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Implementation of continuous flow manufacturing in United States industries

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ABSTRACT

IMPLEMENTATION OF CONTINUOUS FLOW MANUFACTURING IN UNITED STATES INDUSTRIES

by
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Continuous Flow Manufacturing (CFM) is one of the key strategies to enable the United States industries to adapt to any volume increase and rapidly changing requirements of the market place. CFM is an on-going analysis and improvement activity used to optimize the efficiency, effectiveness and flexibility of any process. The two basic goals of CFM are to reduce cycle time to less than customer order leadtime and to eliminate inefficiencies from the overall manufacturing processes.

The thesis will describe reasons for the scarcity of CFM in United States industries. The methodology applied was a detailed six page questionnaire sent to over thirty-five industries in United States, using CFM as a part in their manufacturing operations. The research focused on difficulties experienced during preparation and implementation of CFM.

The theoretical research and the questionnaire analysis revealed that CFM is indeed partially culture-based, difficult to understand, not easy to accept and hard enough to implement. Although the research was taken from a stratified sample of already known CFM implementors, full scale implementation fell very short. In fact, most industries in United States seemed to be engaged in preparing for CFM.

Hopefully, the information presented will help the United States industries to formulate plans and strategies to implement further actions that will lead to more efficiency and effectiveness in their manufacturing operations.

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by
Rohit P. Patel

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This thesis is dedicated to my Father
Mr. Prabhudas P. Patel

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INTRODUCTION

1.1 The Historical Perspective

American Manufacturers today are functioning in a rapidly changing environment - an environment characterized by increased global competition, pressures to improve productivity, accelerating technological developments, and the shortening of product life cycles. Collectively these factors are squeezing the margins and revenues of United States manufacturers and impacting their performance in the marketplace.

Prior to the 1980s, many United States manufacturers had what might be described as an "internal perspective." Planning and forecasting was an "inward" process-based on historic sales performance and desired internal improvements in productivity and quality. Few companies did global competitive benchmarking...or tried to build production plans based on actual customer requirements.

The traditional approach to growing a business was "more is better." It was typical to concentrate on short-term goals. Planning and decision-making were conducted in a centralized fashion. Manufacturers based decisions on a desired forecast that would meet internally generated business plans, and many were satisfied to produce a little bit more from year to year. The goal was to operate at some level of efficiency and turn in a "report card" that showed incremental improvements from year to year(9).

However, in the 1980s, most manufacturers discovered that this method or style of business simply was no longer sufficient-not if they wanted to compete in the global marketplace. The `80s might be described as a decade of discovery. Not only were manufacturers forced to take a look at the **external** world around them, but they began to scrutinize many other areas of their management process which, as they were discovering, have a profound impact on the effectiveness of their production systems ranging from their organization structure to reward and compensation systems. Concepts like participative management, Total Quality, the power of integration, and business simplification began to generate attention. Certainly, managers started to understand that what needed to be done could not be accompanied in the short term They realized that something had to be created that would allow the organization to **continuously** improve and **continuously** learn(13).

The `80s could also be characterized as a time of trial and error. Many companies spent an enormous amount of time and energy trying to find a solution to their problems. The growth of many businesses, the increased level of competition, the explosion of technology, and the proliferation of suppliers led to a more complex environment. Add to those factors the various "improvement" programs such as JIT, MRP II, SPC, SMED and others (which have had some success in the operations area, but were rarely implemented in a holistic manner) that were attempted, and it becomes an even more complex picture.

In a sense, manufacturers really have been operating with an unfinished vision-a vision that has sometimes excluded the most important ingredient-namely, the customer.

1.2 Managing Change and Measuring Success

Although the various improvement programs United States manufacturers began to implement in the 1980s have added value from an operational standpoint, it has been very difficult to see that improvement on the bottom line. The pressures placed on managers by this dilemma may well be caused by an accounting system that acts as a major stumbling block for implementing enterprise-wide change - the kind of change necessary to produce the long-term benefits that manufacturers cover(2).

Change itself is never easy, and as most managers found in the 1980s, the stimulation for change did not come from some self-directed higher vision. Rather, the impetus came from the "outside" world-primarily, the impact of global competition.

However, something else is needed in addition to this external stimulus to force a major change. In some cases, that "something" is the way the end result of this desired change is valued. In the manufacturing world, that usually translates into a change in the cost accounting system. How many manufacturers have implemented programs in factories only to find a huge delay between the time the program is implemented and the time when the benefits actually show up on the bottom line? How long does it take for the benefits to be reflected in the cost accounting or financial reports? Only in the last few years, has there been significant literature, such as the writings of Robert Kaplan of Harvard, that recognizes the inadequacies of traditional cost accounting systems. Mr. Kaplan calls it "the lost relevance of our cost accounting systems".

Most of these systems allocate extraneous costs of materials and labor, which at the turn of the century made up the majority of product cost. Over time, the percentage of the cost associated with direct labor has been continuously decreasing. It is being replaced by increases in the costs associated with overhead, depreciation, and technology. The very fact that a labor-based accounting system issued to allocate costs creates a distortion that, in many cases, covers up the fine work that many manufacturers are doing in the areas of productivity and quality improvement(17).

Perhaps this inadequate measurement system is causing more grief than any other dilemma. Otherwise, the whole notion of management by objectives sounds right, looks right, feels right. How many manufacturers have had the unpleasant experience of directing improvement efforts and getting a response that was not in line with the original intent of the program? To a certain degree, this is very much like desiring one thing and rewarding another. Managers do not purposely put programs in place to do this-it just happens.

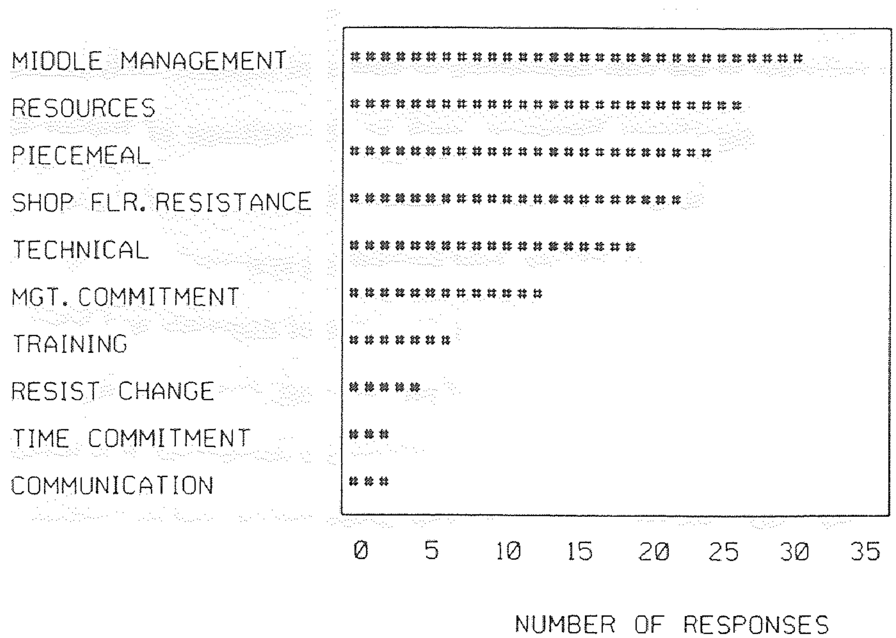

FIGURE 1. BIGGEST OBSTACLES TO CHANGE

1.3 Band Aid Solutions

Experience shows that manufacturing in the United States certainly has been going through a tremendous amount of trial-and-error change activity. But step back for a moment. What a manager really needs is not more individual "band-aid solutions," but rather a more integrated approach for managing change across the organization and across the total enterprise. Using a medical analogy, U.S. industry has a complex illness. Most manufacturers have been treating the symptoms-not the cause. There is a tremendous amount of remedies out there for the symptoms. But for the most part, they represent "band aid solutions". What is really needed here is an in-depth understanding of the illness so that aholistic plan for the wellness of the entire organization can be prescribed. This will lead to long-lasting change. Just as an ill individual may need to make a *lifestyle* change, an organization needs to make a *cultural* change-one that will simplify actions and reduce "stress" while creating a new value system that will be long-lasting(3).

1.4 Cultural Change

Recently a survey of top manufacturers in the United States had been taken - for both discrete and process industries, to gain a better understanding of what they were experiencing. The study revealed that almost every manufacturer is involved in some type of program to change the organization. However, less than ten percent of American manufacturers are really moving forward with a truly *integrated* approach. When asked, "What is the biggest obstacle to change?," the overwhelming response was "middle management" (meaning anybody between executive management and first line managers). Major reductions in resources are cited as the second most common obstacle to change, while a "piecemeal" approach to implementing new programs was cited as the third major obstacle to change(5).

facing (5)

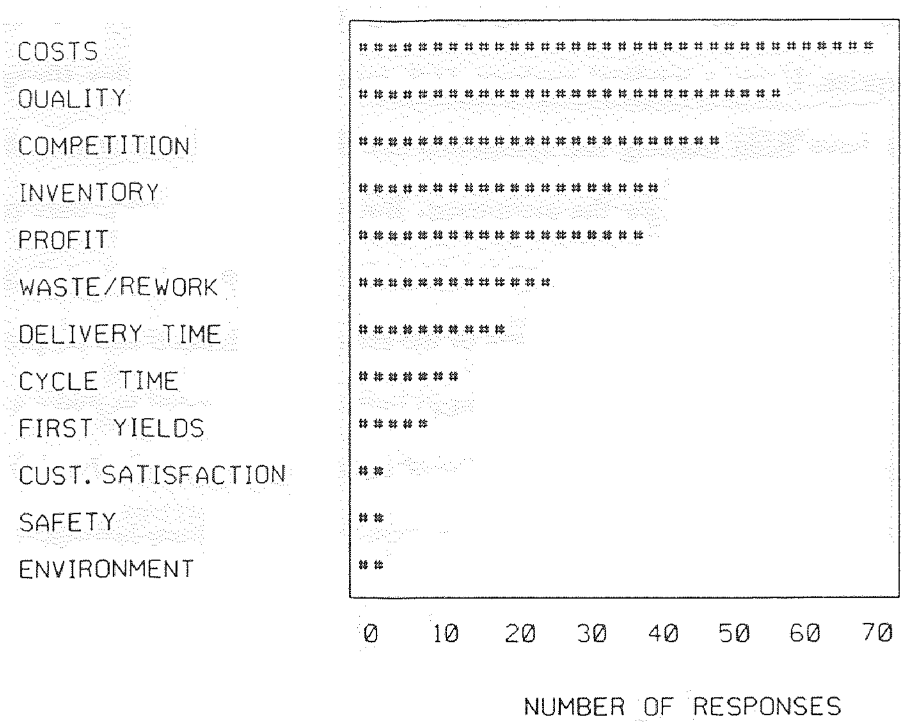

FIGURE 2. WHAT MANUFACTURERS ARE CONCERNED ABOUT

1.5 Biggest Obstacles to Change

Many of the response to questions posed in the research point to an obvious problem with programs that have been implemented to date. In many companies, a piecemeal introduction of new programs is often viewed by middle managers and employees as "the program of the month." In many cases management has not really had the resolve to stick with a program they have instituted. This lack of resolve causes a lack of credibility in future programs. In many cases, programs simply have not been given enough time to develop and show the anticipated returns.

In some instances, this resistance to change is a result of a deeper problem which has been described as "functional myopia." Functional myopia results from having a narrow vision-which is an outgrowth of the increasing specialization and functional division which has been promoted within organizational structures. There is simply far too little cross-fertilization among people in most manufacturing organizations. The absence of this cross-fertilization causes people to get caught up in their own worlds, rules, and value systems. As a result, individual management functions have been created that do an excellent job of focusing on individual "trees," but no one is looking at ways to improve the total "forest."

There is, of course, a real need to perform specific functions such as marketing, engineering and manufacturing. But as an organization grows, further specialization occurs, and the gap between the top and bottom of the organization expands. This specialization and expansion causes the development of specialized languages associated with particular disciplines within the organization. The advent of the personal computer has also played a role in this. Certainly more computing power is in the hands of individuals, but at the same time, a further segregation of information was promoted without the ability to connect the databases. Combine this with the lack of macrocosmic vision, and it is easy to see why many companies become so *introspective* that they fail to see what's occurring in the outside world-and thus never see the need for change.

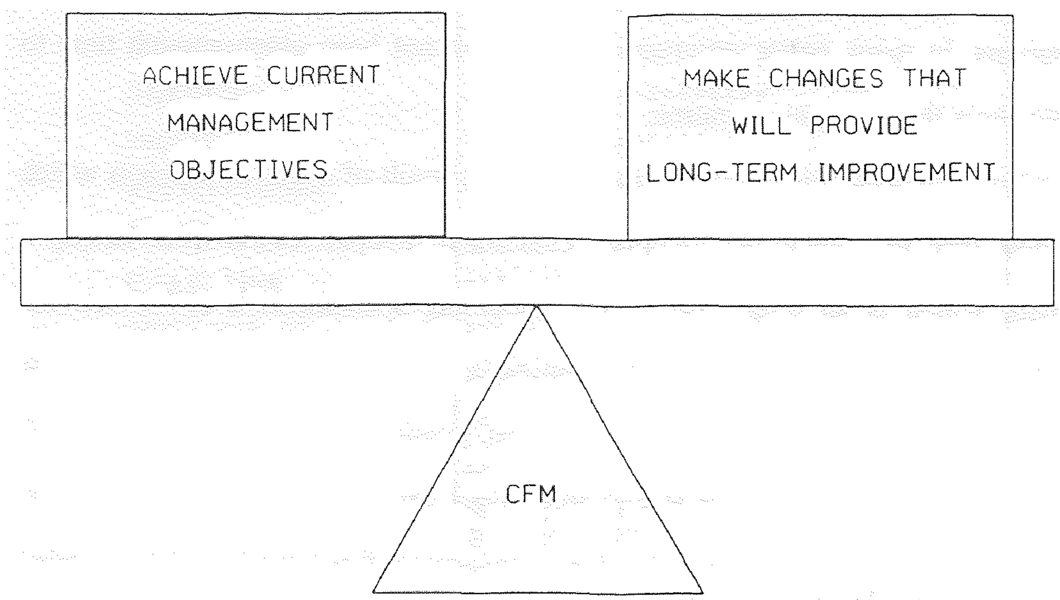

FIGURE 3. THE CHALLENGE OF THE '90S

Fortunately, however, in the late 1980s, more and more manufacturers began to adopt more global visions of what manufacturing can be. In 1987, the Malcolm Baldrige National Quality Improvement Act was signed into law, and for the first time in our history, American industry had a set of national standards for manufacturing excellence. This award program provides a real shot-in-the-arm for American industry. Not only does it present excellent guidelines for improving the *total* manufacturing enterprise, but it encourages companies to broaden their vision and gain a global understanding of what is means to be "worldclass." While American industry is awakening to new ways to manage the manufacturing enterprise, the concerns of manufacturers are the same today as they always were. In the research study, cost, quality, competition, and inventory were consistently pointed out as the primary concerns of executives(13).

1.6 Striking a Balance

The management challenge of the `90s is simply to achieve short-term management improvement objectives in cost, quality, and delivery while balancing those objectives with the implementation of an enterprise-wide program that will deliver continuous long-term improvement.

In order to perfect this delicate balance, new performance measures need to be considered: factors such as customer satisfaction; comparison to industry benchmarks; return assets; responsiveness to the market; and the objective to six sigma, which focuses on the need to balance process capability with the design tolerances associated with the process and the products developed(10).

It takes a long-term investment to become worldclass. In fact, it is a never-ending journey. A long-term commitment and a desire for a quantum improvement in operations must be developed. In order to do this on a sustained level, a continuous learning mindset must be installed throughout the organization.

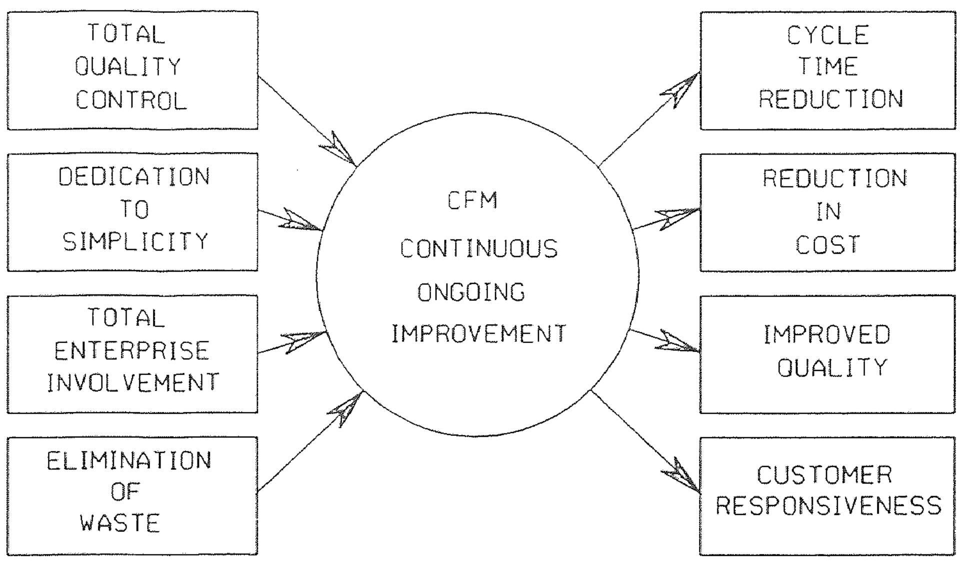

FIGURE 4. CFM - CONTINUOUS ONGOING IMPROVEMENT

CHAPTER 2

CFM OVERVIEWS

2.1 Definition and Principles of CFM

"Continuous Flow Manufacturing is an on-going analysis and improvement activity used to optimize the efficiency, effectiveness, and flexibility of any process".

CFM is about improving manufacturing performance (Figure 4). It is not a single technique, but a set of a basic principles and simple philosophies. It is an approach to problem solving. It is not possible to completely describe CFM in seven principles. The principles below, however, do explain the fundamental aspects of the methodology and offer a good foundation and basic definition(6).

Principle # 1: "*Produce only what is needed, when it is needed-no more, no less.*" In effect, produce to customer demand. Create a pull system that precisely balances the pace of production. This will set a tempo which will regulate the volume and rhythm of production.

Principle # 2: "*Any process or activity that does not add value is considered waste.*" The CFM process looks for all forms of waste, whether in manufacturing, processing, transportation, support functions, planning (such as forecasting unnecessary quantities), engineering, or administrative functions.

Principle # 3: "*For real change to happen, all stakeholders must have ownership in the change process.*" This means empowering the entire organization, concentrating on the team concept, getting support from top management, offering everyone a chance to share visions and goals, and then planing and implementing the program together.

Principle # 4: "*Continuous enterprise-wide learning is the key to worldclass competitiveness.*" This road to self-sustained organizational learning leads through three distinct phases (Figure 5):

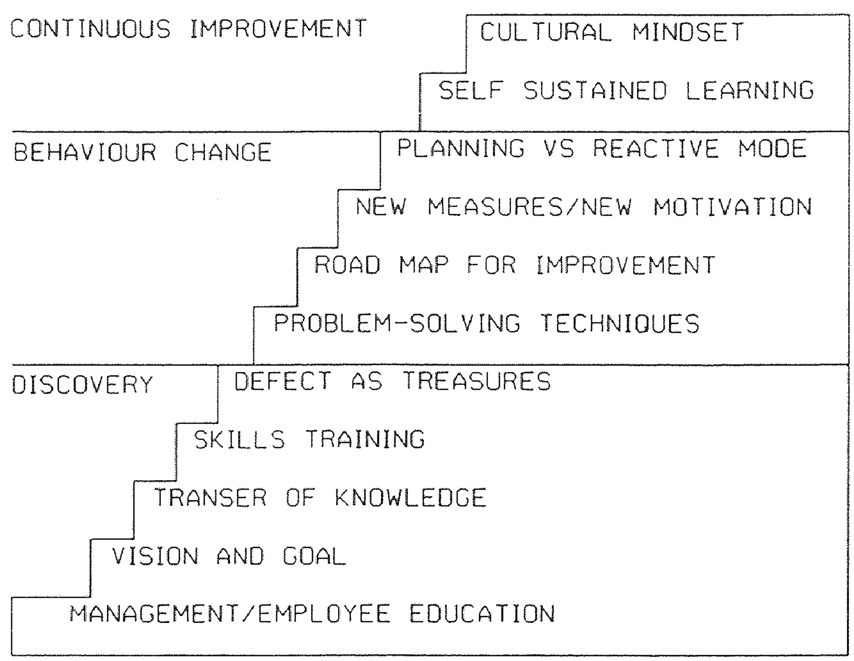

FIGURE 5. ORGANIZATIONAL LEARNING

a. The stage of discovery which includes management and education, vision creation and goal-setting, knowledge transfer, and skill training.

b. The achievement of behavior change, which can only be accomplished by the adoption of a new mindset and measures that encourage employees to view defects as treasures, and empower them to solve problems at the source.

c. The third plateau is reached only when continuous improvement becomes a self-sustaining proposition.

Principle # 5: "*Reducing process variations is the path to continuous total quality improvement.*" With reduction of variation comes improvement and predictability. First, variation must be measured, understood, and reduced. This is not just a manufacturing process, but one that can be implemented throughout the organization. The real goal here is to have this quality assurance at each step of the value-added chain. Not only does this reduce waste, but it promotes a better understanding by the employees doing their assigned jobs.

Principle # 6: "*Build upon a foundation of existing assets before adding unnecessary sophistication.*" Some industries has found that CFM is really a self-funding project. In fact, it enhances return on assets because, in most cases, the process reduces assets while it increases profits. CFM is a methodology-not a technology or a machine. Very often, there are immediate opportunities that can result from its implementation, freeing up the resources for this process to be self-funding.

Principle # 7: "*Quantum improvement can only be obtained by focusing on the total production system.*" This includes the hidden factory as well as visible equipment and systems. the total enterprise needs to be engaged in the understanding and simplification of the process. As witnessed during implementation of CFM by some industries, functional management systems and controls sometimes establish conflicting objectives. Total optimization of the organization can only come about from tearing these functional biases down and working together.

2.2 Main Techniques of CFM

WIP reduction - cuts cost and uncovers productivity problems otherwise `hidden' by costly inventory. The goal is the batch size of one.

Group Technology - sees production as one continuous process from receipt to shipment. Ideally it is one location giving flexibility of space and manpower through process. This eliminates long distances between operations, large WIP inventory and difficult communications created through having specialized departments.

Balanced/mixed production - aims for the cycle time to equal the raw process time. Balanced production needs flexible space, equipment and manpower to match order demand. Total flexibility results from mixed production where resources can be moved from one model or product type to the next according to demand.

Kanban - to manage material movement. It can be anything from an empty bin to a phone call to a vendor or a reminder card. It triggers action when material is pulled through the process from one operation to the next.

Tightly coupled logistics - tightening of logistics from supplier to customer, giving rise to better visibility of requirements, greater awareness of problems, improved communications.

Supplier integration - good relationships between the plant and outside vendors who are seen as an extension of the whole manufacturing process.

Zero defects - CFM increases the emphasis. People responsible for manufacturing also carry out quality control - eliminating the need for inspection and auditing.

Management by sight - CFM materials flow through layouts designed so that problems become immediately obvious.

Multi-skilled people - CFM at its best means people are masters of several trades, contributing to line balancing. Symptoms are seen first in manufacturing where they should be dealt with as they arise.

2.3 Quality/CFM Interlink

In some industries, there were small obstacles in the way of coordinated improvement: some felt that quality had to come before CFM, and others had contrary beliefs. The issue seems to have melted away, and well it should. Good quality surely does make it easy to look good in implementing CFM; that is, when the quality is right, the main reason for buffer stock disappears(21).

The reverse is also true: The dominant CFM technique of cutting lot sizes and transit quantities takes inventory out of the system; in so doing, it takes scrap and rework out, immediately lowering the cost of quality. Furthermore, the successful CFM companies are seeing that the most important benefit is to take out delay time so that few changes can occur between when a part is made and when it is used. Then finding the cause of bad quality is easy. The operator who just made the bad part will often know the cause, because only one or two changes will have occurred in the make-use time span. With a little encouragement and training, the operator then becomes the focal point for problem diagnosis and for recommending solutions.

2.4 Quality and Quantity Application Principles for CFM

For CFM to be successful and function properly, part quality and quantity must be under control. This means that all parts that arrive for assembly must be usable parts and also all parts must arrive where they are needed, when they are needed, and in the exact quantities needed. Problems related to quality in an organization should be addressed before quantity issues because it becomes very difficult to focus on quantity and delivery issues if part quality is questionable(19).

The primary quality CFM principles are:

a. Train every person in the organization on quality issues and heighten their sense of quality awareness.

b. Make continuous improvement toward zero defects a way of life and make defects visible.

c. Control quality at the source by making each production worker responsible for quality and eliminate trying to "inspect quality into the parts".

d. Make every worker responsible for his or her own rework.

e. Establish preventive maintenance and make production equipment maintenance the responsibility of the production worker using that machine.

f. Encourage teamwork and worker involvement in decision making.

g. Reduce multiple job classifications and make workers multifunctional through cross-training.

h. Qualify vendors, with source inspection and validation required before delivery.

i. Simplify product design so that it incorporates producibility, simplicity, standardization, modularity, flexibility, quality, and cost effectiveness for total productivity.

j. Emphasize total quality control, which begins with designing a product and process to produce a quality product that does not rely on inspection after it is produced.

The primary quantity CFM principles are:

a. Improve plant layout by designing for flow rather than function, cutting manufacturing cycle times, and emphasizing flexibility and responsiveness.

b. Avoid moving parts to unofficial queue areas.

c. Make continuous improvement toward eliminating setup time.

d. Reduce lot sizes and produce in small lots using a "pull" production system rather than a "push" system.

e. Reduce inventory levels to approach zero where possible because excess inventory is a waste and a cover-up for other problems and poor planning.

f. Develop a uniform plant load and avoid overloading capacity.

g. Eliminate high safety stock required because of errors in production planning, long lead times, and vendor reliability problems.

h. Part scheduling should be based on finished part due dates, not operation start dates.

i. Shop supervision should be trained to be sensitive to throughput time and delivery dates, not direct labor cost.

2.5 CFM and Supplier Relationships

One myth about CFM is that it is only for large companies, because large companies have the buying clout to enforce the kind of delivery and responsiveness that CFM implies. Some of the initial implementors of CFM in the U.S. fed this myth: they simply demanded that their suppliers deliver when wanted--which led to inventory build-up rather than reduction for the suppliers(25).

Relationships with suppliers are changing because of CFM: they are becoming more cooperative. The companies that are at the forefront of CFM now are working closely with their suppliers to ensure quality and to help them implement CFM themselves. Manufacturing in the U.S. is interwoven and interdependent: very few companies manufacture all of a product from raw material to boxed product.

2.6 CFM Production

The idea of producing the necessary units in the necessary quantities at the necessary time is described by the short term CFM. CFM means the necessary kinds of subassemblies of the preceding processes should arrive at the product line at the same time needed in the necessary quantities. If CFM is realized in the entire firm, then unnecessary inventories in the factory will be completely eliminated, making stores or warehouses unnecessary. The inventory carrying costs will be diminished, and the ratio of capital turnover will be increased(7).

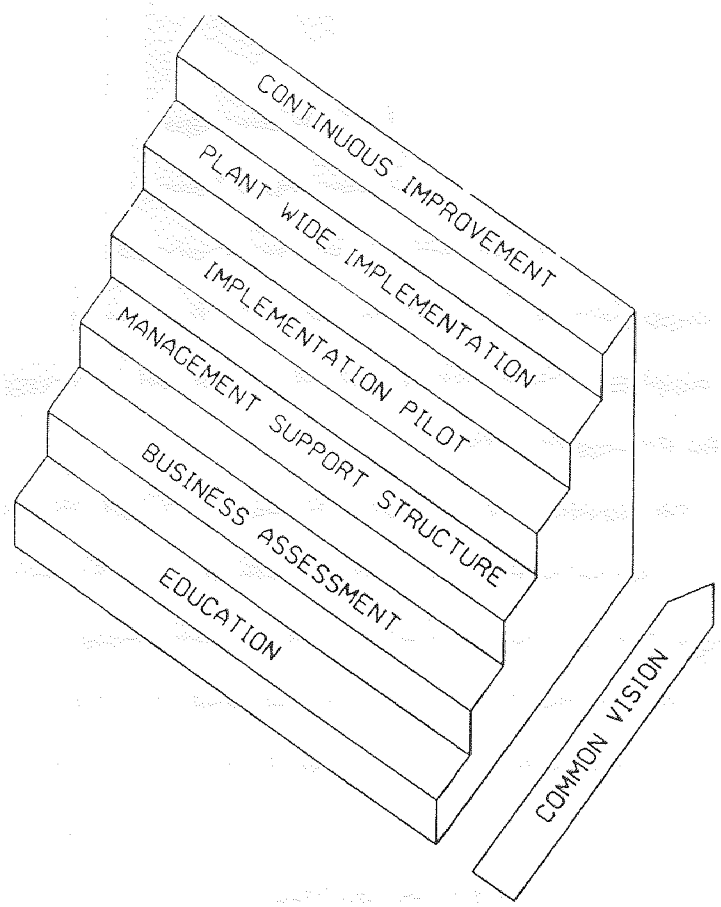

FIGURE 6. COMMON VISION

However, to rely solely on the central planning approach which instructs the production schedules to all processes simultaneously, it is very difficult to realize CFM in all the processes for a product like an automobile, which consists of thousands of parts.

2.7 Elimination of Waste and CFM

Any input of raw material, labor, capital or any other resource above the minimum required for the desired output is waste and will reduce productivity. The total quality control methodology identifies the sources of defects and complexity in the process. Less material is wasted in scrap. Less labor is wasted because scrap does not have to be reworked(26).

CFM approaches the elimination of waste from another perspective. Because products are not assembled until they are needed, there is less inventory throughout the manufacturing process. This has the direct benefit of increasing asset productivity, but the indirect benefits are even more valuable. With less inventory separating the various production operations, less time is wasted between the start of manufacturing for a product and its completion. The flexibility added by the shorter cycle times enables manufacturing to be more responsive to changing customer demands. A less obvious benefit is elimination of the wasted space which was used to store all the unnecessary in-process inventory.

Making problems visible - Both CFM and total quality control promote the solution by making them visible. After a process has been accurately documented, performance data are collected on the output of the process to determine how well it is operating. These data are analyzed to determine the causes and seriousness of defects, and hard facts can replace opinions in the allocation of problem-solving resources. CFM makes problems visible through direct, but often more compelling approach: stripping away the cover of inventory which is used to hide problems. Thus CFM forces managers to face problems and solve them.

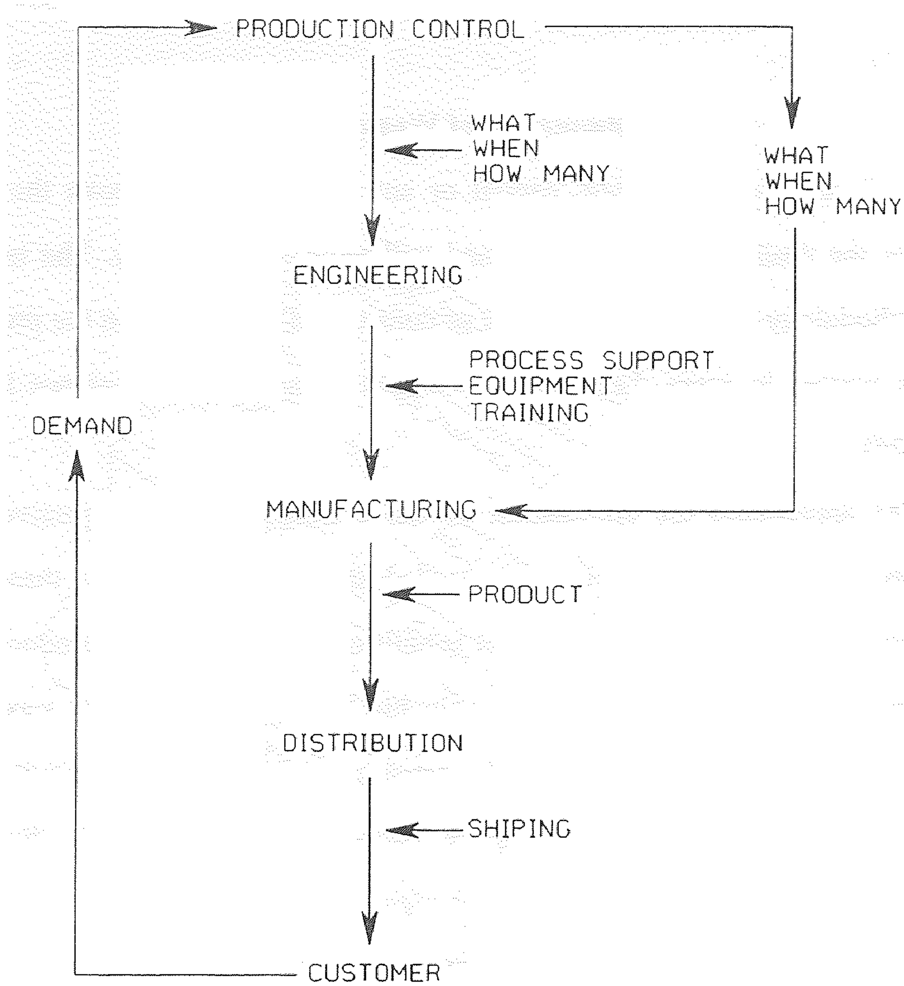

FIGURE 7. FLOW CHART FOR CFM PROCESS LINK

Creating a climate for continuous improvement - Both CFM and total quality control fundamentally alter the culture and operation of manufacturing. Their goals are zero defects and zero excess inventory, which can continually be approached. These goals must be accepted and internalized throughout the organization, so that continuous improvement becomes part of the manufacturing routine (Figure VI).

Naturally, top management needs to be involved in and supportive of any major programme for it to be successful. On the other hand, the people who are closet to the work are the ones who know best what the problems are. These people are also often the ones who know best how to eliminate them and make operations simpler. Such changes will have a profound effect on their daily working lives. If they do not understand and participate in these changes, they may perceive them negatively and resist them(29).

Working on improving the process gives the individual employee a break from the routine of manual labor and also provides an opportunity to use thinking ability and knowledge. Most importantly, it provides a needed sense of ownership of the process they are involved in carrying out.

2.8 CFM Process Link

The CFM process has some general assumptions for successful implementation. These are:

a. Mixing of different parts should not be allowed.

b. Build-around production should be stopped.

c. Kanban squares should be strictly followed by the production people.

d. No interruption in the production schedule should be allowed.

The CFM process links the product cycle from the initial stage through shipment of the product to the customer (Figure 7). Thus, each area related to the product is responsible for its success. Different areas responsible for the process include the following:

a. The manufacturing operation should be responsible for cycle time, productivity, kanban squares, no build-around production, cross training, maintenance, people involvement, and Cause and Effect diagrams.

b. The industrial-manufacturing engineering group should be responsible for SPC, layout design, line flow and balance, process capability, capacity and cost analysis, and eliminating the non-value-added in the process.

c. Production control should be responsible for scheduling and forecasting, vendor and customer coordination, CFM logistics system, and optimizing the lot size.

Quality and cost are not negotiable terms for the customer or manufacturer any more. Enhanced competition makes Continuous Flow Manufacturing a fundamental requirement for the manufacturing operation on which everything else is built. CFM is a message of continuous improvement, with ultimate goal of providing the best possible service to our customers(4).

CHAPTER 3

MANUFACTURING TECHNIQUES OF CFM

This chapter considers the core techniques of CFM in manufacturing. These are in three main areas: cellular manufacturing, Kanban (pull scheduling) and set-up time reduction. CFM focuses on balance and flow and cellular manufacturing is one of the key techniques supporting this. Group Technology is an analytical technique leading to cellular manufacturing. To achieve CFM production, cellular manufacturing needs to be brought about by the reduction of set up times. The best known CFM technique is pull scheduling, normally known as the Kanban system(1).

3.1 Cellular Manufacturing Systems

The emergence of the cellular manufacturing system, and its highly automated form - the flexible manufacturing system (FMS) - has resulted in a new type of production system which is capable of producing high quality products at low cost. This new production system has a greater acceptance and has been implemented on sizeable scale in the US industries(19).

Group Technology is a systems based rationale for solving the reorganization problems involved in setting up cellular manufacturing systems. It provides a computer-oriented database and tools the manufacturing engineer can use to design the workcell. A GT analysis develops the families of parts which can be manufactured by a flexible, cellular grouping of machines. The machines in the cells can be retooled so that one can rapidly change from one lot of components to another, eliminating set-up time or reducing it to a matter of minutes. Eliminating set-up time dramatically alters the economics of lot or batch production to permit the economical production of very small lots(11).

In cellular arrangements, one worker can hand a part directly to the next worker for another operation. If the part is defective, the process is halted to find out what went wrong. Quality feedback is immediate, and high quality products emerge. This is integration of the function of quality control into the manufacturing system. Small lot quantity, coupled with a 100% perfect product (another hard-sought ideal), smooths the production flow.

After many years and much hard work, the discrete part system begins to look more and more like continuous flow process in which products flow like water through the plant. But the key first step to transforming a production systems is the transformation to a cellular manufacturing system.

3.1.1 Designing Cellular Systems

Cellular manufacturing has existed for many years, but it has not been properly defined or well understood, and it certainly hasn't been recognized as a particular type of manufacturing system. Manufacturing cell can be defined as a cluster or collection of machines designed and arranged to produce a specific group of component parts. Few rules, and virtually no theory, exists for designing cellular manufacturing systems. However, the first rule is that the design should be as flexible as possible so that it can readily expand to include other components or be modified to handle additional members of the family. The objective is to link the cells into a large manned or unmanned integrated manufacturing system. Cells can be categorized into two general groups: **manned and unmanned**(20).

Manned cells contain machine tools which are conventional or programmable (NC or CNC machines) and production workers who have been trained and are skilled in the operation of more than one piece of equipment within the cell. The multifunctional worker is unusual in the typical job shop, but not in micro-electronics job shops, where workers have been extensively cross-trained with no difficulty. Manned cells are efficient because the number of workers can be adjusted and minimized to meet the desired output.

Unmanned cells contain machine tools that are programmable (CNC machine tolls or other automated equipment), and there are few if any workers within the cell. Unmanned cells have a number of classes or arrangements. These are:

a. Fixed automated - in which cells are classically represented by the transfer line, in which the quantities are large (large lots) and the runs long. Such systems are generally arranged in lines, circles or the U-shape. They usually have a conveyor which both locates the part and transports it from the machine station, and the line is balanced such that the part spends the same amount of time at each station. The volume of parts is very large and the variety very small. These cells are not very flexible.

b. Flexible automated - These cells are represented by the FMS (flexible manufacturing system) and the robotic cell. The FMS is generally arranged in a line or a rectangular design with a computer-controlled conveyor to transport the parts to any machine in any order. The machines are programmable and therefore can change tools and machining programs to handle different parts.

3.1.2 Characteristics of Cellular Manufacturing Systems

* Small to medium-sized lots of families of parts (1-200). A special set of parts or products.

* 1-15 machines

* Rapid changeover-'single set-up'

* One-at-a-time part movement within the cell

* Defect prevention through integrated quality control

Manned:

* A group of general purpose machines & equipment laid out in specific area

* Multifunctional workers

* Enhanced worker input leading to job enlargement

* Job enrichment

* Machine tools capable of completing cycle imitated by man

* Significant reduction in inventory between cells

Unmanned:

* Flexible/programmable machines (CNC)

* Robotic integration for parts handling (1-5 machines)

* Network computer control

* Decouplers needed for flexibility

3.1.3 Cellular Manufacturing at John Deere

Cellular manufacturing at Deere & Co. has grown from its 1975 introduction at the component works facility in Waterloo, Iowa, to become a major management philosophy. Cellular manufacturing is the transfer of raw material into subassemblies or finished parts within a single organizational entity, or a cell. Deere has implemented a large number of manufacturing cells containing from 10 to 30 machine tools producing several thousand part numbers. The introduction of these cellular manufacturing systems has coincided with facility reorganization and modernization activities. Studies of various manufacturing techniques, particularly the relationship of cells to the CFM philosophy, have further demonstrated the importance of cellular manufacturing as a cost effective management strategy. The actual benefits of the completed cellular manufacturing at three manufacturing facilities have validated the predicted benefits. Typically, the results are:

a. A 25% reduction in the number of required machine tools.

b. A 70% reduction in the number of departments responsible for the manufacture of a part.

c. A 56% reduction in job change and material handling.

d. An 8-to-1 reduction in required lead-times and a corresponding reduction of inventory.

e. Shop supervisors who now have more control over processing, with clear delineation of responsibility.

The past success of the implemented manufacturing cells and the continued expansion of the concepts demonstrate the importance of cellular manufacturing(13).

3.2 The KANBAN Systems

A Kanban system is a control mechanism used in a manufacturing facility (or cell) that consists of both a production process and an inventory storage location. The facility, which may process one item or many, may itself draw upon other inventories or production facilities to operate. It is assumed that the inputs to the production facilities to operate. It is assumed that the inputs to the production process, whether raw material or labor, are always available. Essential properties of the Kanban scheme are:

a. Production is carried out in multiples of a minimum quantity or batch. Each batch, whether completed or authorized for production, must correspond to an identifier, that is typically a card or container. The word "kanban" itself means "action-plate" or "work-order', and refers to a card that serves this function.

b. The number of cards (or containers) in the system is fixed, hence the total quantity of on-hand and on-order inventory in the facility is also fixed.

c. Production is only initiated when finished inventory is removed from the cell, thereby releasing a card (or container).

It is the triggering or release mechanism by which card acts as a work order released by the occurrence of demand that identifies the Kanban system as a "pull" approach. In principle, the Kanban scheme can be used to control not only production in manufacturing cells, but also transportation between cells or facilities. In the latter case-the cards controlling transportation travel between facilities-material cannot be transported until the operating facility draws on incoming inventory, thereby releasing a card that authorizes the movement of more material. To distinguish the physical transportation operations from production processes, the terms "production kanban" and "conveyance" or "transportation kanban" are sometimes used to identify the kanban cards used in either of the two types of application. It should be noted, however, that there is essentially no logical difference in the two applications of the scheme(12).

In the single card system, the items within the production cell are controlled by the kanban scheme; transportation away from the cell, however, is not. To use the terminology just given, the system has production kanbans but no conveyance kanbans. The substantive implication is that while the quantity in the cell is constrained by the number of cards (kanbans) in the cell, there is no limit on the demand for output from the cell. Consequently, if material is not available in the output storage locations, there is no upper bound on the back orders or unfilled demand that can accumulate.

In the dual card configuration, both the facility and transportation out of the facility are controlled by production and withdrawal kanbans respectively. The total number of back orders possible in this configuration is limited by the number of conveyance kanbans.

A two-stage Kanban system consists of two cells in series with one drawing upon the other. This is the simplest example of a multistage Kanban controlled process; here it becomes evident what interactions can occur between Kanban systems in a production network(8).

3.2.1 Rules for the KANBAN

In order to realize the CFM purpose of Kanban, the following rules must be followed:

RULE 1. Do not send defective products to the subsequent process

Making defective products means investing materials, equipment and labor in something that cannot be sold. This is the greatest waste of all. It is the worst offense against cost reduction, which is the goal of an industry. If a defective is discovered, measures to prevent its recurrence must be taken ahead of everything else, to make certain that similar defectives will not be produced again. To thoroughly implement activities for eliminating defects, the first rule must be that defective items will not be sent to the subsequent process.

Observation of the first rule means the following:

a. The process that has just produced a defective product can immediately discover it.

b. The problem in that process is immediately called to everyone's attention. If it is left unsolved, the subsequent process may stop or the process itself may be saddled with a pile of defects. Thus, managers and supervisors are forced to engage in the task of undertaking measures against recurrence.

In order to abide by this rule scrupulously, machines must be made to stop their operations. This is where the concept of automation with a human touch comes into play. If defective products get mixed up with good products, exchange them promptly. If defective products are supplied by subsidiaries, do not modify their delivery cards. Ask them to replace the exact number of defective items in the next delivery. Unless there is an assurance that parts flowing through all the processes are good products, the kanban system itself will collapse.

RULE 2: The subsequent process comes to withdraw only what is needed

The second rule is that the subsequent process comes to the preceding process to withdraw parts and materials at the time needed and in the quantity needed. A loss is created if the preceding process supplies parts and materials to the subsequent process at the time it does not need them or in a quantity above the latter's needs. The loss can come from many quarters, including a loss from excessive overtime, a loss from excess inventory, and a loss from investing in new facilities without knowing that the existing facility is actually sufficient. Then there is a loss arising from the inability to take countermeasures when the existing facilities create a terrible bottleneck, again without knowing the exact situation. The worst loss arises when the process cannot produce what is necessary, because it has been producing what is not necessary. To eliminate these types of waste, the second rule comes into play.

If we abide by the first rule that no defective products be shipped to the subsequent process, the process in question can always discover defects appearing within the process. There is no need to obtain information from other sources. The process can supply good quality parts and materials. However, this process does not have the ability to determine the time and quantity the subsequent process will require of it products. In order for the process to function properly, this information must be supplied by another source. Therefore, we have changed the thinking from "supplying to the subsequent process" to one of "the subsequent process coming to withdraw" from the preceding process at the time needed and in the quantity needed.

From the final assembly line which is the final process, to the process where materials leave the storage room, which is the first process, if all processes can agree on a procedure whereby the subsequent process goes to the preceding process to withdraw materials needed at the time needed and in the quantity needed, then no process has to worry about information concerning the time and quantity of the materials to be supplied to the subsequent process. The foundation of the second rule is that the subsequent process must come to the preceding process to withdraw. But a number of concrete steps are needed to ensure that the subsequent process will not arbitrarily withdraw from the preceding process. They are as follows:

a. No withdrawal without a kanban

b. Items withdrawn cannot exceed the number of kanban submitted

c. A kanban must always accompany each item

These three major principles ensure that second rule will be correctly carried out.

RULE 3. Produce only the exact quantity withdrawn by the subsequent process

The importance of the third rule, to produce only the exact quantity withdrawn by the subsequent process, can be inferred from the discussion of the second rule. It is, after all, a logical extension of the second rule. This rule is predicted on the condition that the process itself must restrict its inventory to the absolute minimum. For this reason, the following must be observed:

a. Do not produce more than the number of kanban

b. Produce in the sequence in which the kanban are received

Only through observance of these operational guidelines will the third rule become functional. One further consideration is that by observing the second and third rules, the entire production process can function in unison, almost like a single conveyor.

RULE 4: Equalize production

In order to observe the third rule, to produce only the exact quantity withdrawn by the subsequent process, it becomes necessary for all processes to maintain equipment and workers in such a way that materials can be produced at the time needed and in the quantity needed. In this case, if the subsequent process comes to withdraw materials unevenly with regard to time and quantity, the preceding process will require excess personnel and facilities to accommodate its requests. The end result is that the earlier the process stands in the total manufacturing process, the greater the need for excess capacity. This is something that absolutely cannot be tolerated. Yet, if the preceding process has no excess capacity at all, it may not be able to deal with the requirements of the subsequent process without resorting to producing materials ahead of time when it has time on hand. This is a clear violation of the third rule; and, of course, we do not allow any violations of rules. This is where the fourth rule, which insists on load smoothing (equalizing) in production, comes in.

RULE 5: Kanban is a means to fine tuning

One of the functions of the kanban has been described as an automatic directional device containing information for workers concerning their work order. Therefore, when the kanban system is adopted, we can dispense with the start-up plan chart and the transportation plan chart which are normally provided for the workplace. For the workers, the kanban becomes the source of information for production and transportation. Because the workers must rely heavily on the kanban to do their work, the load-smoothing system of production becomes extremely important.

Kanban can only respond to the need for fine tuning, but not to a major change. Kanban's full potential is realized when it is used effectively for fine tuning.

RULE 6: Stabilize and rationalize the process

The fourth rule, which requires load smoothing in production, is effective in guaranteeing an adequate supply for the subsequent process and, at the same time, in fulfilling the objective of producing materials as inexpensively as possible. In following this rule, we must not forget the sixth rule, which requires that the process be stabilized and rationalized.

In studying the first rule, to refrain from sending defective products to the subsequent process, we have learned the importance of automation with a human touch. If we extend the meaning of defectives beyond defective parts to include defective work, then the sixth rule becomes easy to understand. Defective work exists because there is not sufficient standardization and rationalization of work. When waste, unevenness and unreasonableness exist in work methods and work hours, they can result in the production of defective parts. Without resolving this issue, no guarantee can be given to the subsequent process that there will be an adequate supply, or that the products can be inexpensively produced. Efforts toward standardization and rationalization of the process are key to the successful implementation of automation. The load-smoothing system of production requires this kind of support to become truly effective.

A lot of effort is necessary to observe these six rules. If the kanban system is introduced without them, it cannot function effectively(13).

3.2.2 Basis of the KANBAN System

3.2.2.1 Defect-free Production ... A method for creating high-quality products

a. Automation with human mind (Jidoka)

In order to supply high-quality products to customers, quality checks are necessary to be performed during the production processes. Jidoka allows automatic stopping of the machinery if the defects are found during production. This method requires constant effort and attention by assembly line personnel to achieve defect-free production.

b. Visual Control

The CFM operation process aims to eliminate the need for holding unnecessary inventory. When defects are found in a particular area, further production will be stopped as a result. Great pressure is no doubt placed on assembly line operators if the andon warning light is used to signal caution. Foolproofs are also often used for this purpose.

c. Standard operating procedure

It is believed that defects are the result of operator carelessness, excessive force, irregular procedures, and waste. This has been proven by the fact that the rate of defective production is below one percent when such problems are minimized. Standardization and rationalization of operation tasks are likely to provide answers to such difficulties. This is referred to as automation of manual operation(5).

3.2.2.2 Single-unit Production ... Continuous Flow of Production

a. Cycle Time

The kanban system will probably reveal imbalances in production as well as over-production problems occurring during the process. Smooth production flow is required to solve these problems. This implies a consistent production process line (from materials to finished goods and from parts production to shipping) within the cycle time. This is an important prerequisite for realizing the CFM production concept. For every successful results, cooperation is required on the part of both factories and auto parts manufacturers.

Accumulation of merchandise, unnecessary reloading, and inefficient delivery all result from poorly balanced channels.

b. Creation of multi-process holding method

The traditional lot production method requires large work-in-process inventory for each process. There are two problems inherent in this method: one is the long lead time involved; the other is the increase in costs due to inefficiency of operation. The concept of the continuous flow of production is very important in solving the problem and can only be achieved by creating multi-process holdings by each worker. This involves training and education of workers to broaden their skills, transfer of personnel to different tasks, and changes in the production process and factory layout. These changes are implemented based on the discussions held between the company and the union. It is believed that the problems concerning lead time and transportation operations can be solved by the multi-process holding method(5).

3.2.3 Basis for Mixed Model Assembly Line

Several industries have employed the mixing of production lines as a countermeasure to face diversification and individualization activity on the part of competitors in the market. The decisions were made to enable flexible adaptations to demand changes in the market, together with a desire to reduce investments, space and facilities(7).

a. Leveling (smoothing) of Production

The rule that "preceding processes produce only those amounts which were withdrawn by subsequent processes" is a key concept in the Kanban system. This requires, in each preceding process, preparation of those personnel and facilities necessary for assigned production quantities by Kanban. If the subsequent process withdraws parts in a fluctuating manner in regards to time or quantity, then burden is carried by the preceding process. Production leveling was originated to solve this imbalance between two processes and to equalize production of various kinds of products in the final assembly line. This method will eliminate labor and require less backstock by allowing parts of the preceding process to be utilized.

b. Organization of Operational Tasks

The time for producing a part varies as the price of that part changes according to style and quality. Each assembly line requires different production times for different kinds of parts, thus tasks should be organized to maintain a good work flow. This task scheduling can be achieved by dividing whole tasks into common and special processes based on the time required for each task. Even though the proportion of different part styles varies on a periodic basis, the special processes can be handled by adjusting the number of personnel.

c. Rapid Setup Actions

Since the subsequent process withdraws parts on a leveled basis, the preceding process must minimize the number of lots produced and rapidly implement setup actions; otherwise the parts will be exhausted during the later process. However, if this condition of scarcity in parts inventory is not maintained by minimizing lot size, improvements can never be achieved.

d. In-line Processing

There is some limitation for adopting improvements in shortening the setup time and it is most desirable not to do setup actions at all. To ease the process, a simplified tool can be developed for installation beside the assembly line. This can permit single-unit production in accordance with the cycle time. Reduction of costs and lead time, along with maintenance of high quality may also be effected. Moreover, by employing such methods, industries can achieve synchronization of production.

3.2.4 KANBAN Limitations

Kanban is feasible in almost any plant that makes goods in whole (discrete) units (but not in the process industries). It is beneficial only in certain circumstances:

facing (29)

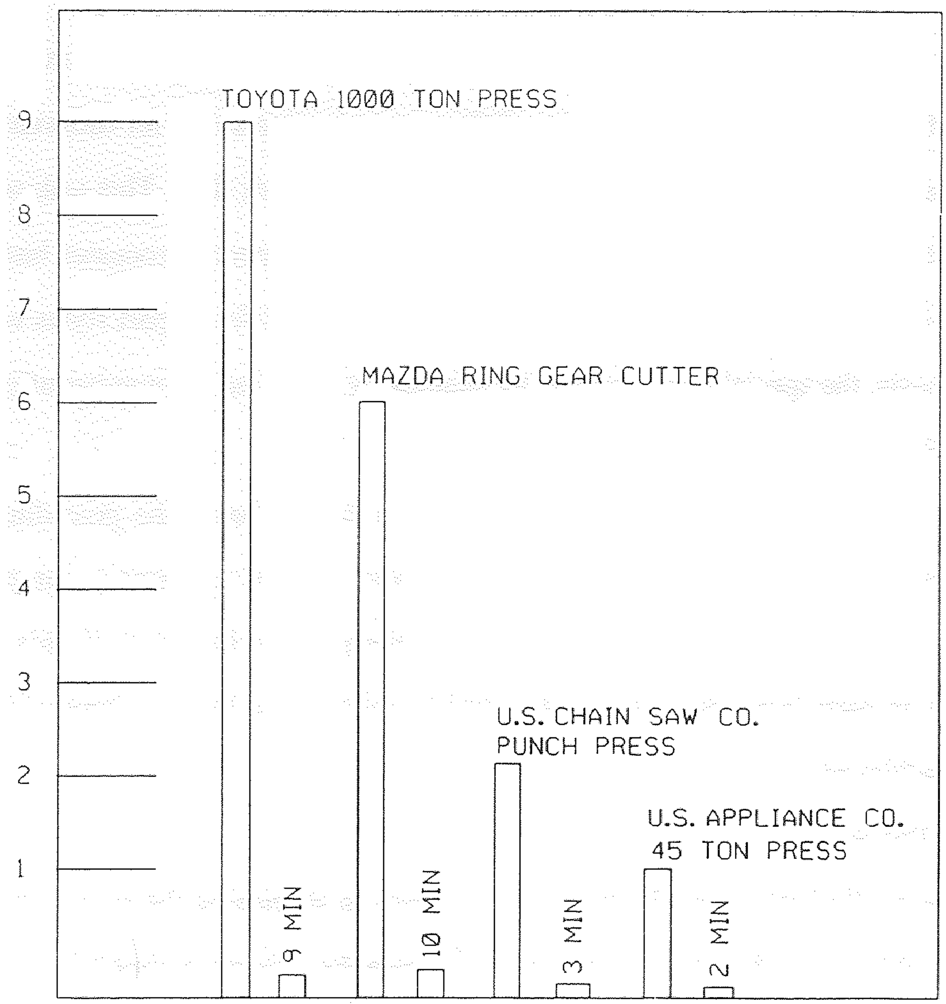

FIGURE 8. EXAMPLES OF SETUP TIME REDUCTION

a. Kanban should be an element of a CFM system. A pull system makes little sense if it takes interminably long to pull the necessary parts from the producing workcentre, as would be the case if set-up times took hours or lot sizes were large. The central feature of CFM is cutting set-up times and lot sizes, which allows for fast 'pulls' of parts from producing work centers.

b. The parts included in the Kanban system should be used every day. Kanban provides for at least one full container of a given part number to be on hand all the time, which is not much inventory idleness if the full container is used up the same day it is produced. Therefore, companies with a Kanban system generally apply it only to the high-use part numbers, but replenish low-use items by conventional Western techniques (e.g. MRP or reorder point).

c. Very expensive or very large items should not be included in Kanban. Such items are mostly to store and carry. Therefore their ordering and delivery should be regulated very closely under the watchful eye of a planner or buyer.

3.3 Set-up Time Reduction

Small lot production - striving to a unit of one - is dependent upon minimal setup time. Once minimal setup time is achieved, production can be tied up to daily requirements, thereby eliminating waste associated with inefficient production techniques. Setup reduction spurs pulling material through the manufacturing process operation by operation rather than pushed operationally based upon a plan. The objective of many CFM industries is to reduce the set up time due to competitive manufacturing demands. Possible approaches to this reduction are:

a. Design products and processes such that minimal changeover is required.

b. Avoid setups by having single product manufacturing shops.

c. Use methods such as Single Minute Exchange Dies (SMED) to actually reduce the setup time(27).

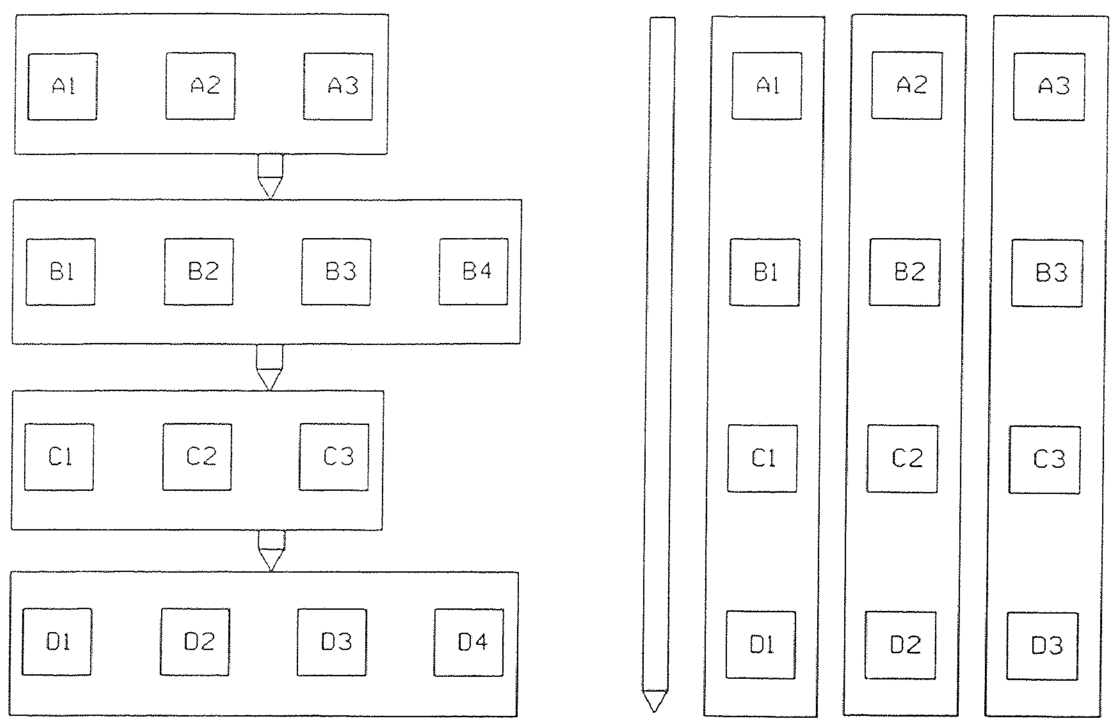

FIGURE 9. THE IMPACT OF PROCESS FLOW SIMPLICITY

The first step in "setup time reduction" consists of separating out the external and internal activities. External activities are those which can be carried out whilst the machine is in operation and producing other work, whereas internal activities require the machine to be devoted solely to the setup operation(28).

3.4 Group Technology and CFM

Group Technology (GT) has been practiced for many years in operating batch manufacturing plants. It was first applied manually to code and classify parts and for machining cells for parts manufacturing. GT coding and classification were applied in a manual mode for design retrieval. With the development of the computer came a renewed interest in GT. Coding and classification were again used for design retrieval, but this time the power of the computer was used to perform the lengthy design database searches. At the same time, GT was being used in manufacturing to help automate the process planning activity and to assist in forming automated manufacturing cells. Today, a new level of application of GT is being explored in the implementation of large-scale factory automation projects(32).

3.4.1 Introduction

Group technology has been used in batch manufacturing for many years as a method of design rationalization and manufacturing standardization. Recently, GT has received widespread attention due primarily to its close association with cellular manufacturing, FMS, CIM, and other factory automation programs. GT is not simply the formation of machinery into manufacturing cells, although cellular arrangement is a logical consequence of group technology application. It involves bringing together and organizing (grouping) common concepts, principles, problems, tasks, and technology to improve productivity. GT involves continuous improvement and structured discipline and must be a fundamental building block of a cell or system if the real benefits of automation

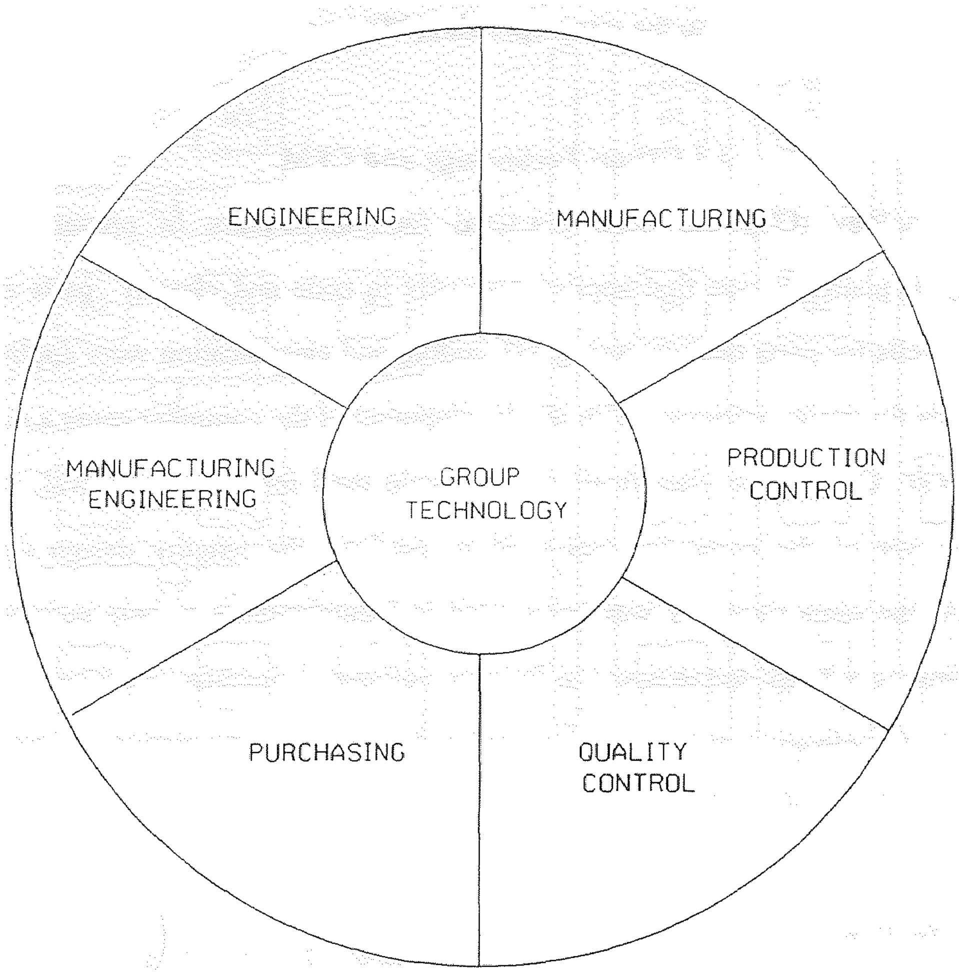

FIGURE 10. GROUP TECHNOLOGY

are to be achieved. It must be approached and applied before, during, and after automation(31).

Broadly defined, group technology implies the grouping of various technologies to achieve a competitive edge based on a predefined operational strategy. GT generally implies the physical rearrangement of manufacturing from the typical job shop cluster of similar machines to the not so typical cluster of dissimilar machines into cells to increase throughput and decrease part move and queue time. Moving further upstream toward engineering, GT further implies discipline, control, and stability of part family designs, along with designs for manufacturing effectiveness through standardization of design features and part attributes within families.

3.4.2 Benefits and relationships to CFM

The benefits of group technology are very closely parallel to those of CFM, CIM, and even FMS and numerical control. Also, they are closely interwoven with each other. It is very difficult to implement one without affecting or seeing the benefits of the other. The traditional payoffs of GT have been well documented by those who have done their homework and implemented a GT program, with or without a high-tech cell or system. Savings in all areas of a company with a well-implemented GT program are typically paid back within the first two or three years. But, like CFM, CIM, FMS, or numerical control, the real benefits can only be derived if understanding, commitment, effort, and involvement are applied. The benefits of GT affect many areas of a company, as seen in the figure # 10. Benefits by functional area include:

a. Purchasing

* Grouping parts for quantity buys at lower cost

* Establishing vendor capabilities by code to build bid lists

b. Engineering Design

* Design standardization and redundancy avoidance
* Rapid design retrieval
* Reduced number of new, similar parts & elimination of duplication parts
* Reduction of drafting and part detailing effort
* Identification of substitute parts

c. Quality Control

* Improved opportunities for controlling quality at the source
* Reduced time to locate part defects
* Reduced sampling and inspection time

d. Manufacturing

* Reduction of parts setups and associated cost and time
* Improved estimation of machine tools requirements
* Improved floor space utilization
* Reduced material handling and transport time
* Improved identification and location of bottlenecked machine groups and under utilized machine tools
* Improved facility planning
* Increased use of manufacturing cells and universal production equipment
* Reduced need to trace and expedite parts
* Improved ability to handle rush orders without causing major disruptions to production
* Improved control and predictability of manufacturing costs
* Improved quality and communications

e. Manufacturing Engineering

* Reduced number of process plans and process planning time
* Reduced number of NC programs and NC programming time

* Reduced producibility analysis
* Improved uniformity and process plan routing
* Reduced tools and fixtures to be used
* Standardization of routings
* Reduction in tool design and procurement
* Use of common tooling and/or avoidance of new tooling

f. Production Control

* Reduced in-process inventory
* Reduced inventory warehousing, material movement, lost or misplaced parts
* Easier location of production difficulties
* Improved equipment monitoring and scheduling
* Tighter and improved shop scheduling
* Improved capacity planning and accountability

CHAPTER 4

CONCLUSION AND FUTURE RECOMMENDATIONS

4.1 Implementation of CFM

The very first step is to gain executive buy-in. A common vision of achieving a cultural paradigm shift must be shared by everyone in the organization. Research shows that once a shared vision has been established, an organization can focus on its current objectives of cost, quality, and delivery. Care must be taken to make sure that a program does not take attention away from these primary concerns. In fact, the process should enhance the ability to successfully address those measures immediately.

In fact, the design aspect of CFM almost guarantees management that a dramatic short-term improvement from existing assets will result without additional capital investment. The organization can realize short-term benefits by reducing costs, inventory, scrap, rework, and cycle times. Additional short-term benefits will result from improvements in quality and productivity.

CFM prepares the organization for continuous learning, total employee involvement, and balanced production based on a "pull system" that starts with customer demand. it creates a cultural orientation that is focused on the customer while it reduces product lead times and planning time. It can develop a sense of certainty for customers.

It is important that the executive management team has a vision - a vision that is far-reaching. This vision will be essential if the organization is to realize the true and continuous benefits of CFM. Not only does CFM implementation bring about improvements in quality and in morale, it also prompts major reductions in inventory, defects and overhead.

Furthermore, discussion about how far the implementation of CFM has been progressed in the US industries in terms of philosophy, management, production planning and control, manufacturing and quality control can be given as follows:

CFM - Philosophy: There seemed to be confusion among the respondents whether or not CFM can be regarded as a philosophy to begin with. About only one third of the respondents appeared to have recognized CFM's philosophical and cultural heritage. Other answers on the philosophy of CFM and its content were focused on technical aspects. In general, the answers seemed to vary widely, sometimes contradicting themselves, probably due to varying managerial, environmental, and cultural premises. Nevertheless, the participants viewed CFM as a strategy or technique for inventory reduction and better quality. However, in the course of entire analysis of the questionnaire it became apparent that the surveyed managers are aware of CFM's all encompassing nature and philosophy. In fact, the majority is believed not to think of CFM as another quick-fix type of program.

CFM - Management: From the surveyed data, approximately 56% of the surveyed managers practice participative management, which meant that 44% of the respondents underwent a change in managerial styles from an autocratic to a participative style because of CFM. Considering that a change in the managerial attitude is almost the most difficult adventure an industry or manager can embark on, it seems safe to conclude that participative management is indispensable for CFM. Participative management means not only the workers get involved but management as well, and that's exactly the point which presented one of the major roadblocks during the CFM journey to excellence. Employee involvement seemed not to have been the problem at all, but upper management commitment towards participative management appeared to be lacking. In fact, the majority of the surveyed industries did not experience adversarial labor-management relations in the past. In this respect, the US implementors of CFM seem to be very special industries to begin with. All in all, the majority has recognized the managerial prerequisites, but they seem not to be fully established yet.

CFM - Production Planning and Control: A truly implemented CFM philosophy must embrace a pull production system which is usually governed by a Kanban card system. From this point of view, 56% of the respondents seems to be ill-prepared for CFM. Substantiating the charge, less than half of the respondents have Kanban in effect, secure stable production schedules, or manufacture daily what they sell daily. In addition, if the aforementioned aspects of CFM are in place, it seems that they apply only to a fraction of the operation. Also, 50% of the surveyed industries already had MRP II systems in place. The majority seemed not to be willing to relinquish its push philosophy. The happy marriage of MRP II as the planning system and CFM as the execution tool as the planning system has not taken hold at the majority of the surveyed industries. In that sense, the reported technical problems (schedule stability, transformation from batch to flow production) seemed to be overridden by managerial and cultural difficulties.

CFM - Manufacturing: When asked to interpret CFM, 29% of the respondents said that they view in CFM a manufacturing strategy or technique. Those and others confirmed that view by giving manufacturing a pivotal role in combating waste. Approximately 56% of the surveyed industries seemed to be actively engaged in preparing their facilities for manufacturing. The managers chose cautiously from a variety of techniques to make manufacturing more flexible as well as more predictable, such as the focused factory, group technology, dedicated equipment, increased capacity, flexible automation and set-up time reduction programs. Although manufacturing and CFM are inextricably linked, there were two sour notes. First, manufacturing is supposed to guarantee perfect quality and thereby assume new responsibilities. On the other hand, manufacturing is neglected by most respondents when it comes to defining and managing those new responsibilities. Second, almost one third of the respondents is tending to leave manufacturing altogether and devote themselves to just assembly.

In addition, 59% of the surveyed managers think that CFM does not lead to reduced automation and robotics, but the comments revealed that the American CFM practitioners approach automation more sensibly and more cautiously. They seem not to automate their problems. CFM appears to be viewed as a problem seeking and solving philosophy. As with production planning and control, the most frequently mentioned problems deal with people and culture, and not with technicalities. In particular, the management of how to change attitudes of both production personnel as well as managers seems to be the roadblock on the way to CFM-Manufacturing.

CFM - Quality: When the respondents were asked about the objectives of CFM, the plurality of 44% mentioned better quality. It was tentatively concluded, that CFM might be just another logistics program on top of already existing quality programs. This assumption fell apart when the quality endeavors were scrutinized. CFM has turned around the quality effort; for example, SPC is used by about 93% of the respondents and quality circles by 79% respectively. When it comes to do not use ppm levels to measure quality and they seem not to sincerely embrace the heart of Total Quality Control - defect prevention. Although 58% of the respondents have total preventive maintenance in place, a whopping 86% reported that they have on-line inspection in effect. In addition, only 29% of the industries include all business functions when it comes to defining quality. 60% cut out manufacturing in this process, Although the makers of quality seem to carry the burden of responsibility of perfect quality.

Further, the answers revealed that either vendor quality must have remarkably improved or vendor inspection has increased. In any event, 56% of the respondents have eliminated receiving inspection for an average of 49% of their deliveries.

Finally, the American CFM aspirants seem to have experienced a variety of quality problems and they seem to be very quality conscious thus recognizing its indispensability. The quality detection mentality has not yet been really superseded by defect prevention and thus the surveyed industries appear not quite ready in this regard.

The preceding sections should have informed the reader that the actual, total implementation of CFM seems to be in the future for most of the surveyed industries. This does not really come as a big surprise considering that almost two thirds of the respondents have been embracing CFM for three or fewer years. This was underscored by the fact that the political and cultural preparation for CFM was most frequently mentioned by the respondents to cause problems during the implementation process, thereby somehow indicating how far implementation has progressed. The resistance to change, mostly displayed by management rather than by workers or organized labor was an especially difficult problem. Managing the change of attitudes is maybe the single most challenging task for aspiring American CFM practitioners.

CFM was initiated only by 14% of the industries top management echelons. As a result, all other industries were forced to go through the ordeal of convincing upper management of CFM's benefits. Last but not least, just over 21% of the surveyed industries indicated that manufacturing has become the champion of CFM. Considering manufacturing's pivotal role in combatting waste and the fact that CFM might be the last chance for them to stop their extinction, these managers should be utmostly motivated to implement CFM.

4.2 Conclusion

In all fairness, the facts and figures analysis of the questionnaire has revealed that the respondents have made quite some progress in all discussed areas, but the majority has not yet succeeded in reaping the benefits of being a CFM producer.

In other words, it became apparent that preparing for CFM is for most companies a cumbersome, as well as monumental task. Each department of the entire company has to be brought in sync with the CFM philosophy. What the questionnaire has done is just to highlight some of the corporate functions to be addressed. Many critics of US manufacturing have considered American CFM practitioners for being too selective in applying the philosophy - practicing peace meal adoption of CFM so to speak. The majority of respondents tried to provide the indispensable prerequisites of CFM: participative management, perfect quality, and balanced flow manufacturing. The fact that just about 40% practice some sort of limited pull manufacturing as the result of not having finished the preparation of these prerequisites. Now, how far has been the implementation of CFM philosophy progressed in the United States industries? The detailed analysis indicates that a number of industries are in the process of providing CFM prerequisites which should be followed by more implementations. Finally, the fact that fully integrated CFM implementations are still very few, rare in the United States, after the CFM philosophy has been known for eight years.

Some of the major problems developed during the implementation process are listed as follows:

* Lack of understanding of CFM principles
* Management commitment and resistance to change
* Overwhelming nature of the task
* Bad in-house as well as vendor quality
* Lack of stable leveled schedules
* Job shop mentality

From the early pioneers of Continuous Flow Manufacturing implementors in the United States industries, prospective CFM implementors should study in detail about the following results obtained so far.

Lesson # 1: When the American implementors of CFM were able to convert parts of their operation to CFM, despite the problems imposed by culture, the reaped benefits are quite substantial. The first lesson to be learned is (CFM means profit) that CFM can contribute very much to the bottom line:

* Work-in-process inventories down by 48%
* Finished goods inventories down by 36%
* Raw material inventories down by 46%
* Lot size down by 49%
* Throughput time down by 41%
* Space requirements down by 37%
* Material handling equipment down by 32%
* Service levels up from 76% to 92%
* Inventory turnover rate up from 5 to 14%
* Capacity up by 29%
* Overall quality levels up

Lesson # 2: The second lesson to be learned is that CFM is not a fad, but an indispensable approach to manufacturing and competitiveness. Its philosophy has been embraced by the surveyed industries over a span of seven years with many recent start us. Presently, some US industries are regaining some of their competitiveness through the sliding dollar compared to other foreign currencies, but it will be fellow American companies, namely those that have embraced CFM, which will knock out CFM ignorant US industries from foreign as well as domestic markets.

Lesson # 3: The third lesson to be learned is that all the problems experienced during implementation of CFM seemed to stem from a hostile attitude towards CFM and not from a technical point of view. The respondents seemed to be very well aware of the indispensability of prefect quality or stable level schedules. The real challenge was how to get the people behind the CFM endeavor so that those problems could even be addressed. The survey revealed that most industries choose participative management as the vehicle.

Participative management, however, should not only mean participating workers but genuinely participating committed management as well. But according to the surveyed managers, it was management commitment which was the hurdle. Therefore, the real lesson to be learned is that before anyone is seriously thinking about preparing for implementing CFM, it seems paramount to have a carefully devised strategy at hand which will buy-in top and middle management.

Lesson # 4: The forth lesson to be learned is that the surveyed industries have approached CFM form very different premises in terms of corporate culture, management style, commitment to manufacturing, or operations environment. Therefore, an implementation strategy for CFM cannot consist of, for example, "seven simple steps towards CFM success," which are universally applicable for all American industries.

Lesson # 5: The fifth and most important lesson learned from the early pioneers of CFM is that the key to a successful CFM implementation can only be a management approach which is culture sensitive. This is not to say that US CFM industries should know all about the Japanese culture, but they should at least aware of the cultural assumptions behind the techniques which they intend to implement under the auspices of CFM. However, it is to say that the very first and may be most important prerequisite of CFM is to develop an extraordinary sensitivity towards the American societal, corporate, and management cultures.

Lesson # 6: The most promising strategy for accomplishing such a change in culture and attitude seems to be organization development, because its definition is somewhat a duplication of CFM's definition. In simple terms, both intend to enhance or reinforce the problem solving capabilities (continuous improvement) of an organization. The organization processes to be intervened could be the structure, reward, and measurement practices, which usually control organizational behavior and the direction of an industry. In other words organizational development could sensitize the entire organization, so that all its members take on the problem seeking and solving attitude of CFM. Therefore, the sixth lesson to be learned is to link the concepts of CFM and organizational development.

4.3 Future Research Recommendations

Hopefully, the surveyed data presented here will help readers formulate plans and strategies to implement further research that will lead to more efficiency and effectiveness in their manufaturing operations. Also, future study in the area of business assesment, education, line analysis, vision creation, goal-setting, cost justification and a road map for implementation can provide a major improvement in terms of finincial performance.

APPENDIX 1

CFM QUESTIONNAIRES

Rohit P. Patel
125 Royal Drive, #500
Piscataway, N.J. 08854
Tel # (908) 968-2658

Dear Sir/Madam,

I am a graduate student at New Jersey Institute of Technology, pursuing a Master's degree in Manufacturing Engineering. Presently, I am doing research for my Master's thesis on "Implementation of Continuous Flow Manufacturing in United States Industries".

This research intends to provide a state-of-the art review on how far implementation of CFM has progressed in U.S. Industries. Specifically, I am interested in the problems which were developed in the implementation of CFM and how they had been resolved.

I have canvassed the technical journals to reach the individual experts in CFM. You and your company drew my particular attention. As this questionnaire has only been sent to a few selected users of the CFM philosophy, my research will be enhanced by your response.

The questionnaire is divided into several parts and designed for a variety of people with different backgrounds. Therefore you may pass the survey on to your colleagues to complete the answers, or send me a partially completed questionnaire.

The information from these questionnaires will be kept strictly confidential. All findings will be reported in terms of groups of companies. None of your answers will be used to evaluate you or your company.

I have tried to ask the most pertinent questions relative to CFM and I hope you find them interesting. Should you desire, you are welcome to a summary of my findings when completed.

Thank you in advance for your kind cooperation and hoping to hear from you soon.

Sincerely,

(Rohit P. Patel)

Do you wish to receive a copy of the findings? Yes No

If yes, please print your name and address below:

Name:
Address:

CONTINUOUS FLOW MANUFACTURING (CFM) QUESTIONNAIRE:

A. CFM Philosophy:

1. How does your company interpret or define the concept of CFM ?

2. What do you hope to accomplish with CFM (objectives) ?

3. Do you agree that the implementation of CFM changes the corporate culture ?

   Yes No

   (please enclose a copy of your corporate mission statement if you have one)

4. Do you think that the CFM management philosophy is a product of Japanese culture ?

   Yes No

5. Does the CFM philosophy span the entire organization including white collar as well as blue collar workers ?

   Yes No

   If no, what organizational functions are involved ?

6. Does your understanding of CFM agree with the notion that system design improvement must relate to production or process design improvement (e.g. Group Technology with Kanban) ?

   Yes No

B. CFM-Management:

1. Since CFM, has your company changed the performance measurement of management control system (e.g. long vs. short-term, group vs. individual performance) ?

Yes No

If yes, in what way ?

2. Has your company integrated the design, manufacturing, engineering and quality control functions within the organization (e.g. team responsibility for one product) ?

Yes No

3. Does CFM need genuine management commitment as well as full worker participation ?

Yes No

4. Did you experience any adversarial relationships between managers and the blue collar workforce due to CFM ?

Yes No

5. Which has been the most important problem for your organization concerning the management of CFM ?

C. CFM-Production Control:

1. Does your company use MRP II ?

Yes No

If yes, how is MRP II integrated into the CFM philosophy ?

2. Do you use Kanban for shop floor control ?

Yes No

If yes, do you use withdrawals of Kanbans as a means of problem detection?

3. Does your organization follow the principle of "what is sold daily will be produced daily" ?

Yes No

4. Do you attempt to arrive at zero inventories ?

Yes No

5. How much did you reduce on the average:

- work-in-process inventory _____%
- finished goods inventory _____%
- raw material inventory _____%

6. How much did you increase the turnover rate of your inventories on an average ?

from_____to_____

7. What has been the most difficult problem associated with CFM and production planning and control ?

D. CFM-Manufacturing:

1. In what kind of production environment is your organization engaged:

- batch/job shop manufacturing	Yes	No
- repetitive manufacturing	Yes	No
- continuous production	Yes	No

Which environment do you think is best suited for CFM-production and why ?

2. Have you converted job shop operations into cellular manufacturing ?

Yes No

3. Are you moving towards flexible automation with multifunctional equipment's and workers ?

Yes No

4. CFM is supposed to lead to reduce automation and robotics implementation. Comment briefly, whether you do or don't agree with the statement.

5. Were you able to increase production capacity in order to strengthen flexibility by setting inventory assets free ?

Yes No

6. Have you reduced set-up time of current processes ?

Yes No

7. Concerning the conversion to CFM-production, which problem was most difficult to resolve ?

E. CFM-Quality Control:

1. Which of the following techniques have you implemented because of CFM:

- total preventive maintenance	Yes	No
- statistical process control	Yes	No
- quality control circles	Yes	No
- suggestion programs	Yes	No
- acceptable quality level in ppm	Yes	No

Which of these areas proved most beneficial and where did you encounter severe problems during implementation ?

2. Who defines the quality of your products: (circle all that apply)

   marketing, user, design, manufacturing, engineering, ________ ?

3. Which of the following elements characterize your quality: (circle all that apply)

   performance, features, reliability, standards, durability, serviceability

4. Prior to CFM implementation, did your company encounter quality problems ?

   Yes No

5. Do you agree that craftsmanship of operators is essential for quality manufacturing ?

   Yes No

6. Did you integrate on line operator inspection into production ?

   Yes No

7. Were you be able to reduce the cost of quality due to CFM ?

   Yes No

F. CFM-Implementation:

1. Since how long has your CFM philosophy been in effect ? _____ years.

2. Assuming that CFM is considered as a philosophy, do you agree that it can only be implemented successfully when the people's attitude has been changed ?

Yes No

3. How long was the duration of your company's philosophy conversion process ?

_____ months.

4. What was your major strategy to change the people's mind set ?

(e.g. education, participation, new responsibilities)

5. Who or which department was the initiator of CFM ?

6. Which department has become the taskforce leader?

7. Have you experienced interdepartmental problems with operation and/or resistance to the formation of a CFM-implementation team ?

8. A CFM implementation plan may consist of these following phases:

- education (commitment)
- organization (task force)
- preparation (technical, political, cultural)
- implementation/conversion
- continuous improvement

Did you use these phases ? Yes No

Explain which were the most difficult phases to implement and why?

Please return survey in the enclosed envelop to:
Rohit P. Patel, 125 Royal Drive, #500, Piscataway, N.J. 08854

APPENDIX 2

DETAILED ANSWERS TO CFM QUESTIONNAIRES

Regarding the format of the above appendix, it should be noted that the questions are highlighted in bold type and the respective - individual answers according to responses of the assigned industries, are listed below each question. Each of the detailed answer report is given a random letter (ranging from a - n for the fourteen respondents), so that the future study in this field for any individual will lead to a particular industry. Also, the number of letters behind each yes or no question indicates response from a particular industry. The percentages used for the answers are nearly close to exact and are used for making conclusion.

A. CFM PHILOSOPHY:

1. How does your company interpret or define the concept of CFM ?

a. An ongoing analysis and improvement activity used to optimize the efficiency, effectiveness and flexibility of any process.

b. Total customer satisfaction.

c. Cooperative improvement effort using right people/disciples - elimination of waste - balanced processes.

d. To provide the customer a product that is defect free, on schedule and at the lowest possible cost.

e. A smoother operation with improved planning and employer participation.

f. Produce only what is needed, when it is needed - no more, no less.

g. A pull system of manufacturing using kanbans.

h. CFM is a quality and productivity activity that eliminates waste.

i. Removing of all unnecessary inventory from receiving dock to shipping.

j. Total people involvement, total quality control and elimination of waste.

k. Everyone gets involved - top management, manufacturing management, support organizations and production employee.

l. A method to obtain improved quality and reliability on an ongoing basis.

m. A process with a continuous flow of parts on an assembly line, from one station to another, with minimum Work In Process (WIP) inventory.

n. Continuous process improvement through relentless pursuit of waste.

2. What do you hope to accomplish with CFM (objectives) ?

a. Improve productivity, quality and cycle time reduction.

b. Reduction in inventory, WIP, leadtime, scrap, waste and rework.

c. Quality product to satisfy customer at minimum production cost.

d. Reduced - floor space, finished good inventory, component inventory and manpower. Increase in customer satisfaction and productivity.

e. Competitive cost in the market and on time delivery.

f. Higher profits, cost reduction, improved efficiency of processes.

g. Customer satisfaction, employee participation, teamwork.

h. Cost reduction, increased market share.

i. Improved quality, reduced inventory.

j. More efficient use of people and machines.

k. Zero defects, reduced cycle time and floor space.

l. Minimization of inventory and defect free products.

m. Highest quality, minimum resources, reduced material handling costs.

n. Increase turnover with better quality products in market.

3. Do you agree that the implementation of CFM changes the corporate culture ?

Yes: abcd eghj klmn (85%)

No: fi (15%)

4. Do you think that the CFM management philosophy is a product of Japanese culture ?

Yes: aehk mn (43%)

No: bcdf gijl (57%)

5. Does the CFM philosophy span the entire organization including white collar as well as blue collar workers ?

Yes: abcd efgi hklm n (93%)

No: h (7%)

6. Does your understanding of CFM agree with the notion that system design improvement must relate to production or process design improvement (e.g. Group Technology with Kanban) ?

Yes: abcd efgh ijlm (86%)

No: kn (14%)

B. CFM-MANAGEMENT:

1. Since CFM, has your company changed the performance measurement of management control system (e.g. long vs. short-term, group vs. individual performance) ?

Yes: abde fgjk lmn (79%)

No: chi (21%)

2. Has your company integrated the design, mfg, engineering and quality control functions within the organization (e.g. team responsibility for one product) ?

Yes: abde hijm (57%)

No: cfgk ln (43%)

3. Does CFM needs genuine management commitment as well as full worker participation ?

Yes: abcd efgh ijkl mn (100%)

No:

4. Did you experience any adversarial relationships between managers and the blue collar workforce due to CFM ?

Yes: acdf ghjl m (64%)

No: beik n (36%)

5. Which has been the most important problem for your organization concerning the management of CFM ?

a. CFM has been used for specific applications and not for all activities.

b. Understanding of different principles and true impacts.

c. Setting the system to work and not expediting.

d. Employee participation.

e. Learning on how to implement CFM.

f. Accuracy of inventory records, continually improving process.

g. Equipment and tooling reliability.

h. Getting marketing involved.

i. Management thinks that it knows everything about CFM, but in fact has not understood the real meaning of it.

j. Long lead time required by process constraints.

k. Utilization of employee assets.

l. Quality and delivery of purchased materials.

m. Establishing a clear understanding in the minds of middle line managers.

n. Convincing management of its value and power.

C. CFM-PRODUCTION CONTROL:

1. Does your company use MRP II ?

Yes: acdh ijkm n (64%)

No: befg l (36%)

If yes, how is MRP II integrated into the CFM philosophy ?

d. By establishing realistic lead times, eliminating possible multiple scheduling points, adapting production processes to become more flexible.

n. Basis of material and capacity planning.

2. Do you use Kanban for shop floor control ?

Yes: abcf ghjk (57%)

No: deil mn (43%)

If yes, do you use withdrawals of Kanbans as a means of problem detection?

Yes: acfg (50%)

No: bhjk (50%)

3. Does your organization follow the principle of "what is sold daily will be produced daily" ?

Yes: adeh k (36%)

No: bcfg ijlm n (64%)

4. Do you attempt to arrive at zero inventories ?

Yes: abce ghij n (64%)

No: dfkl m (36%)

5. How much did you reduce on the average:

- work-in-process inventory (%) a40/b20/c60/d40/e35/f20/g90/h15/i60/j50/k80 /l50/m30/n20

- finished goods inventory (%) a30/b25/c15/d40/e5/f80 /g70/h25/i15/j29/k25 /l40/m25/n33

- raw material inventory (%)

a10/b15/c20/d30/e60/f60/g10/h30/i15/j35/k20 /l30/m25/n10

6. How much did you increase the turnover rate of inventories on an average ?

(from_____to_____%)

a5-7/b6-9/c4-14/d3.5-6/e3-12/f3-4/g3-5/h4-20/i3-6/j2-4/k17-20/l13-15/m20-50/n8-15

7. What has been the most difficult problem associated with CFM and production planning and control ?

a. Trying to get corporate help as and when needed.

b. Fewer queues, lesser flexibility.

c. Eliminating MRP ties.

d. Insecurity of employees if there is not a lot of material on the floor.

e. Debugging the kanban system.

f. TQC - our processes did not make parts to specs.

g. None.

h. Reduction in number of employees in the PPC department due to lower or no inventories.

i. Forecast of supply parts has not matched order.

j. Order rate versus shopfloor line balance.

k. Going from batch mode multiples to smaller lots.

l. Elimination of PP&C.

m. Machine breakdowns, unanticipated expedites of schedules.

n. Stable schedules, vendor quality, vendor delivery.

D. CFM-MANUFACTURING:

1. In what kind of production environment is your organization engaged:

- batch/job shop manufacturing	Yes: abcf gijk n (64%)
	No: dehl m (36%)
- repetitive manufacturing	Yes: acde ghik lm (71%)
	No: bfjn (29%)
- continuous production	Yes: acdf ghjk l (64%)
	No: beim n (36%)

2. Have you converted job shop operations into cellular manufacturing ?

Yes: adef hikl m (64%)

No: bcgj n (36%)

3. Are you moving towards flexible automation with multifunctional equipments and workers ?

Yes: abce fhij kmn (79%)

No: dgl (21%)

4. CFM is supposed to lead to reduce automation and robotics implementation. Comment briefly, whether you do or don't agree with the statement.

Agree: acfm (29%)

a. Automation forces large run sizes.

c. For CFM - changeover must be dome quick. Increased robotics and automation tend to complicate change over times.

f. Robots aren't as flexible as human beings.

m. CFM simplifies manufacturing processes. After successful implementation of CFM, only those areas which were not automated needs justification. In most cases, automation is not needed.

Disagree: bdeg hijk ln (71%)

b. Automation is needed for staying competitive in the market.

d. CFM is a step on the way to automation and robotics.

e. CFM leads to more CAD/CAM/CIM.

g. Use low cost automation and eventually men in which will be replaced by robot.

h. Automation is related to volume, quality and safety.

i. CFM does not replace automation, but it will be used more intelligently.

j. Robots are used when they are cost justifiable.

k. CFM provides environment only. Engineering changes must be justified on their own.

l. CFM depends on revising the process such that material will flow faster. Although the human process comes first, automation is the target.

n. Optimal application of automation and robots are specific to products and processes and have nothing to do with CFM.

5. Were you able to increase production capacity in order to strengthen flexibility by setting inventory assets free ?

Yes: bcef hikl mn (71%)

No: adgj (29%)

6. Have you reduced set-up time of current processes ?

Yes: abde fghi jklm n (93%)

No: c (7%)

7. Concerning the conversion to CFM-production, which problem was most difficult to resolve ?

a. Product and process design.

b. Convincing management of using CFM.

c. Setup time reduction.

d. People, transition from batch to CFM.

e. Getting managers to change.

f. Training and education, changing the corporate culture.

g. Accounting controls, job shop mentality.

h. Total quality control.

i. Parts shortage for some running processes.

j. Upper management emphasis on short term financial goals - conflicts with CFM.

k. Middle management.

l. Education and training for particular application.

m. Resistance to change.

n. Schedule stability which to date has not been resolved.

E. CFM-QUALITY CONTROL:

1. Which of the following techniques have you implemented because of CFM:

- total preventive maintenance

Yes: adef him (50%)

No: bcgj kln (50%)

- statistical process control

Yes: abde ghij klm (79%)

No: cfn (21%)

- quality control circles

Yes: acde fgij klmn (86%)

No: bh (14%)

- suggestion programs

Yes: abdg ijl (50%)

No: cefh kmn (50%)

- acceptable quality level in ppm

Yes: bcgj (29%)

No: adef hikl mn (71%)

2. Who defines the quality of your products: (circle all that apply)

Marketing: acf (21%)

User: bcdf gikm (57%)

Design: adef gklm n (64%)

Manufacturing: bcef hijl m (64%)

Engineering: acef ghjk lmn (79%)

3. Which of the following elements characterize your quality: (circle all that apply)

Performance: acdf gijk mn (71%)

Features: bdhk m (36%)

Reliability: abcf ghik lm (71%)

Standards: abde ghjk mn (71%)

Durability: bcfj l (36%)

Serviceability: adfg hkl (50%)

4. Prior to CFM implementation, did your company encounter quality problems ?

Yes: acde fijk mn (71%)

No: bghl (29%)

5. Do you agree that craftsmanship of operators is essential for quality manufacturing ?

Yes: bcde ghik lm (71%)

No: afjn (29%)

6. Did you integrate on line operator inspection into production ?

Yes: abcd efhi jklm (86%)

No: gn (14%)

7. Were you be able to reduce the cost of quality due to CFM ?

Yes: bcdf ghjk mn (71%)

No: aeil (29%)

F. CFM-IMPLEMENTATION:

1. Since how long has your CFM philosophy been in effect ? _____ years.

1 Year: cfkn (29%)

3 Years: adij lm (43%)

5 Years: begh (29%)

2. Assuming that CFM is considered as a philosophy, do you agree that it can only be implemented successfully when people's attitude has been changed ?

Yes: abcd efgh ijkl m (93%)

No: n (7%)

3. How long was the duration of your company's philosophy conversion process ?

_____ months.

3 months: adi (21%)

6 months: bhk (21%)

9 months: e (7%)

12 months: cgjl n (36%)

Ongoing: fm (14%)

4. What was your major strategy to change the people's mind set ?

(e.g. education, participation, new responsibilities)

a. Practice on what we expect from our customers.

b. Task force study at one assembly plant.

cimn. Education, showing videos and success stories.

dj. Hands on training, sample production lines.

e. Experiment, feedback plan, implementation.

fl. New responsibilities, education, employee participation.

gk. Education by consultants from corporate productivity and quality center.

h. Demonstration, process ownership, actual results.

5. Who or which department was the initiator of CFM ?

Technical services: aci (21%)

Top management: bgf (21%)

Materials department: dhjk (29%)

Production control: en (14%)

Manufacturing: m (7%)

Customer: l (7%)

6. Have you experienced interdepartmental problems with operation and/or resistance to the formation of a CFM-implementation team ?

Yes: acdf ghjn (57%)

No: beik lm (43%)

7. A CFM implementation plan may consist of these following phases:

- education (commitment)

- organization (task force)

- preparation (technical, political, cultural)

- implementation/conversion

- continuous improvement

Did you use these phases ?

Yes: abce ghik lmn (79%)

No: dfj (21%)

Explain which were the most difficult phases to implement and why ?

a. Preparation, implementation.

b. Commitment from management.

c. Continuous improvement, people want to relax after initiation of CFM.

d. Education, considered too time consuming.

e. Organization : fear in middle management.

f. Preparation, very cultural and political.

g. All phases are equally hard when one tries to change 20 years of doing something one way to doing in another way in 2-3 years.

h. Upscaling from experiment to existing product lines.

i. Preparation, resistance to change.

j. People were skeptical that it would work.

k. It is difficult to prepare detailed plans, because you learn as you go. New opportunities arise and priorities are constantly arising.

l. Due to fear of losing backlog.

m. Implementation was a much longer process than we had believed. As one area was resolved several more surfaced. There was a problem in the factory wanting to do too much at all the time.

n. Unions and old thinking management are the biggest barriers to US becoming world competitive.

APPENDIX 3

MAILING LIST OF PARTICIPATING US INDUSTRIES

The CFM questionnaire had been mailed to thirty-five different industries throughout the United States. Eventhough fourteen industries had participated to answer the questionnaire in detail, the whole mailing list is included for possible future research.

1. Allied Signal-Kansas City Division, P.O.Box 419159, Kansas City, MO 64141.
2. Aluminium Company of America, Alcoa Building, Pittsburg, PA 15219.
3. AT&T Technologies, 100 Southgate Parkway, Morristown, NJ 07960.
4. BDM International Inc., 7915 Jones Branch Drive, McLean, VA 22102.
5. Boeing Helicopters, Box 16858, Philadelphia, PA 19142.
6. Boeing Seattle, P.O.Box 3707-C17, Seattle, WA 98124.
7. Chrysler Corporation, 12000 Chrysler Drive, Highland Park, MI 48288.
8. Ciba-Geigy Corporation, 7 Skyline Drive, Hawthorne, NY 10532.
9. Douglas Aircraft Company, 3855 Lake Wood Blvd, Long Beach, CA 90846.
10. E.I. Du Pont and Company, 1007 Market St, Wilmington, DE 19898.
11. Eveready Battery Company, Inc., P.O.Box 450777, Westlake, OH 44145.
12. Ford Motor Company, The American Road, Dearborn, MI 48121.
13. General Motors Corporation, AC Rochester Division, Flint, MI 48556.
14. GTE Corporation, One Stamford Forum, Stamford, CT 06904.
15. Hayes Microcomputer Products, P.O.Box 105203, Atlanta, GA 30348.
16. Hercules Incorporated, Hercules Plaza, Wilmington, DE 19894.
17. Honeywell Inc., Honeywell Plaza, Minneapolis, MN 55408.
18. Hutchinson Technology, 40 W. Highland Park, Hutchinson, MN 55350.
19. IBM Corporation, 11400 Burnet Road, Austin, TX 78758.
20. IBM Corporation, P.O.Box 950, South Road, Poughkeepsie, NY 12602.

23. Lockheed Sanders, Inc., P.O.Box 2029, Nashua, NH 03061.

24. LTV Aircraft Products Group, P.O.Box 655907, Dallas, TX 75265-5907.

25. Lutron Electronics Co., Inc., 7180 Suter Road, Coopersburg, PA 18036.

26. McDonnell Douglas Corporation, P.O.Box 516, St. Louis, MO 63166.

27. NEC Electronics Inc., 7501 Foothills Blvd, Roseville, CA 95678.

28. Northrop Corporation, B-2 Division, P.O.Box 1138, Pico Rivera, CA 93550.

29. Precision Castparts Corp., 4600 S.E. Harney Drive, Portland, OR 97206.

30. Polaroid Corporation, 750 Main Street, Cambridge, MA 02139.

31. Raytheon Company, 141 Spring Street, Lexington, MA 02173.

32. Schindler Elevator Company, 20 Whippany Road, Morristown, NJ 07962.

33. The Clorox Company, P.O.Box 24305, Oakland, CA-94623.

34. Tennessee Eastman Company, P.O.Box 1975, Kingsport, TN 37662.

35. Texas Instruments, P.O. Drawer 1255, Johnson City, TN 37605.

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