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A Total Quality Leadership Process Improvement Model

by
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DEPARTMENT OF THE NAVY
TQL
OFFICE

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ABOUT THE TQL OFFICE

The Total Quality Leadership (TQL) Office is a part of the Office of the Under Secretary of the Navy. Its mission is to provide technical guidance to Navy and Marine Corps senior leaders on the consistency between Department of the Navy (DON) policy and TQL principles and practices.

The TQL Office works on quality improvement efforts with many organizations inside and outside the Federal Government. The director and members of the TQL Office staff recently participated on the Vice President's National Performance Review (NPR) team. The Office is also a key player in an NPR follow-up effort called the Defense Performance Review (DPR). The DPR team tasked the DON to take the lead in developing and implementing a total quality in defense management prototype in the Department of Defense.

The TQL Office staff handles responsibilities in five key areas: **TQL education and training, TQL consultation, networking** with organizations inside and outside government, **program management,** and **publications and videos.**

TQL EDUCATION AND TRAINING

The TQL Office has worked closely with the Chief of Naval Education and Training (CNET) in developing a TQL curriculum and in implementing a train-the-trainer strategy. Staff members have provided much of the instruction needed to prepare TQL specialists, who themselves now conduct training of command-level leaders and TQL coordinators and quality advisors at two TQL training sites located at Little Creek, VA, and Coronado, CA.

The TQL Office also developed the Senior Leaders Seminar, which is offered to top Navy and Marine Corps leaders at the TQL training sites and in Washington, DC.

The TQL Office continues to be responsible for the management, update, and evaluation of the TQL curriculum to ensure technical accuracy and internal consistency.

TQL CONSULTATION

In addition to providing technical advice and guidance to DON senior leaders, TQL Office staff members serve as consultants and facilitators to selected groups undertaking strategic planning.

NETWORKING

Benchmarking is a valuable tool for improving processes. Recently, in conjunction with the National Aeronautics and Space Administration and with the Internal Revenue Service, the TQL Office financed a one-time initiation fee required to join the International Benchmarking Clearinghouse (IBC) established by the American Productivity and Quality Center. As a result of this funding, all federal agencies can now participate in IBC services without paying individual initiation fees.

The TQL Office also sponsored four people from the DON for membership in the IBC who are providing specific guidance on how the DON can benefit from benchmarking.

The TQL Office has established a Washington, DC-based TQL advocates group that meets monthly to share information about process improvement efforts.

As part of the TQL Office's networking function, staff members publish articles in technical and military journals and deliver papers at conferences and symposia on the DON TQL approach.

PROGRAM MANAGEMENT

The TQL Office evaluates nominee packages for productivity and quality awards that are given by the DON and by other government organizations. It also manages projects to develop TQL tools and products, such as survey instruments, for use by DON activities.

PUBLICATIONS AND VIDEOS

The TQL Office publishes the *TQLeader*, a newsletter that reports on DON policy changes, presents case studies, and offers technical advice on quality issues. It also publishes other materials, such as this report. The intent of the publication series is to clarify what TQL is and how it works within the DON.

Recently, the TQL Office began a program to develop educational and informational videotapes.

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FOREWORD

The Process Improvement Model, or PIM, describes a systems approach to analyzing and improving processes associated with an organization's products and services. The model is a modification of the method developed by Walter Shewhart and W. Edwards Deming, eminent statisticians who pioneered the use of statistical methods to gain control over product quality. They understood that quality control means continuous improvement, a never-ending cycle of *planning, doing, checking, and acting* to improve quality as new knowledge is acquired.

The PIM was first described in a 1988 technical report prepared by Dr. Archester Houston and Dr. Steven L. Dockstader, researchers at the Navy Personnel Research and Development Center. Its reception was a quiet one. Not many organizations, DON or otherwise, were thinking about quality management and how it might be implemented. Since then it has become an indispensable guide to DON organizations as they pursue quality management and to the TQL schoolhouses in Little Creek, VA, and Coronado, CA. Demand for the publication goes far beyond the Department of the Navy. To accommodate these requests, copies are now available through the federal bookstores and the Defense Technical Information Center.

The PIM report serves as a bridge between the theory and the practice of total quality management. It has three objectives: (1) to define the steps of the PIM by describing specific activities associated with each step; (2) to describe roles and responsibilities of managers and others in relation to the model; and (3) to give a brief overview of basic statistical process control methods.

The appendices include an exercise for developing a process flowchart, exercises in creating Pareto charts, a format to follow in writing up a case study, and a fictitious case study to show how the format can be used.

The authors have made only minor changes to this version of the PIM. What made sense in 1988 still makes sense today. We hope that you will find it useful to your own organization.

Linda M. Doherty

LINDA M. DOHERTY
Director
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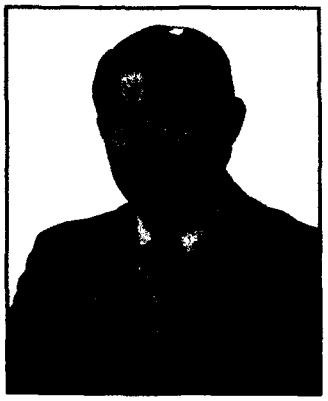
Archester Houston received his Ph.D. in social psychology from Oklahoma State University in 1982. Upon graduation, he joined the Organizational Systems Department of the Navy Personnel Research and Development Center (NPRDC) in San Diego, having previously served there as an American Psychological Association research intern.

While at NPRDC, Dr. Houston directed a research team that investigated innovative management practices used in private industry to improve quality. The results of that investigation provided much of the framework for the Department of the Navy's Total Quality Leadership (TQL) approach. Another outcome of his work at NPRDC was development of a Total Quality Management process improvement model (the subject of this report), for which he received the NPRDC Technical Director's Special Award in 1988.

In 1990, Dr. Houston transferred to the Total Quality Leadership office in Arlington, Virginia, where he is currently Director of the Research and Technical Review Division. He is a technical advisor to the Under Secretary of the Navy, the Department of the Navy's Executive Steering Group (ESG), and the Department of the Navy Review Commission, providing educational sessions on such topics as systems thinking, organizational culture, and strategic management. He was also involved with the ESG's planning efforts that resulted in formulation of the Department of the Navy's strategic goals.

Dr. Houston is overseeing the development of a quality measurement system to aid in the assessment and documentation of Navy organizations' efforts to adopt the TQL approach. He is also investigating the use of benchmarking, multimedia, and simulations to support TQL.



STEVEN L. DOCKSTADER, Ph.D.

Steve Dockstader received his Ph.D. in experimental psychology from the University of Denver in 1973. He has taught statistics and experimental methods at Denver University, Chico State University, and San Diego State University.

He is currently a Senior Scientist in the Organizational Systems Department at the Navy Personnel Research and Development Center (NPRDC) in San Diego. The focus of his research has been on quality and productivity in logistics and maintenance organizations. In this capacity, he and his colleagues have developed individual and group incentive systems and have consulted on development of a variety of performance management systems for the Department of the Navy, Air Force, Army, and Office of Personnel Management.

Since 1984 most of his work has been directed at the "total quality" concept. That year he managed a study of the application of this management technique in civilian industry in the United States and subsequently determined the feasibility for application in Navy shore support organizations. The term "Total Quality Management" was coined and defined by this research, and has since been adopted by the Department of the Navy as the principal means by which to maintain effectiveness and efficiency during the 1990's.

For the past two years he has been director for development of the TQL Senior Leaders Seminar and research consultant to the Chief of Naval Education and Training for development of TQL curricula. Most recently, he completed training of 60 TQL specialists and 12 Senior Leaders Seminar instructors.

SUMMARY

In an effort to improve quality and productivity, Navy organizations are adopting a management approach known as Total Quality Leadership (TQL). This approach is based on a set of management practices and statistical measures that, when combined, can remove the causes of poor product and service quality and excessive cost.

The management practices and analytic methods first adopted in the Navy by its aviation maintenance organizations are based primarily on the TQL concepts of W. E. Deming. Some of the critical concepts are:

- Quality is defined by customers' requirements.
- Top management has direct responsibility for quality improvement.
- Increased quality comes from systematic analysis and improvement of work processes.
- Quality improvement is a continuous effort and conducted throughout the organization.

The TQL approach emphasizes the major role that managers have in achieving quality and productivity improvement for an organization. Deming and other TQL proponents, such as P. B. Crosby and J. M. Juran, estimate that up to 85 percent of quality improvement is under the direct control of management and can not be remedied by the hourly employee or staff member.

Under the TQL approach, managers are expected to achieve quality improvements through the use of a process improvement approach known as a "Plan-Do-Check-Act" cycle. This approach was originally associated with the analytic work of W. A. Shewhart, a colleague of Deming.

This report describes an approach to integrating the procedures of process improvement with an organization made up of cross-functional teams. Specifically, the report presents how the Plan-Do-Check-Act cycle developed by Shewhart and Deming has been interpreted by the authors for use by Navy organizations.

Deming advocates teamwork, particularly across functional groups. He emphasizes two-way communication to identify sources of quality problems and to reduce fear of change and loss of job security. Combining these concepts with those of others, such as K. Ishikawa and D. J. Lu, as well as R. L. Ackoff concerning cross-functional groups, Navy organizations are adopting an organizational structure to complement the TQL approach.

The structure is composed of hierarchically linked, cross-functional teams called Quality Management Boards or QMBs. Each board contains a group of managers who are principally responsible for a process that was targeted by top management for improvement. A QMB also includes a member from senior management, as well as one or more subordinate-level managers or staff with process expertise. Thus, each board is made up of three levels to increase vertical communication and several functional departments to increase horizontal communication.

Process improvement using the Plan-Do-Check-Act cycle requires two kinds of improvements: (1) those that address the occasional and unpredictable problems that occur in a system, referred as "special causes of variation" by Deming and others; and (2) those concerned with the system itself. The latter are referred to by the experts as "systems causes" or "common causes of variation." In order for management to improve the system, it must first establish system stability by removing the special causes. Because this activity depends upon real-time interventions in the process, the QMBs must establish teams of workers, called "Process Action Teams (PATs)," to work on the various phases in the process.

The fundamental purpose of this report is to provide a detailed description of the roles and activities of the QMBs and the PATs in the context of the Plan-Do-Check-Act cycle. Clarification and differentiation of these roles are necessary for effective process improvement.

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INTRODUCTION

BACKGROUND

In an effort to improve quality and productivity, Navy organizations are adopting a management approach known as Total Quality Leadership (TQL). This approach is based on a set of management practices and statistical measures that, when combined, can remove the causes of poor product and service quality and excessive cost (Houston, Shettel-Neuber, & Sheposh, 1986).

The management practices and analytic methods being adopted by the Navy's organizations are based primarily on the TQL concepts of W. E. Deming (1986). Some of the critical concepts are:

- Quality is defined by customers' requirements.
- Top management has direct responsibility for quality improvement.
- Increased quality comes from systematic analysis and improvement of work processes.
- Quality improvement is a continuous effort and conducted throughout the organization.

Appendix A lists Deming's 14 management principles.

The TQL approach emphasizes the major role that managers have in achieving quality and productivity improvement for an organization. Deming and other TQL proponents such as Crosby (1979) and Juran (1974) estimate that up to 85 percent of quality improvement is under the direct control of management and cannot be remedied by the hourly employee or staff member.

Under the TQL approach, managers are expected to achieve quality improvements through the use of a process improvement approach known as a "Plan-Do-Check-Act" cycle (see Figure 1). This approach was originally associated with the analytic work of W. A. Shewhart (1931), a colleague of Deming.

This cycle is now closely associated with Deming's philosophy of quality improvement. The cycle, as illustrated in Figure 1, describes a method which is best suited to off-line quality control where experiments are conducted. For an elaboration of that approach, see Moen and Nolan (1987). In this technical report, an adaptation of the cycle for on-line quality control is presented (Figure 2).

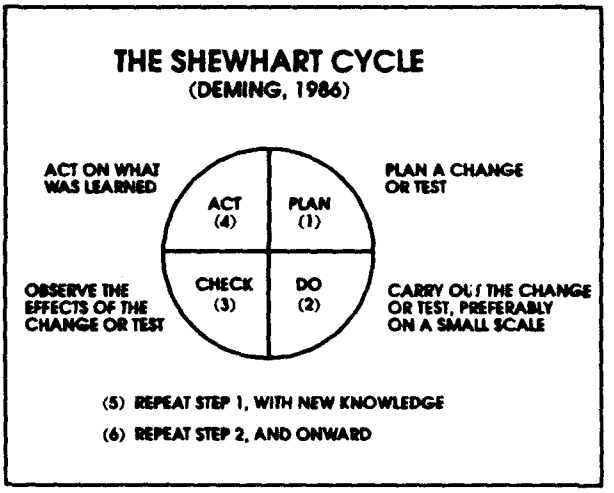

Figure 1. The Plan-Do-Check-Act cycle for continuous improvement.

In this version of the cycle, management identifies important organizational goals during the *Plan* phase. Activities in the *Do* and *Check* phases involve the identification and analysis of process variables that affect achievement of the goals. During the *Act* phase of the cycle, process corrections and improvements are made and evaluated. Effective changes are formally installed and the process is monitored to maintain the improved performance. The cycle is then repeated to pursue continuous improvement.

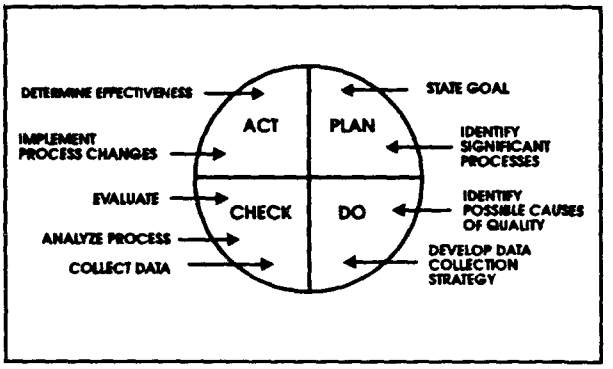

Figure 2. The Plan-Do-Check-Act cycle during process improvement.

In an effort to assist managers to understand the specific activities in the Plan-Do-Check-Act cycle, an elaboration of the cycle was developed by the Navy Personnel Research and Development Center. The cycle is presented in the form of a flowchart, referred to here as the Process Improvement Model (PIM), and is displayed in Figure 3.

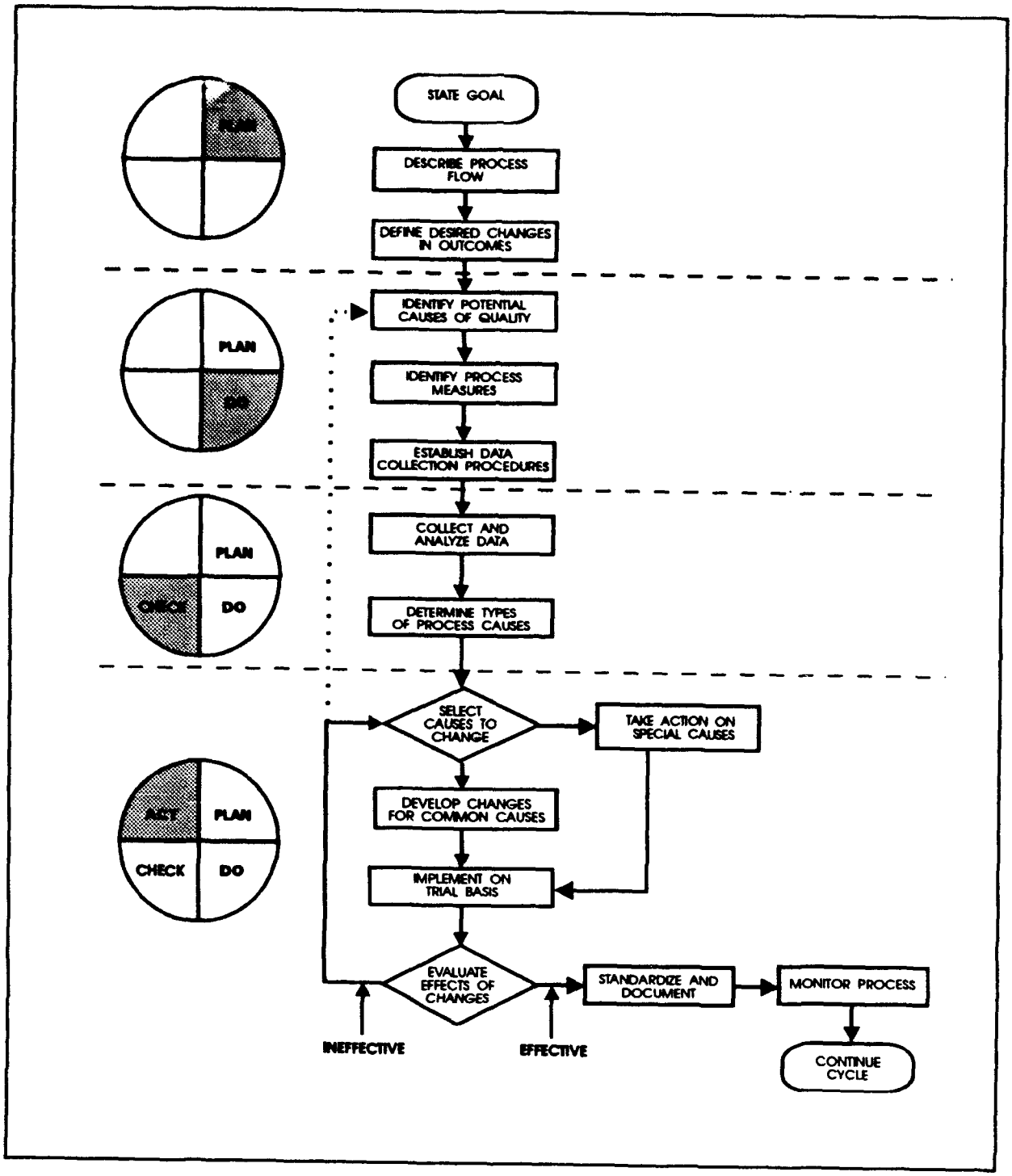

Figure 3. Process Improvement Model for Total Quality Leadership.

PURPOSE OF REPORT

The use of TQL principles and the Plan-Do-Check-Act cycle in Navy organizations requires the adoption of managerial practices and responsibilities that managers have little, if any, experience in applying.

This report has been written to serve as a bridge between theory and practice. Specifically this report has three objectives: (1) to define the steps of the PIM by describing specific activities associated with each step; (2) to describe roles and responsibilities of managers and others in relation to the model; and (3) to give a brief overview of basic statistical process control methods.

This report is not a how-to manual for improving product quality, but rather documentation of one approach to process improvement that has general applications. The reader is encouraged to consult other writings on the subject (e.g., Moen & Nolan, 1987; Tunner, 1987) and more technically comprehensive treatments of statistical process control methods (AT&T, 1956; Grant & Leavenworth, 1974; Ott, 1975).

ORGANIZATIONAL STRUCTURE

The use of the PIM requires the cooperation and coordination of all organizational levels. The following organizational structure is presented as a way to manage people involved in process improvement efforts. The structure consists of three levels: Executive Steering Committee, Quality Management Boards, and Process Action Teams.

EXECUTIVE STEERING COMMITTEE

Membership

The Executive Steering Committee (ESC) represents the highest level of management and as such is made up of a number of top managers in the organization. For naval organizations, an ESC would probably include the commanding officer and department-level managers.

Function

The ESC identifies strategic goals for organizational quality improvement efforts. It obtains information from customers to identify major product and service requirements. It is through the identification of these major requirements that quality goals for the organization are defined. After the ESC has identified customer requirements, it prioritizes and lists the organizational goals for quality improvement. During the course of quality improvement efforts there will be changes that require support and resources that can only be provided by top management. The ESC is expected to ensure that these requirements are met.

After process changes have been made, the ESC is involved in determining the effectiveness of the changes in meeting the quality needs of customers. As effective process changes are made, the ESC provides the resources needed to standardize and document these changes.

QUALITY MANAGEMENT BOARDS

Membership

Quality Management Boards (QMBs) are permanent cross-functional teams made up of top- and mid-level managers who are jointly responsible for a specific product or service (see principle number 9 of "Deming's 14 Management Principles," 1986, in Appendix A). The structure of the boards is intended to improve communication and cooperation by providing vertical and horizontal links throughout the organization (Ackoff, 1981; Dockstader, 1984).

Although the members of QMBs are expected to be permanent, the chair and the focus of a specific QMB can shift, depending on the current product or service goal. During the formation of QMBs, it is crucial that the members selected have the knowledge and ability to relate the ESC's quality improvement goals to specific outputs and processes.

Function

The QMB carries out the majority of PIM activities. The QMB uses its combined knowledge to select the organizational areas that might have the most significant impact on the goals. The QMB works with the ESC to define indicators of quality improvement and cost reduction.

The QMB organizes ad hoc Process Action Teams (PATs) that collect and analyze information about work processes. As the teams perform their work, the QMB conducts experiments to identify what common causes of variation appear to be most critical to process performance. Based on these causes, the QMB makes changes

designed to improve process performance. The QMB tracks the performance of the process to determine the impact of the changes on the selected goals.

PROCESS ACTION TEAMS

MEMBERSHIP

PATs are composed of staff and/or hourly workers involved in the processes being investigated by the QMBs. The members of a PAT are chosen by their respective managers on the QMBs. The primary consideration in choosing PAT members is that the individuals selected be highly knowledgeable about the operations in their shop or unit.

FUNCTION

The main function of a PAT is to collect and summarize process data for QMBs. A major task of a PAT is to collect baseline information on process performance. PATs use basic statistical process control (SPC) methods to analyze a process and identify potential areas for improvement. It is important to note that PATs and, by extension, the entire PIM are only of use when dealing with quality goals that can be achieved by using objective data. Such data can be obtained by a variety of means, including expert judgments and other scaling methods.

PLAN PHASE (ESC/QMB RESPONSIBILITY)

The *Plan* phase involves identifying the critical product and service requirements of major customers (see Figure 4). Process improvement efforts are based on these critical customer requirements. The ESC and QMBs work together in translating customers' requirements into appropriate goals.

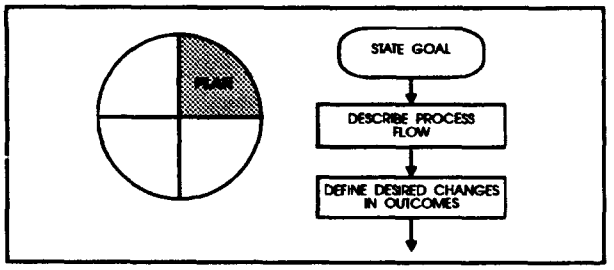

Figure 4. The Plan *phase of the PIM.*

A fundamental assumption of the TQL approach is that "quality" is defined by the customer. Therefore, the selection of major quality goals must be based on the information received from customers. During the planning phase there are several questions that should be answered:

- Who are our major customers?
- Which products or services are most important to them?
- What characteristics of these products or services could be improved? (What are the "true" quality characteristics? [Ishikawa & Lu, 1985].)
- What operations in the process have the greatest effect on the products or services?
- How does the performance of these operations need to change?

Addressing these questions aids in the development of a quality improvement plan. A well-developed plan enables an organization to concentrate its resources on achieving maximum quality improvements. Failure to develop a well-defined plan with specific, measurable goals can result in wasted time, misused resources, and needless frustration. The following paragraphs describe some of the major activities associated with the *Plan* phase under the PIM.

STATE GOAL

A goal within this context refers to some desired change in products or services. Examples of such goals are (1) reducing processing time for customer orders, (2) increasing the service life of a product, (3) shortening delivery time to customers, or (4) reducing the cost charged to the customer.

While TQL is a very effective way of obtaining quality improvements, certain conditions must be met before using the TQL methods and structure to address a goal. For instance, goals addressed by TQL should be *relevant* to the mission of the organization and *measurable.*

RELEVANT

Selected goals should reflect the potential for significant improvements in the product or service. Avoid "so what?" goals that have little, if any, impact on the central mission of the organization. For example, if the central mission of an organization is to repair naval aircraft, then it is unlikely that a major quality concern would be processing travel orders for personnel. However, if the business is a travel agency, it may be entirely appropriate to optimize travel processing procedures. Whenever possible, it is best to establish goals that will provide a direct benefit to the final customer.

MEASURABLE

TQL is often concerned with economically related goals and relies on Statistical Process Control (SPC) methods to achieve these goals. Use of these methods requires that goals be defined so that their achievement can be verified by data, not subjective opinion. A goal that cannot be measured in some fashion is not appropriate for the PIM.

DESCRIBE PROCESS FLOW

In many traditional organizations, managers and employees are encouraged to specialize in the activities and operations they perform. This emphasis has advantages, such as the development of operational expertise, clear job responsibilities, and well-defined management boundaries. There are potentially serious disadvantages associated with this "departmentalizing" of a work process, however. Some of the disadvantages include: conflict between interrelated operations in separate departments, restriction of needed information, duplicated efforts, and suboptimization. Suboptimization occurs when actions are taken to improve the performance of an isolated operation to the detriment of related or subsequent operations.

One way to avoid the disadvantages of a narrow process focus in a QMB is for that group to identify major interrelated process operations and departmental responsibilities. The flowchart is a method of accomplishing this. The flowchart graphically describes the interrelationship of operations and decisions required to transform resources into outputs (see Figure 5).

After the QMB has constructed a process flowchart, it should analyze the chart to identify such things as duplicated efforts between operations, gaps in accountability, overuse of inspection, and ways to streamline the process. Streamlining a process is sometimes known as "imagineering." During imagineering the QMB constructs a flowchart of the ideal process--that is, a depiction of a process that creates perfect products in the most efficient manner. The comparison of the actual operations with the imagineered process can then be used to guide improvement activities. Appendix B presents a series of exercises that provide practice in developing and using a process flowchart.

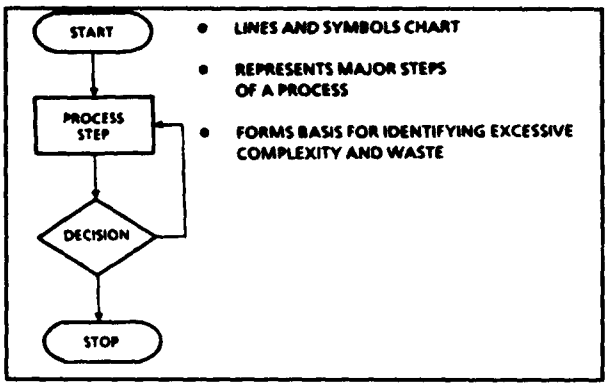

Figure 5. Process flowchart.

DEFINE DESIRED CHANGES IN OUTCOMES

The achievement of quality goals will require specific changes in process performance. A critical task of the ESC and QMBs is to identify and define these needed changes. During the planning and other phases of the PIM, there are three types of information that will be needed to achieve and maintain quality improvements. These types of information are: outcome, output, and process.

OUTCOME

This information represents the customers' evaluation of the product or service. This information can include timeliness, price, or "fitness for use." These measures are provided by customers external to the organization. It is information from such customers that is the basis for defining product or service quality. If the organization's current customer information system is considered inadequate, then different methods of obtaining information must be developed. Failure to obtain accurate definitions of customers' requirements seriously weakens the entire foundation of the TQL approach.

Output

Output information describes objective features of a product or service. This information typically represents a comparison of critical characteristics of the final product or service with customer-defined requirements. These requirements might address physical specifications, degree of accuracy, manufacturing costs, or time standards. This type of information can usually be obtained through the review of inspection or audit records.

Process

Process information describes the resources and operations required to develop a product or service. This information can address equipment performance, condition of incoming material, variations in work methods, or worker characteristics. In the TQL approach, this information is gathered by individuals who work directly with the process. Process information is collected to identify the variables that have the greatest effect on the product or service.

Measures of outcome, output, and process are used throughout the process improvement cycle. The ESC obtains *outcome* information to identify major organizational goals. The ESC and QMBs work together to relate the outcome requirements to specific process *outputs*. They then define how the outputs need to change. The QMBs and PATs work together to identify the *process variables* that have the greatest effect on output quality. As these variables are changed, output and outcome information is collected. This information is analyzed to check progress toward the quality improvement goals.

DO PHASE (PAT RESPONSIBILITY)

After quality goals have been defined, the process variables related to improved quality need to be identified. The identification of these variables is the task of PATs. A PAT consists of individuals working on the process selected for improvement. In the *Do* phase of the PIM, the team has three major responsibilities (see Figure 6). First, the PAT studies the current process and its outputs to identify variables related to quality. Second, the team develops measures of those variables. Third, the team creates a format to collect data.

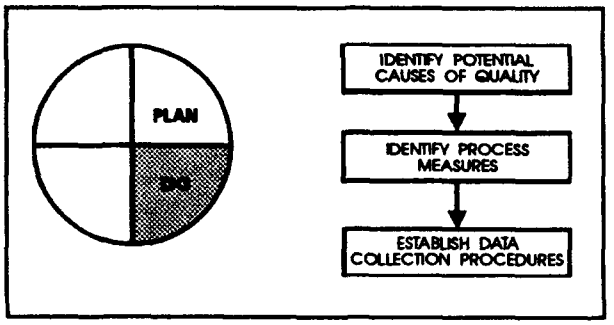

Figure 6. The Do *phase of the PIM.*

IDENTIFY POTENTIAL CAUSES OF QUALITY

PATs are expected to use their knowledge and experience to identify variables that affect output quality. Statistical methods are used by PATs to study process performance. First, information on past performance of output characteristics is gathered. This is known as *baseline information*. Second, a description of the process as it currently exists is developed. It takes the form of an *as-is flowchart*. Third, the identification of specific process variables is accomplished through a *cause-and-effect analysis*. The following sections provide further discussion of these steps.

Develop Baseline for Process Outputs

The first step in baseline development is to clearly define what quality characteristics of the process output will be studied. This definition is critical to subsequent process analysis and improvement efforts. Development of a baseline for a process output involves evaluation of the output over a period of time. The purpose is to determine how the process performs prior to and following any improvement efforts.

The output studied by a PAT depends on the type of process. The output of a production process is usually a physical product, such as an automobile, a camera, or clothing. Such outputs have physical dimensions that can often be quantified and objectively evaluated. The outputs of service processes tend to be more difficult to measure (Albrecht & Zemke, 1985). Examples of services include medical examinations, haircuts, management consulting, and report editing. The results of these types of processes can vary greatly from customer to customer and are often evaluated on the basis of subjective criteria. Thus, collecting baseline information on service outputs can

require much more continuous and direct communication with customers than is required when the output is a product.

There is no easy answer for determining what output characteristics should be measured to create a baseline. The characteristics should have a logical relationship to the goals defined by the ESC and QMB. For example, if the goal is to reduce the amount of backlogged material, then a logical output to measure would be the ratio of completed orders to total orders received per day.

Develop As-Is Flowchart

Each PAT should develop a flowchart that depicts its section of the process as it actually functions. Such flowcharts should be used to flesh out formal descriptions of operations. It might be discovered that the as-is description includes redundant steps or that the informal process omits critical activities. It is also important to determine how the operations within a process interact. Process improvements must relate to the process as it functions. The as-is flowchart can also serve to provide QMB members with more detailed knowledge of critical processes.

Perform Cause-and-Effect Analysis

Cause-and-effect analysis is a brainstorming method used by a team to create a branching diagram. It shows the relationship between a set of possible process variables and a specific process result (Ishikawa, 1983). The results often focused on during cause-and-effect analysis concern quality, costs, or schedule (see Figure 7).

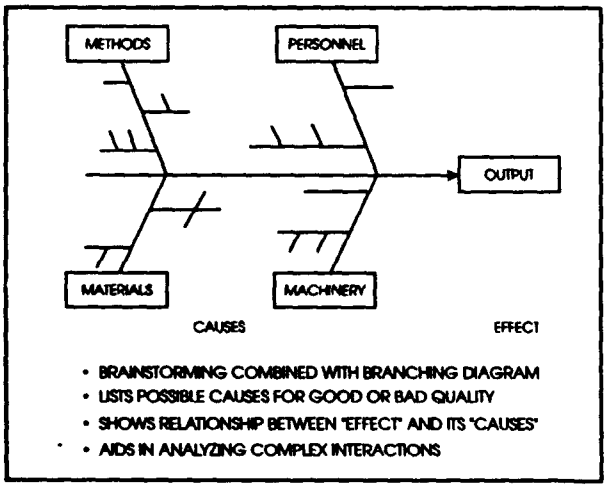

Figure 7. Cause-and-effect analysis chart.

Most cause-and-effect analysis concentrates on four categories of process variables. These categories are:

Personnel — The attributes of the people involved in the process, such as their experience, training, strength, or even eyesight and reading ability.

Materials — The physical resources or raw materials used in the process; within the setting of Navy aviation maintenance organizations, these resources can include materials such as sheet metal, packing material, or chemicals.

Methods — The combination of information and procedures used to create process output. Information sources may be standardized as, for example, technical data manuals or forms. Methods can include informal work experiences, such as shortcuts workers learn from others.

Machines — The equipment and tools used in a process. For a supply operation, this might include forklift trucks, computer terminals, or conveyance systems.

While these four categories are commonly used in the identification of important *causes* of process performance, other categories can be added to or substituted for them. An example of cause-and-effect analysis of a problem concerning inventory accuracy in a supply operation is depicted in Figures 8 and 9. Inventory accuracy as presented in the diagrams refers to the location of the correct amount of material within its assigned storage space. Inventory accuracy is the result or *effect* of a combination of variables or *causes*.

The purpose of conducting the cause-and-effect analysis is to identify the variables that appear to have a major influence on process results. Once these potential causes have been identified, they can be analyzed using an SPC graph such as a scatter diagram. Such analysis is conducted to verify that the causes significantly affect process performance. The variables identified during the cause-and-effect analysis are also studied to determine the type of influence these variables have on process results.

IDENTIFY PROCESS MEASURES

As important as it is to have valid data on outcomes and outputs, it is vital to obtain process measures as well. Unfortunately, organizations rarely have systems established to collect data on process characteristics. When such data are not available, it becomes necessary to develop the process measures.

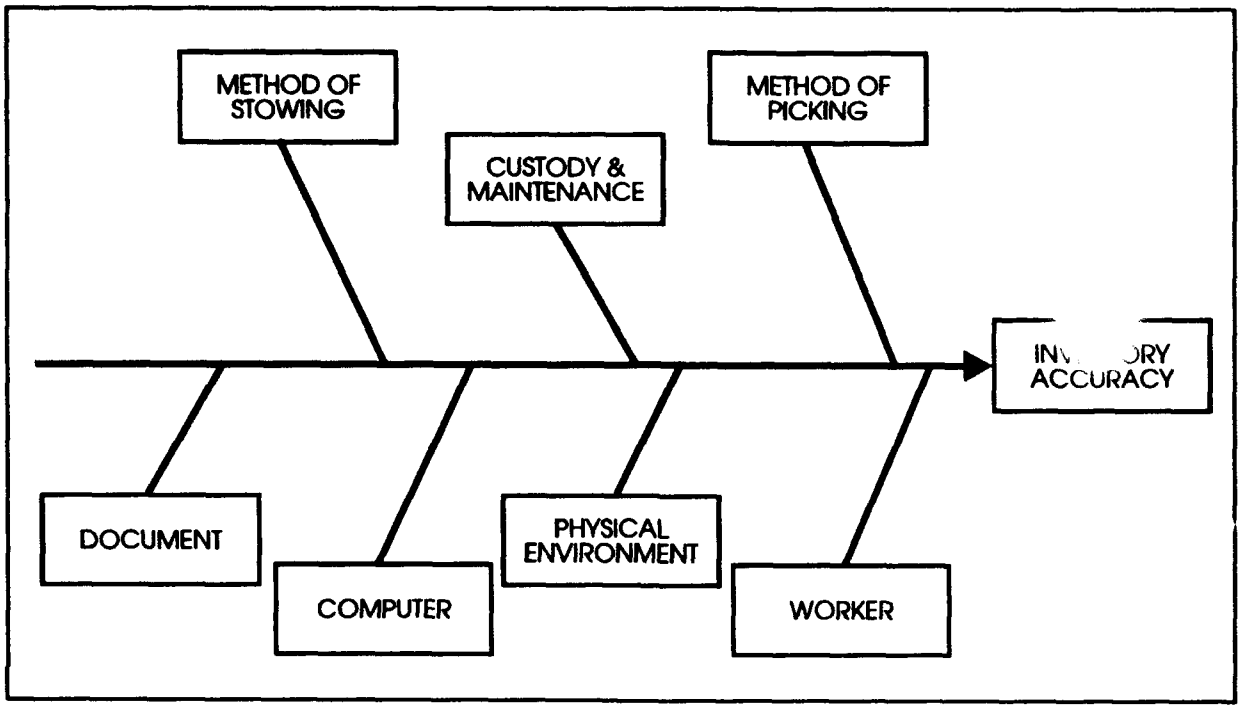

Figure 8. Example of cause-and-effect chart.

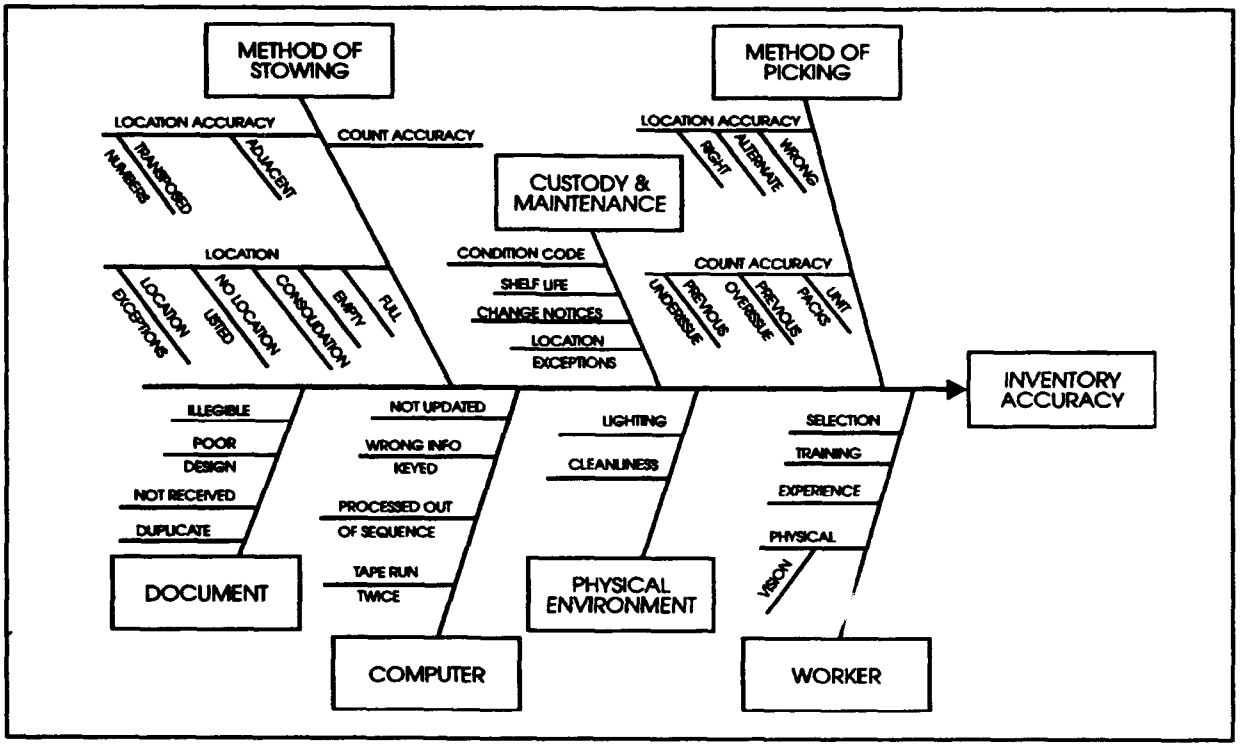

Figure 9. An expansion of information displayed in Figure 8.

Developing process measures is not easy. Take, for example, a process variable such as legibility of documents. Members of a team might agree that it is critical to performing their job, but measuring the legibility of a form can be very difficult.

Unfortunately, there is no single method of developing measures for process variables. This is a problem that each team will have to work through by using its best judgment. However, once process measures have been identified and developed, it is possible to statistically determine the validity and reliability of these measures. As more knowledge is acquired on processes, it becomes easier to determine what variables should be measured and how they should be defined.

ESTABLISH DATA COLLECTION PROCEDURES

After a PAT has developed measures, it must decide how to collect the data. Data must be collected in a systematic fashion to ensure accuracy of analysis and interpretation. After they have been collected, they are analyzed to identify those variables that are most critical to quality.

Collect Baseline Process Information

The first part of the data collection strategy requires that the team collect information on the causes of variation identified through cause-and-effect analysis. This information is collected to determine how the various causes influence the output or effect. Five questions need to be addressed prior to collecting baseline data on causes:

- **What process information will be collected?** This question concerns the type of information that will be collected on each cause. In some cases a measure is a simple tally, such as counting defects in a product, counting forklift trucks available at a receiving dock, or counting documents that are illegible. Some variables require detailed measurement; examples are visual acuity of material handlers, size of packages received from vendors, or minutes required to assemble and deliver an aircraft component kit.

- **How will the data be collected?** There are two issues that need to be addressed here. First, the PAT must develop a standard data collection format. In some cases this might require the team to construct check sheets or other recording forms. The individuals who use the forms must use them in a consistent fashion. The second issue is that of sampling. Sampling involves collecting data in such a way that it represents the effect of process variables accurately. The services of a professional statistician are often required to ensure proper sampling.

- **Who will collect the information?** An obvious, but sometimes overlooked, item is deciding individual responsibility for data collection. If individuals are not given specific data collection tasks, there is considerable danger of data collection failing to be carried out because no one was responsible for it. The individuals selected to conduct data collection should be able to do so as a routine part of their duties. This is likely to occur when the data collector works in the part of the process where the variable is found. For example, if a team is concerned with inaccurate documentation attached to vendor-supplied material, then someone who currently checks documents at the receiving operation would be an appropriate choice as a data collector.

- **Where will the data be collected?** A PAT must decide at what points in a process data should be collected. The as-is flowchart developed by the PAT could be used to identify appropriate process data collection points. Data should be collected on causes at the points where they occur, rather than waiting to infer the existence of the cause through a change in the effect. For example, an insufficient number of wooden pallets could be identified as a cause of material backlog in a storage area. It would be more appropriate to measure the difference between available versus needed pallets than to measure the amount of backlog to determine whether or not the supply is adequate.

- **When will the data be collected?** This question refers to identifying deadlines for data collection activities. Data collection deadlines are used to obtain process data in a timely manner. The time span should be long enough to provide a representative sample of measures. For example, if it takes an hour to process an aircraft component, then collecting data once a week could miss valuable information. In this instance, collecting data on an hourly basis during each work day would be more appropriate. Expert assistance from statisticians or operations analysts could be used to help the team determine an adequate time frame.

Perform Pareto Analysis

After baseline measures of the process causes have been gathered, the relative importance of the causes must be determined. Rather than expend the organization's resources to correct a host of causes all at one time, it would be more effective to address those causes that have the greatest impact on the effect first. A method commonly used to identify the most important causes is the Pareto analysis (see Figure 10). This analytic technique involves the use of a vertical bar chart that depicts causes sorted in descending order according to their impact on the selected effect.

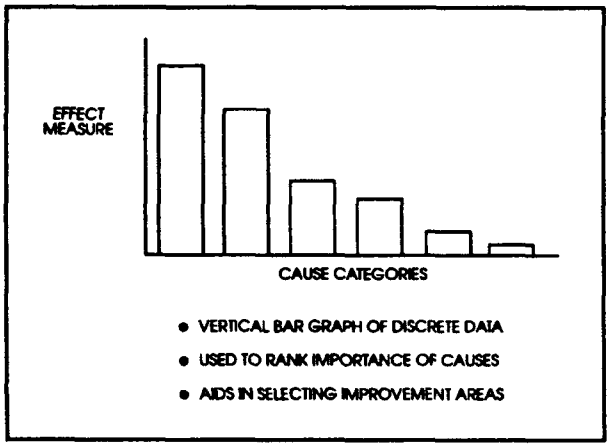

Figure 10. Pareto chart.

A Pareto analysis could be used to display the relationship between such data as:

- Type of accident (cause) compared with labor hours lost (effect).
- Vendor sources used (cause) compared with defective material found (effect).
- Complexity of travel requirements (cause) compared with time required to process orders (effect).
- Type of product defect (cause) compared with the cost of reworking the product (effect).

From a review of a Pareto chart, a PAT could identify those variables that have the greatest effect on an output characteristic. Those variables could then be analyzed to determine their precise influence within the process. Appendix C presents an exercise that can be used for developing a set of Pareto charts. The following section describes the methods frequently used to study process variables.

CHECK PHASE (PAT/QMB RESPONSIBILITY)

COLLECT AND ANALYZE DATA

In the *Check* phase (Figure 11), a PAT collects process and output data. During the data collection period, the data are summarized using graphic methods. Once the data have been summarized, the PAT and QMB interpret the findings to confirm which process variables have a significant effect on outputs and, subsequently, outcomes. As significant variables are identified, statistical experiments are conducted to determine the precise type of effect each variable has on output quality.

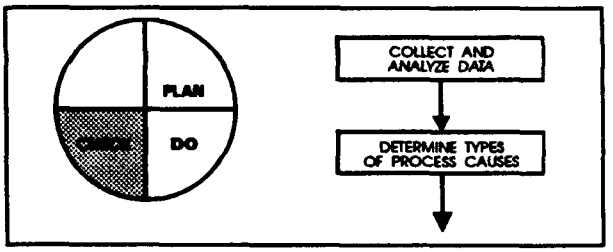

Figure 11. The Check *phase of the PIM.*

In addition to flowcharts, cause-and-effect diagrams, and Pareto charts, there are four other methods commonly associated with process analysis—histograms, scatter diagrams, run charts, and control charts (G.O.A.L., 1985; Houston, Hulton, Landau, Monda, & Shettel-Neuber, 1987; Ishikawa, 1983). These graphic methods are presented below along with brief definitions.

It should also be pointed out that these are the most basic analytic methods and are most often used with online process analysis. Other, more advanced, techniques associated with design of experiments (AT&T, 1956) are beyond the scope of the present discussion.

Histograms

These graphs can be used to depict variation in process performance or results (see Figure 12). They can also be used to show how the majority of process outputs compare with a goal value as well as with its specification limits.

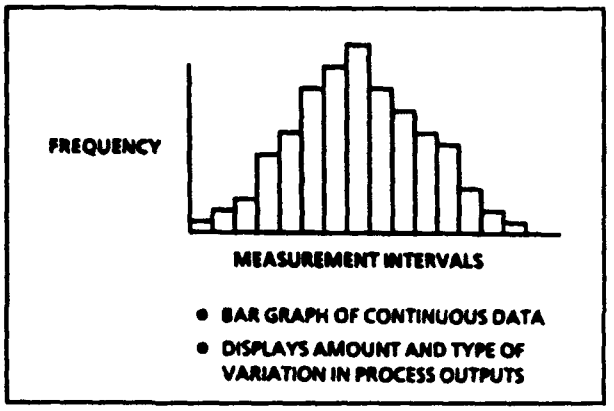

Figure 12. Histogram.

Scatter Diagrams

These diagrams are often used to check the strength of the possible cause-and-effect relationships identified in the *Do* phase. These diagrams can be used to show whether changes in a process variable result in changes in the output (see Figure 13).

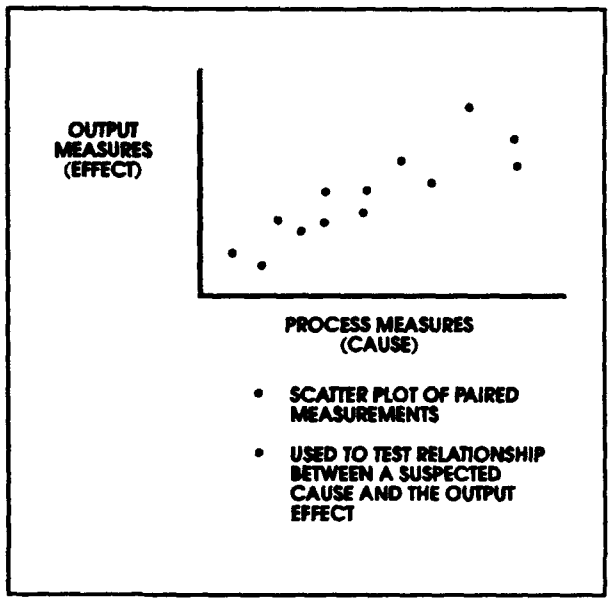

Figure 13. Scatter diagram.

Run Charts

These charts are constructed to determine whether there are time-related patterns in process performance (see Figure 14). They can also be used to test before-and-after effects of process changes.

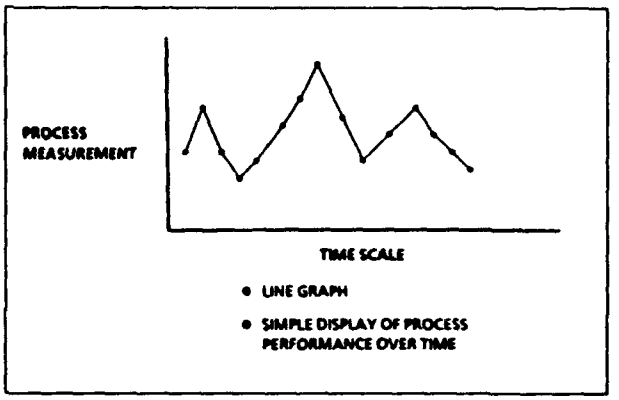

Figure 14. Run chart.

Control Charts

These charts depict process performance from samples taken over a period of time (see Figure 15). Control charts can be used to predict how a process should perform under stable conditions. These charts can be used to distinguish among variables that consistently affect all of a process's outputs (common causes) and those that have an unpredictable effect on outputs (special causes).

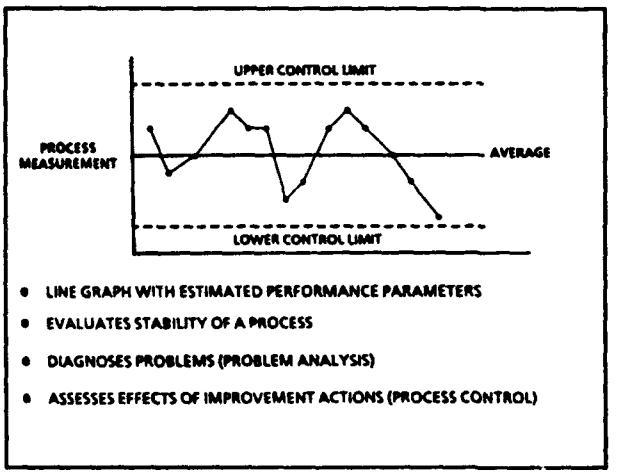

Figure 15. Control chart.

These methods are used, when appropriate, by QMBs and PATs to uncover causes of unwanted variation in process performance. Once the data have been graphed, both the PAT and the QMB interpret the findings. Based on the results of their interpretation, process improvement changes are made and evaluated in the *Act* phase. To assist in the selection and use of appropriate analytic methods, some organizations provide their QMBs and

PATs with process consultants specifically trained to provide instruction in the analytic and problem-solving methods associated with TQL. In the absence of specially trained consultants, it is often necessary to have a professional statistician help with these matters.

DETERMINE TYPES OF PROCESS CAUSES

Before taking actions to improve quality, QMBs and PATs should determine what types of causes or variables are within the process. Causes have either a *common* or *special* influence on a process. *Common causes* are those that arise from the system itself and influence overall performance in a statistically predictable fashion. Some examples of common causes are the accuracy of standards supplied to a work area, the training given to workers, or the consistency of materials used in the process.

The term *special causes* refers to variables that are not regarded as part of the system and have an isolated and statistically unpredictable influence on outputs. Special causes are often local to a specific operation, machine, or lot of material. Some examples of special causes include a bad lot of material, a single malfunctioning machine, or a new worker using inappropriate procedures. Sometimes the source of a special cause cannot be determined or reflects an unusual statistical event (sometimes called "bad luck").

Failing to identify the exact nature of a problem could result in short-term solutions (band-aid solutions or quick fixes) being used on long-term problems. This is usually the result of incorrectly assuming that a common cause is a special cause. It is also possible to err by implementing broad-scope, long-term changes on what could have been a short-term aberration. Common and special causes can often be identified through the use of control charts (Wheeler & Chambers, 1986).

ACT PHASE (QMB/ESC RESPONSIBILITY)

SELECT CAUSES TO CHANGE

At the conclusion of the *Check* phase, the PAT selects process variables believed to be major contributors to process quality. These variables are used during the *Act* phase in efforts to improve process quality (see Figure 16). At this point in the model, a critical task of the QMB is to identify those variables that can be handled at the lower organizational levels and those that require the efforts of upper management. Typically, actions on spe-

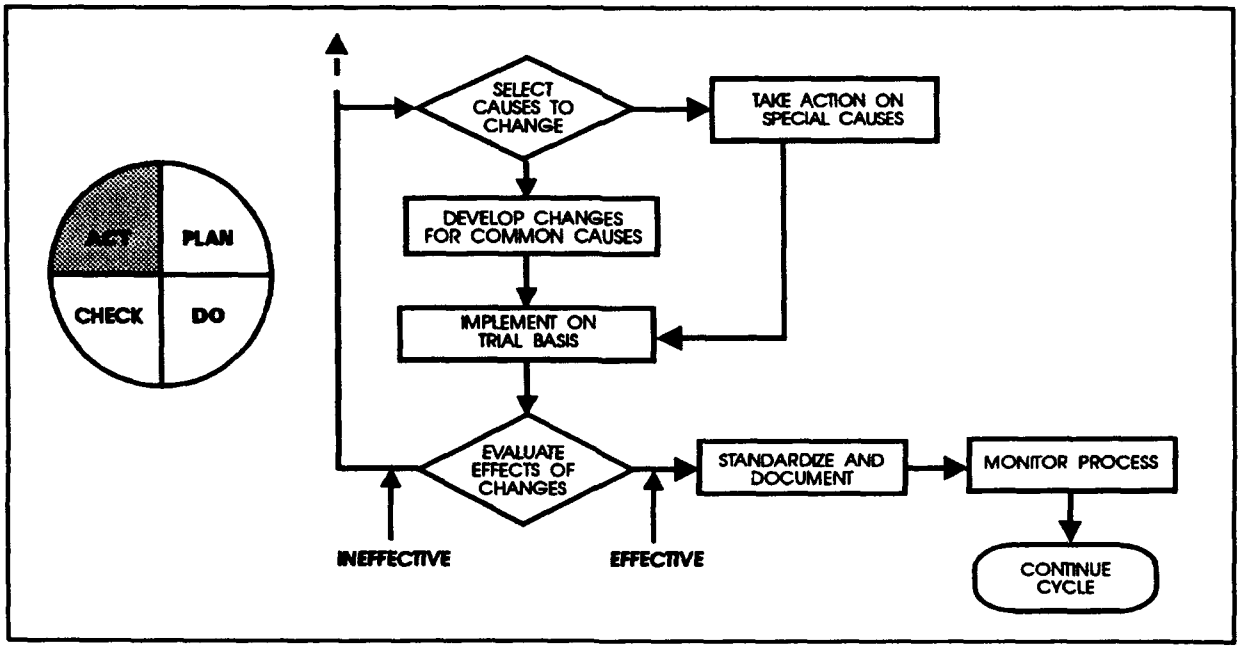

Figure 16. The Act *phase of the PIM.*

cial causes, those isolated and unpredictable process influences, can be dealt with at the worker or first supervisory level. Changing common causes, those variables that affect total process performance, usually involves major changes that require the attention of higher management.

TAKE ACTION ON SPECIAL CAUSES

In some cases it is necessary to take corrective action as soon as a *special cause* is identified. If unsafe working conditions are discovered, it is not necessary to wait until all of the analytic efforts have been carried out to improve the working conditions. Early in an organization's TQL effort, many causes identified might require immediate action. Often these actions can be taken at the lowest organizational level. For example, a PAT might identify a machine with an incorrect setting; the team members could have the authority to correct the setting without any management assistance. It should be remembered that the main purpose of correcting special causes is to stabilize a process. After a process is stabilized, it is possible to address common causes and improve overall performance.

DEVELOP CHANGES FOR COMMON CAUSES

As a process is stabilized and *common causes* are identified, the QMB and ESC work to improve process-wide influences on quality. The QMB and ESC identify the resources and authority levels required to make the changes. As part of the change design, the QMB and ESC will have to decide how long a trial period should be used to test the change. Two factors that should be taken into consideration are the nature of the change and production time. Some changes might take a relatively short time to put in place and be expected to show immediate results. Other changes might require a longer period of time to install and affect the outputs.

The determination of trial periods should be made using statistical criteria before the change is implemented to avoid incorrectly evaluating the effectiveness of a change. For example, a change might be considered to be effective before it is actually tried. Once it has been put in place, any positive results could be interpreted as sufficient evidence that it is working. The trial would then be stopped and a potentially ineffective change established as part of the process. By collecting data for a sufficient time period, changes that only have a temporary effect can be ruled out.

IMPLEMENT COMMON CAUSE CHANGES ON A TRIAL BASIS

After changes have been designed by the QMB and the ESC, the changes are put into effect for a trial period. The QMB continues to work with the PATs and others involved in the changes to ensure that the designed changes are properly executed. Failure to follow the change plan could lead to poor results and the discontinuing of an effective process change.

EVALUATE EFFECTS OF CHANGES

After the process change, the QMB and ESC need to evaluate the effect of the change relative to the original goals identified during the *Plan* phase. Evaluation should be conducted at the process level, the output level, and the outcome level. These levels of evaluation are used to determine whether the process change should be standardized or further investigation is required. The following sections describe evaluation activities.

COLLECT AND ANALYZE PROCESS AND OUTPUT DATA

Once changes have been installed, the process is allowed to operate for the preselected trial period. Data are collected by PATs to assess the effects of the change, using, for example, a run or control chart to determine whether the change has a significant influence on the output characteristic. The findings of the PATs are summarized and submitted along with graphs to be reviewed by the ESC and QMB. The QMB integrates the data obtained from PATs to form a complete description of the effects that changes have had on outputs.

Determine Impact on Outcomes

After the PATS have completed their collection of evaluative output data, the QMB and the ESC compare those data with outcome information. The purpose of this comparison is to determine what effect the changes have made on meeting customer requirements. It is possible that a change could have a positive effect on performance at an internal level without those benefits being transferred to the user of the product or service. That is why it is very important for the QMB to identify all of the major process operations during the *Plan* phase. If a critical operation is ignored within a process, its poor performance could neutralize other gains.

Determine Whether Original Improvement Goals have been Achieved

After reviewing evaluation data, the QMB and ESC must determine whether the process improvement goals have been achieved. If the changes lead to desired improvements, then the QMB and ESC take the steps needed to make the changes permanent parts of the process. If there has been no significant change in the outcomes selected during the *Plan* phase, then other possible causes of performance must be investigated. This could require returning to the lists created during the *Plan* and *Do* phases and selecting different variables to work on. In an extreme case, a new set of causes might have to be identified for the process.

STANDARDIZE AND DOCUMENT PROCESS IMPROVEMENTS

If the results show a significant increase in process quality, then the QMB and ESC take actions to make the changes permanent. Such actions might include changing specifications, work methods, or vendors, or providing new training to workers.

An important step in maintaining process improvements is documentation of improvement actions and results. By recording such efforts it is possible to develop case studies for the continuing education of managers new to the TQL approach, for informing vendors of their responsibilities under a changed process, and for briefing customers on the organization's efforts to meet their requirements. Appendix D presents a case study format and guide that can be used to document process improvements. Appendix E presents a fictitious case study to demonstrate the use of the format.

MONITOR PROCESS

The final step of this model is the establishment of monitoring procedures. Once a process has been improved so that it meets the requirements of customers, the process changes that led to the improvement must be maintained. Maintenance of a process at a higher level of quality requires the ongoing measurement of critical process variables. The purpose of such measurement or monitoring is to ensure that process performance does not deteriorate.

At the conclusion of a successful improvement effort, the participating groups should develop the procedures and forms necessary to monitor the process. Unlike the previous process analysis efforts, data collection for monitoring is expected to be a regular task of the people involved in the process. Simplicity in data collection and analysis should be a major consideration in the development of a monitoring system.

CONTINUE IMPROVEMENT CYCLE

Although this model focuses on the individual process improvement effort, it should be remembered that under TQL, process improvement efforts are a continuous activity. The ESC should always search for new areas for improvement. At the organizational level, the ESC works to address new customer concerns and requirements as the previous goals are met. This might require increasingly detailed customer information systems. At the QMB and PAT levels, continuing efforts to reduce process variation and refinement of process improvements provide additional quality gains.

CONCLUSION

Although the PIM was developed for Navy industrial organizations, the activities presented in the model can be applied to a variety of organizations, private as well as public.

The major impediments to the use of the PIM and, by extension, to the use of TQL, are not likely to lie in the nature of the process under investigation, but rather to originate from inappropriate attitudes and practices of managers. Successful use of the PIM to improve an organization's products and services will be heavily affected by the ability of managers to adopt the concepts associated with TQL.

RECOMMENDATIONS

The following conditions are considered essential for successful application of the PIM:

1. Managers should understand the principles and techniques associated with TQL.
2. Managers should believe that they are capable of making significant changes in the ways the organization does business.
3. Managers at all levels should have a shared perception that improvement in product and service quality is essential to their organization's mission.
4. Managers should agree that the TQL approach could be used to significantly improve the products and services of their organization.
5. Managers should clearly define their responsibilities, as well as the responsibilities of their subordinates, in process improvement activities.

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APPENDIX A
DEMING'S 14 MANAGEMENT PRINCIPLES

DEMING'S 14 MANAGEMENT PRINCIPLES

1. Create and publish to all employees a statement of the aims and purposes of the company or other organization. The management must demonstrate constantly their commitment to this statement.

2. Learn the new philosophy, top management and everybody.

3. Understand the purpose of inspection, for improvement of processes and reduction of cost.

4. End the practice of awarding business on the basis of price tag alone.

5. Improve constantly and forever the system of production and service.

6. Institute training for skills.

7. Teach and institute leadership.

8. Drive out fear. Create trust. Create a climate for innovation.

9. Optimize toward the aims and purposes of the company, the efforts of teams, groups, staff areas, too.

10. Eliminate exhortations for the work force.

11. (a) Eliminate numerical quotas for production. Instead, learn and institute methods for improvement.

    (b) Eliminate MBO (management by objective). Instead, learn the capabilities of processes and how to improve them.

12. Remove barriers that rob people of pride of workmanship.

13. Encourage education and self-improvement for everyone.

14. Take action to accomplish the transformation.

APPENDIX B
PROCESS FLOWCHART EXERCISES

PROCESS FLOWCHART EXERCISES

SPRAY PAINTING PROCESS FLOWCHART EXERCISE (PART ONE)

This exercise is designed to provide some practice in developing a process flowchart. The following unordered list presents operations for a spray painting process. For this exercise:

- Number the operations in what you think is the most likely sequence of occurrence.
- Indicate with an asterisk the decision points along the process; that is, mark where you think the quality of the work is being evaluated.

Spray Painting Process Operations (not in order)

_____mask nonpainted surfaces

_____apply first primer coat

_____in-process check, second primer coat

_____apply final color coat

_____in-process check, first color coat

_____fill depressions

_____touchup final coat

_____sand down to base metal

_____move material to storage area

_____apply first color coat

_____sand filler

_____bake first color coat

_____sand first primer coat

_____Q.C. approval of final coat

_____sand second primer coat

_____in-process check, final color coat

_____in-process check, filler level

_____sand first color coat

_____bake final color coat

_____in-process check, first primer coat

_____apply second primer coat

_____ receive surface components

SPRAY PAINTING PROCESS FLOWCHART EXERCISE (PART 1)

ANSWER SHEET

Steps in Order

1 - receive surface components
2 - sand down to base metal
3 - fill depressions
4 - sand filler
* 5 - in-process check, filler level
6 - mask nonpainted surfaces
7 - apply first primer coat
8 - sand first primer coat
* 9 - in-process check, first primer coat
10 - apply second primer coat
11 - sand second primer coat
* 12 - in-process check, second primer coat
13 - apply first color coat
14 - bake first color coat
15 - sand first color coat
* 16 - in-process check, first color coat
17 - apply final color coat
18 - bake final color coat
* 19 - in-process check, final color coat
20 - touchup final coat
* 21 - quality control approval of final coat
22 - move material to storage area

* *Indicates decision point.*

SPRAY PAINTING DEFECT LOCATION EXERCISE (PART TWO)

The following list presents possible defects that could occur during the spray painting process.

- **Identify where in the spray painting process the defects could occur.**
- **Use numbers to identify the defects in the blanks next to the process steps.**

1. **Blisters (raised portions of finish coat)**
2. **Underbaking (insufficient heat or time in oven)**
3. **Cracks (breaks in final coat)**
4. **Incorrect coating (wrong primer or paint)**
5. **Overbaking (excessive heat or time in oven)**
6. **Sanding scratch (marks caused by excessive abrasion)**
7. **Roughness ("orange peel," sags, runs)**
8. **Unfilled depression**
9. **Contamination (dirt or foreign matter in coating)**
10. **Overspraying (paint or primer on unwanted surface)**
11. **Insufficient coating (not enough primer or paint to provide adequate protection)**

Spray Painting Process Steps	*Defects That Could Occur at This Step*	*Spray Painting Process Steps*	*Defects That Could Occur at This Step*
(1) receive surface components	_____	(13) apply first color coat	_____
(2) sand down to base metal	_____	(14) bake first color coat	_____
(3) fill depressions	_____	(15) sand first color coat	_____
(4) sand filler	_____	(16) in-process check of first color coat	_____
(5) in-process check of filled depressions	_____	(17) apply final color coat	_____
(6) mask nonpainted surfaces	_____	(18) bake final color coat	_____
(7) apply first primer coat	_____	(19) in-process check of final color coat	_____
(8) sand first primer coat	_____	(20) touchup final coat	_____
(9) in-process check of first primer coat	_____	(21) quality control approval of final coat	_____
(10) apply second primer coat	_____	(22) move material to storage area	_____
(11) sand second primer coat	_____		
(12) in-process check of second primer coat	_____		

SPRAY PAINTING DEFECT LOCATION EXERCISE (PART 2)

ANSWER SHEET

1. Blisters (raised portions of finish coat)
2. Underbaking (insufficient heat or time in oven)
3. Cracks (breaks in final coat)
4. Incorrect coating (wrong primer or paint)
5. Overbaking (excessive heat or time in oven)
6. Sanding scratch (marks caused by excessive abrasion)
7. Roughness ("orange peel," sags, runs)
8. Unfilled depression
9. Contamination (dirt or foreign matter in coating)
10. Overspraying (paint or primer on unwanted surface)
11. Insufficient coating (not enough primer or paint to provide adequate protection)

Spray Painting Process Steps	*Defects That Could Occur at This Step*
(1) receive surface components	
(2) sand down to base metal	6
(3) fill depressions	8
(4) sand filler	6
(5) in-process check of filled depressions	
(6) mask nonpainted surfaces	
(7) apply first primer coat	4, 7, 9, 10, 11
(8) sand first primer coat	6
(9) in-process check of first primer coat	
(10) apply second primer coat	4, 7, 9, 10, 11
(11) sand second primer coat	6
(12) in-process check of second primer coat	
(13) apply first color coat	1, 4, 7, 9, 10, 11
(14) bake first color coat	2, 3, 5
(15) sand first color coat	6
(16) in-process check of first color coat	
(17) apply final color coat	1, 4, 7, 9, 10, 11
(18) bake final color coat	2, 3, 5
(19) in-process check of final color coat	
(20) touchup final coat	4, 7, 9
(21) quality control approval of final coat	
(22) move material to storage area	9

APPENDIX C
PARETO CHART EXERCISE

PARETO CHART EXERCISE

In this exercise, you are asked to create two Pareto charts.

Step One - Complete the data sheet provided below by calculating the total cost per paint spraying defect.

Type of Defect	Frequency of Defect	Rework Cost Per Defect ($)	Total Cost ($)*
Blisters	20	5.00	
Underbaking	5	12.00	
Cracks	3	3.00	
Incorrect coating	7	18.00	
Overbaking	6	14.00	
Sanding scratch	26	3.00	
Roughness	2	2.00	
Unfilled depression	9	1.00	
Contamination	4	8.00	
Overspraying	18	4.00	

* Total cost equals frequency of defect times the rework cost per defect. For example, the total cost of blisters equals 20 x $5.00 or $100.00.

Step Two - Use the frequency-of-defect information to create a Pareto chart using the Figure C-1 worksheet. Rank the categories of defects from the highest to the lowest frequency. Figure C-3 is a completed Pareto chart that you can use for comparison.

Step Three - Use the total-cost-of-defects information to create a Pareto chart using the Figure C-2 worksheet. Rank the costs of defects from the highest to the lowest. Figure C-4 is a completed Pareto chart that you can use for comparison.

Step Four - Use the data provided on the completed worksheets to answer the following questions:

- Which three defects appear to occur most often?

- Which three defects contribute most to the cost of repairing defects?

PARETO CHART EXERCISE

ANSWER SHEET

Step One

Type of Defect	Frequency of Defect	Rework Cost Per Defect ($)	Total Cost ($)*
Blisters	20	5.00	100.00
Underbaking	5	12.00	60.00
Cracks	3	3.00	9.00
Incorrect coating	7	18.00	126.00
Overbaking	6	14.00	84.00
Sanding scratch	26	3.00	78.00
Roughness	2	2.00	4.00
Unfilled depression	9	1.00	9.00
Contamination	4	8.00	32.00
Overspraying	18	4.00	72.00

Step Four

- Which three defects appear to occur most often?

  1. Sanding Scratch
  2. Blisters
  3. Overspraying

- Which three defects contribute most to the cost of repairing defects?

  1. Incorrect coating
  2. Blisters
  3. Overbaking

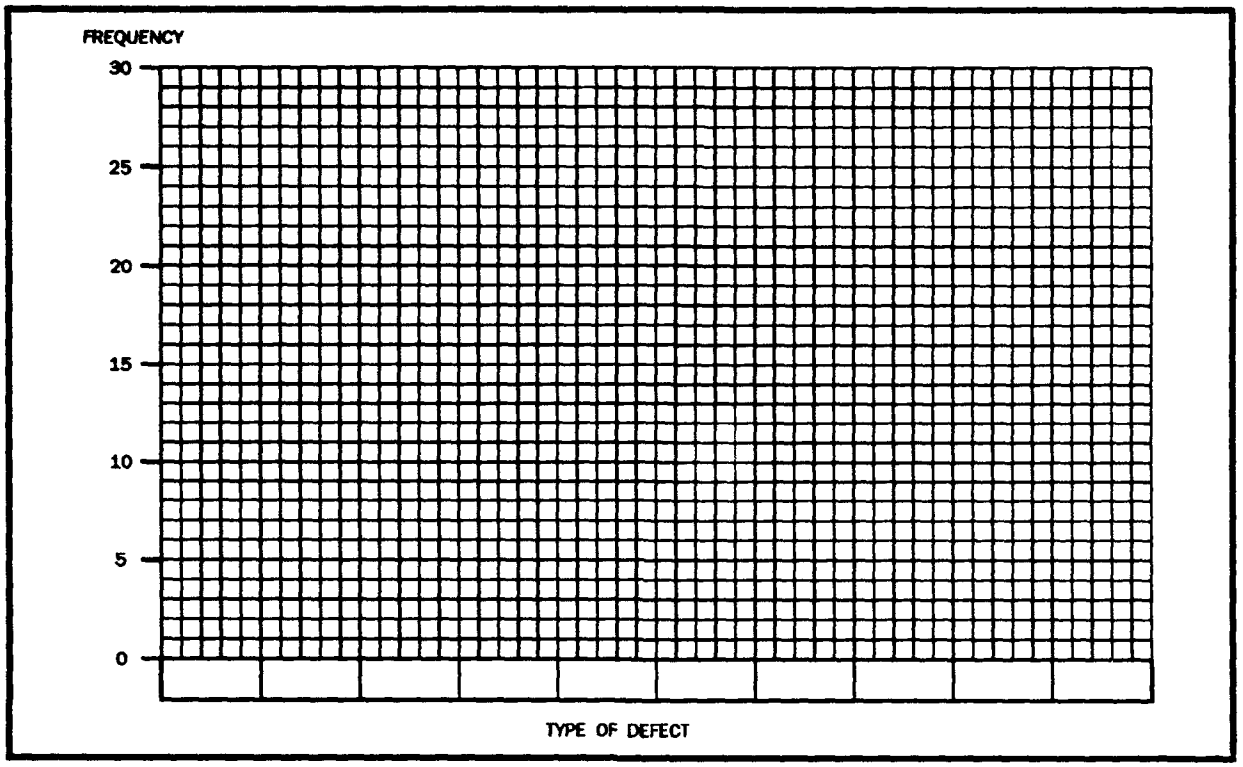

Figure C-1. Worksheet for plotting frequency of paint spraying defects.

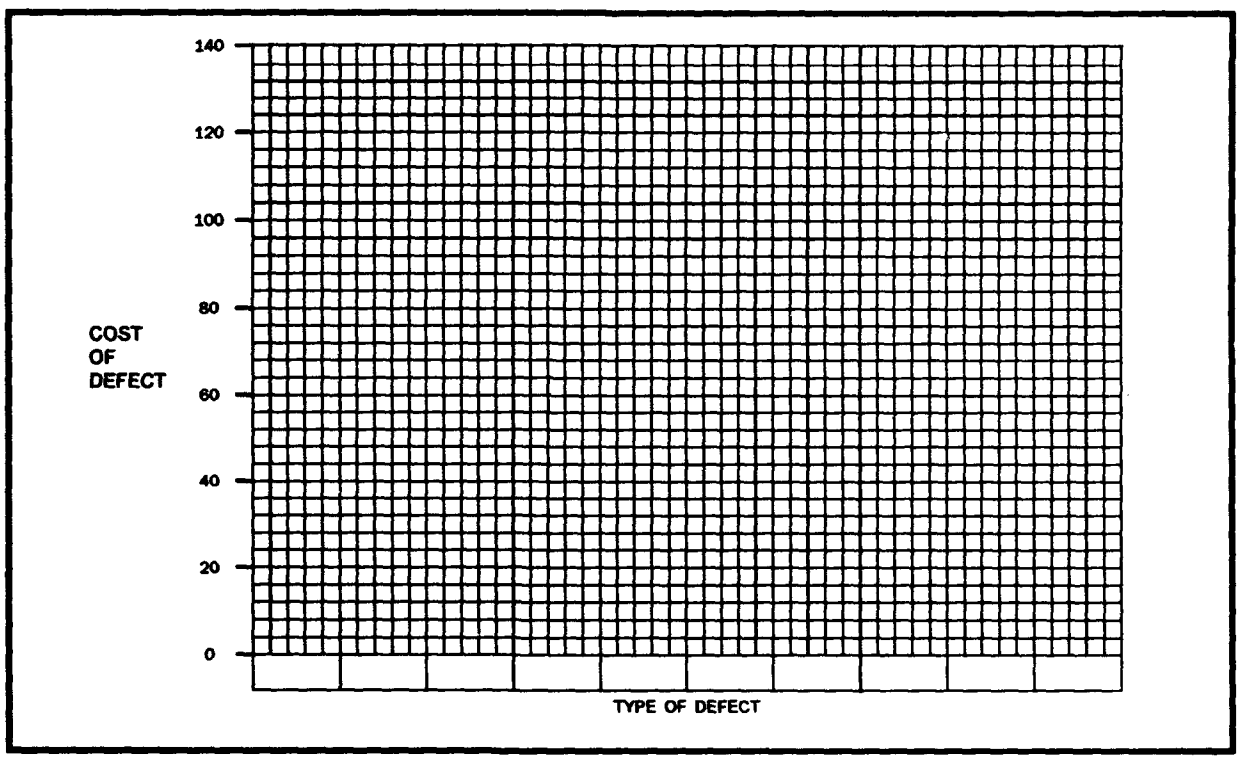

Figure C-2. Worksheet for plotting total costs of paint spraying defects.

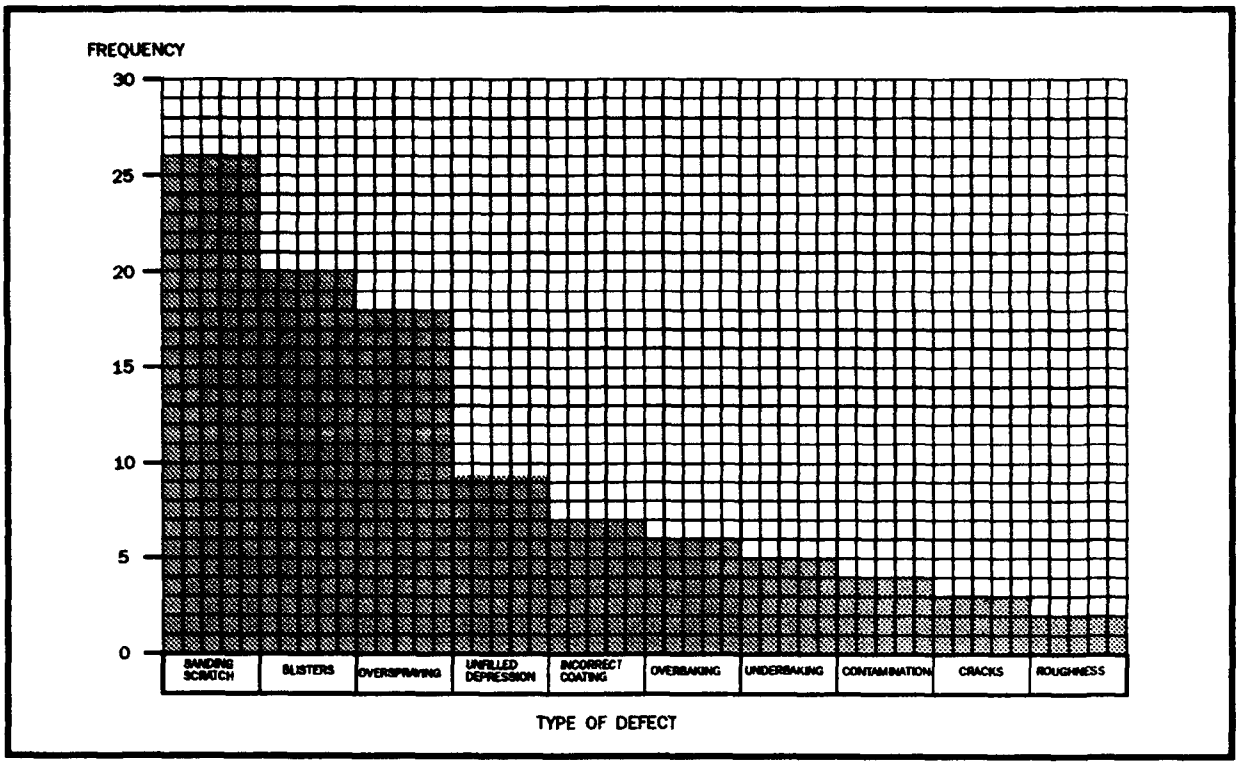

Figure C-3. Answer sheet showing how a Pareto chart can display the ranked frequencies of paint spraying defects.

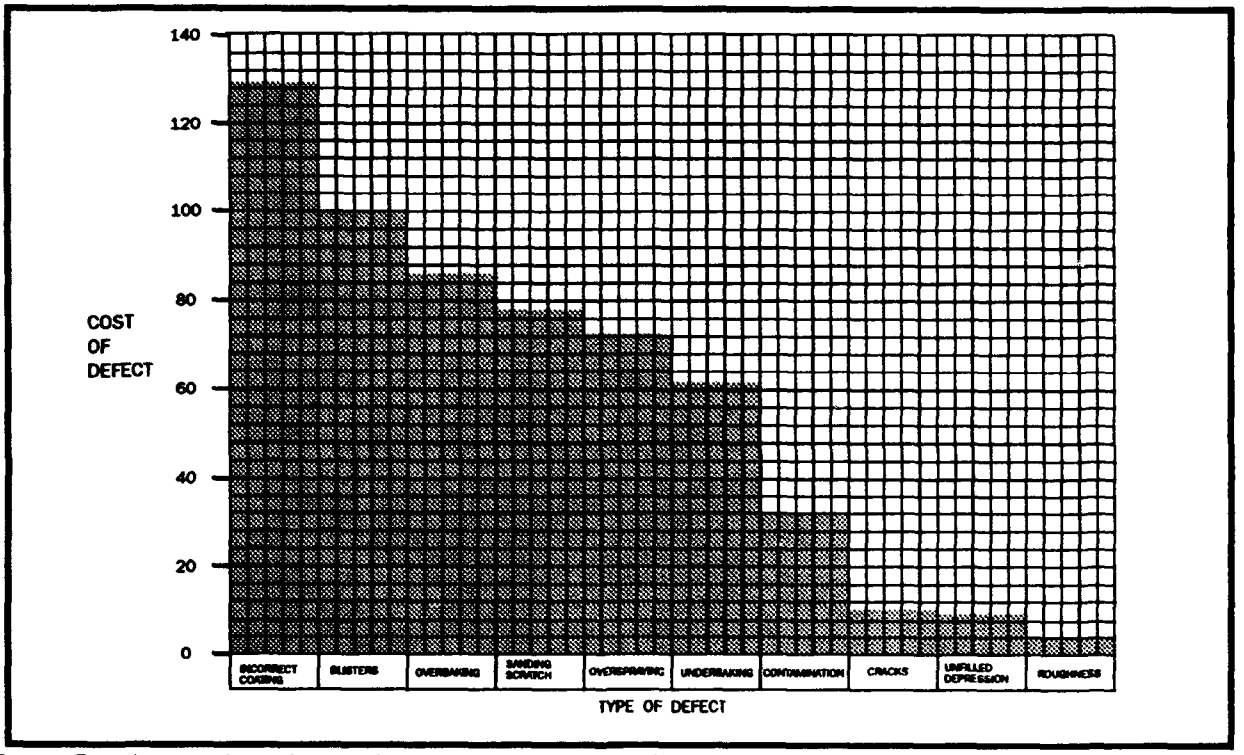

Figure C-4. Answer sheet showing how a Pareto chart can display the ranked total costs of paint spraying defects.

APPENDIX D
TQL PROCESS IMPROVEMENT CASE STUDY FORMAT

TQL PROCESS IMPROVEMENT CASE STUDY FORMAT

BACKGROUND: State issue addressed by the case study here. Use information obtained from customers.

CURRENT PERFORMANCE: Give an overview of the quality, cost, and schedule performance of the process.

IMPROVEMENT GOALS: State goals of process improvement effort. Use outcome goals defined by the ESC.

GENERAL PROCESS STEPS: List major operations and decisions used in the process. Use general knowledge of ESC.

GROUPS INVOLVED IN IMPROVEMENT EFFORT: Describe the composition of the QMBs and PATs which conducted the process analysis. Use records of ESC meetings.

ANALYSIS OF PROCESS: Present and discuss findings of process analysis conducted by the PATs. Include process-specific flowchart, Pareto charts, and cause-and-effect diagrams as needed.

QUALITY CHARACTERISTICS AND RELATED PROCESS VARIABLES: List the characteristics of the product or service that significantly affect its quality. Along with each characteristic, identify the process variables that were found to lead to the characteristic. Use the information obtained during the *Do* and *Check* phases of the PIM. Present SPC charts to illustrate relationships between the process variables and specific quality characteristics.

PROCESS IMPROVEMENT ACTIONS: Describe the actions taken by the PATs and the QMBs on the process variables to meet the stated goals. Use the information obtained during the *Act* phase of the PIM. List the improvement actions under their related quality characteristic. The following format is suggested.

> **QUALITY CHARACTERISTIC:** Name specific defect or feature of product or service.
>
> **CRITICAL VARIABLE:** Name specific variable.
>
> **ACTION:** Describe the steps taken to correct current problems and prevent future defects.

EVALUATION OF PROCESS IMPROVEMENT ACTIONS: Summarize the results of the process improvement actions. Use the goals and baseline information obtained during the *Plan* and *Do* phases of the PIM. Compare this information with the information obtained during the *Act* phase of the PIM.

REQUIREMENTS FOR THE LONG-TERM MAINTENANCE OF THE PROCESS IMPROVEMENT ACTIONS: Describe the process-specific and organization-wide support and resources required to permanently establish the process changes.[1]

> **PERSONNEL:** Describe changes made in the work force involved in the process.
>
> **METHODS:** Describe changes made in the operations of the process.
>
> **MATERIALS:** Describe changes made in the supplies used in the process.
>
> **MACHINES:** Describe changes made in the equipment used in the process.
>
> **MONITORING:** Describe changes made in how process performance is measured.

FUTURE IMPROVEMENT OPPORTUNITIES: This is an optional section. Use customer feedback information to describe new process improvement goals. Use information obtained during the process analysis described in this case study to identify different aspects of the process that should be improved.

[1] "Permanent" in the context of TQL means "until a better way of doing work is found and verified."

APPENDIX E
FICTITIOUS STUDY OF THE F/A-32 WOLVERINE AIRFRAME REPAINTING PROCESS

FICTITIOUS CASE STUDY OF THE F/A-32 WOLVERINE AIRFRAME REPAINTING PROCESS

BACKGROUND

The Mort de Mer Aviation Depot (MMAD), Point Loma, provides aviation maintenance and logistical services for the 13th Gyrene Aircraft Wing at Araphel Gyrene Corps Air Station. The Air Wing includes three F/A-32 Wolverine Squadrons, each with 12 aircraft. The F/A-32 is designed for use in low-intensity conflicts that require precision strikes in areas protected by extensive antiaircraft systems. A major component of the F/A-32 defensive system is its distinctive "ghost rider" paint coating. This coating is radar-reflective and minimizes the possibility of early detection of the aircraft by hostile forces.

As part of MMAD's Total Quality Leadership (TQL) efforts, organizational goals are determined through customer information. Members of the TQL Executive Steering Committee are responsible for obtaining customer information. During the gathering of such information, discussions with the Air Wing Commander and Wolverine pilots confirmed that the quality of the F/A-32 paint coating is a major factor in maintaining the combat readiness of the aircraft. Other customer concerns are the cost of painting the F/A-32 and delivery delays caused by paint defects.

CURRENT PERFORMANCE

The MMAD Executive Steering Committee conducted a review of archival information to determine current levels of quality, cost, and schedule performance (baseline data) associated with the F/A-32 painting process. Painting data for 1987 from the three Air Wing squadrons were retrieved and analyzed. The following information about quality, cost, and schedule was found:

QUALITY

An average of 37 paint defects occurred per aircraft. Some defects were minor (surface roughness), but others were major (insufficient coating).

COST

Fixing these defects cost $8,000 per squadron, a total cost overrun of $24,000 to the Air Wing.

SCHEDULE

Analysis of labor transactions and delivery data indicated that correcting paint defects added an average of 3 days to the time required to complete the overhaul of an F/A-32.

IMPROVEMENT GOALS

The identification and removal of unwanted variation in the F/A-32 Wolverine painting process are expected to lead to fewer defects per aircraft, lowered processing costs, and improved turnaround time. The results of process improvement actions will be compared with the baseline data. By preventing defects in the F/A-32 painting process, there is a potential yearly cost savings of $24,000. Reduction in the 3-day delay in turnaround time is expected to contribute to the combat readiness of the 13th Gyrene Air Wing.

GENERAL PROCESS STEPS

The Executive Steering Committee developed a general process flowchart to aid in identifying critical management areas of responsibility in the painting process. The following chart presents the major operations required in the maintenance of the F/A-32 Wolverine (see Figure E-1).

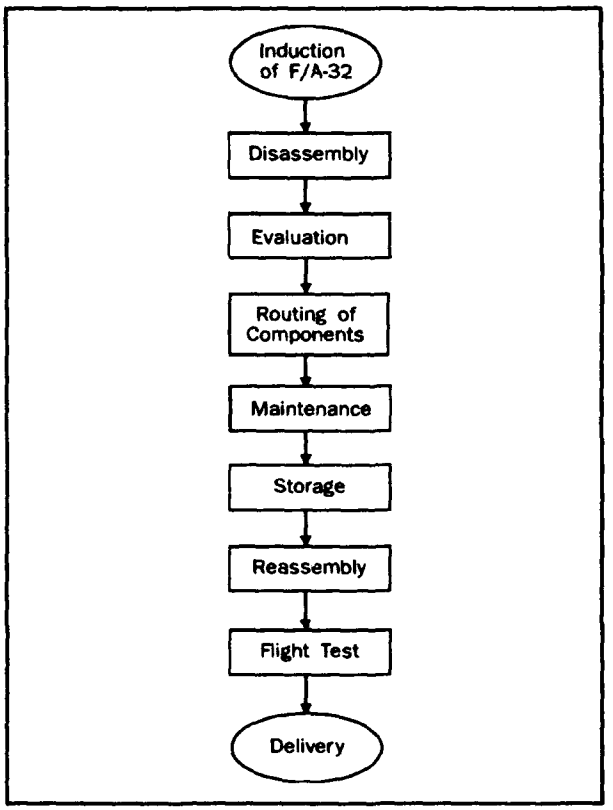

Figure E-1. General F/A-32 maintenance process flow.

GROUPS INVOLVED IN IMPROVEMENT EFFORT

Based on a review of the process flowchart and its cumulative knowledge, the MMAD Executive Steering Committee chartered a Quality Management Board (QMB). QMB members were drawn from six divisions -- Engineering, Production, Management Controls, Quality Assurance, Material, and Purchasing. It was given the responsibility of analyzing the output of the painting process to determine process areas for detailed investigation.

The QMB chartered a Process Action Team (PAT) to identify specific process variables that affected quality. This team comprised paint shop artisans (Production) and individuals from the other divisions represented on the QMB.

ANALYSIS OF THE F/A-32 PAINTING PROCESS

The QMB reviewed quality control and budget records to identify the defects that had a major influence on painting quality and rework costs. Ten types of painting process defects were analyzed through the use of Pareto analysis:

Blisters (Blis) -- raised portions of finish coat

Contamination (Con) -- dirt, etc., in coating

Cracks (Crck) -- breaks in final coat

Decal misplacement (Dec) -- squadron insignia placed on wrong aircraft or in improper location

Unfilled Depression (Ufd) -- dents in surface

Insufficient coating (Coat) -- not enough coating to provide adequate radar protection

Overspraying (Ovsp) -- paint or primer on unwanted surface

Roughness (Rgh) -- "orange peel," sags, or runs in coating

Sanding scratches (Scr) -- marks due to excessive abrasion

Underbaking (Unbk) -- insufficient heat or time in drying oven

As cost was a critical customer concern, the effects that were the most expensive to correct were targeted for the first improvement efforts. The Pareto analysis revealed that these defects were: insufficient coating, blisters in the paint surface, and cracks (see Figure E-2).

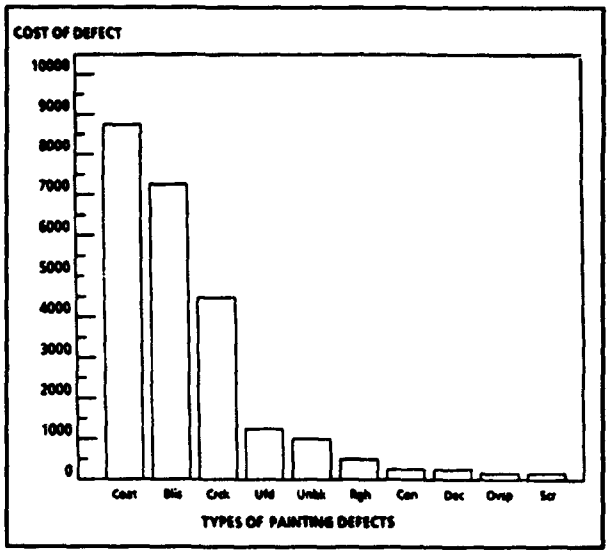

Figure E-2. F/A-32 painting defect costs for 1987.

The PAT developed a flowchart describing the painting process (Figure E-3). This chart describes the process as it actually operated and was compared with existing instructions and operations documents. Very little was found in the way of formal documentation. Apparently, the F/A-32 painting process had been developed and maintained informally. The current flowchart of the painting process will be used in future efforts to streamline and standardize operations.

The PAT developed a cause-and-effect diagram to identify process variables that could affect the quality of F/A-32 painting (Figure E-4). The information shared during the construction of the diagram was valuable in directing the PAT's efforts to begin preliminary data collection. The next section presents the quality characteristics and process variables that were found to be critical in the process.

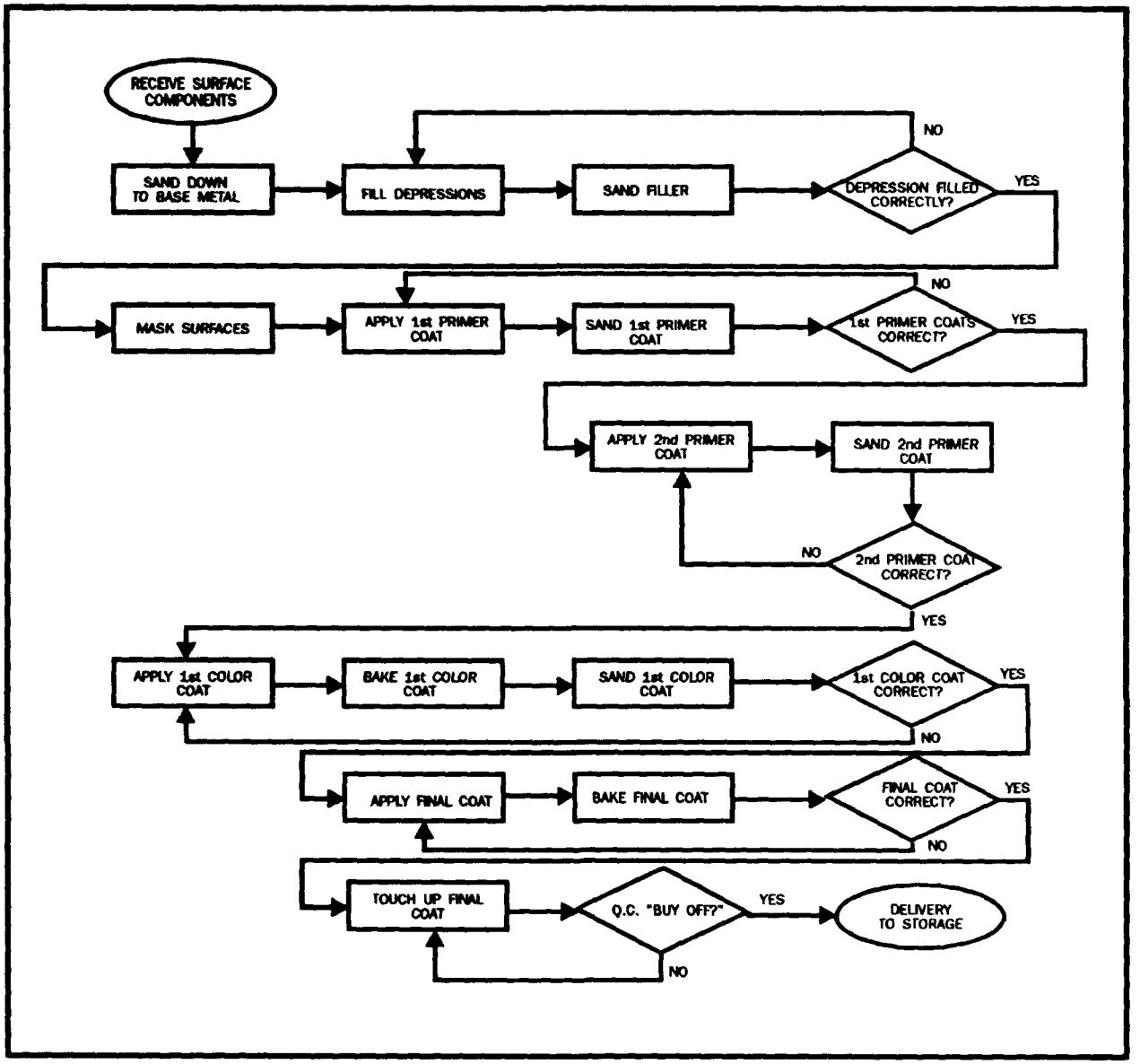

Figure E-3. F/A-32 painting process flowchart.

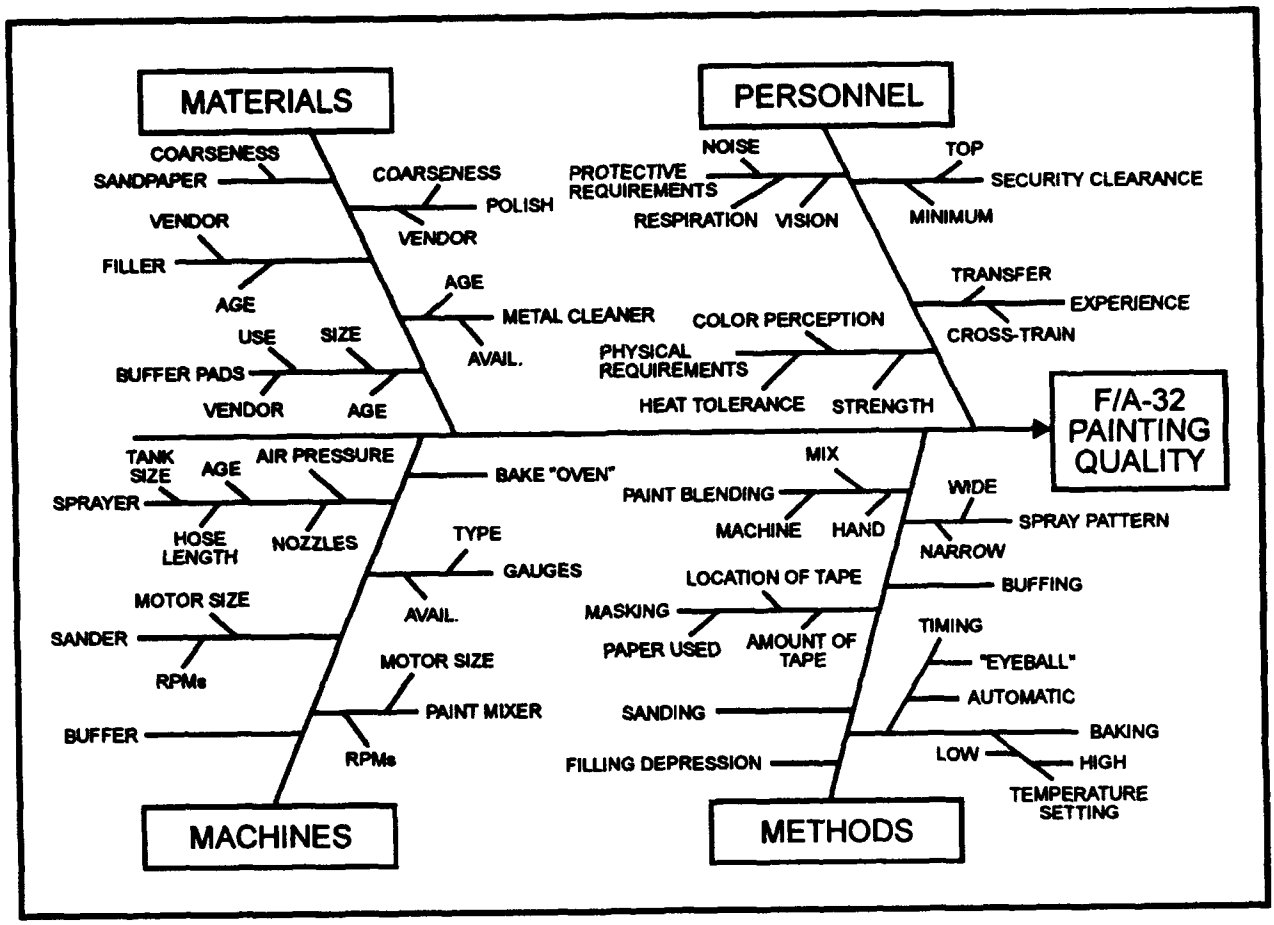

Figure E-4. Cause-and-effect diagram developed by the PAT.

QUALITY CHARACTERISTICS AND CRITICAL VARIABLES

The PAT used scatter diagrams to identify the process variables that had the greatest effect on the quality problems associated with the F/A-32 painting process. The findings of the PAT have been organized by quality characteristic.

Quality Characteristic: Insufficient coating
Critical Variable: Air pressure of paint sprayer (Figure E-5)

Quality Characteristic: Blisters in the paint surface
Critical Variable: Contamination in filler for surface depressions (Figure E-6)

Quality Characteristic: Cracks
Critical Variable: Temperature of paint baking oven (Figure E-7)

Interpretation of the scatter diagrams supported the belief that cause-and-effect relationships existed among the variables and the quality characteristics. The next section presents the general actions taken to improve and control process performance.

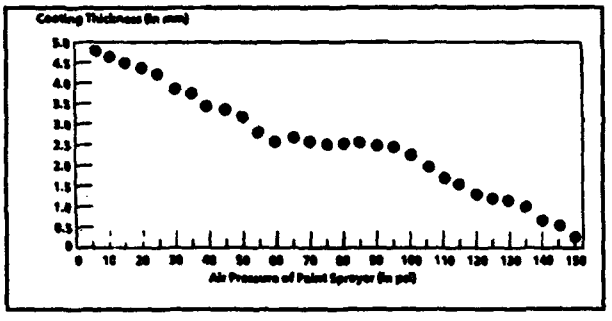

Figure E-5. Air pressure of paint sprayer and thickness of paint coating.

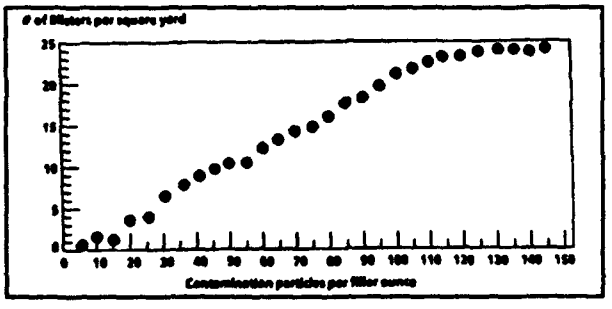

Figure E-6. Depression filler contamination and number of blisters per square yard.

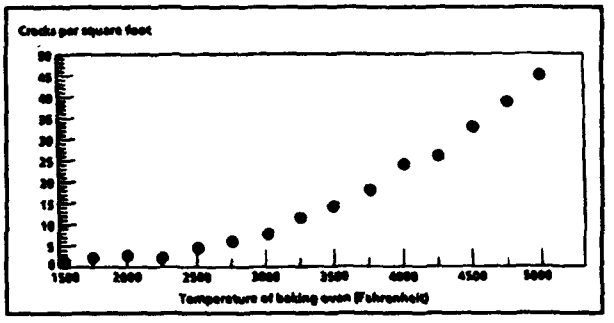

Figure E-7. F/A-32 paint coating cracks and relationship to oven temperature.

PROCESS IMPROVEMENT ACTIONS

Based on the information provided by the PAT, the QMB and the ESC took corrective actions. These actions have been organized according to their related quality characteristics and critical variables.

Quality Characteristic: Insufficient paint coating
Critical Variable: Air pressure of paint sprayer
Action: Chronically under- and over-pressurized sprayers have been replaced. Regular maintenance of sprayers has been established to ensure more consistent air pressure. Air pressure data will be collected on a sampling basis at the floor level by workers.

Quality Characteristic: Blisters
Critical Variable: Filler contamination
Action: Airtight containers for filler material have been installed in the preparation areas. Workers have been shown the relationship between filler contamination and paint blisters (Figure E-6). Purchasing will order filler from the vendor that has the best quality. All vendors have been informed by Purchasing of quality requirements and the TQL approach. Quality of incoming filler material will be monitored by workers at the receiving area. Purchasing will be given information on vendor performance on a regular basis.

Quality Characteristic: Cracks
Critical Variable: Oven temperature
Action: Oven thermostats have been reset to ensure the optimum bake setting. Oven tenders have been instructed to use actual oven temperature instead of relying on time in oven to determine bake. The QMB has begun looking for heat monitors that are more accurate and easier to read than the ones currently used.

EVALUATION OF PROCESS IMPROVEMENT ACTIONS

Evaluation data were collected on the painting of the aircraft in the three squadrons. The effects of the process improvement actions on the quality, cost, and schedule of the F/A-32 painting process are presented below.

Changes in quality: The average number of paint defects per aircraft dropped from 37 to 19.

Changes in cost: Overexpenditures due to paint defects decreased by $6,000 per squadron. This has resulted in a total cost savings of $18,000 to the 13th Gyrene Air Wing.

Changes in schedule: Delays resulting from the correction of paint defects have been reduced from an average of 3 days to an average of 1.6 days.

REQUIREMENTS FOR THE LONG-TERM MAINTENANCE OF PROCESS IMPROVEMENTS

PERSONNEL

Based on the findings of the F/A-32 painting PAT, training in machine settings and use will be given to paint shop workers. Those paint shop workers who were not part of the PAT will also be given instruction in statistical process control methods so they can help monitor the process.

METHODS

Written instructions on the optimum machine settings and painting methods will be developed.

MATERIALS

Purchasing has been authorized to buy airtight containers for filler material.

MACHINES

A new, regular schedule of preventive maintenance has been authorized for paint sprayers and baking ovens.

MONITORING

Control charts have been established to monitor the performance of the following critical process variables within the F/A-32 painting process.

- Paint sprayer air pressure
- Filler contamination
- Oven temperature

These control charts will be maintained at the floor level. Workers will collect process data on a sampling basis.

FUTURE IMPROVEMENT OPPORTUNITIES

Process monitoring and improvement efforts will be continued on the three quality characteristics identified by analysis. The problems of unfilled depressions and underbaking will be addressed in upcoming process improvement efforts. The QMB is investigating the possible use of new painting technologies, such as microwave baking and electrostatic paint application.