good business. They furnish all the benefits listed in the beginning of this chapter.

Internal Audit

The ideal internal audit should be done with the Quality Assurance or Internal Audit Department. If you have no such organization, or they are not able to do a system audit, the CM manager should do the auditing. Either way, it must not be taken lightly. Repeated audits are necessary to attain best in class status.

Without written standards, auditing the CM processes is a very limited effort. Still, some of the "sanity tests" in later paragraphs can be done. With written standards, the task makes more sense. The approach is then to verify that what is said in the standards is, in fact, followed.

Audit Plan

Make sure that there is a plan for performance of the audit before it starts. The plan should address several issues:

- Why is the audit being done?
- Who will do the audit? Will CM be free to work with the auditor?
- When will it be done?
- What documents will be audited?
- What processes will be audited?
- What sample size will be taken? How will the sample be chosen?
- How will a discrepancy be defined?
- Will a report be written? By whom? When?

The detail with which each issue is answered will vary depending upon whether the CM Manager is performing his/her own audit, whether the customer is involved, etc. Regardless of the type of audit, it will be a waste, even counter productive, unless the CM Manager is dedicated to proper follow up.

Audit Follow Up

Every audit must have a conclusion. The conclusion should be to have each discrepant item resolved and closed. Each discrepancy must be followed to find out the root cause of the problem. Effort must be expended to fix the root cause of each problem. A few "anomalies" are allowed, but most problems must be traced and fixed. The "fix" might be training, revising a standard, etc.

If this follow up is not done, the people involved in the process will quickly figure out that it was a "white wash." This can affect their morale and even increase the errors made. Issue a final report that closes the audit and informs the people and the management of the root cause fixes.

Auditing the CM processes can be done by a number of different methods. The audit plan should determine which method will be followed. Some possibilities for "sanity tests" are:

Release Process Audit

- ♦ Sample drawings, specifications, and other design documents:
  - Were the documents prepared according to the standard?
  - Were the documents signed according to the standard?
  - Was the revision level assigned by CM as part of the release process?
  - Were all who need to know notified of the release?
  - Is the release "document" readily available?
- ♦ Sample purchase orders:
  - Were purchases for prototype, pilot, and production made from documents released for that or a "higher" release level?
  - Were the drawings "modified" by the purchase order?
- ♦ Sample a product:
  - Is it obvious as to what release level (prototype, pilot, or production) the product was made for?

- Does the product match the documentation for that release level.

♦ Sample recent release notice "forms:"

- Were the forms apparently completed per the standard?
- Do the forms cross check to the logs?

♦ Walk through the process:

- Are the people aware of what the standards say and are they following them?
- Is the form as complete as it should be at each step in the process?
- Can all the release form numbers be accounted for?

BOM Process Audit

♦ Sample recent Parts Lists:

- Do they cross reference (find number or balloon number) to the pictorial drawing?
- Is there an item for item match to the pictorial?
- Do they use units of measure and quantities per the standard?
- Are the units of measure the correct ones for purchasing purposes?
- Are any assemblies at a higher release level (development/pilot/production) than its lowest level part?
- Are referenced documents properly noted?
- Is the parts list a product of the MRP / database?

♦ Sample a product:

- Does the product contain all the parts in the BOM and no more?
- Does the product contain the quantity of parts per the BOM?

- Given the nameplate data, can the non-interchangeable changes be identified?

♦ Sample a current BOM:
- Does it contain the ECOs that it should?
- Is the effectivity in the BOM per the ECO?
- Is there only one BOM data-base that is universally used?
- If more than one BOM, do they agree?

Request Process Audit

♦ Sample recent request forms:
- Does the requester receive an answer to each request?
- Are requests answered on a timely basis?
- Are the reasons given for rejection reasonable?

♦ Walk through the process:
- Are the people aware of what the standards say, and are they following them?
- Does the form appear as it should at each step in the process?

Change Process Audit

♦ Sample recent ECOs:
- Do the ECOs contain the information required by the standards?
- Does the average process time agree with the report?
- Do the forms cross check to the logs?
- Are the ECOs properly delineated on the traceability reports?
- Does the product contain the change per the actual effectivity?

♦ Sample Waivers and Deviations:

- Were they done according to standard?
- Are they properly reflected in the traceability reports?
- Are deviations being used to make design changes?

♦ Sample traceability reports:

- Do they contain all the class I ECOs that are closed?
- Is the stated effectivity per the ECO?

♦ Sample a finished product:

- Does the product contain what the ECO effectivity says it should?
- Does the product contain what the traceability report says it should?

♦ Walk through the process:

- Do the people understand what is required by the standards and do they follow them?
- Is the form as complete as it should at each step in the process?
- Can all the ECO numbers be accounted for?

These may not be the correct questions for your company. If troublesome conditions have been known to exist, those error conditions should be added to your audit. If prior audits found little problem in a given area, the current audit may not check that area.

Audit Frequency

Most quality department folks say that an audit should be performed about once a year. The writer would be happy to see most folks do their first audit. Too often, the first audit occurs when the customer or his representative or ISO auditors show up.

Start by developing the standards on the most troublesome process. Then set about doing an audit that process once a year. Next, move to the next most troublesome process. Follow with a yearly audit review of the problem areas. Depending upon the results, a different set of problem areas might be chosen each year.

Train Without a Whistle

Publish the results of the audit. Publish the follow up resolution of all discrepancies. The occurrence or recognition of problems should not be viewed as a weakness. The failure to follow each to its root cause and fixing the problem is a weakness. Let folks know that you not only recognized the problems, but that you fixed them.

An old timer once told the writer; "A train don't run by its whistle, but you never saw a train without a whistle!" The meaning was clear—when you achieve something good, you should toot your whistle. You want a best in class or world class CM system that you can toot your whistle about. World class CM systems don't get that way, or stay that way, without regular auditing. Nor do they get that way without hard work and continuously improvement. Creating a new system has always been a difficult task. Witness what **Machiavelli** "The Prince" wrote in the year **1513**;

"It must be remembered that there is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new system. For the initiator has the enmity of all who would profit by the preservation of the old institutions and merely lukewarm defenders in those who would gain by the new ones."

13

Benchmarking

The art of benchmarking is simply defined—to compare your process to others in a similar segment of company or to any group of companies. When you choose to read this book you choose to do a form of benchmarking. Hopefully you will see here the best of the best practices that this author has witnessed or heard adequate testimony about.

If you have attended one of our University of Wisconsin Milwaukee seminars on the EDC/CM subject you witnessed two kinds of benchmarking:

1. A form was filled out and then summarized to show what kind of company environments the attendees came from.

2. The author asked lots of questions and asked for "hand raising" to categorize the attendees environments further.

When you ask a co-worker how it was done at their previous company you are benchmarking. Those who have worked in the function at more than one company have some valuable, though limited, benchmark(s). If you ask the author a question about industry practices you get an answer based on over fifty personal company EDC/CM experiences and literally thousands of seminar attendees.

The definition of benchmarking is relatively easy, but writing questions and thus getting the answers that you need is difficult. As you will see, the way the question is framed, the experience of the respondents and the personal contact in the survey are significant variables.

Benchmarking Pitfall

It must be emphasized that just because a practice is widespread, doesn't mean that it is the best practice for you or for any company. For example: Just because the average company has 2.4 ways to make a design change doesn't mean that it is a good idea to have more than one. In most cases it should help, however, to know when you are using a generally accepted practice and when you are not.

It can be a good "sanity test." The issue will still remain—how do I know that the practice is a good one even if a vast majority of the companies method agree with mine? Conversely, if you are in the minority is that necessarily bad? Benchmarks are especially useful if the results can be compared to the best of the best practices.

How to Benchmark

Benchmarking can be a powerful tool. Have you ever wondered how your EDC/CM processes stack up against your competition, others in your kind of business or product manufacturing in general? Do a survey and find out! It is simply said, but not so easy to do. The following is a process to follow when benchmarking:

- First you need to determine which of your processes you would like to benchmark. Then ask what specifically you would like to know about those processes. What specific questions are most likely to get the answers you need? Framing the questions in the most universally used language, acronyms and abbreviations are critical. Questions can be asked in different ways as a sanity test. Often the process must be defined in generic terms in order to get meaningful questions / answers.

- Then pick some companies you would like to benchmark against. Contact them and find out if they are interested in sharing the kind of information you are looking for. You must get to the Chief Engineer, CM manager or Director of Engineering Services for best results. They must feel that they will equally benefit by seeing a summary report. A third party is very effective in this regard.
- The survey can be emailed and/or taken over the telephone. The best of questions may still require explaining–so telephone is best.
- You may want to seek help to; develop your survey, contact the potential participants, conduct the survey, summarize and interpret the results, or just some of those things.

The following survey and discussion may help. To the best of the author's knowledge the survey included here and the one referenced may be the only available benchmarking in our discipline!

Survey—Questionnaire Example

This survey was actually used to benchmark sixteen companies most of whom were automotive suppliers. It was done for an automotive supplier. The client received a detailed report with comment and comparison to the best of the best practices. The client also received a copy of the survey results database. The participants all received a copy of the summary results. No company names, locations or interviewed parties were revealed in the survey or the summary. The questionnaire follows:

Survey Participants,
You have agreed to participate in a survey of your Configuration Management (CM) / Engineering Documentation Control (EDC) processes. The following questions should be answered in the context of current conditions, not past or planned conditions.

Company Background:
Type of product(s)

Number of plants _____ Physical relationship of plants_____
Engineering and Manufacturing at each plant? •Yes • No Explain:

_____

CM / EDC organization answers to: (Engr, Mfg, Quality, Project Office, etc.)

_____

Quality Standard(s) • ISO 9000 • QS 9000 • Other

_____

Are you • Certified • Working toward certification • Not required

1. What is CM / EDC organization responsible for:

Filing all released design doc masters	• Yes • No_____
Distribution of forms and docs	• Yes • No_____
Document / Item release control	• Yes • No_____
Change request monitoring	• Yes • No_____
Change control / facilitation	• Yes • No_____
Defining the change for/with the engineer	• Yes • No_____
Developing the impact of the change	• Yes • No_____
Assignment of PN, Doc #, DCN #	• Yes • No_____
Assignment of revs	• Yes • No_____
Input of BOM design info	• Yes • No_____
Input of all BOM data	• Yes • No_____
Setting effectivity of changes	• Yes • No_____
Knowing product configuration	• Yes • No_____
Design of the CM / EDC processes	• Yes • No_____
Control of the CM / EDC process docs	• Yes • No_____
Change Incorporation into “master”	• Yes • No_____
Measure the CM / EDC system	• Yes • No_____
Microfilm / Digitizing	• Yes • No_____
CAD control	• Yes • No_____
Engineering Library	• Yes • No_____
Standard component engineering	• Yes • No_____
Manufacturing / Purchasing doc control	• Yes • No_____
Quality / validation / testing doc control	• Yes • No_____
Publications / service document control	• Yes • No_____

Sales document control • Yes • No_____
Drafting Standards Manual ownership • Yes • No_____
Other • Yes • No_____

2. Release Stages:

How many stages of release do you have ____, what do you call them _____and how do you identify if the document / part is "ready for" a particular stage:

On the drawing (example: Rev blank = development, rev numeric = pilot, rev alpha = production):_____
_____

In the BOM (example: Status code 1 = Development, 2 = Pilot, 3 = Production):_____
_____

3. BOMs

Is the parts list; on the assembly drawing
on a separate controlled document both

How many manual or computer data bases of the parts lists are maintained in the company (example; Engr CAD, MRP plant 1 and 3, ERP plant 2, Publications, total = 4)_____ List them:
_____
_____

Is there a plan to reduce / attain one BOM database • Yes • No
_____

4. Supplier Items

Are supplier items part number differently than other items • Yes • No
_____

Do you have a separate part number for each supplier you buy the same part from • Yes • No
_____

Do you use a SCD (Spec Control Drawing or Source Control Drawing) to buy a given part from more than one Supplier • Yes • No
_____

Do you identify the supplier on the part drawing • Yes • No
_____

Do you maintain an AVL (Approved Vendor List) • Yes • No
_____

Do you create drawings for solvents, glue, solder, etc. • Yes • No

_____

5. Deviation (and other similar) forms:

What form(s) do you use_____

Are these forms sometimes used to make design changes

• Yes • No

_____

Who signs_____

Where are they filed; • CM / Doc Control • other_____

6. Forms:

Some companies use separate form / process to **release**, **request changes**, and to **specify changes** and to **implement changes**. Do you (and your plants) use:

- Separate form for each purpose
- No form to **release**, One form to **request**, **specify** and **implement** change
- One form to **request**, another to **release**, **specify** and **implement** change
- One form for all
- Other - describe _____

_____

If you use a separate form to **release**:

Can a change requiring a new part have that part released in the change • Yes • No, or do you first have the part released by that form / process and then "picked up" in the change form / process • Yes • No

7. Change Process:

If we generally describe the change process as having the following major events:

Responsible Engineer **Recognize Problem** / challenge

Redesign Complete

Change Control Board / "signers" **approval**

CAD / Hand-drawn **Master Drawings** / **Docs Updated** (change incorporated in docs)

MRP Updated

Change Incorporated in Product (excluded on "document only" changes)

Does CM / EDC play a roll in the redesign (**Recognize Problem** to **Redesign Complete**) • Yes No Describe:

_____

Is **Redesign Complete** defined by

Marked up documents "attached" to DCN • Yes • No (might be hand marked, CAD overlays / redlines, or word document mark ups)

From-To detailed description in the DCN • Yes • No

Flag Notes on the drawing • Yes • No

Detailed description in the Drawing Revision Block • Yes • No

Where in the process are approvals obtained:

_____

Are the changes incorporated into the masters before or after approval:

_____

Is the responsible engineer required to sign the master after incorporation: • Yes • No

Where in the process is the impact of the change identified:

_____

Do you have a team / board that reviews / approves changes
• Yes • No

Where in the process does the team / board first see a change:

_____

How many people approve / sign the typical change: _____
What functions do they represent:_____

_____

Must the MRP be updated before the Drawings are updated:
• Yes • No _____

Must the Drawings be updated before the MRP is updated
• Yes • No _____

Does Manufacturing proceed to implement the change from the approved DCN (mark ups or whatever) • Yes • No, or must they have the updated documents before proceeding • Yes • No

An ADCN process would allow several changes (by mark up or "from-to") to the same document to be queued-up and incorporated after a limit (typically 5) has been reached.

Do you use this feature • Yes • No
Do your internal customers like this feature • Yes • No

Does CM / EDC get feedback from Manufacturing as to the actual effectivity of any changes • Yes • No If yes, which changes

_____

Do you generally limit one change to a "fix" for one problem / challenge • Yes • No

Do you measure the volume of changes done per week
• Yes • No How many / wk _____

Do you measure (change by change) the thru-put time of changes
• Yes • No If yes, describe those measurements and results in the above terminology and be precise (example: The time from Design Complete to Update of the MRP and Update of the Master documents, which ever is later, averages seven workdays)

_____
_____
_____

8. General Comment about Survey

_____
_____
_____

The results are best put into a data-base to be most easily summarized and analyzed.

Automotive Suppliers - Summary Results

The following is an exact copy of the summary results of the above survey taken for the automotive supplier. Their responses and twelve other auto supplier responses are included. At the client's request, a couple of non-automotive suppliers were included and one of the client's sister divisions was included. Two of the automotive suppliers were the author's prior clients. The survey was done in cooperation with Teltec, a Minnesota based expert service. The author reserved rights to the survey and to the summary results. The complete summary results follows:

Survey Participants,

You participated in a survey of your Configuration Management (CM)/Engineering Documentation Control (EDC) processes. The following questions were answered in the context of current conditions, not past or planned conditions. The following is a summary of the results of the 16 companies surveyed.

Company Background:

Type of product(s): Automation, Auto Sub Assemblies/Components, PCBs, Refrigerators, Auto Sensors & Controls, Auto Fuel Sys, Auto AC & Heat, Tractors, Ignition Sys/Generators, Batteries, Auto Windows/ Glass/Mechanical Assemblies, Relays, Auto Electronics, Washers & Dryers, Air Bags, Thermostats.

Number of plants: Ave 8 Physical relationship of plants: From single site to World Wide

Engineering and Manufacturing at each plant? 5 Yes 11 No

CM / EDC organization answers to: Engr = 11, Mfg, = 1, Quality = 2, Pgm Mgmt = 1, Corp Office = 1

Quality Standard(s) 5 ISO 9000 9 QS 9000 1 ISO & QS 1 Own / Industry

Are you: 10 Certified 4 Working toward certification
1 Not required 1 Almost all plants

1. What is CM / EDC organization responsible for:

Filing all released design doc masters	15 Yes	1 No
Distribution of forms and docs	15 Yes	1 No
Document / Item release control	15 Yes	1 No
Change request monitoring	14 Yes	2 No
Change control / facilitation	15 Yes	1 No
Defining the change for/with the engineer	8 Yes	8 No
Most "check for complete package"		
Developing the impact of the change	7 Yes	9 No
(question was often interpreted to mean checking where used / products affected)		
Assignment of PN, Doc #, DCN #	13 Yes	3 No
Assignment of revs	12 Yes	4 No
Input of BOM design info	12 Yes	4 No
Input of all BOM data	7 Yes	9 No
Setting effectivity of changes	8 Yes	8 No
Knowing product configuration	10 Yes	6 No
Means knowing part/change content		
Design of the CM / EDC processes	14 Yes	2 No
Control of the CM / EDC process docs	15 Yes	1 No
Change Incorporation into "master"	9 Yes	7 No
Measure the CM / EDC system	11 Yes	5 No
Microfilm / Digitizing	11 Yes	5 No
3 yes don't microfilm, just digitize		
CAD control	10 Yes	6 No
Engineering Library	9 Yes	7 No
Standard component engineering	7 Yes	9 No
Manufacturing / Purchasing doc control	5 Yes	11 No
Quality / validation / testing doc control	3 Yes	13 No
Publications / service document control	5 Yes	11 No
Sales document control	2 Yes	14 No
Drafting Standards Manualownership	8 Yes	8 No
Other	3 Yes	13 No
1 software, 1 mat'l & process specs, 1 all company forms		

2. Release Stages:

How many stages (phases) of release do you have? Ave 3.06

What do you call them? (The most common answers are as follows)

1 Design / experimental / Development / Proto
2 Prerelease / Proto / Pilot
3 Production

How do you tell (on the drawing) that a document / part is "ready for" a particular stage? (example: Rev blank = development, rev numeric = pilot, rev alpha = production):

Can tell each / all stages by looking at the drawing = 10
Can tell some but not all by looking at the drawing = 5
Can't tell any = 1

How do you tell (on a BOM) ?
(example: Status code 1 = Development, 2 = Pilot, 3 = Production):

Can tell each / all stages by looking at the BOM = 7
Can tell some but not all by looking at the BOM = 7
(4 don't input to the BOM / MRP until production)
Can't tell any = 2

3. BOMs

Is the parts list;

on the assembly drawing?	9	Yes	7	No
on a separate controlled document?	15	Yes	1	No
both?	8			

How many manual or computer data bases of the parts lists are maintained in the company? (example; Engr CAD, MRP plant 1 and 3, MRP plant 2, Publications = 4) Ave 2.3

Plan to reduce / attain one BOM database?	8	Yes	3 No
already have only one database!	5		

4. Supplier Items:

Are supplier items part number differently than other items?
2 Yes 14 No

Do you have a separate part number for each supplier you buy the same part from? 2 Yes 14 No

Do you use a SCD (Spec Control Drawing or Source Control Drawing) to buy a given part from more than one Supplier? 14 Yes 2 No
Some didn't recognize acronym "SCD"

Do you identify the supplier on the part drawing / SCD?
5 Yes 11 No

Do you maintain an AVL (Approved Vendor List)? 13 Yes 3 No

Do you create drawings for solvents, glue, solder, etc.? 5 Yes 11 No

5. Deviation (and other similar) forms:

Have this process? What form(s) do you use? 16 Yes
Mostly called "Deviation"

Are these forms sometimes used to make design changes?
7 Yes * 9 No * Almost always followed by formal DCN.

How many & who signs? Ave 4.07
Almost always include QA, Mfg & Engr.

Where are they filed? 7 CM / Doc Control 9 other places
(Quality, Plant, etc.)

6. Forms:

Some companies use separate form / process to **release**, **request changes**, and to **specify changes** and to **implement changes**. Ave 1.67 forms (one on line with multiple screens)

What forms do you (and your plants) use?
Many combinations used
8 have only one form to do all
2 do not use a form to release
(drawing notations suffice for them)

If you use a separate form to **release**:
Can a change requiring a new part have that part released in the change, 11 Yes 1 No or do you first have the part released by that form / process and then "picked up" in the change form / process?
1 Yes 11 No

7. Change Process:

If we generally describe the change process as having the following major events:

Responsible Engineer **Recognize Problem** / challenge

Redesign Complete

Change Control Board / "signers" **approval**

CAD / Hand-drawn **Master Drawings / Docs Updated** (change incorporated in docs)

MRP Updated

Change Incorporated in Product
(excluded on "document only" changes)

Does CM / EDC play a roll in the redesign (**Recognize Problem** to **Redesign Complete**)? 7 Yes 9 No Note slight difference than question #1 "define change with the engineer?"

Is **Redesign Complete** defined by

Marked up documents "attached" to DCN? (might be hand marked, CAD overlays / redlines, or word document mark ups)	15 Yes	1 No
From-To detailed description in the DCN?	13 Yes	3 No
Flag Notes on the drawing?	9 Yes	7 No
Detailed description in the Drawing Revision Block?		
Note word "detailed."	2 Yes	14 No

Where in the process are approvals obtained ? Most later in the process—at team/CCB meeting.

Are the changes incorporated into the masters before or after approval?
5 before 11 after

Is the responsible engineer required to sign the master after incorporation
7 Yes 9 No

Where in the process is the impact of the change identified?
8 early 8 later at CCB, etc.

Do you have a team / board that reviews / approves changes
13 Yes 3 No

Where in the process does the team / board first see a change?
8 early 8 later

How many people approve / sign the typical change? Ave 5.6

What functions do signers represent?
Usually Engr, Mfg, Materials, Quality, CM and others

Must the MRP be updated before the Drawings are updated?
1 Yes 15 No 2 Neither

Must the Drawings be updated before the MRP is updated?
13 Yes 3 No 2 Neither

Does Manufacturing proceed to implement the change from the approved DCN (mark ups or whatever), 8 Yes 8 No or must they have the up dated documents before proceeding?

An ADCN process would allow several changes (by mark up or "from - to") to the same document to be queued-up and incorporated after a limit (typically 5) has been reached.
Do you use this feature? 5 Yes 11 No
Do your internal customers like this feature? 3 Yes 2 No
(One yes marks up a "master" with all queued changes)

Does CM / EDC get feedback from Manufacturing as to the actual effectivity of any changes? 5 Yes 11 No (5 no keep actual in plant / mfg)
If yes, which changes? Any product change.

Do you generally limit one change to a "fix" for one problem / challenge?
6 Yes 10 No

Do you measure the volume of changes done per week? 11 Yes 5 No

How many / wk? Ave 47.9 (for those answering "Yes")

Do you measure (change by change) the thru-put time of changes?
7 Yes 9 No

If yes, describe those measurements and results in the above terminology and be precise (example: The time from Design Complete to Update of the MRP and Update of the Master documents, which ever is later, averages seven work days): Highly variable answers for the 7 "yes." Range as follows:

5 work days thru CM (From Engr complete to Docs and MRP updated) 45 work days recognition of problem to Docs and MRP updated.

8. General Comment about survey:

4 no comment
1 negative
2 neutral
9 positive

Notice the opinion question about the survey itself. Those with no comment were not pressed to give a negative, positive or neutral response. In retrospect, they probably should have been.

Survey—University Seminar Attendees

The results have been compiled from 58 companies / divisions of companies who responded to the survey. All respondents were seminar attendees. A few have been clients of the author's company.

When raw numbers are given they may not add up to the 58 contributors because some didn't answer that question. When percents are given they were based upon those who did respond to that question. In those cases where more than one choice could be made, the percents may add up to more than 100%

The survey included over one hundred questions. A sample of the results for a few of those questions is included here. The complete survey results are available from the author.

GENERAL -

Size (no. of people):

0 - 100 17% 101 - 500 55% 01 - 1000 9% over 1000 19%

Design and Manufacturing:	1. Are in the same building	27
	2. Same site	7
	3. Same city, different sites	7
	4. Different cities	11
	5. Different countries	7
	6. Combo of above	8

Comment: May have checked more than one choice. The further apart the longer the bridge.

Name you call your EDC / CM group:

22 - Documentation or Doc Control
6 - Configuration Management or Control
6 - Engineering Service or Support
4 - Drafting or Design
20 - many and various (two or fewer of same name)

People in the CM group (including manager if full time):

People in Co.	People in Group
0-100	2.2 ave
101-500	6.0
501-1000	8.0
over 1000	12.3
overall	6.7
Range	0-35

Briefly describe products: Detection Devices, Jet Engines, Telecom, Metrology, Rock Crushers, Hotel Communication, Aircraft & Antennas, Hose & Ducts, Mail Machines, Broadcast Antenna, Batteries, Wheel Chairs, Medical Devices, Rail & Mass Transit, Digital Radios, Physics Education, Equip to Mfg. Optic Lenses, Microwave Hybrid, Membrane Keyboards, Video Systems, PC Disk Drives, Automation Components, Industrial Heating Systems, Auto & Appliance Controls, Control / Inspect Gauging Equip, Truck Hydraulic Lifts, Wafer Track, Irrigation Sprinklers & Valves, Time/Temp Humidity Instruments, HVAC Controls, Tele Multimedia, Batteries & Chargers, High-End Print Inspection & Counterfeit Detection EQ, Telecom Switching, Diagnostic and Test Eq, Mechanical Assemblies, Liquid Level Measurement, Airplane Windows & Lenses, Medical Diagnostic, Capitol Process Equip, Induction Heating, Auto Brakes - Pumps - Fuel Injection, Wiring Devices, RF/M-Wave Power Amplifiers, Automotive Lamps, Children's toys, Respiratory Protection, Refrigerated Food Cases, Circuit Protection, Network Anal Test Equip, Mach Tool Components, CPM Capitol Equip / ICs, Adhesives & Sealants, Medical Products, Electronics.

Regulated by (check all applicable):

Good Commercial Practices	57%
UL / CSA / OSHA Etc	50%
FDA / GMP	17%
DOD / MIL Specs	17%
FAA / JAA	10%
NASA	3%
Other	16% *

*DOH, VDE, DIN, DOT, FCC, NIOSH, SSPA, EN 71, ANSI, NACE, ASTM

RELEASE PROCESS -

Part Numbers assigned per week: 26 ave,
Form used: Yes 64% No 36%

Part / Doc number maintained in:
Hand kept file 17% Database 40% Both 43%

Part Number is:
Significant 24% Non Significant 17% Semi Significant 59%

Releases / Phases used:

Quote / Definition 36%	Design / Development 79%
Pilot 46%	Production 88%

Comment: Phase names weren't consistent nor as named above.

BILL OF MATERIAL PROCESS -

Manufacturing Resource Planning (MRP) system used:
Yes 89% No 11%

MRP based on: PC 24% or Mainframe 76%

Parts list entry by EDC / CM: Yes 71% No 29%

Number of parts in a typical product: 353 ave. Range 3 - 3700

Structure two part numbers in order to purchase an item from two vendors (example: buy an untreated part from vendor A and send to vendor B for heat treatment): Yes 61% No 39%

The Parts List data is hand / key entered to the following data bases:

CAD • Structure tree drawing • MRP •
MRP at several (___qty) plants • Assembly drawing •
Process / Routing • Pubs • Other ____qty

Comment: Question poorly stated. Some interpreted as "done by Doc Control" and some interpreted as "done by the entire company" (as intended). Informal seminar polls indicate that a few have one, some 5 or 6, and an average about 3.

Company makes a conscious decision as to what items are to be sold as spares:

NA (inseparable or throw away product) 25% Yes 52% No 23%

REQUEST PROCESS -

Number of requests per month: 55 ave. Range 5 – 300

Number of people who sign the request before the right engineer sees it:
2.4 ave. Comment: What value do they add to the process?

Is requester given a "accept/reject" response: Yes 79% No 21%

Quantity of Requests in process: 75 ave.
Comment: 75 requests in process divided by 55 ave. requests per month = 1.36 months. Thus the average throughput time is almost 6 weeks.

DESIGN CHANGE PROCESS -
Changes made per wk: 22 ave

Ways to make a design change are (check all applicable):

Quick Change form followed by formal change form	29%
Deviation / Waiver form followed by formal change form	50%
Mark ups on production floor	23%
Change form is only way to make design changes	76%
Other:	10%

Hold Order, QC Form, MRB Response, PCR, Revise Drawing
Comment: Some folks missed the word "only."

Total number of ways to make a change: 2.4 ave, Range 1 – 4
Comment: Several different ways to make a change! This is a symptom of a problem—the formal system is too slow!

We have a CCB (Change Control Board): Yes 49% No 51%

Number of people who regularly attend the CCB:
7.2 ave. Range 4 – 15 CCBs per wk: 1.6

Change Form is called: ECO 16 ECN 14
3 companies or fewer; DAN, ADCN, PCO, ECP, EDCR, ECR, EO, EC, EA, CO, EDCF, ECF, EDC, EAR, DLO, REA.

The change is specifically defined in the change package by:

Marked Prints	84%
Was - now description	62%
New condition - refer to old print for "was" condition	19%
Not specifically defined - compare old and new docs	10%
Other (Revised Master)	3%

Comment: Don't think that there is a difference between the last (other) and "New Condition" but 3% of respondents did! Obviously many companies allow more than one method. The author believes that only the first two are acceptable practices.

Some changes are field installed: Yes 67% No 33%

Some changes are installed on product return: Yes 79% No 21%

We precisely measure the Change Process time: Yes 31% No 69%
Comment: Only four were willing to furnish their report. Based on informal seminar polls the 31% number is suspect. Was the word precisely overlooked? In the seminar the question is framed "change by change" and the results are about 10%.

The Benchmark Report

The report of survey results should contain:

- Who the report is for / Why was the survey done?

- What dates (inclusive) of the survey?
- Who wrote the report?
- Methods used.
- Executive summary.
- Strengths of the Company compared to the benchmarks and compared to best in class.
- Needs of the company compared to the benchmarks and to best in class.
- Detailed results.
- Comment and Interpretation.

Interpretation

Careful framing of the survey questions is a critical starting point. Use of "plain English" helps. But nothing substitutes for in depth questioning aboutthe survey with the participants. In the automotive supplier survey, the personal discussion with the participants was invaluable. Questions/answers were discussed in detail. Acronyms were defined, terminology analyzed and language parsed.

It is very easy to say that you know the change throughput time, but from where to where in the process? What point in the process to what other point in the process? Does "Design Complete" mean the same thing to different people or companies? The writer could go on but you get the point. If you feel uncomfortable asking your competition detailed process questions put a third party in the process.

After all the questions are framed, asked and answered, there is then a need to interpret the results. If the questions weren't properly framed, recognize that fact and either discard the answer or reframe the question and retake the survey.

It pays to begin the process with your flow diagram in place, your time and volume measurement in place and your "facts bank" in place. Doing a benchmark survey is certainly a challenge and interesting to compare your world with your counterparts.

14

CM in the Future / Summary

It is somewhat presumptive to predict the future, however, it may be more permissible as a wish, rather than a forecast. What should the future hold? The following is a result of a mixture of ideas from engineering, repair, manufacturing and operations experience, consulting experience, holding seminars, discussion with peers, doing surveys / benchmarking, as well as researching and writing this book.

System Standards

Documentation of the system will not be viewed as merely a way to satisfy an agency or ISO 9000 requirement. Standards will be viewed as the first step in constant improvement and a necessity for management by exception. Appreciation for single-subject, brief standards will evolve.

Part Numbers

There will be a gradual movement away from smart part numbers, except for the end product top level. Classification coding systems will be developed (such as smart descriptions) or purchased to fill the needs of significance. The "ideal" part number will have minimum significance. The part number will have the document number embedded in it. It will also have a tab in order to facilitate part number changing on non-interchangeable changes.

Interchangeability

The significance of interchangeability and part number changing will be "rediscovered." Reliance on the product specification to interpret form and function interchangeability will be the norm. There will be a recognition that changing the part number is the least painless way to track non-interchangeable changes in the long run.

Engineering functions will come to realize that the manufacturing systems depend upon revision levels being interchangeable, and therefore relatively insignificant in their processes. The revision level will be reserved for interchangeable changes to the document that represents the revised item. The parts will not be identified by revision level. The relationship between Purchasing, Receiving Inspection, and Suppliers will be on the basis of purchase order and purchase order revision (design change) and interchangeability rules.

Traceability of non-interchangeable changes to the end product will be recognized as a task that needs the full co-operation of Engineering and Manufacturing. It will not be done by use of rolling the drawing revision levels.

The BOM

The design portion of the Bill of Material will be recognized as a key configuration management process. The singular BOM database will become a significant way to bridge the gap between engineering and the rest of the company. Many companies will achieve a single BOM database by simply not putting the parts lists into CAD.

More simplified BOMs will emerge—fewer structure levels—driving toward one, two or three level bills. These BOMs will evolve with a one level structure until Engineering and Manufacturing agree on a slim structure. It will be recognized that the BOM needs to be jointly and minimally structured by Engineering and Manufacturing to be mutually beneficial.

More and more companies will realize that assembly instructions with mini-pictorials is a better solution than trying to make and use assembly drawings on the production floor.

There will be more wide spread use of modular BOMs as a better method of documenting features and options and, more importantly, as a powerful tool in responding quickly to customer orders. There will be gradual recognition that Configurator Modules are only for those who have more than a few dozen real world, sold configurations.

Clear and Crisp Release Process

Design development and the documentation release will be recognized as a marriage of necessity. Clear, crisp, fast, accurate, and well-understood methods will result. Small companies will develop a process where none existed before. Larger companies will simplify their processes.

The major emphasis will be upon encouraging a part by part assembly by assembly evolutionary release in part lead-time, rather than today's tendency to massive batches of documentation for release.

The release phase chart will become an industry standard for the best of the best processes. The release process will be complimented by increased use of Cross Functional Teams.

Simplified Request Process

There will be an increasing tendency for companies to continue the use of teams into the request and change processes.

There will be a tendency to more quickly recognize the need for change and a simple change request process. There will be a gradual recognition that the simpler request process is better. Whatever process is used, a list of "challenges" will result that is worked frequently by the team.

Companies will abandon the tendency to process the request as though it were already a change. The process savings will translate into competitive advantage and cost savings.

One Fast Change Process

If for no other reason, the competition will force the abandonment of multiple formal and informal systems in favor of one fast, accurate, and well understood process.

The fast change process will allow the horse (documentation) to get in front of the cart (the product).

The trend will be away from boards and committees, replaced by a process with "up front" crossfunctional teams.

Increased emphasis on costing changes will occur. There will be gradual recognition that not costing at least "cost reduction changes" results in creeping elegance and profit erosion.

More and more, companies will realize that the mature product line does not have to be continuously improved, thus saving tremendous amounts of money.

Process design and writing standards for the "rule" as opposed to the "exception" will evolve. This will free management time to handle exceptions.

More methods for avoiding and eliminating some changes will be devised. Development of good cost estimating tools and use of teams early in the processes being the most significant.

Many "myths" apparent in change processes will be exposed. Primary among the disappearing myths will be the queuing of approved changes for incorporation into master documents.

CM functions will gradually be trained and organized to incorporate the redline changes into the master documents. CAD redline/overlay ability will make this a matter of a few keystrokes.

This fast change process time will also translate into significant competitive advantage and cost savings.

Automation

Putting the release, request, and change forms "on line" will be the rule. Putting the rest of the package and "flow" on line will come with improved application programs. The relatively expensive PDM and ERP programs currently offer design your own forms and design your own work flow for form approval. There will be application programs of a "cook book" variety that will be tailorable specifically to your processes.

There may be a tendency to measure every operation in the process because computers make it so "easy." Eventual recognition that "no one can use all that data" will be followed by a movement to measuring only a few key process points for volume, thru put time and quality.

More and more software will allow "linking" of CAD and MRP. This is a necessity for many companies to achieve a single integrated Bill of Material. Applications are available for some MRP-ERP / CAD-PDM and more will follow to fill that gap. A key element—security on the revision field for CM —will come with some of those packages.

All in all the fast movement in this area will aid the CM discipline move toward "paperless" but still being satisfied with "less paper."

Goals and Plans

A chief engineer who had been at one of our seminars called to ask if this author had any CM Goals or Plans. The following, which you may find useful, resulted:

Reduce the time to market new products, new features, and options and problem fixes:

- Measure the design time and the CM time to release and change. The design time probably measured in work-days per new drawing. The release time probably measured in the work-days to release to manufacture any signed document or group of documents released by a single release notice.
- Set time goals based upon the measured current design time and release time. Goals probably reset each year.
- Assure that sales/marketing and management are part of each cross-functional team for development of new products, features, and options in order to optimize the available engineering manpower.
- Assure that the cross-functional team reviews all requests for changes and that criteria for filtering out undesirable changes are developed. Costing of changes called reduce manufacturing time, reduce maintenance time, ease of manufacture and cost reductions to be done including consideration of all start up / one time costs to be paid back within ___ months by the unit cost reduction. Also make a list of products to be continuously improved and products which will not be continuously improved and review that list each ___ months with sales/marketing and management.

Improve the quality of new designs and engineering changes:

- Measure the changes per new drawing per year (measures the quality of the new product and document release process). Set goals after the measurement is established.

- Measure the current fixes to correct a prior fix after the change is turned over to CM based on a percentage of changes done in the same period (Change Process quality measurement). Set goals after the measurement is established.
- Assure that the cross-functional team reviews all new designs and changes.

Assure that every practical measure is taken to bridge the gap between Engineering and the rest of the business.

- Establish effective cross-functional teams for new designs and for changes.
- Assure the existence of and support for an effective, well trained Configuration Management function that is dedicated to documenting, measuring and continuously improving the processes for Release, BOM Structuring and Control, Requesting of Changes and Making Changes.

Perhaps the above document can help you set some goals for your company.

The Government

The military has moved towards commercial standards and away from DoD specifications. Some contracts have even carried a default clause on change approval time. They seem to be headed in the right direction.

The FDA continues to be paranoid about the manufacturing process changes even when dealing with hardware products not implanted or used in the operating room. The FDA new product approval time continues to be unacceptably long. Each president in the last several administrations has responded to that problem by adding hundreds of people to the FDA bureaucracy. What they apparently need is fewer people and a serious overhaul of their processes.

Unfortunately, the other agencies seem to be generally driving to more complex requirements rather than simplifying them.

ISO and Copycats

These standards are plain English, make sense requirements. They have served the manufacturing industry fairly well. The August of 1994 changes to the ISO 9000 standards increased their weight by almost 50% without an apparent corresponding 50% increase in substance. This is somewhat alarming especially if it is a trend. The December 1995 *Guidelines for Configuration Management* at least recognize the discipline but seem to be too DOD oriented. The standards run the risk of being too much of a good thing—taking on a life of their own. The changes now under consideration might include more of a good thing than we need.

The copycats AS 9000, QS 9000, etc., have typically added requirements for OEMs to approve all supplier changes. A requirement that will add and has added to the cost of the product without any apparent value added. They obviously do not understand specifications and interchangeability and how they can and should be applied to suppliers.

The ISO paragraph on Documentation and Data Control has the highest deviation from standards—in fact nearly twice that of any other paragraph. Recognition of this fact has caused heightened interest in EDC/CM.

The Discipline

The dominance by DoD oriented organizations and societies has given way to society memberships who will find a significant majority of their members are interested in generic CM. The International Standards Organization may be the driving force here. The discipline will gradually shift from the traditional "Identification, Control, Accounting, and Planning" to emphasis on the processes involved. ISO has started that trend.

There will be an increased use of operative Cross Functional Teams in the CM processes—Release, BOM, Request, and Change. There will be recognition that poor implementation of cross-functional team practices does not negate the power of the concept.

There will be increased emphasis on the product specification and its interchangeability as the key procurement tools. Companies will realize that

approval of supplier design changes is a poor substitute for well thought out component specifications and interchangeability requirements. A move to limit the time for customer approval is occurring and will increase.

Education and Training

There is an increasing recognition of Configuration Management / Engineering Documentation Control as a teachable discipline. Significant increases in CM societies and society membership will occur—most notably the ACDM. Several organizations and groups will eventually unite just enough to merge the certification requirements. **Hopefully these will be based upon testing to certify the capabilities of the practitioners.**

There are some who believe that engineering or other students could benefit significantly from an EDC / CM course while in school. Others feel they won't fully appreciate the discipline until being in the "real world" for at least a couple of years. There is, in this writers opinion, a place for teaching the discipline to the practitioners of the discipline in "trade schools," and to engineers in colleges and universities. Academia has been very slow to respond. Continuing education programs at a few far-sighted schools will be the primary education and training tool for some time.

Industry in General

American industry will lead the world in developing simplistic methods to handle the CM processes, integrated with CAD / PDM and MRP / ERP, in a systematic approach.

Document Control will be distributed to the functions that own the documentation while the CM function will be centralized with one of those document control functions. Functions that are now dispersed in the organization will be brought together into a meaningful CM function.
There will be an increasing demand for CM managers who have proven that they can "bridge the gap."

There will be an ever-increasing emphasis on CM as a practical way to bridge the gap between Engineering and the rest of the company. The discipline will be recognized as the most significant way to eliminate the "throw it over the wall" syndrome. Minimum control, better and faster!

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