Navy Personnel Research and Development Center

San Diego, CA 92152-6800 TR 89-3 December 1988

A Total Quality Management Process Improvement Model

NPRDC TR 89-3 December 1988

A TOTAL QUALITY MANAGEMENT PROCESS IMPROVEMENT MODEL

A. Houston
S. L. Dockstader

Approved by
Laurie A. Broedling

Released by
B. E. Bacon
Captain, U.S. Navy
Commanding Officer

and

James S. McMichael
Technical Director

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Navy Personnel Research and Development Center
San Diego, California 92152-6800

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED.	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	3 DISTRIBUTION / AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.
4 PERFORMING ORGANIZATION REPORT NUMBER(S) NPRDC TR 89-3	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER 6b. OFFICE SYMBOL (If applicable) CODE 16	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) SAN DIEGO, CA 92152-6800	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION NAVAL AVIATION DEPOT, ALAMEDA NAVAL AVIATION DEPOT, NORTH ISLAND 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) NAVAL AIR STATION, ALAMEDA, CA 94501 NAVAL AIR STATION, NORTH ISLAND, SAN DIEGO, CA 92135-5112	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO.: PE63739N PROJECT NO.: T1885 TASK NO.: N/A WORK UNIT ACCESSION NO.:

11. TITLE (Include Security Classification)

A TOTAL QUALITY MANAGEMENT PROCESS IMPROVEMENT MODEL

12. PERSONAL AUTHOR(S)
HOUSTON, ARCHESTER AND DOCKSTADER, STEVEN L.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
FINAL	FROM 4-10-87 TO 9-30-87	1988 DECEMBER	62

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	~~QUALITY~~, STATISTICAL PROCESS CONTROL, PROCESS ANALYSIS, TOTAL QUALITY MANAGEMENT, DEMING, QUALITY MANAGEMENT BOARDS, "PLAN-DO-CHECK-ACT" CYCLE. (SDW)
05	01		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The purpose of this report was to enhance the quality and productivity performance of naval logistics organizations through the application of a process improvement model. The process improvement model represents a systematic approach for the analysis and improvement of operations and resources used to create products or services. The present report describes the activities required to use the model. Keywords:)

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL ARCHESTER HOUSTON	22b. TELEPHONE (Include Area Code) (619) 553-7934 22c. OFFICE SYMBOL CODE 161

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

FOREWORD

This report was prepared by the Navy Personnel Research and Development Center (NAVPERSRANDCEN) as part of the Navy Logistics Research and Development Program (PE63739N, Project NR T1885) sponsored by the Deputy Chief of Naval Operations for Logistics (OP-40B). Claimancy for the work was established through the Naval Supply Systems Command (PML5505). The thrust of this project was to enhance the performance of naval logistics organizations through the application of total quality management (TQM) principles and methods.

The present work describes a model for the systematic improvement of an organization's products or services through analysis and correction of the processes that create them. The model is an elaboration of the method developed by Shewhart and Deming for process analysis and improvement.

Related readings are listed in a Bibliography at the end of this report. Most of this material was developed in connection with research projects begun in 1983 in the naval aviation depots. More recent efforts in the shipyard community, supply centers, contracts administration centers, and the offices of the Secretary of the Navy and the Secretary of Defense will be documented in future publications.

The authors express appreciation for the assistance of TQM executive steering committees and facilitators from Naval Aviation Depots, North Island and Alameda, and the Naval Supply Center, San Diego, in the development of this model.

Questions regarding this work can be directed to Dr. Steven L. Dockstader, Navy Personnel Research and Development Center, Code 16, San Diego, California 92152-6800, AUTOVON 553-7967 or (619) 553-7967.

B. E. Bacon
Captain, U.S. Navy
Commanding Officer

J. S. McMichael
Technical Director

SUMMARY

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

The management practices and analytic methods adopted by the Navy's aviation maintenance organizations are based primarily on the TQM 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 TQM approach emphasizes the major role that managers have in achieving quality and productivity improvement for an organization. Deming and other TQM proponents, such as Crosby and Juran, estimate that up to 85 percent of quality improvement is under direct control of management and can not be remedied by the hourly employee or staff member.

Under the TQM 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 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 Ishikawa and Lu as well as Ackoff concerning cross-functional groups, Navy aviation maintenance organizations adopted an organizational structure to complement the TQM approach in their organizations.

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: (l) 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," 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 Process Action Teams 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 industrial organizations are adopting a management approach known as total quality management (TQM). This approach is based on a set of management practices and statistical measures that, when combined, can remove the causes of poor product quality and excessive cost (Dockstader, Doherty, & Konoske, in press; Houston, Shettel-Neuber, & Sheposh, 1986).

The management practices and analytic methods adopted by the Navy's aviation maintenance organizations are based primarily on the TQM 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 provides a complete listing of Deming's management principles. Dockstader, Doherty, and Konoske (in press) discuss them in depth.

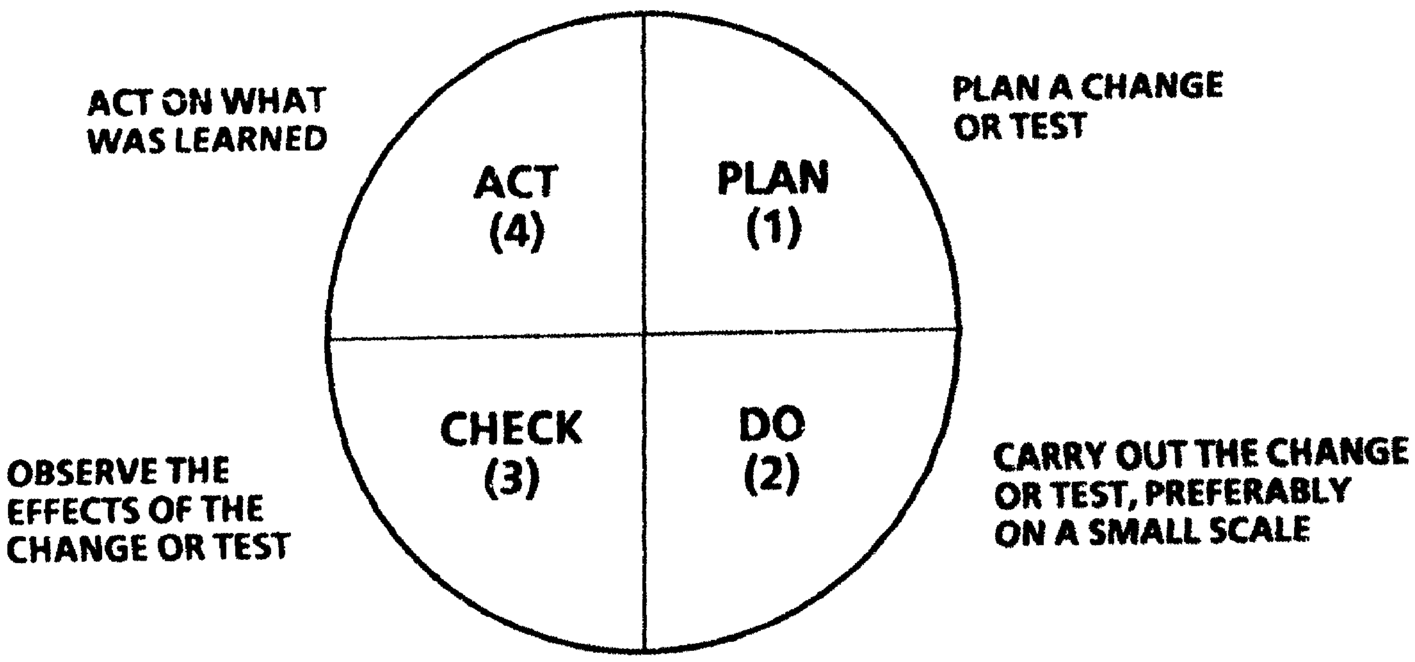
The TQM approach emphasizes the major role that managers have in achieving quality and productivity improvement for an organization. Deming and other TQM proponents such as Crosby (1979) and Juran (1974) estimate that up to 85 percent of quality improvement is under direct control of management and can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

Under the TQM 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 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). 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.

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 flow chart and referred to here as the process improvement model (PIM), and is displayed in Figure 3.

THE SHEWHART CYCLE
(Deming, 1986)



5. REPEAT STEP 1, WITH NEW KNOWLEDGE.

6. REPEAT STEP 2, AND ONWARD.

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

USE OF "PLAN-DO-CHECK-ACT" CYCLE

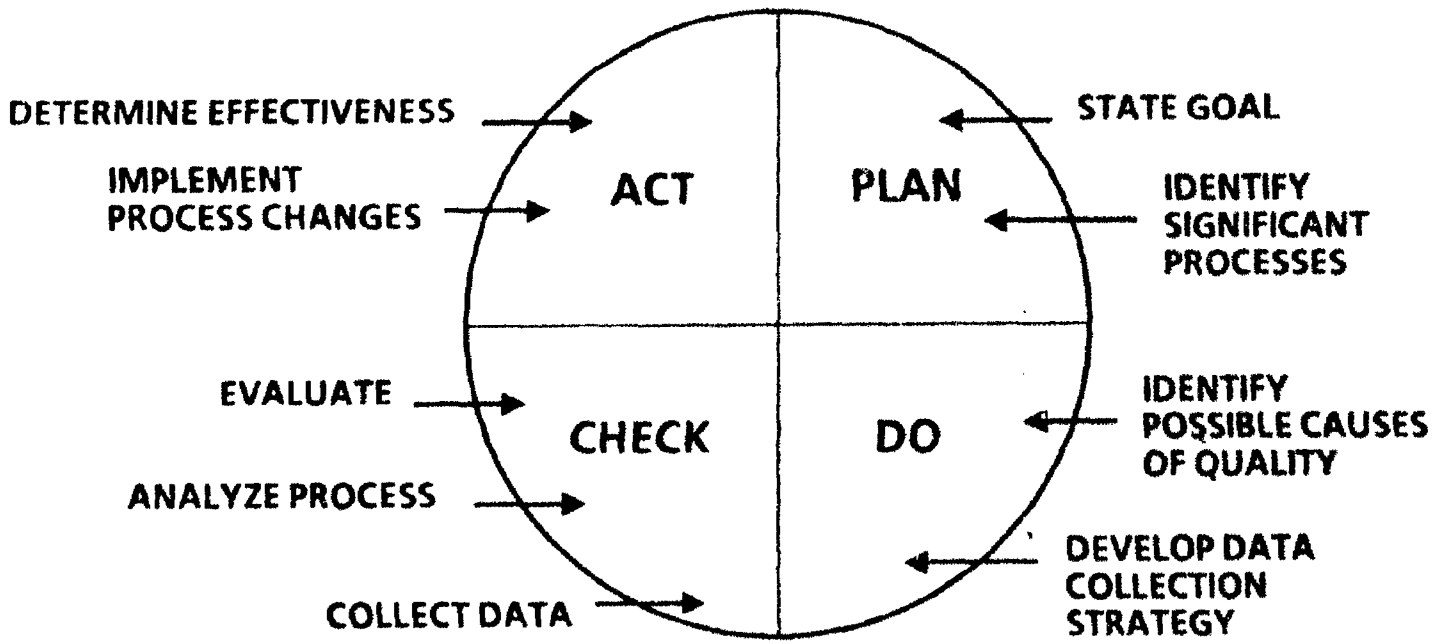


Figure 2. **The "Plan-Do-Check-Act" cycle during process improvement.**

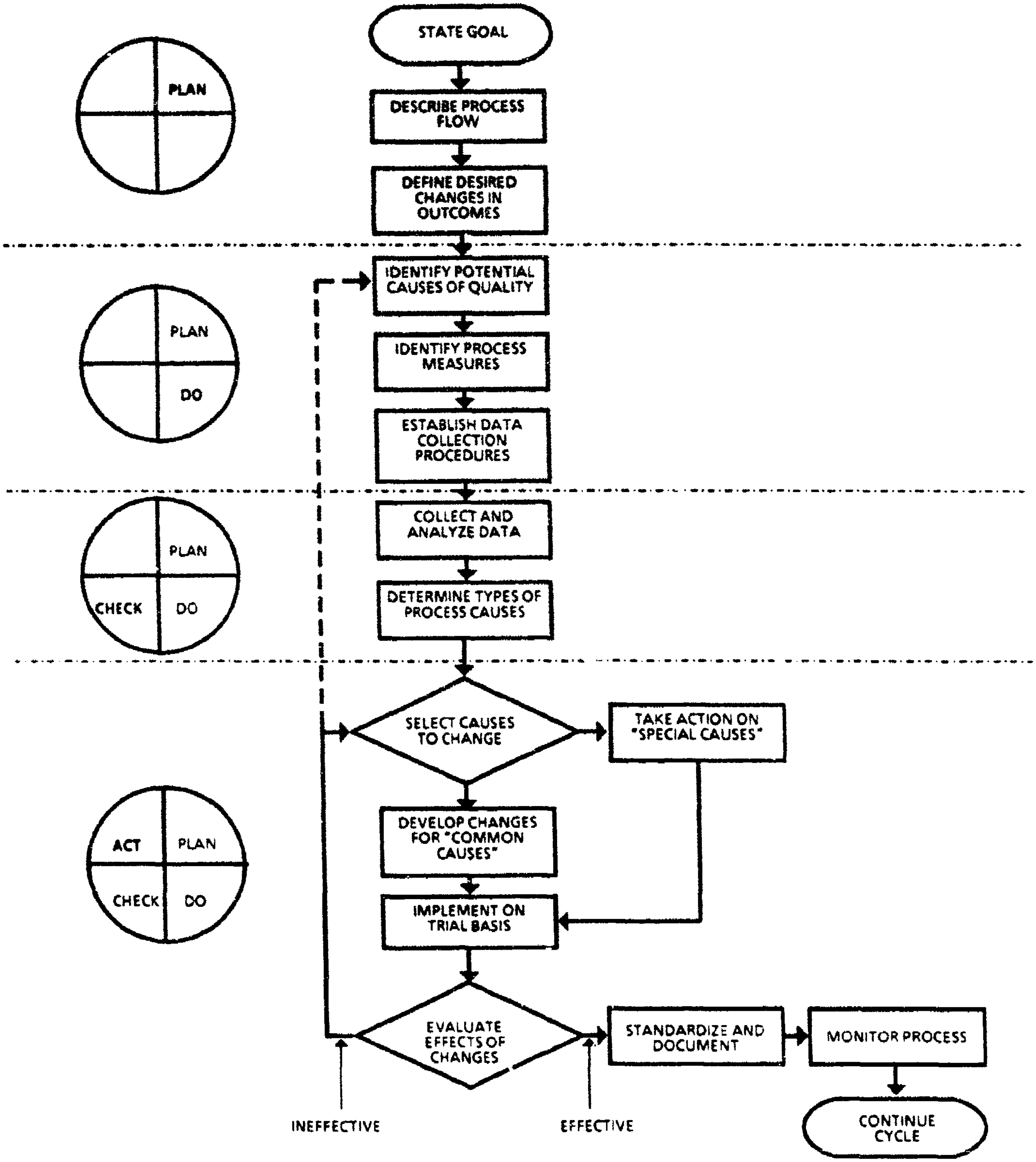


Figure 3. Process improvement model for total quality management.

Purpose of Report

The use of TQM principles and the "Plan-Do-Check-Act" cycle in Navy industrial 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 process improvement model 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 might have 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 (A T & T, 1956; Grant & Leavenworth, 1974; Ott, 1975).

ORGANIZATIONAL STRUCTURE

The use of PIM requires 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 #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

Process Action Teams or PATs are comprised 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 for PAT membership is that the individuals selected be highly knowledgeable about the operations in their shop or unit.

Function

The main function of PATs 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 achieved 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.

A fundamental assumption of the TQM 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?" (i.e., 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 PIM.

State Goal

A goal within this context refers to some desired change in products or service. Examples of goals could be (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 TQM is a very effective way of obtaining quality improvements, certain conditions must be met before using the TQM methods and structure to address a goal. For instance, goals addressed by TQM 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.

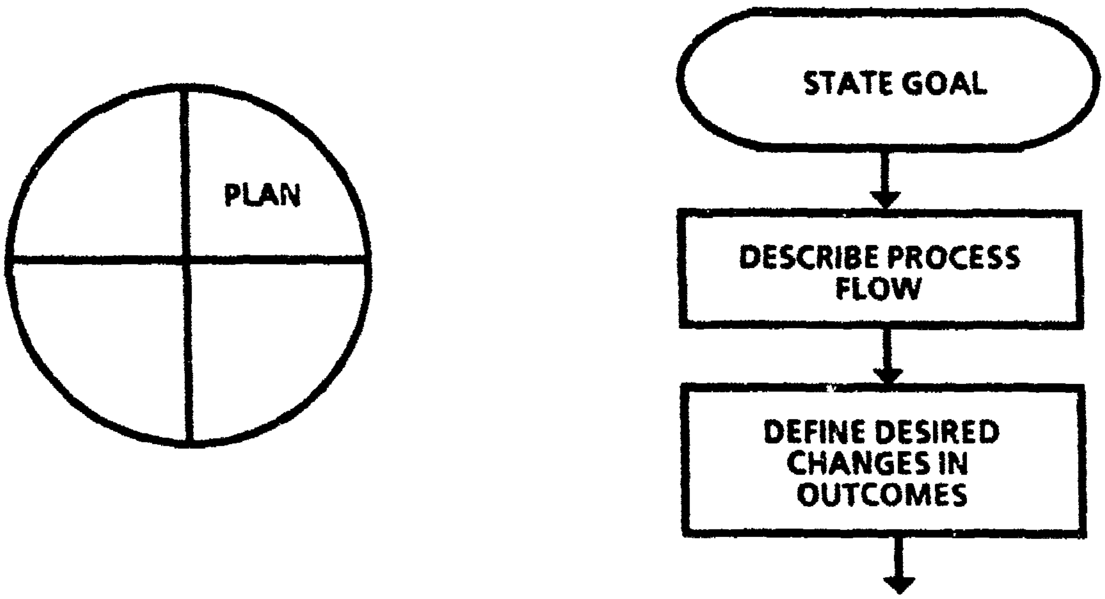


Figure 4. The "Plan" phase of the process improvement model.

Measurable

TQM is often concerned with economically related goals and relies on 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 can not be measured in some fashion is not appropriate for the process improvement model.

Describe Process Flow

In many traditional organizations, managers and employees are encouraged to specialize in those 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 sub-optimization. Sub-optimization occurs when actions are taken to improve the performance of an isolated operation to the detriment of related or subsequent operations.

One aid 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. One way of accomplishing this is by using the flowchart method. The flowchart is a graphic method of describing the interrelation of operations and decisions required to transform resources into outputs (see Figure 5).

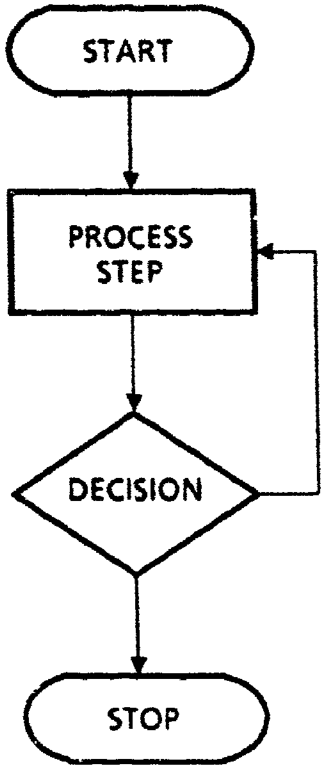
After the QMB has constructed a process flowchart, it should analyze the chart to identify such things as duplicated efforts between operations, "gaps" in accountability, overuse of inspection, and ways to streamline the process. Streamlining a process is sometimes known as "imagineering." During "imagineering" 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.

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 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 TQM approach.



- LINES AND SYMBOLS CHART
- REPRESENTS MAJOR STEPS OF A PROCESS
- FORMS BASIS FOR IDENTIFYING EXCESSIVE COMPLEXITY AND WASTE

Figure 5. Process flowchart.

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 could 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 TQM approach, this information is gathered by individuals who work directly with the process. Process information is collected to identify variables that have the greatest effect on the product or service.

Measures of outcome, output, and processes 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 *Process Action Teams* (PATs). PATs consist of individuals working on the processes selected for improvement. In the "Do" phase of PIM, these teams have three major responsibilities (see Figure 6). First, PATs study the current process and its outputs to identify variables related to quality. Second, the teams develop measures of those variables. Third, the teams create a format to collect data.

Identify Potential Causes of Quality

PATs are expected to use their experience and knowledge 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, for example, automobiles, cameras, or clothing.

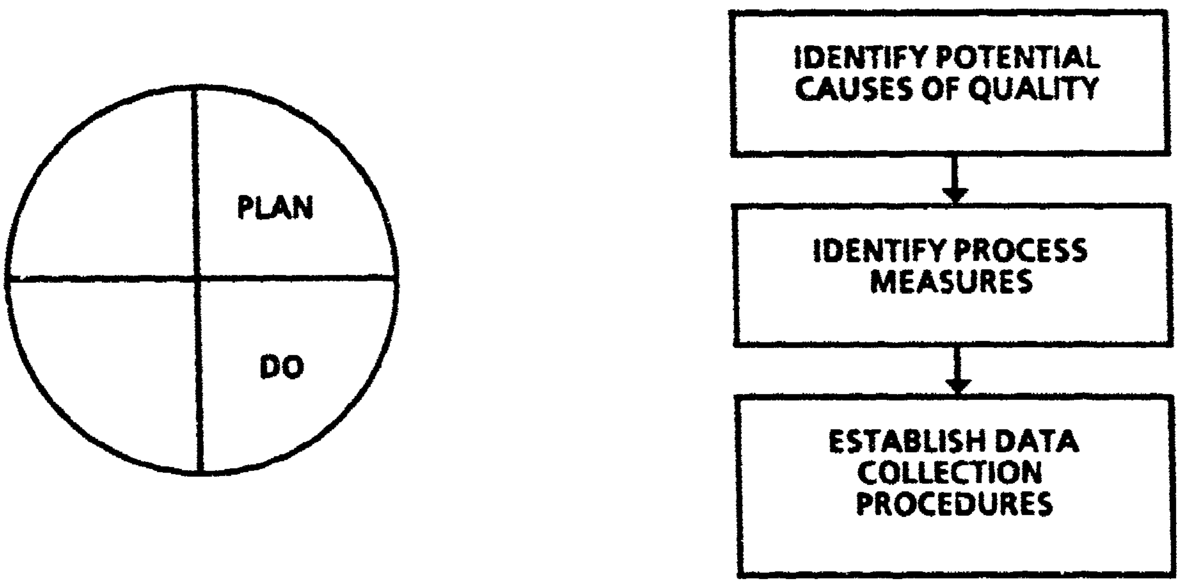


Figure 6. The "Do" phase of the process improvement model.

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

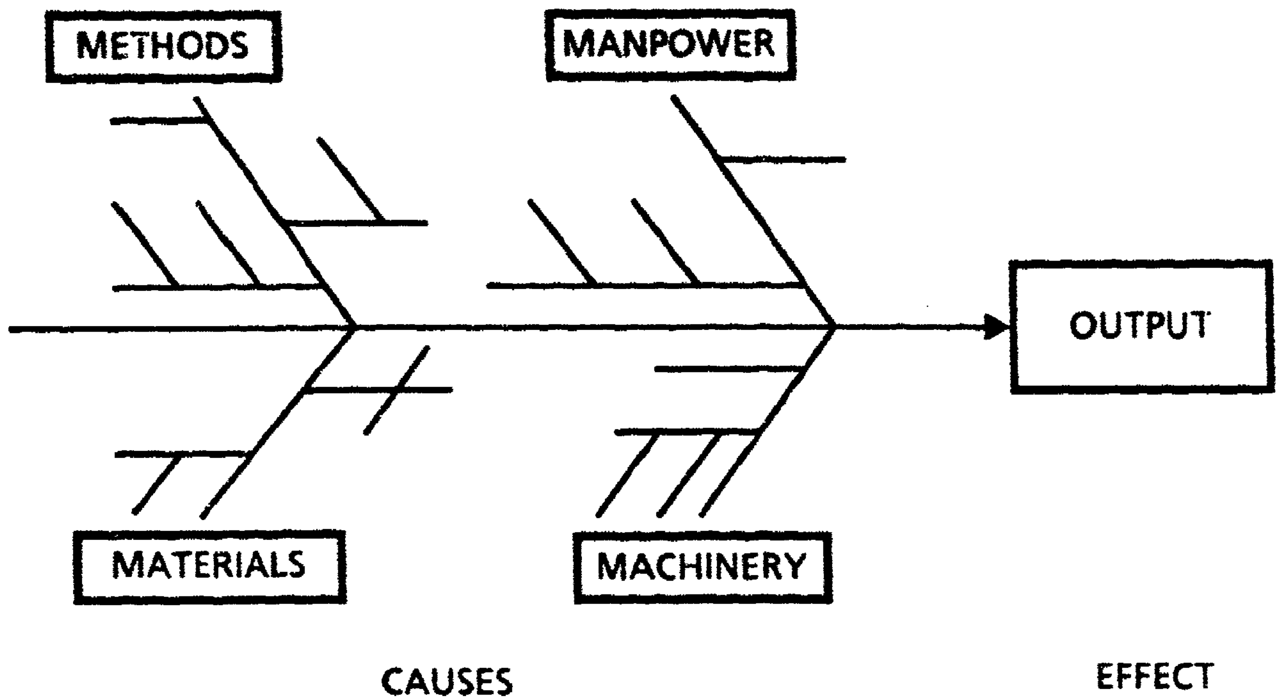
Manpower--the attributes of the people involved in the process such as their experience, training, strength, or even eyesight and reading ability.

Materials--the physical resources or raw materials used in the process; within the setting of Navy aviation maintenance organizations, these resources can include material 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, for example, technical data manuals or forms. Methods can include informal work experiences such as "short cuts" workers learn from others.

Machines--the equipment and tools used in a process. For a supply operation, this could 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. The following figures depict an example of cause-and-effect analysis of a problem concerning inventory accuracy in a supply operation (see 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."



- BRAINSTORMING COMBINED WITH BRANCHING DIAGRAM
- LISTS POSSIBLE CAUSES FOR GOOD OR BAD QUALITY
- SHOWS RELATIONSHIP BETWEEN "EFFECT" AND ITS "CAUSES"
- AIDS IN ANALYZING COMPLEX INTERACTIONS

Figure 7. Cause-and-effect analysis chart.

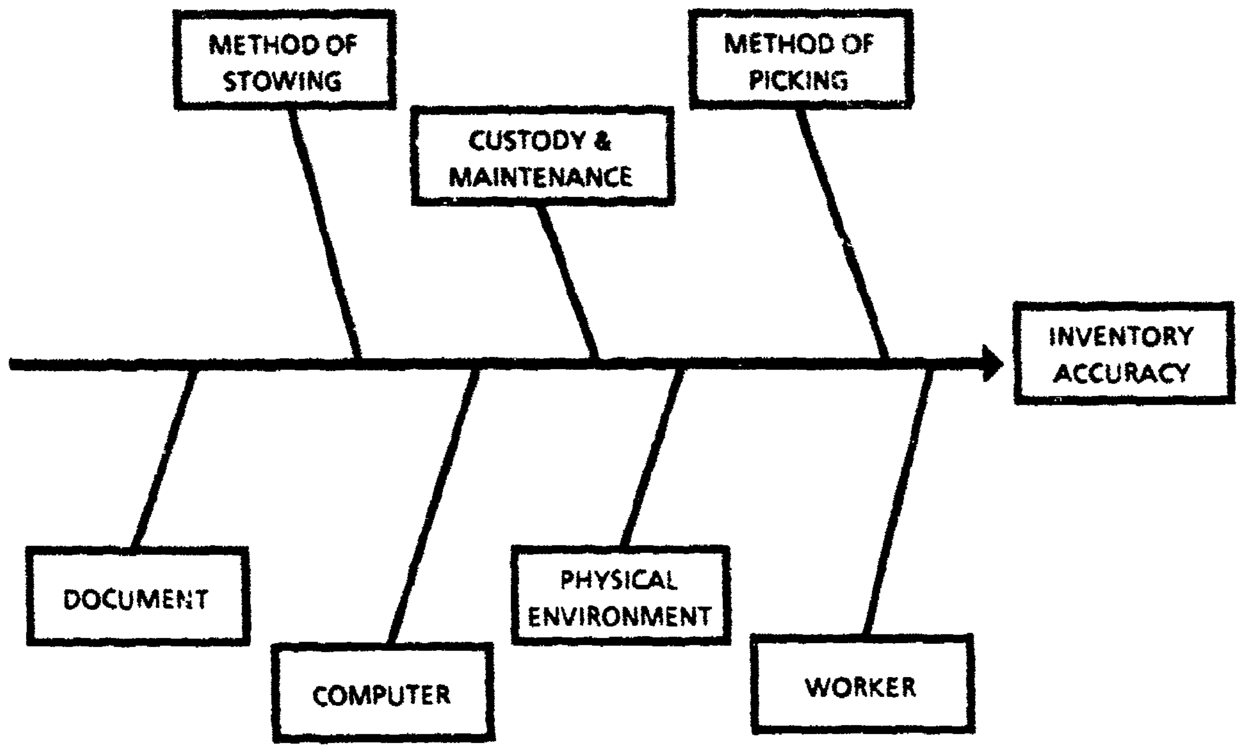


Figure 8. Example of cause-and-effect chart.

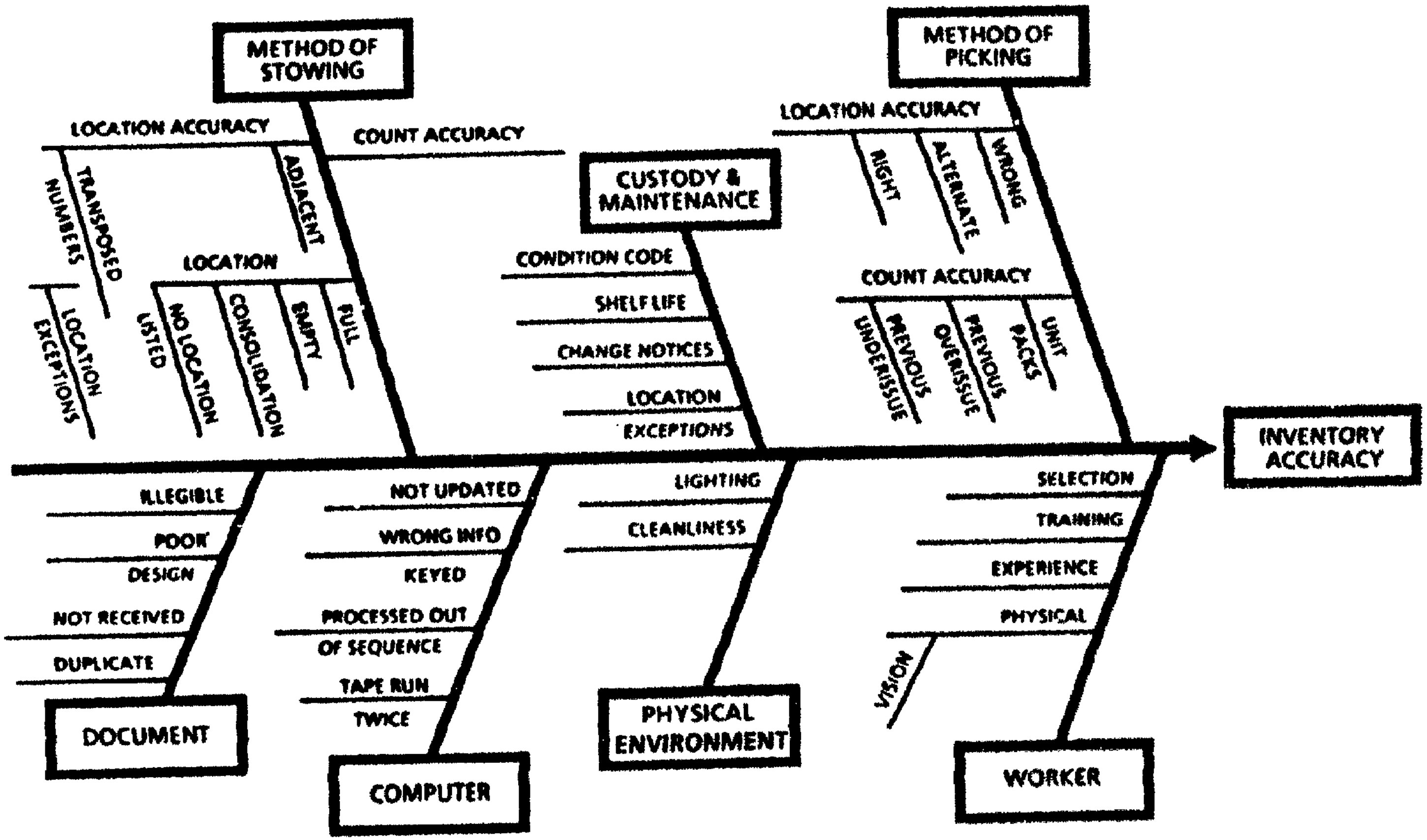


Figure 9. An expansion of information displayed in Figure 8.

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.

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 could 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, the easier it will probably become to determine what variables should be measured and how they should be defined.

Establish Data Collection Procedures

After the 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 it has been collected, it is 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, for example, counting defects in a product, counting forklift trucks available at a receiving dock, or counting documents that are illegible. Some variables require detailed measurement, for example, 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 a number of 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. A professional statistician is 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 "things falling through the cracks," that is, 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? The 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 a 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."

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

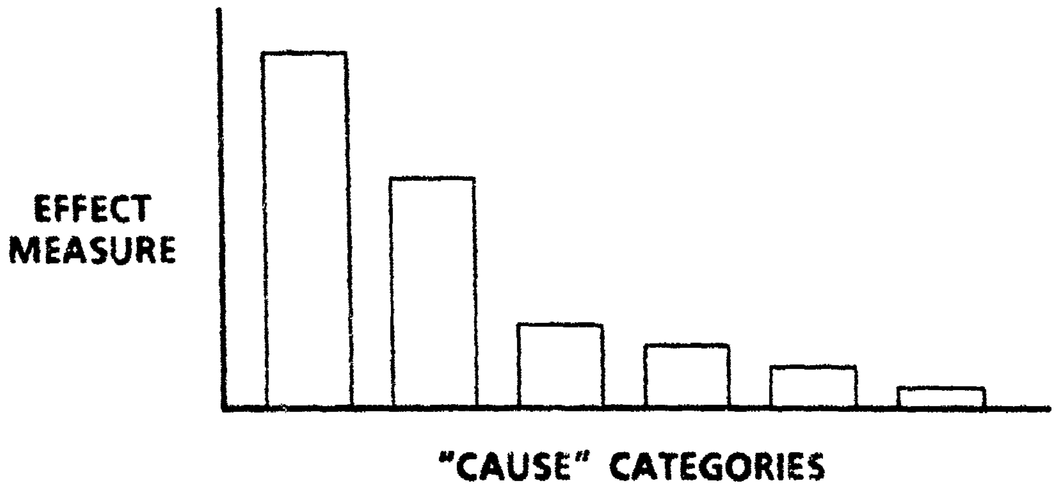
. Types of accident (cause) compared with labor hours lost (effect).

. 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 defects (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



- VERTICAL BAR GRAPH OF DISCRETE DATA
- USED TO RANK IMPORTANCE OF CAUSES
- AIDS IN SELECTING IMPROVEMENT AREAS

Figure 10. Pareto chart.

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), the PATs collect process and output data. During the data collection period, they summarize the data using graphic methods. Once the data have been summarized, the PATs and QMBs 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.

In addition to flow charts, 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 "on line" process analysis. Other more advanced techniques associated with design of experiments (A.T.&.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.

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 if changes in a process variable result in changes in the output (see Figure 13).

Run Charts

These charts are constructed to determine if 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.

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 processes' outputs ("common causes") and those that have an unpredictable effect on outputs ("special causes").

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 PATs and the QMB interpret the findings. Based on the results of their interpretation, process improvement changes are made and evaluated in the "Act" phase.

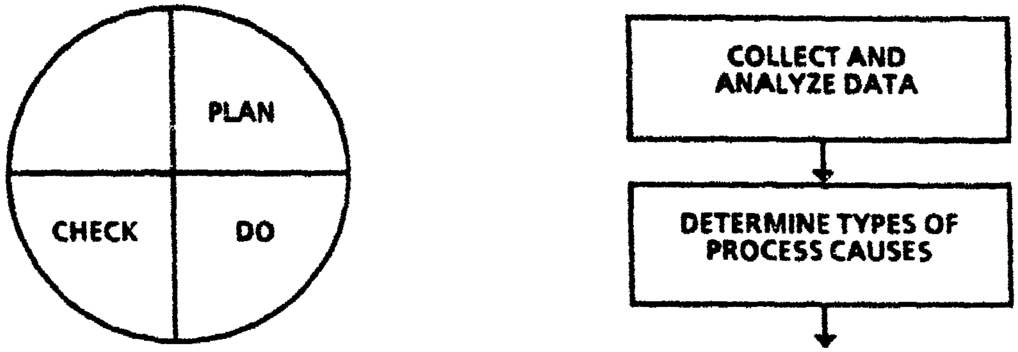
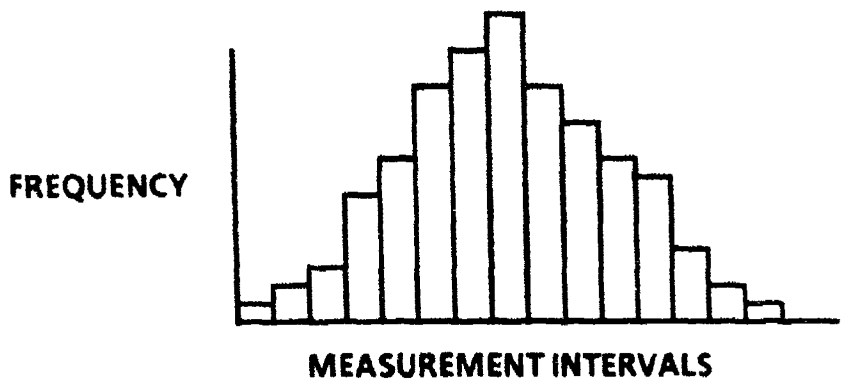
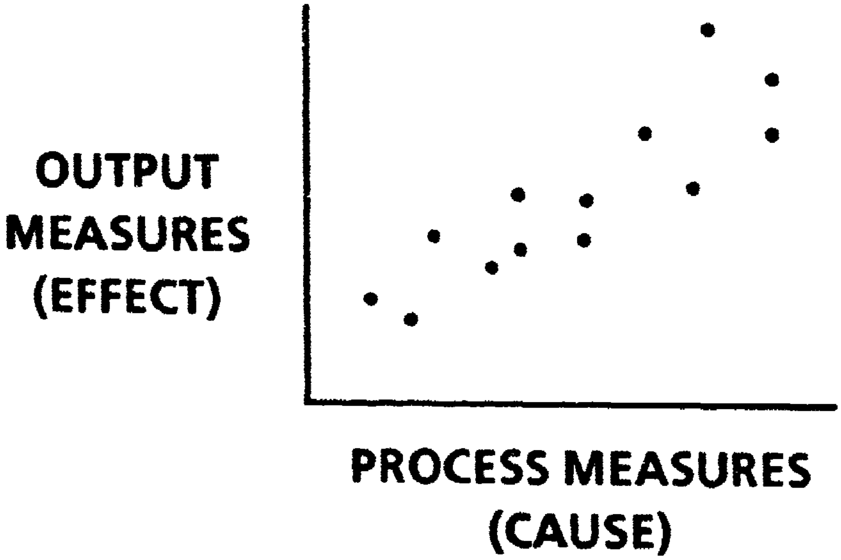


Figure 11. The "Check" phase of the process improvement model.



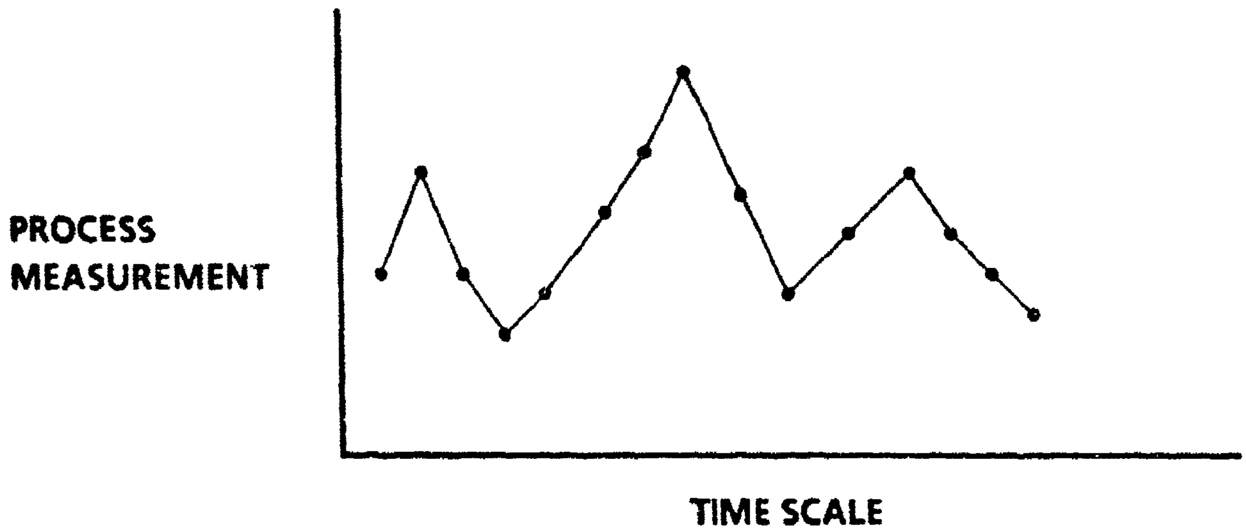
- BAR GRAPH OF CONTINUOUS DATA
- DISPLAYS AMOUNT AND TYPE OF VARIATION IN PROCESS OUTPUTS

Figure 12. Histogram.



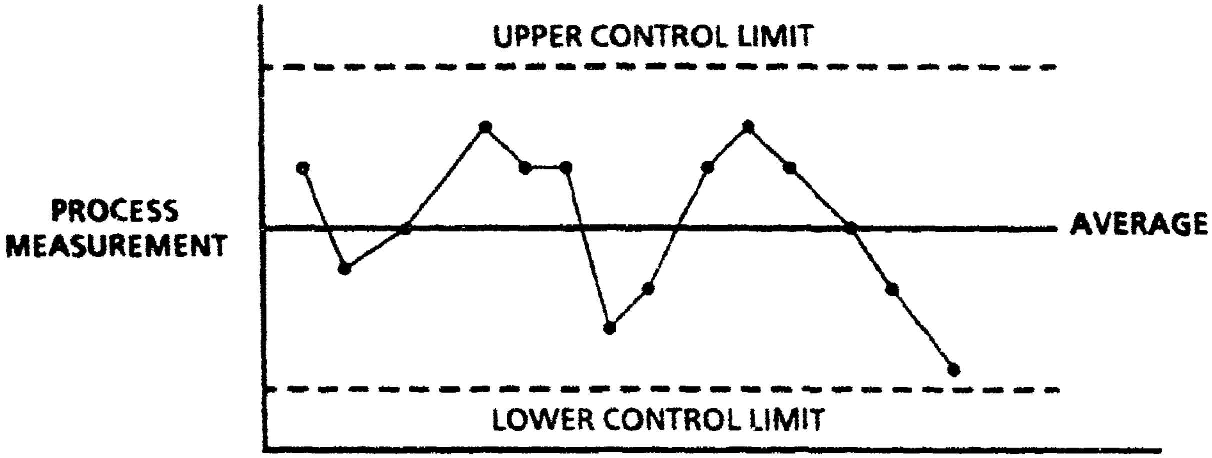
- SCATTER PLOT OF PAIRED MEASUREMENTS
- USED TO TEST RELATIONSHIP BETWEEN A SUSPECTED "CAUSE" AND THE OUTPUT EFFECT

Figure 13. Scatter diagram.



- LINE GRAPH
- SIMPLE DISPLAY OF PROCESS PERFORMANCE OVER TIME

Figure 14. Run chart.



- LINE GRAPH WITH ESTIMATED PERFORMANCE PARAMETERS
- EVALUATES STABILITY OF A PROCESS
- DIAGNOSES PROBLEMS (PROBLEM ANALYSIS)
- ASSESSES EFFECTS OF IMPROVEMENT ACTIONS (PROCESS CONTROL)

Figure 15. Control chart.

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 TQM. In the absence of specially trained consultants, it is often necessary to have a professional statistician to 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. Examples of common causes could include the accuracy of standards supplied to a work area, the training given to workers, or the consistency of materials used in the process.

Special causes refer to variables that are not regarded as part of the system and have isolated and statistically unpredictable influence on outputs. Special causes are often "local" to a specific operation, machine, or lot of material. 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 can not be determined or could reflect an unusual statistical event (sometimes known as "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 PATs select 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 QMBs 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 special 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 involve 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 analytic efforts have been carried out to improve the working conditions. Early in an organization's TQM effort many "causes" identified could 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

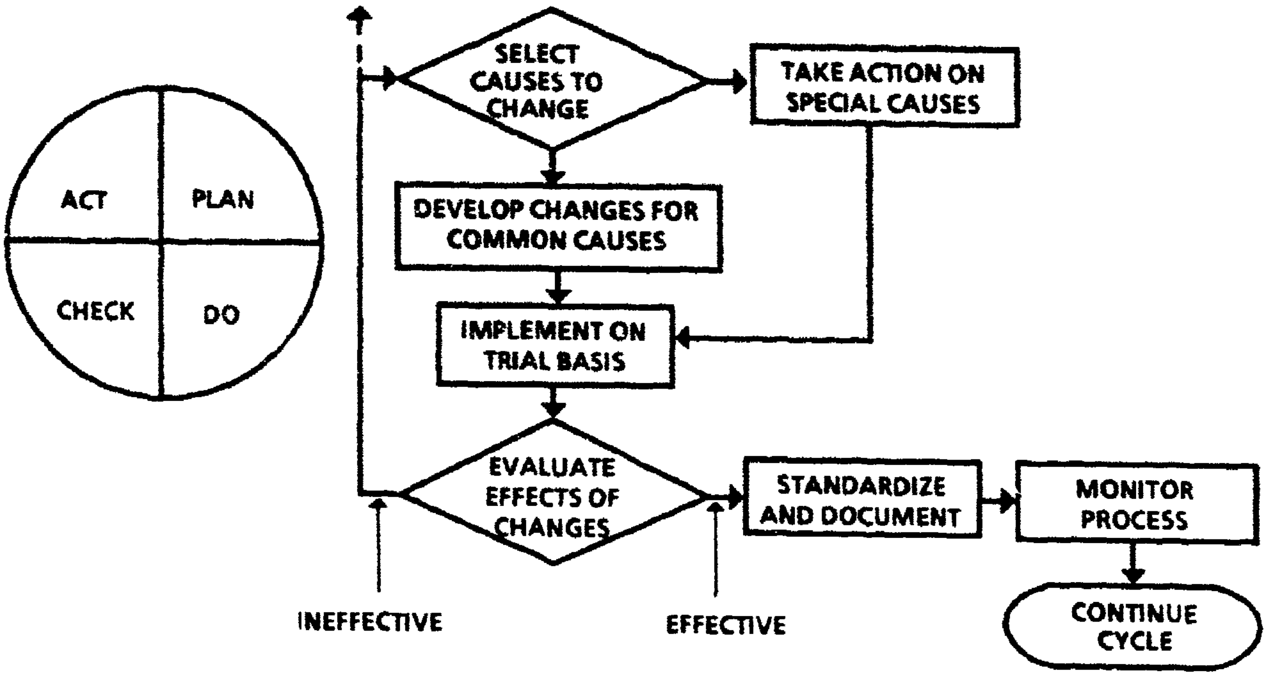


Figure 16. The "Act" phase of the process improvement model.

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 QMBs and ESC work to improve process-wide influences on quality. The QMBs and ESC identify the resources and authority levels required to make the changes. As part of the change design, the QMBs 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 could require a longer period of time to install and affect the outputs.

The determination of trial periods should be decided 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. And once it has been put in place, any positive results could be interpreted as sufficient evidence that it was 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 QMBs and the ESC, the changes are put into effect for a trial period. The QMBs continue to work with the PATs and others involved in the changes to ensure that the design plan is 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, QMBs and ESCs 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 if the process change should be standardized or if 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 pre-selected trial period. Data are collected by PATs to assess the effects of the change, for example, use of a run or control chart to determine if 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 QMBs. QMBs integrate 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 QMBs and the ESC compare those data with outcome information. The purpose of this comparison is to determine what effect the changes have made on the meeting of 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 QMBs 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 if Original Improvement Goals have been Achieved

After reviewing evaluation data, the QMBs and ESC must determine if the process improvement goals have been achieved. If the changes lead to desired improvements, then the QMBs 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 QMBs and ESC take actions to make the changes permanent. Such actions could include changing specifications, work methods, 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 TQM 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 could 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, then 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 TQM 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 could 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 process improvement model was developed for naval logistical organizations, the activities presented in the model could be applied to a variety of organizations, private as well as public.

The major impediments to the use of the process improvement model and, by extension, to the use of TQM 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 process improvement model to improve an organization's products and services will be heavily affected by the ability of managers to adopt the concepts associated with TQM.

RECOMMENDATIONS

At this time, no naval logistical organization has completed a process improvement effort based on this model. But based on review of preliminary results, the following conditions are considered essential for its successful application:

1. Managers should understand the principles and techniques associated with TQM.

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 TQM 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 MANAGEMENT PRINCIPLES

1. *Create constancy of purpose toward improvement* of product and service, with the aim to become competitive and to stay in business, and to provide jobs.

2. *Adopt the new philosophy.* We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.

3. *Cease dependence on inspection to achieve quality.* Eliminate the need for inspection on a mass basis by building quality into the product in the first place.

4. *End the practice of awarding business on the basis of price tag.* Instead, minimize total cost. Move toward a single supplier for any one item, on a long-term relationship of loyalty and trust.

5. *Improve constantly and forever the system* of production and service, to improve quality and productivity, and thus constantly decrease costs.

6. *Institute training on the job.*

7. *Institute leadership* [see point 12]. *The aim of leadership should be to help people* and machines and gadgets to do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers.

8. *Drive out fear*, so that everyone may work effectively for the company.

9. *Break down barriers between departments.* People in research, design, sales, and production must work as a team, to foresee problems of production and in use that may be encountered with the product or service.

10. *Eliminate slogans, exhortations, and targets for the work force* asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force.

11a. *Eliminate work standards* (quotas) on the factory floor. Substitute leadership.

11b. *Eliminate management by objective.* Eliminate management by numbers, numerical goals. Substitute leadership.

12a. *Remove barriers* that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.

12b. Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, inter alia, *abolishment of the annual or merit rating* and management by objective.

13. Institute a vigorous program of *education* and self-improvement.

14. Put everybody in the company to work to accomplish the transformation. *The transformation is everybody's job.*

APPENDIX B
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:

-Put the operations in what you think is the most likely sequence of occurrence.

-Indicate the decision points along the process, that is, where you think the quality of the work is being evaluated.

Spray Painting Process Operations (not in order)

_______mask non-painted surfaces

_______apply first primer coat

_______in-process check, second primer coat

_______apply final color coat

_______in-process check, first color coat

_______fill depressions

_______touch-up final coat

_______sand base metal

_______move material to kitting area

_______apply first color coat

_______sand depressions

_______bake first color coat

_______sand first primer coat

_______Q.C. buy-off final coat

_______sand second primer coat

_______in-process check, final color coat

_______in-process check, sand depressions _______sand first color coat

_______bake final color coat

_______in-process check, first primer coat

_______apply second primer coat

SPRAY PAINTING FLOWCHART EXERCISE
(Part One Answer Sheet Presenting Steps in Order)

1______sand base metal
2______fill depressions
3______sand depressions
4______in-process check, sand depressions
5______mask non-painted surfaces
6______apply first primer coat
7______sand first primer coat
8______in-process check, first primer coat
9______apply second primer coat
10____sand second primer coat
11____in-process check, second primer coat
12____apply first color coat
13____bake first color coat
14____sand first color coat
15____in-process check, first color coat
16____apply final color coat
17____bake final color coat
18____in-process check, final color coat
19____touch-up final coat
20____Q.C. buy-off final coat
21____move material to kitting area

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. Under-baking (insufficient heat or time in oven)
3. Cracks (break in final coat)
4. Incorrect coating (wrong primer or paint)
5. Over-baking (excessive heat or time in oven)
6. Sanding scratch
7. Roughness ("orange peel," sags, runs)
8. Unfilled depression
9. Contamination (dirt, etc., in coating)
10. Over-spraying (paint or primer on unwanted surface)

Spray Painting Process Steps	Defects that Could Occur at This Step
1--sand base metal	________________
2--fill depressions	________________
3--sand depressions	________________
4--in-process check for depressions	________________
5--mask non-painted surfaces	________________
6--apply first primer coat	________________
7--sand first primer coat	________________
8--in-process check of first primer coat	________________
9--apply second primer coat	________________
10--sand second primer coat	________________

Spray Painting Process Steps	Defects that Could Occur at This Step
11--in-process check of second primer coat	______________________
12--apply first color coat	______________________
13--bake first color coat	______________________
14--sand first color coat	______________________
15--in-process check of first color coat	______________________
16--apply final color coat	______________________
17--bake final color coat	______________________
18--in-process check of final color coat	______________________
19--touch-up final coat	______________________
20--quality control "buy-off" of final coat	______________________
21--move material to kitting area	______________________

APPENDIX C
PARETO CHART EXERCISE

PARETO CHART EXERCISE

In this exercise, you are asked to create two Pareto charts. First, complete the data sheet provided below by calculating the total costs per paint spraying defect. Second, use the frequency of defect information to create a Pareto chart using the worksheet displayed as Figure C-1. Rank the categories of defects from the highest to the lowest frequency. Third, use the total costs of defects information to create a Pareto chart using the worksheet displayed as Figure C-2. Rank the costs of defects from the highest to the lowest.

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 the most to the cost of repairing defects?

Figures C-3 and C-4 show completed Pareto charts for comparison.

Type of Defect	Frequency of Defect	Rework Costs per Defect	Total Cost*
1. Blisters	20	5.00	______
2. Under-baking	5	12.00	______
3. Cracks	3	3.00	______
4. Incorrect coating	7	18.00	______
5. Over-baking	6	14.00	______
6. Sanding scratch	26	3.00	______
7. Roughness	2	2.00	______
8. Unfilled depression	9	1.00	______
9. Contamination	4	8.00	______
10. Over-spraying	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.

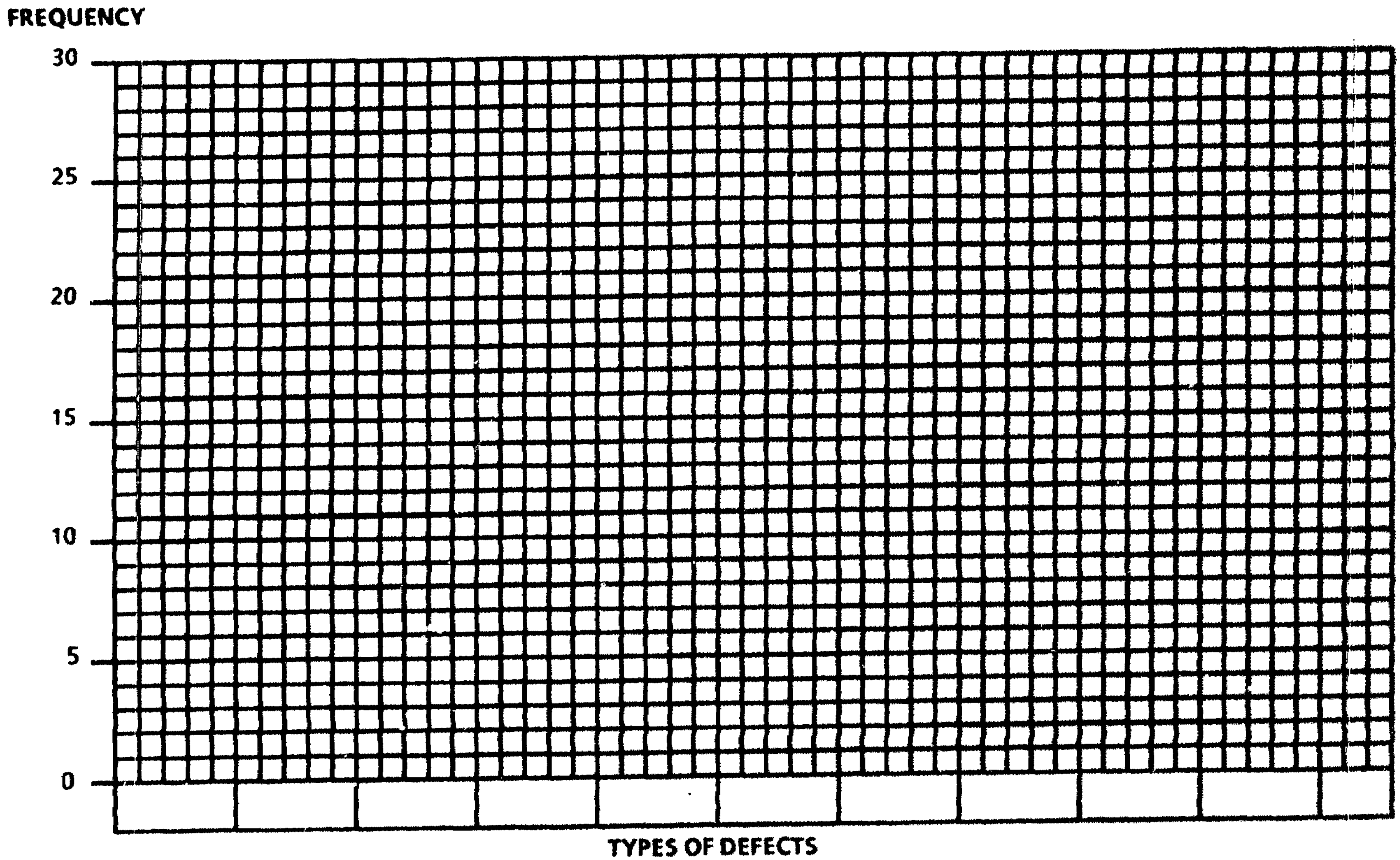

Figure C-1. Worksheet for plotting frequency of paint spraying defects.

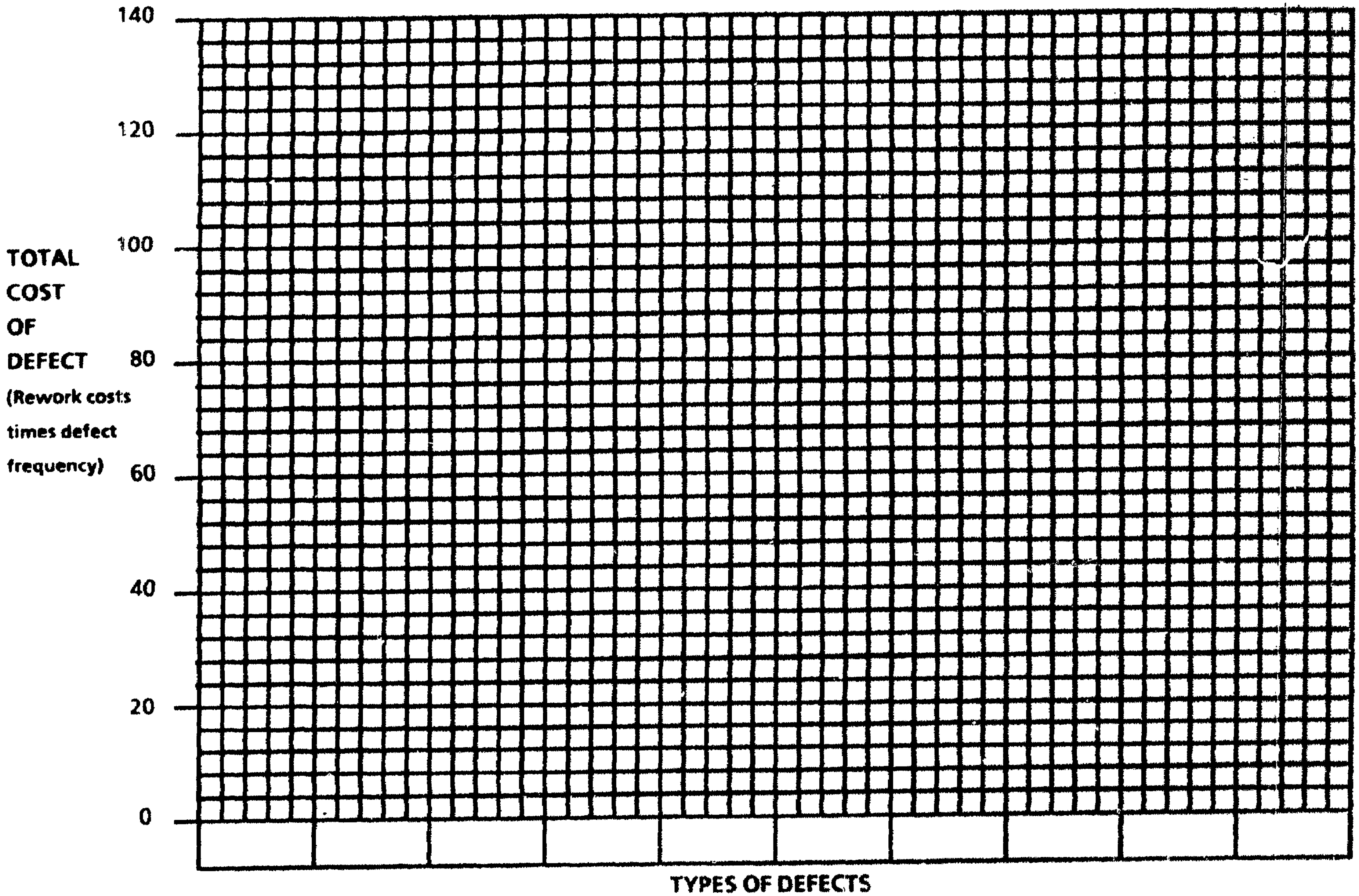

Figure C-2. Worksheet for plotting total costs of paint spraying defects.

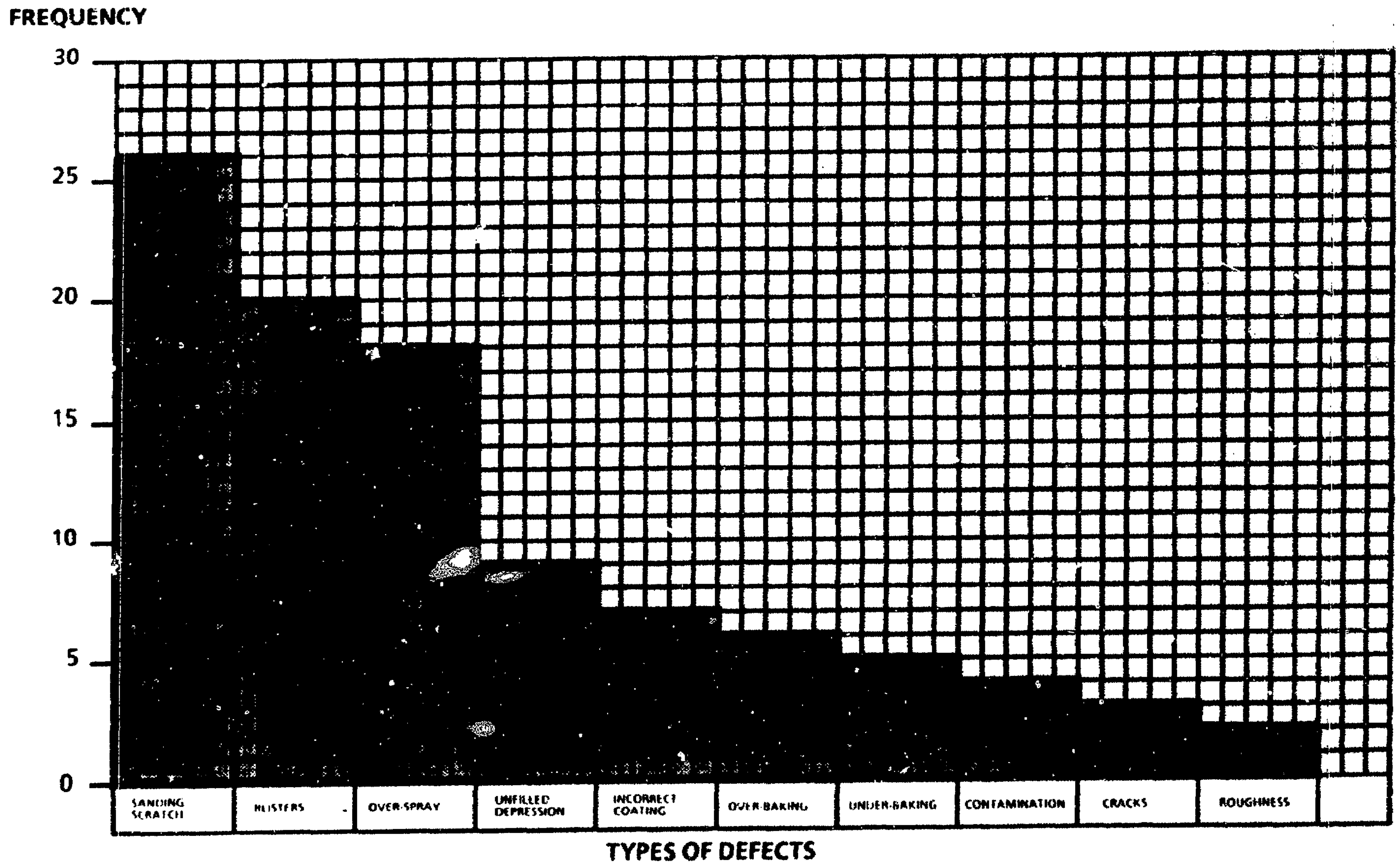

Figure C-3. Answer sheet showing how a Pareto graph can display the ranked frequencies of paint spraying defects.

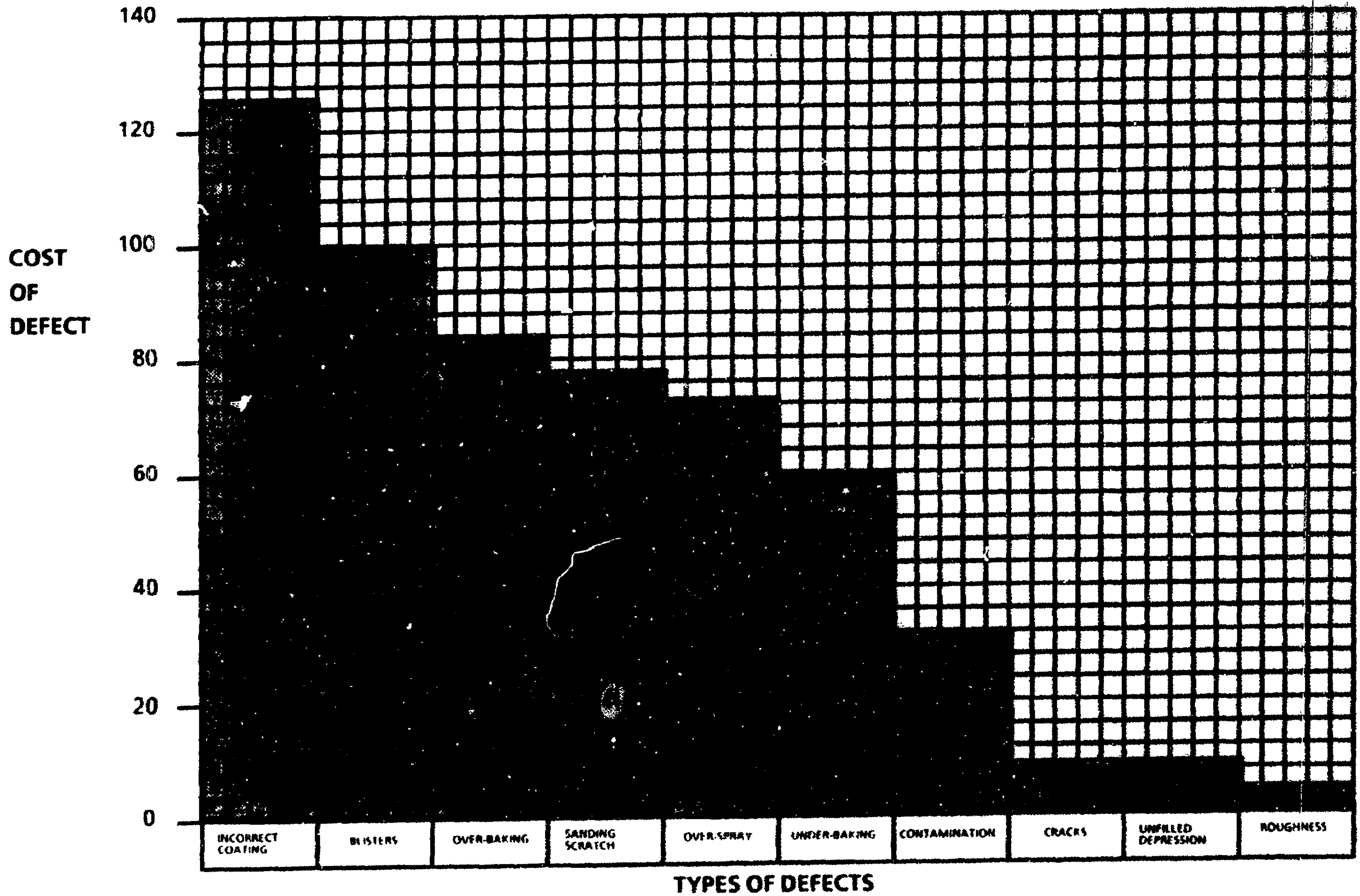

Figure C-4. Answer sheet showing how a Pareto graph can display the ranked total costs of paint spraying defects.

APPENDIX D
TQM PROCESS IMPROVEMENT CASE STUDY FORMAT

TQM PROCESS IMPROVEMENT CASE STUDY FORMAT

Background: State problem addressed by the case study you are working on. Use information obtained from customers.

Current Performance: Give an overview of the quality, costs, and schedule performance of the process.

Improvement Goals: State goals of process improvement effort. Use outcome goals defined by the Executive Steering Committee.

General Process Steps: List major operations and decisions used in the process. Use general experience of Executive Steering Committee.

Groups Involved in Improvement Effort: Describe the composition of the Quality Management Board and the Process Action Teams who conducted the process analysis. Use records of Executive Steering Committee meetings.

Analysis of Process: Present and discuss findings of process analysis conducted by the Process Action Team. 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 process improvement model (PIM). Present SPC charts to illustrate relationships between the process variables and specific quality characteristics.

Process Improvement Actions: Describe the actions taken by the Process Action Teams and the Quality Management Boards on the process variables to meet the stated goals. Use the information obtained during the "Act" phase of 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 Variables: 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 PIM. Compare this information with the information obtained during the "Act" phase of 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 TQM 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 anti-aircraft 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 management (TQM) efforts, organizational goals are determined through customer information. Members of the TQM 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, costs, 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, costs, and schedule were 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 Aircraft 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).

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). The QMB was made up of seven divisions from 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 to identify specific process variables that affected quality. This team was comprised of 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 finish 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

Over-spraying (Ovsp)--paint or primer on unwanted surface

Roughness (Rgh)--sags or runs in coating

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

Under-baking (Unbk)--insufficient heat or time in drying oven

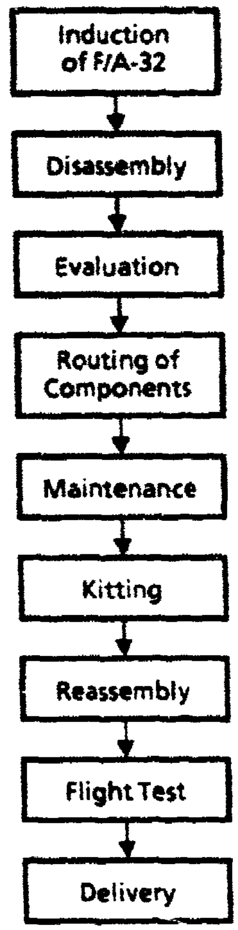

Figure E-1. General F/A-32 maintenance process flow.

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

The Process Action Team 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.

F/A-32 Painting Quality Cause-and-Effect Analysis

The Process Action Team 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 Process Action Team'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.

Quality Characteristics and Related Process Variables

The Process Action Team 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 Process Action Team have been organized by quality characteristic.

Quality Characteristic: Insufficient coating.

Related Process Variable: Air pressure of paint sprayer (Figure E-5).

Quality Characteristic: Blisters in the paint surface.

Related Process Variable: Contamination in filler for surface depressions (Figure E-6).

Quality Characteristic: Cracks.

Related Process 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.

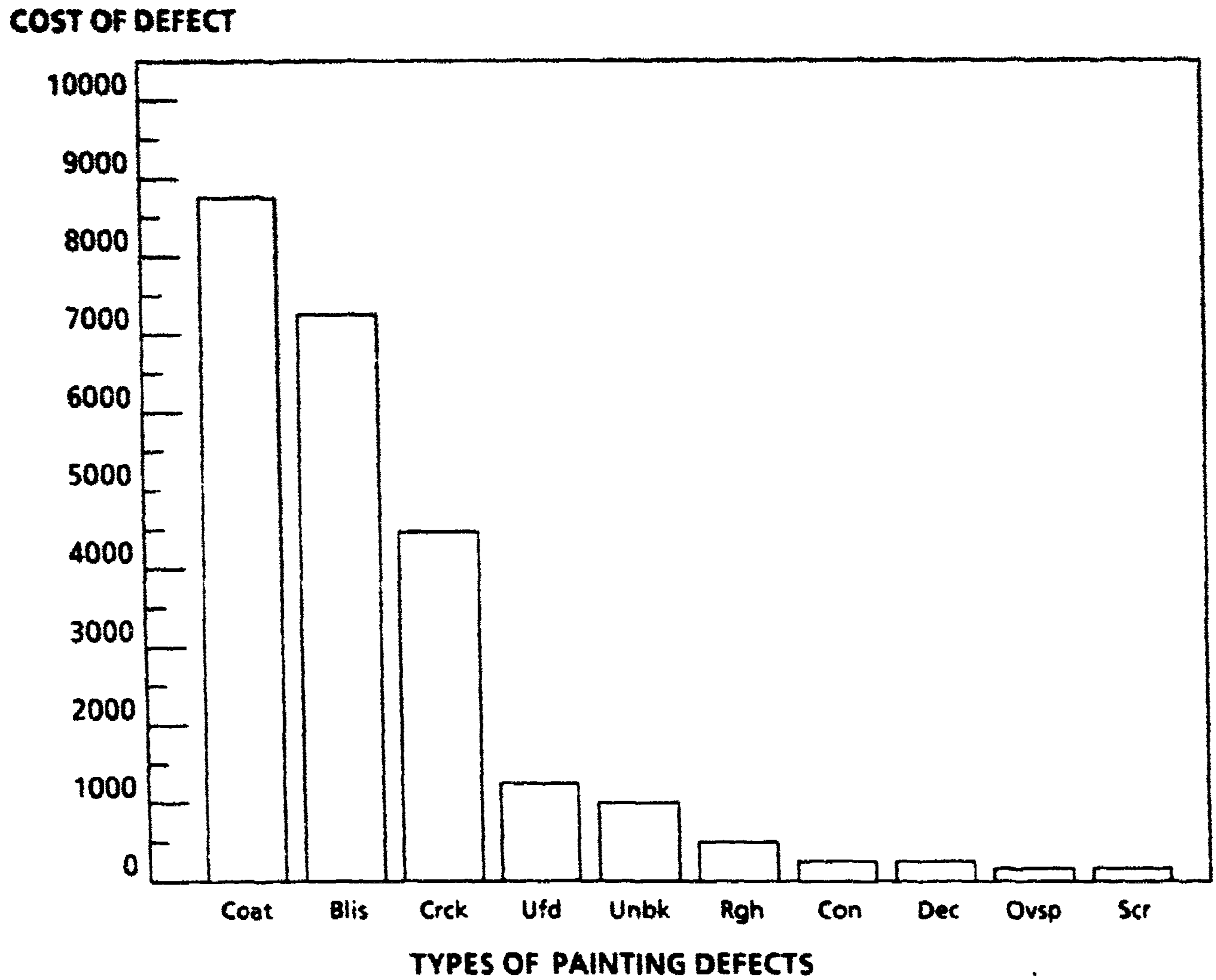

Figure E-2. F/A-32 painting defect costs for 1987.

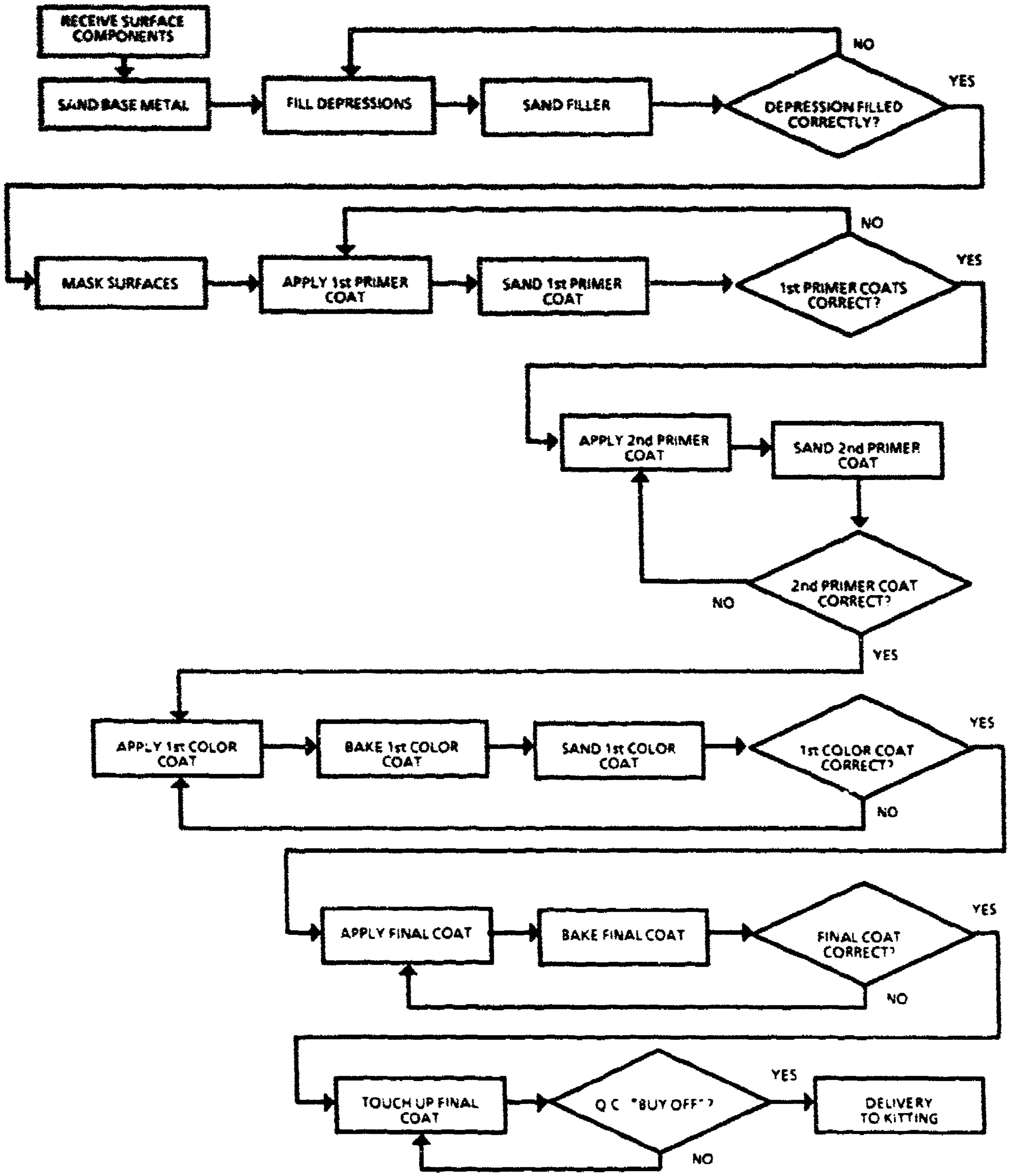

Figure E-3. F/A-32 painting process flowchart.

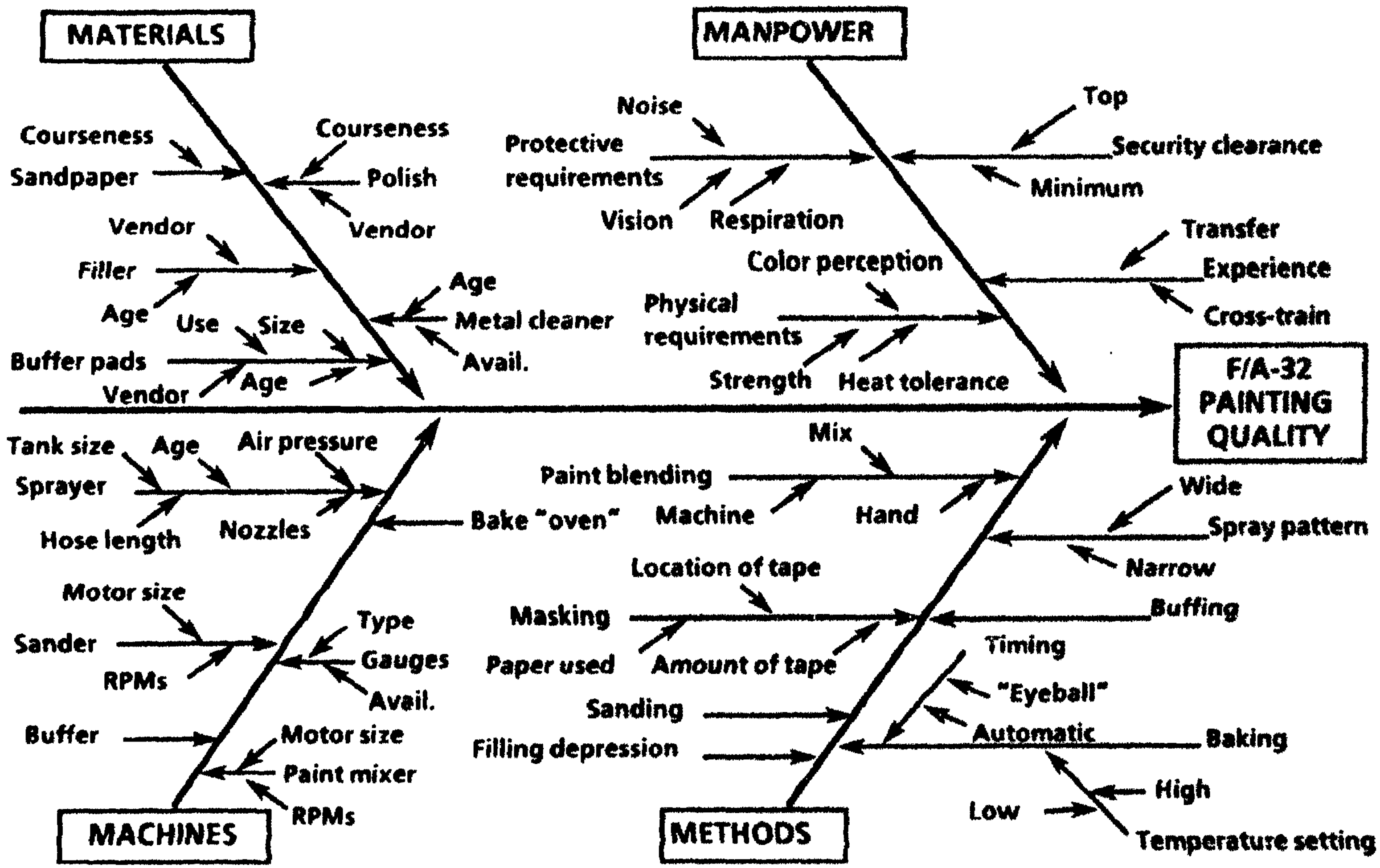

Figure E-4. *Cause-and-effect diagram developed by the Process Action Team.*

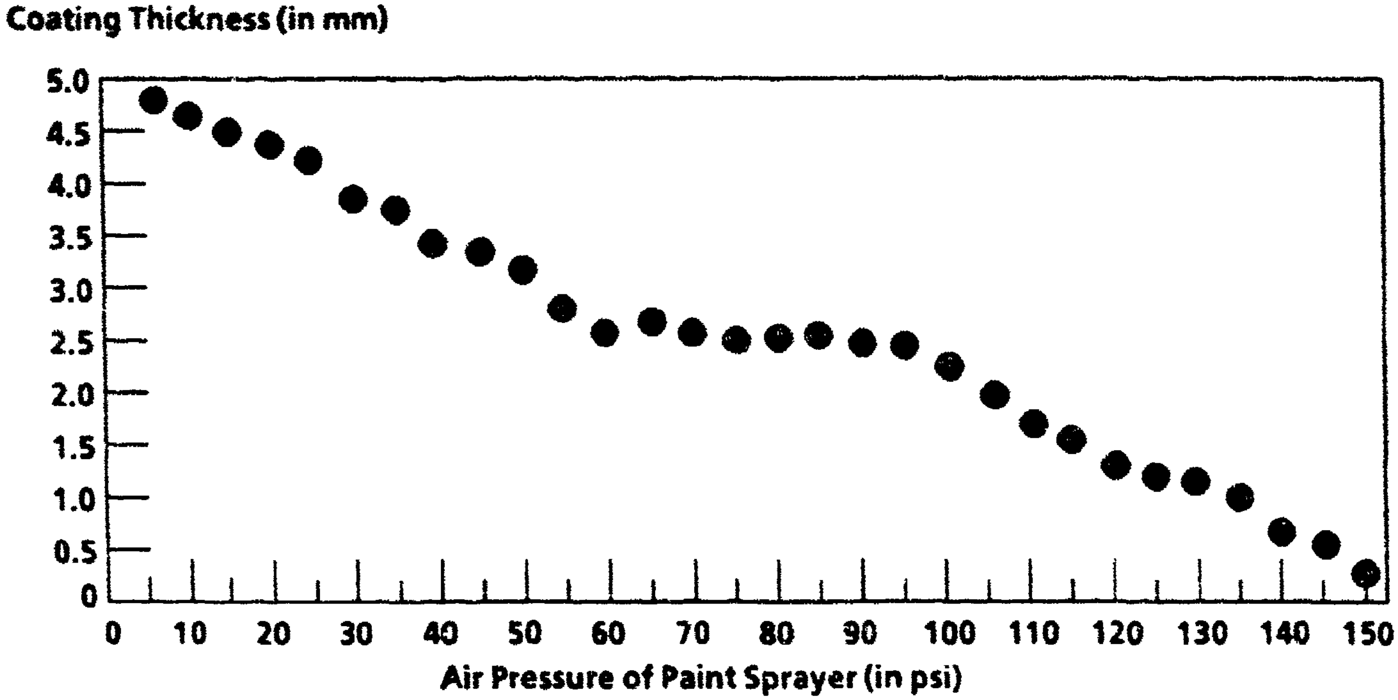

Figure E-5. Air pressure of paint sprayer and thickness of painting coating.

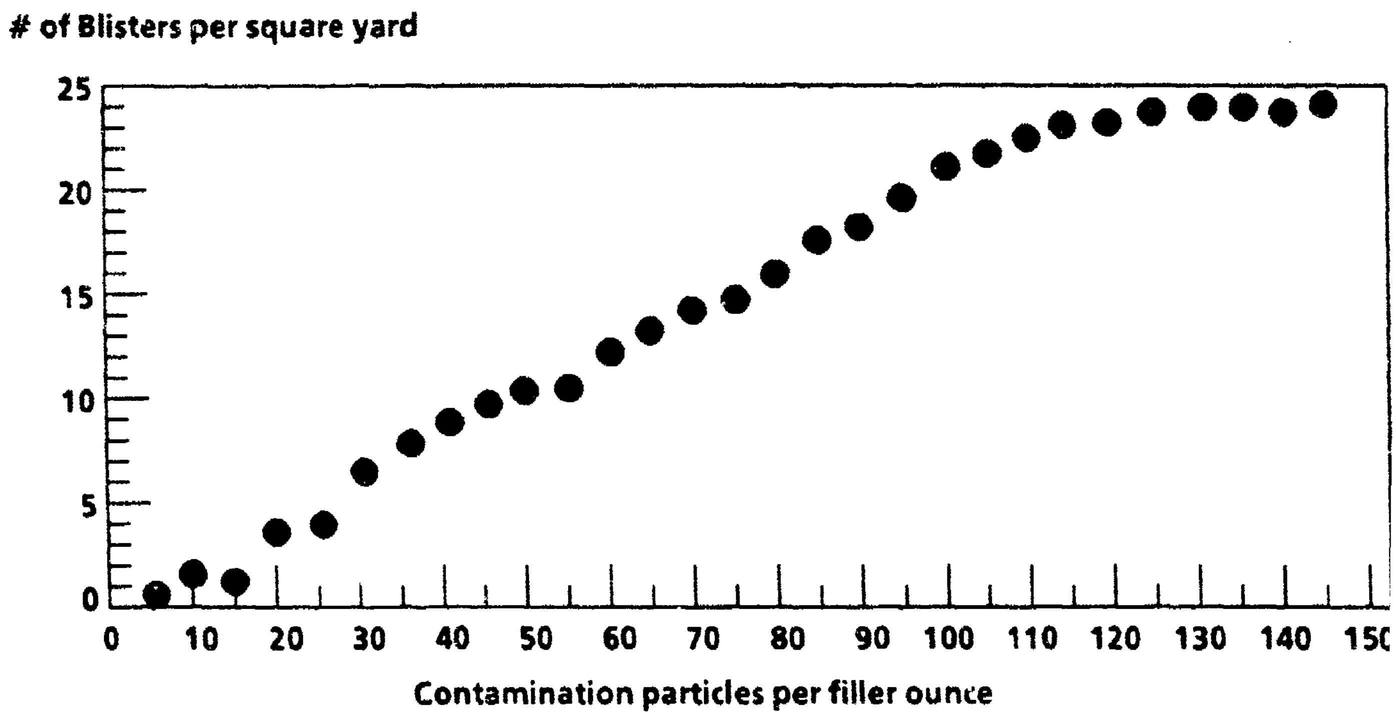

Figure E-6. Depression filler contamination and number of blisters per square yard.

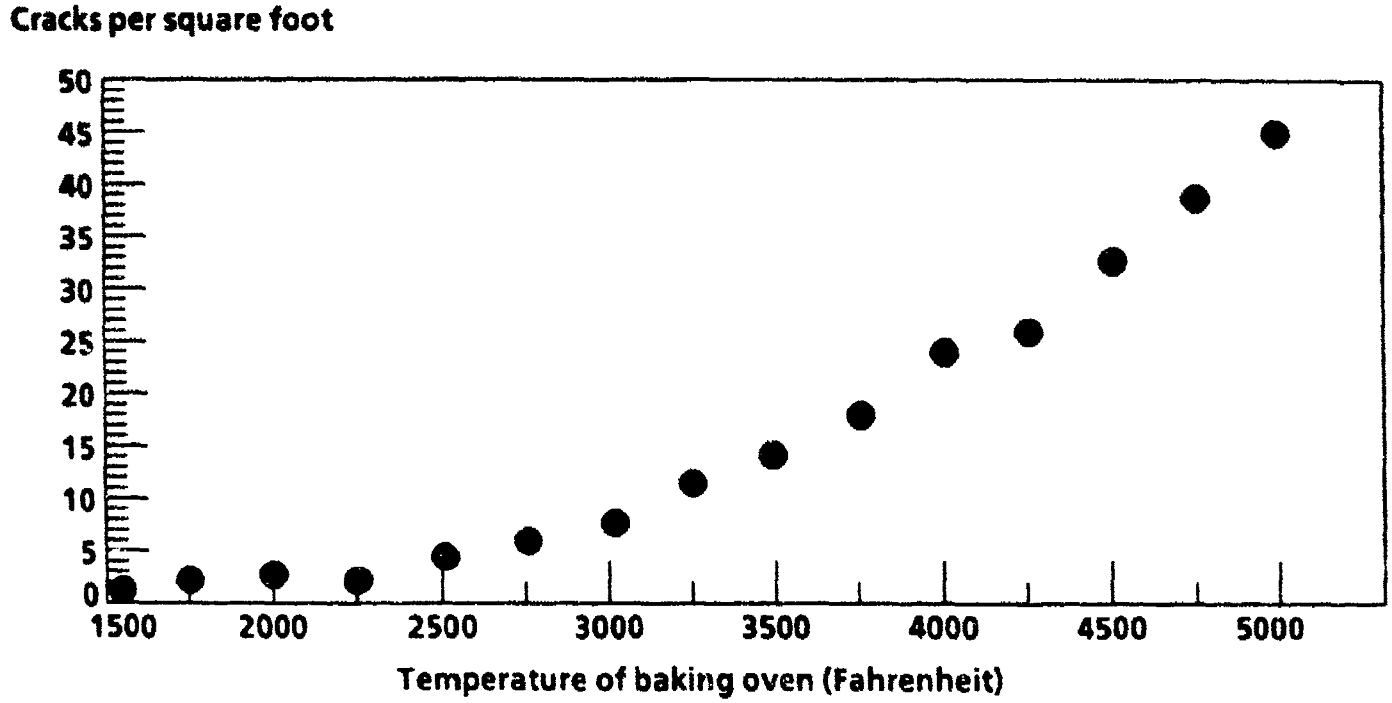

Figure E-7. F/A-32 paint coating cracks and relationship to oven temperature.

Process Improvement Actions

Based on the information provided by the Process Action Team, 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: Air-tight 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 TQM 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 currently used ones.

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 Aircraft 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 Process Action Team, training in machine settings and use will be given to paint shop workers. Those paint shop workers who were not part of the Process Action Team will also be given instruction in SPC methods so they can help monitor the process.

Methods

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

Materials

Purchasing has been authorized to buy air-tight 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 under-baking 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.

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