



TOTAL
QUALITY
MANAGEMENT

Guiding Principles
for Application

Jack P. Pekar



Total Quality Management: Guiding Principles for Application

Jack P. Pekar

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Foreword

Committee F16 on Fasteners is very concerned with the Fastener Quality Assurance Act (FQA) of 1990, which is expected to be implemented in 1995. F16 is comprised of fastener manufacturers, users, and distributors, all of whom have a large stake in this law. As a consequence, F16 requested and sponsored me to write a manual that would show our members how to comply with the law and remain competitive. But this book goes beyond assisting those in the fastener industry to cope with the FQA. It can be of benefit to any industry or enterprise because it is about total quality management (TQM).

This book was written so that others may share what I have learned during my 30 years in the quality profession. It is a book that presents principles and guidelines that, when applied, can be used to develop and implement a total quality management system. Today, more than ever, we in the business community face challenges at every turn from every corner of the world. Those businesses that survive will be those that demonstrate leadership and innovation and listen to the voices of their customers.

Those who practice the teachings in this book have a better chance than most to achieve success. They may find the journey difficult and cluttered with obstacles that impede their progress, but, if they are true leaders, their message will be heard. They must not and will not be discouraged for they must lead us to and through the new global market.

Acknowledgment

I wish to thank all those who helped provide background information for this book. The list includes companies I've worked for past and present, people I worked with in the past, those with whom I currently work, and family members. There are a few whom I wish to give special thanks. I could not have completed my manuscript without my very talented administrative assistant, LaVerne Craven. The topics on futuristic quality planning and supplier partnerships are in large part an adaptation of programs developed in concert with my manager, Gary Fitzgerald, Kennametal's MWM Quality Manager. But most of all, I want to thank my wife, Liz, for all the encouragement I received while writing and editing this book. It took considerable time away from our personal life, but she never complained because she saw the value this work would provide to those who accept the challenge it presents.

Contents

Introduction	vii
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PART 1: MANAGEMENT'S RESPONSIBILITY

Chapter 1—Management's Role	3
Chapter 2—Strategic Planning	9
Chapter 3—Continuous Improvement	21

PART 2: QUALITY ORGANIZATION FUNCTION

Chapter 4—Quality Systems	31
Chapter 5—Quality Reporting	37
Chapter 6—Supplier Qualification	40

PART 3: STATISTICAL QUALITY CONTROL

Chapter 7—Statistical Quality Control	47
--	-----------

PART 4: THE QUALITY ASSURANCE MANUAL

Introduction to Part 4: The Quality Assurance Manual	57
Chapter 8—Manufacturing Company Quality Assurance Manual	59
Chapter 9—Service Industry Quality Assurance Manual	63
Chapter 10—Distributor Industry Quality Assurance Manual	67

PART 5: FASTENER QUALITY ASSURANCE ACT

Chapter 11—Public Law 101-592	73
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APPENDICES

Appendix A—ASTM Standards F 1469, F 1470, and F 1503	81
Appendix B—IFI Standards IFI-139 and IFI-140	97
Appendix C—Public Law 101-592—Fastener Quality Act	133
Appendix D—Supplier Quality Systems Survey	147
Appendix E—Attribute Gauge Analysis Form	155
Index	157

Acronyms

ANSI	American National Standards Institute
ASME-FAP-1	Quality Assurance Program Requirements for Fastener Manufacturers and Distributors
ASQC	American Society of Quality Control
ASTM	American Society for Testing and Materials
CMM	Coordinate Measuring Machine
CPI	Critical Performance Indicators
E&I	Empowerment and Involvement
FAC	Fastener Advisory Committee
FMEA	Failure Mode and Effects Analysis
FQA	Fastener Quality Act
HRC	Hardness Rockwell C
JIT	Just in Time
NIST	National Institute of Standards and Technology
NVLAP	National Voluntary Laboratory Accreditation Program
P&IC	Production and Inventory Control
PIE	Plan, Initiate, Evaluate
QFD	Quality Function Deployment
R&R	Repeatability and Reproducibility
SCD value	Severity rank times the Capability rank times the Detection rank
SEM	Scanning Electron Microscope
SPC	Statistical Process Control
SPQP	Service/Product Quality Planning
SQC	Statistical Quality Control
TCQ	Total Cost of Quality
TQM	Total Quality Management

Introduction¹

THE PATH TO TOTAL QUALITY

THERE IS NO single path to achieving total quality within an organization. There are no hard and fast rules to follow to become a world class company. The only constants are basic guidelines, that, when followed, lead to success. This is because all organizations have their own cultures, people, and technologies. What may work well for one company will not necessarily work for another. These guidelines are as follows.

Leadership Commitment

The leadership of an organization must be committed to continuous improvement. This commitment must be visible throughout all layers of management. Management must “walk the talk.” Only when management is committed will employees excel at what they do. It takes time to change work cultures and work habits, but with perseverance the message of enlightened management will prevail. Employees want to do a good job. All they need are the right tools and the right systems. These can be supplied only by management.

Customer Focus

The organization must be customer focused. Everyone in the organization must understand that without the customer there would be no purpose to their work, no paycheck, no capital investment, and no company picnic. What must also be understood is that the external customers are served by the internal customers (employees). There is, therefore, a need to focus on the requirements and expectations of *both* internal and external customers. One of the first steps management should take in this regard is to conduct surveys of external and the internal customers. Employees (internal customers) should be apprised of the results of external customer surveys. A truly committed management team will also allow employees to see the results of internal surveys. This brings “the good, the bad, and the ugly” to the table for discussion. The good can be improved upon. The bad can lead to opportunities for improvement. The ugly must be addressed through open, two-way communication with cross-functional teams to find solutions.

¹Portions of this introduction were taken either in whole or in part from an SME technical paper by the author entitled, “Continuous Improvement—Managing Yesterday, Leading Today.” Reprinted with permission of the Society of Manufacturing Engineers, Copyright 1993, from the Cold Forming '93 Conference.

Training

The organization must assess the current skill level and awareness of total quality principles of all employees. The idea is to start with top management and move through the organization. Begin by training top management; with their commitment and knowledge of total quality, it will be easy to train those who follow. This training will pay high dividends at every level in the organization. Through training, we assure that our employees have the necessary skills and technical knowledge to perform their jobs effectively. We can also count on them to be effective participants in contributing to the total quality process. Information should be provided to employees describing educational programs available to them through various professional organizations and community colleges. By creating an awareness of these opportunities, the organization demonstrates its commitment to a continuous improvement of employee skills.

Empowerment and Involvement

Soon after the commencement of training, management must provide opportunities for employees to apply what they have learned. They need to test their skills. They will not and should not be content with the way things are. Every aspect of their job should be evaluated and measured against the new paradigms. This will bring new challenges to their supervisors. The supervisors, in turn, through their own training will now be equipped with the attitudes and analytical skills to consider their suggestions. They will no longer feel the threat of losing control.

Measurement

Before those of us in management can find out if we have made improvements, we need to know where we were. If we don't have historical data to let us know, we must at least determine where we are through a short-term study.

The first step is to define the organization's critical performance indicators (CPIs). Critical performance indicators are defined as *those measures that contribute to customer satisfaction*. There are several tiers of indicators in any organization, and they can be broken down as primary, secondary, and tertiary. Examples of first-tier CPIs include On Time Delivery, Customer Satisfaction Indicators, and Cost of Quality. Second-tier CPIs are measures that contribute to the first-tier CPI's. Examples of second-tier CPIs to *On Time Delivery* may be *quote turn around, manufacturing lead time reduction, and supplier performance*. Third-tier CPIs are the em-

ployee involvement action items. Examples of third-tier CPIs for *manufacturing lead time reduction* could be (1) set up reduction and (2) scrap and rework reduction. CPIs are discussed in detail in Chapter 2.

Recognition and Awards

Everyone appreciates a pat on the back after they have achieved a noteworthy goal or successfully completed a difficult or important task. This encourages further participation by the employee and shows other employees that their efforts are appreciated. When a team has met an established goal, the entire team should be recognized.

The form of recognition should fit the accomplishment; in other words, the value of the recognition should be commensurate with the value of the accomplishment. Too, when recognition is given, it should be consistent. To assure consistency, a panel of management and nonmanagement employees should be established to set up a recognition program to acknowledge those individuals and/or teams who meet company objectives.

Communication

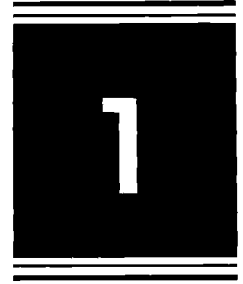
This last guideline is by no means the least important. The organization must communicate with the work force, their

suppliers, and their customers. I cannot provide enough differentiation among this trilogy to say one is more important than the other. All participants in this trilogy of communication must interface for an organization to be truly successful. Within the organization, employees at all levels need information on continuous improvement projects so they can become aware of progress, their contribution, and the effect these projects have on critical performance indicators.

Business goals must be communicated to suppliers. Suppliers should be viewed as extensions of the organization who contribute to the overall success of continuous improvement. They should be part of decisions to utilize purchased services. Suppliers are specialists in their fields of expertise; therefore, their input should be required when decisions are made to use them. World class purchasers understand the difference between price and value. As purchasers (customers) we expect, and should demand, products that contribute to our success.

The voice of the customer must be heard. Customers are the reason we are in business. Without customers, no provider of goods or services could survive. To understand customers' needs, we must listen to their messages. Invite existing and potential customers to your facilities and ask them to apprise your teams of their business objectives. Let them tell you how you can assist them in achieving their goals.

Part 1: Management's Responsibility



Management's Role

THE PRIMARY ROLE OF MANAGEMENT is to provide employees with the leadership necessary to meet the goals of the organization. This leadership must reflect the principles of total quality management. These principles were presented in the Introduction: *leadership commitment, customer focus, training, empowerment and involvement, measurement, recognition and rewards, and communication.*

LEADERSHIP COMMITMENT

Management must first examine how they manage. Is their style tailored to encourage input from other managers and departments? Or is their style that of not allowing other departments or disciplines to influence their decisions? In other words, do they operate as team leaders or as *silos*? When I refer to managers operating as silos, I mean that they stand alone within the organizational structure by excluding input from other managers or departments. This concept is explained further below.

Silos

Management in the past relied on experts in given disciplines to develop systems and procedures to guide the organization. These experts headed up their own departments (silos) and had specialists working for them who created the culture and systems for the *silos* master.

The silo master made it clear to all other silo masters in the organization how his department functioned and that there would be no interference from other groups or departments. This allowed the silo master to keep control of his territory. This also assured that the other department managers did not fully understand the requirements for positive interaction between groups or departments within the organizational structure.

Here's a classic example of how silos can thwart satisfying customer requirements. The marketing group receives an order from a customer and tells the design group what the customer wants. The design group gives their interpretation of the customer's needs to the manufacturing engineering group. Manufacturing engineering tells manufacturing what process to use to create the product that will satisfy the needs of the customer. Manufacturing does their very best to manufacture the part according to criteria supplied by manufacturing engineering. The quality department inspects the final product and decides it is manufactured incorrectly. Rework is performed and the part is shipped to the cus-

tomers. The customer rejects the part because it does not meet his requirements! (See Fig. 1-1.)

Management needs to break down silos in their organizations because they create waste, redundancy, and poor quality. We are getting better today at breaking down silos and allowing interaction through cross-functional team management. Management should evaluate themselves to determine if their management style is autocratic or team oriented.

Autocratic Management

I remember when I first started working. I was told that in order to succeed and to keep my job, I had to remember two rules. Rule 1: The boss is always right. Rule 2: When the boss is wrong, remember Rule 1. Those were the days when systems were more important than people. Employee involvement consisted of doing only what the boss told you to do, whether it made sense or not. Management felt that empowering the worker took control away from management.

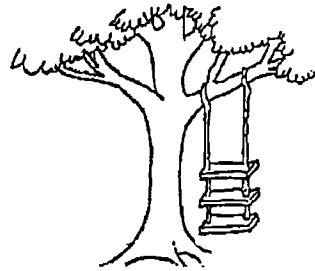
Switching to a management style that encourages employee involvement and empowerment is a tough transition for many. Unless special training is provided for middle and first-line management, the transition may never take place. And, unless upper management invests and participates in this training, the organization is bound to fail. It will be overtaken by other organizations who have invested in their most valuable resource, their employees, and are cashing in on that investment. Employees of an enlightened organization contribute every day to improved operations and systems.

Once management has committed itself to breaking down silos, it must embrace the concept of *Team Management*.

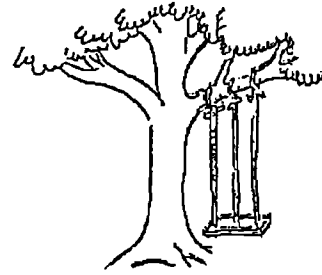
Team Management

Gone are the days when managers are expected to be proficient in only one discipline. Today managers must be part of a management team, and they must have a working knowledge of their peers' responsibilities. For example, the quality manager needs to understand how design engineering, manufacturing engineering, purchasing, sales, production control, customer service, and every other department functions. And every other manager should know the roles of the others.

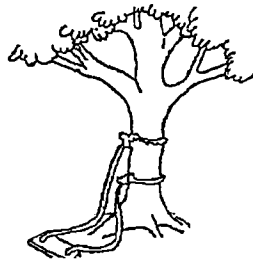
This is not to say that they need to be as well trained in the other disciplines as their peers, but they must understand how the entire organization functions. We want to break down silos so we can move freely throughout the or-



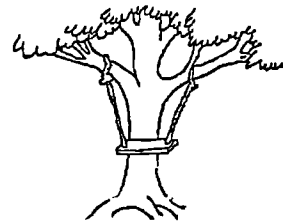
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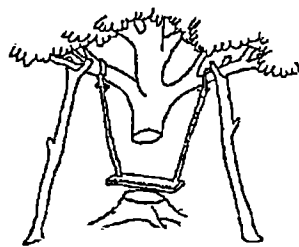
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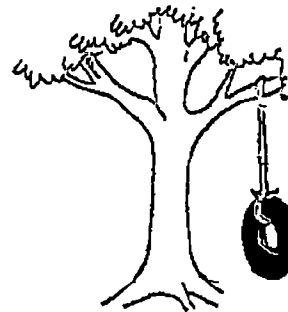
AS MANUFACTURING ENGINEERING SAW IT



AS MANUFACTURED



QUALITY REJECTS DESIGN DRAWING



WHAT THE CUSTOMER WANTED

Figure 1-1 — Customer requirements.

ganization. This creates another dilemma because now we need to allow managers who are outside our responsibility to be permitted, even welcomed, to handle situations that structurally may belong to us.

It's time for the goose story. We as managers should take a lesson from the goose. I'm sure you have observed geese in flight. They fly in a pattern that forms a horizontal V. There is a good reason why geese fly in a V pattern. The lead goose breaks the air current and creates an uplift behind him that the other geese can take advantage of. The second tier of geese likewise does the same for the third tier and so on and so forth for the entire flock.

The lead goose eventually tires of butting his head against the wind, so he drops back in the formation. Here's when something interesting takes place. Another goose from the flock moves to the front to assume the lead. This goose does

so until he tires. Then he drops back and another goose moves in to lead. Geese in a flock are willing to follow the lead of whoever is leading at the time because they all have a common goal.

We can learn a lot from the goose! Geese have learned how to work as a team. All in the flock are willing and able to lead when necessary. The leader who drops back is not intimidated by another taking his place. He understands that for now it is best that someone else assumes leadership.

CUSTOMER FOCUS

Management must develop an attitude that puts the customer in every decision made. The customer is the reason we are in business. Without customers there would be no

job to perform, no requirements to be met, and no reason anyone would wish to purchase your company's stock.

As explained in the Introduction, there are two kinds of customers: *internal* and *external*. External customers provide income for the organization through purchasing goods or services. Internal customers (employees) satisfy the requirements of the external customers and the requirements of others in their own organization. Both are important and need to be understood for an organization to succeed and prosper.

External Customers

The expression "The customer is always right" is not always true; however, one right of the customer is always true: "The customer has the right to purchase from whomever he wants." With this in mind, we should make every attempt to make sure the customer wants to buy from us.

To assess the needs of your customers, utilize input from all customer contact personnel. In an organization that follows TQM principles, input can come from the sales representative, your marketing group, the quality department, manufacturing, customer service, and engineering. The method in which the input is provided can be *reactive* or *proactive*. Both sources should be looked upon as opportunities for satisfying your customers' needs.

Reactive input is in the form of customer complaints or from interpreting customer purchase orders or sales inquiries. When customer complaints are received, either as written complaints or in the form of returned goods, most organizations react as fire fighters and focus on the hot spot. We sometimes ignore the system that created the problem in the first place. When a purchase order or sales inquiry is received, most organizations interpret their customer's requirements through the mirror of their own paradigms.

Proactive input is solicited through visits to the customer's place of business, visits to your facility by your customer, customer satisfaction surveys, and by cross-functional teams consisting of employees from customer and supplier facilities. All these activities should be part of management's strategic business plan. The strategic business plan will be discussed further in Chapter 3.

Internal Customers

In a TQM environment, the attention paid to employees is as important as, if not more important than, attention paid to the customer. The employee is the internal customer of the organization, the individual who can make things happen. His or her understanding of the organization's goals and commitment to the customer must be complete. This can be assured by following a three-step process that includes (1) an employee survey, (2) an employee training program, and (3) regular communication sessions to continually reinforce the organization's goals.

Employee Survey

The employee survey should be designed to provide an assessment of how the employee feels about the company and how he perceives his role to the customer. An example of a survey I used successfully is provided in Fig. 1-2.

The TQM steering committee (discussed in Chapter 3) should review and analyze employee survey results and determine the training program required to bring employees up to speed on company goals. Training can be conducted by inside experts or by using outside resources. There are advantages and disadvantages to both approaches.

The advantages to using inside experts are cash flow containment and assuring that the training is tailored to existing company paradigms. The disadvantages of using in-house experts are having to overcome existing negative perceptions of the expert, if there are any, and removing the expert from his duties to provide preparation and training.

The advantages of using outside sources for training are many. Among them is the natural perception that an outside consultant knows more about a subject than inside people. This advantage can create a more receptive learning environment for the employee. Another advantage is that no time is taken from anyone's schedule for preparation of lesson plans. Two major disadvantages are expense and the fact that the outside resource is not familiar with your company culture.

Both options of training must be evaluated by the TQM steering committee, and selection of training resources should be made on the best fit analysis. The key is to assure that whatever training source is utilized that the source emulates the goals of the organization.

Activities concerning customers need to be communicated to everyone in the organization in a timely manner. Most information can be distributed on a monthly basis, but special news should be disseminated as required. An ideal method of sharing news is through a company newsletter that contains information on employees, customers, and continuous improvement activities.

TRAINING

Continuous improvement cannot occur within an organization unless training is part of management's agenda. Leaders in respective departments should take the initiative to conduct an analysis of each employee's ability to perform his or her job. This is often referred to as a *needs assessment analysis*.

The needs assessment analysis should be performed on the job function, not the individual performing the job. For example, suppose the job is to prepare an accurate product certification document. A flow diagram on completing a product certification is shown in Fig. 1-3.

The focus should be on preparing an accurate product certification, not on the skills of the final product auditor, the material handler, or the typist. Study each step in the flow diagram for the job and determine exactly what is required for that step to be successful. For example, let's look at the step: *Inspect All Critical Characteristics Per Sample Plan*.

To be successful at this step, every step preceding must have been performed correctly and accurately. All critical characteristics must be identified on the inspection plan or engineering drawing. The sample plan should be available and germane to the product being inspected. The test equipment and inspection equipment should be in full calibration and acceptable for the tolerances being examined. The individual conducting the task must be qualified for the task.

IN PLANT "ASK ME" BOX

<p>(1) How do you perceive your role in service for customers?</p> <p>_____ Directly Involved</p> <p>_____ Indirectly Involved</p> <p>_____ Not Involved</p> <p>(2) How do feel about service you receive from related departments?</p> <p>_____ Satisfied</p> <p>_____ Not Satisfied</p> <p>_____ No Opinion</p> <p>(3) Do you have enough authority to make improvements to better serve our customers?</p> <p>If No, Suggestions: _____</p> <p>_____</p> <p>_____</p> <p>_____</p>	<p>(4) Do you receive everything you need from the previous operation or department to do your job well?</p> <p>Yes No (circle one)</p> <p>If no suggestions: _____</p> <p>_____</p> <p>_____</p> <p>(5) If you could make one change in either your department or the company as a whole, what would you change to improve service for our customers?</p> <p>_____</p> <p>_____</p> <p>_____</p>
<p>(6) If you could rate overall the products and services provided to our customers, what would that rating be?</p> <p>_____ Superior _____ Good _____ Average _____ Poor _____ Other</p> <p>Please explain: _____</p>	

Figure 1-2—Employee survey.

Any deficiency found in any of the subgroups contributing to the successful completion of the main task of *inspecting all critical characteristics per sample plan* may require training for the individual doing the inspection or correcting some upstream activities.

EMPOWERMENT AND INVOLVEMENT

One of the more responsible acts management can perform is recognizing that their employees can make significant contributions to the success of the organization. If management provides the tools and training, a great deal can be accomplished through employee empowerment and involvement (E & I). However, the employee must be properly prepared for such responsibilities.

The first employees that should be prepared for Employee E & I are managers and supervisors. The concepts of TQM must be provided through several training sessions and should be reinforced through appropriate actions from senior management. One of the better methods of demonstrating senior management's commitment to Employee E & I is by forming management teams and allowing these teams to

evaluate and suggest how to improve current systems. It is through these management teams that lower-level employee teams are created.

The teams formed at all levels will concentrate on improving the organizations critical performance indicators (CPIs). CPIs are tracked and evaluated through measurement parameters established by management E & I teams.

MEASUREMENT

Management should establish measurements to track progress on CPIs. The unit of measurement should fit the indicator being evaluated and should be understood by those who contribute to the improvement process for that indicator. For instance, the cost of quality CPI should be measured in dollars and compared to several key values, such as cost of sales or cost of manufacturing. Another example is on time performance. This CPI can be measured in several ways, which should all relate directly to customer requirements. For example, this CPI can track orders shipped to customer-required dates (external customer measure), or it could track design engineering input to manufacturing en-

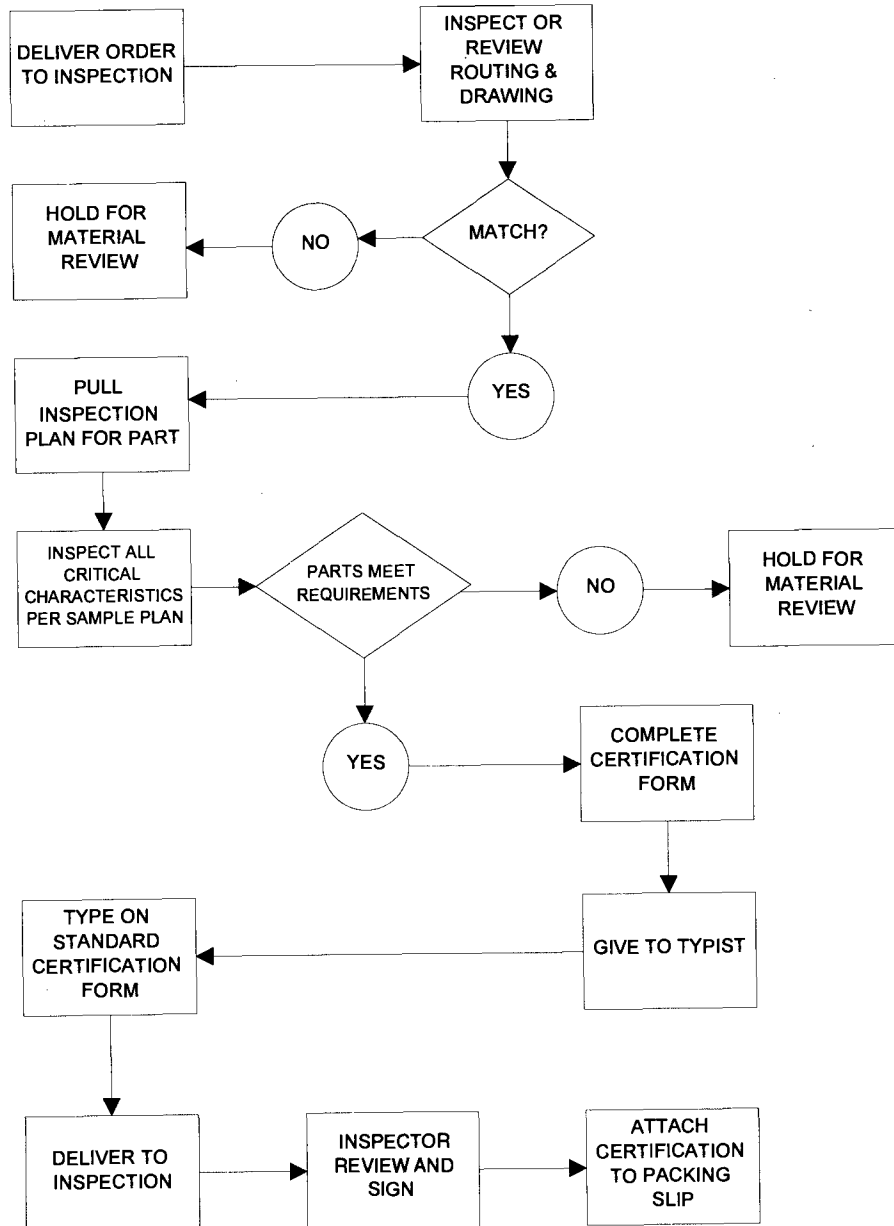


Figure 1-3—Product certification flow chart.

gineering (internal customer measure), or it could track quote turn around from your suppliers (a measure of your needs as a customer of your supplier).

CPIs will be discussed further in Chapter 2 when methods of continuous improvement are explored.

RECOGNITION AND REWARDS

Management has the responsibility to provide an environment for the work force that is safe and environmentally clean. This environment should also lay the foundation for supporting the employees' quality of work life. Once this foundation has been established, management must develop

a recognition and rewards program designed to improve and maintain employee job satisfaction.

A three-tiered system should be developed that includes: (1) day-to-day recognition, (2) informal recognition, and (3) formal recognition programs. The best way to get started is to create a steering committee made up of staff management. This committee can define the scope of the program and establish guidelines to be followed by employee teams established to implement the program. Employee teams should include participants from all levels of the organization.

The steering committee can set the scope of the program to include as many systems as they feel the company can support and effectively manage, but some systems should always be included because of their proven effectiveness.

8 TOTAL QUALITY MANAGEMENT MANUAL

The following systems, when properly structured and administered, are very cost effective and contribute directly to a company's profitability through various improvements. In no particular order, these proven systems are: *pay-for-performance*, *perfect attendance*, *service awards*, and *continuous improvement programs*. Pay-for-performance recognizes employees for their performance on the job and should include such criteria as quality of work produced, productivity, attendance, initiative, job knowledge, and safety. An attendance policy should establish rules to define when employees are to be on the job and when they are excused from their job. This may seem like a basic idea, but it is surprising how many companies do not have an established and documented policy on absence from the job. When there is no written policy, there is no consistency, and this leads to dissatisfied employees who see management as untrustworthy or at the very least prone to favoritism. A service awards policy recognizes employees for their length of service with the company and can be very rewarding in enhancing employee esteem and fostering employee loyalty.

COMMUNICATION

This guideline is one of the more important for both management and employees. It is a two-way street, and both should strive to keep the airwaves open. Even though communication is a two-way street, it must start with management. Management should set the standard by creating an environment conducive to openness without fear of reprisal or ridicule. At all times communication must be polite and conducive to enhancing self-esteem. The best way to get started is as with all the other guidelines: establish a steering committee to set the policy and the guidelines for implementation. Then create the opportunity for employee involvement teams to get the program underway.

Some of the more common and effective programs include: company newsletters, staff and employee meetings, and an open invitation from management to allow employees at all levels to hold informal conversations or brainstorming sessions in employee lounges during breaks.

Strategic Planning

ONCE MANAGEMENT'S ROLE AND commitment are defined and established, the top executives of the organization should establish a *quality policy*. The quality policy should state the organization's commitment to: (1) continuous improvement and (2) customer satisfaction. These seem like basic organizational goals, but, unless stated, the rest of the organization will not be aware of them or will not have a clearly stated policy from which to develop their own planning for improvement.

Quality policies can be from one paragraph to a full page. The policy's length is not as important as its contents. For lasting impact on employees and customers, it is best to keep them short. After all, it is easier to recall one paragraph than an entire page. An example of a quality policy could be:

(insert company name here) is committed to continuous improvement and providing products and services that are of the highest quality. At *(insert company name here)*, we believe customer satisfaction is the most important service our employees can provide.

Although short, this policy is very much to the point. It says a lot about the philosophy of the company's top executives. It says, "The most important goal of this organization is to satisfy the customer and to find better ways to manufacture products and/or provide services." I do not want to become too involved with what *quality* means in this quality policy statement. There are as many definitions of this word as there are words on this page. The following are a few definitions of the word *quality* that should provide a basis for developing many more.

Quality is:

1. When a product is consistently represented.
2. An attitude of excellence with an objective of error-free performance shared by all employees.
3. Achieved through dedicated and skilled employees, modern facilities, controlled manufacturing processes, continuing education, and a positive work environment.
4. Directly related to superior value and performance and is provided to customers in terms of productivity improvements, reduced operating costs, and outstanding service.

For the rest of this book, *quality* is simply defined as: providing goods and services that meet or exceed customer requirements.

To provide goods and services that meet this definition, the executives of the organization must have a strategic plan to lead the company along this path. The plan should contain both long-term and short-term objectives. The window for long-term objectives should be no more than four years and

preferably three years. The world changes so fast that planning more than four years ahead is not practical. Markets change at almost a constant pace. Customers' requirements do the same.

A long-term strategic plan should consist of four main programs. There should be: (1) a program for futuristic quality planning, (2) a program for service and product improvement, (3) a program for employee involvement and education, and (4) a program for business systems. These programs require a mission statement so that the goals of the program are understood. As with the quality policy statement, the mission statements for these programs should be short and to the point. This gives precise direction to steering committees implementing these programs. Mission statements for the programs I recommend are:

1. *Futuristic quality planning*—Develop and drive business decisions that utilize quality tools and concepts to assure the successful introduction and implementation of new products, processes, and services to our customers.
2. *Service and product improvement*—Develop and implement programs to improve office and manufacturing operations, processes, and systems leading to improvements and consistency in service and products, and reductions in internal waste.
3. *Employee involvement and education*—Utilize the inherent knowledge and expertise of our employees to identify and participate in opportunities for improvement, and provide appropriate education as needed in support of these goals.
4. *Business systems*—Develop and manage the business systems required to assure quality, improve operations, and support our internal and external customers.

These programs require further definition to understand how they are applied to effect continuous improvement.

FUTURISTIC QUALITY PLANNING

Futuristic quality planning is necessary to assure successful applications of new systems, processes, and products. Futuristic quality planning applies equally well to existing processes or products because it perpetuates continuous improvement. This planning program almost always requires the use of cross-functional teams. The core members of this team should consist of people who have the necessary authority to make decisions that support the program. During the course of planning activities, it will often be necessary to recruit employees who have special insight or knowledge of the process being evaluated.

It is best to use a structured approach for this planning process. This will assure consistency of purpose and allow easy inclusion of participants who have had experience on other quality planning teams.

A method I have applied over the years fits the needs of both service and product manufacturing. Both activities require futuristic quality planning to assure efficiency of operations and customer satisfaction. Service/product quality planning (SPQP) is a structured approach that can be applied to any business activity. It does not matter if we are working in a manufacturing or service environment. It does not matter if we are looking to improve office systems or manufacturing processes. The principles are the same: (1) flow chart the process chain for the activity or product; (2) assess the current method and effectiveness of quality control; (3) do a failure mode and effects analysis of high-risk process steps; and (4) develop a control plan to assure quality.

The SPQP process is designed to improve the quality of current services and products. When new services or products are under consideration, another quality tool should be applied to achieve maximum customer satisfaction. This other tool is quality function deployment (QFD). QFD is a very structured and extensive analysis of customer requirements and needs. The study and application of QFD warrants a book of its own and will not be covered in this manual.

We can still develop a strategic plan for customer satisfaction using only the tools contained within SPQP when applied toward new services or products if the customer is permitted to participate. I feel that most readers of this book are more interested in finding methods to improve current services, processes, or products. The study of QFD is recommended for marketing functions and design engineers.

The steps and tools required to prepare an SPQP are as follows:

Phase 1: Flow Chart

There are universal rules to follow when preparing a flow chart. A square box should be used to describe each major process step involved in creating the service or product. Arrows should be used to show the direction each process step takes as the total process evolves. Diamonds should indicate decision points along the process chain. Either inside or adjacent to the diamond is usually a question. Process flow lines (arrows) from the diamond points are used to act upon the answer and lead to the next process step. Other universal symbols are used to reduce the amount of text contained in a flow chart. One example is an inverted triangle to indicate that an evaluation or an inspection must take place at a particular process step.

An example of a flow chart using these symbols is shown in Fig. 2-1. This is a flow chart for heat treating a threaded bolt in a molten salt bath. This flow chart has ten process steps. Each individual process step could be expanded to describe the actions necessary to complete its task, but generally this is not necessary unless that particular step needs to be improved upon. This process has two decision points controlled by the furnace operator. A "yes" answer by the fur-

nace operator allows the process to continue, but a "no" answer requires assistance from quality control.

Phase 2: Flow Chart Analysis

After the process is defined so that each major process step is identified, the next phase is to assess the contribution each step has in reaching the desired end result of the process. In this case, the end result is a bolt (or a processing lot of bolts) meeting all metallurgical and design requirements after the salt heat-treating process.

Let's review the process step LOAD PARTS IN BASKET (see Fig. 2-1). This step requires the furnace operator to verify several facts to assure compliance with meeting all quality requirements of his work order. These quality requirements are the contributions that this step has in satisfying the metallurgical and design requirements for salt heat treating.

The operator has to assure that all paperwork received with the product matches. This includes drawings, manufacturing routings, the heat treat process sheet, the quality assurance control plan, etc. The operator must assure that when the parts are loaded into the basket the parts are positioned so there will be an even transfer of heat during the heat-treating operation. The operator must assure that the parts are positioned to minimize distortion. And the operator must assure that if there are parts from other orders in the same basket, that these parts have weight and mass similar to the parts for the current order. All aspects of this one step, LOAD PARTS IN BASKET, can be evaluated as to its overall effectiveness.

In flow chart analysis, we evaluate each step in a process as to the severity of failing to perform the step correctly, the capability of the process itself to perform the step correctly, and the probability of knowing when the process is not performing as expected. We assign values to the severity, capability, and detection criteria to weigh the results so it is possible to prioritize required actions when the failure mode and effects analysis (FMEA) is prepared. The guideline values for severity, capability, and detection are presented in Tables 2-1, 2-2, and 2-3, respectively.

To see how these guidelines apply, let us continue to work with our example for heat treating. In Step three (see Fig. 2-1), LOAD PARTS IN BASKET, the SPQP team made the following decisions as shown in Table 2-4.

1. For "paper work matches," the team chose a severity rating of 3 because they felt that incorrect information as to material type, for instance, would prevent the product from responding as expected in the high-heat furnace. A capability of 3 was chosen because past experience has been positive with hardly any cases of mixed paperwork. For detection, the team chose "1," because mixed paperwork is very easy to detect when it occurs.
2. For "parts are positioned to assure even heat transfer," a 4 was chosen on severity because failure to satisfy this requirement could result in nonconformance to metallurgical properties. A 3 was chosen for capability because the baskets are designed with a partition that properly spaces the parts for even heat transfer. When it came to detection, the team picked "2" because if the operator put more than one part in a partition it would most likely be detected.

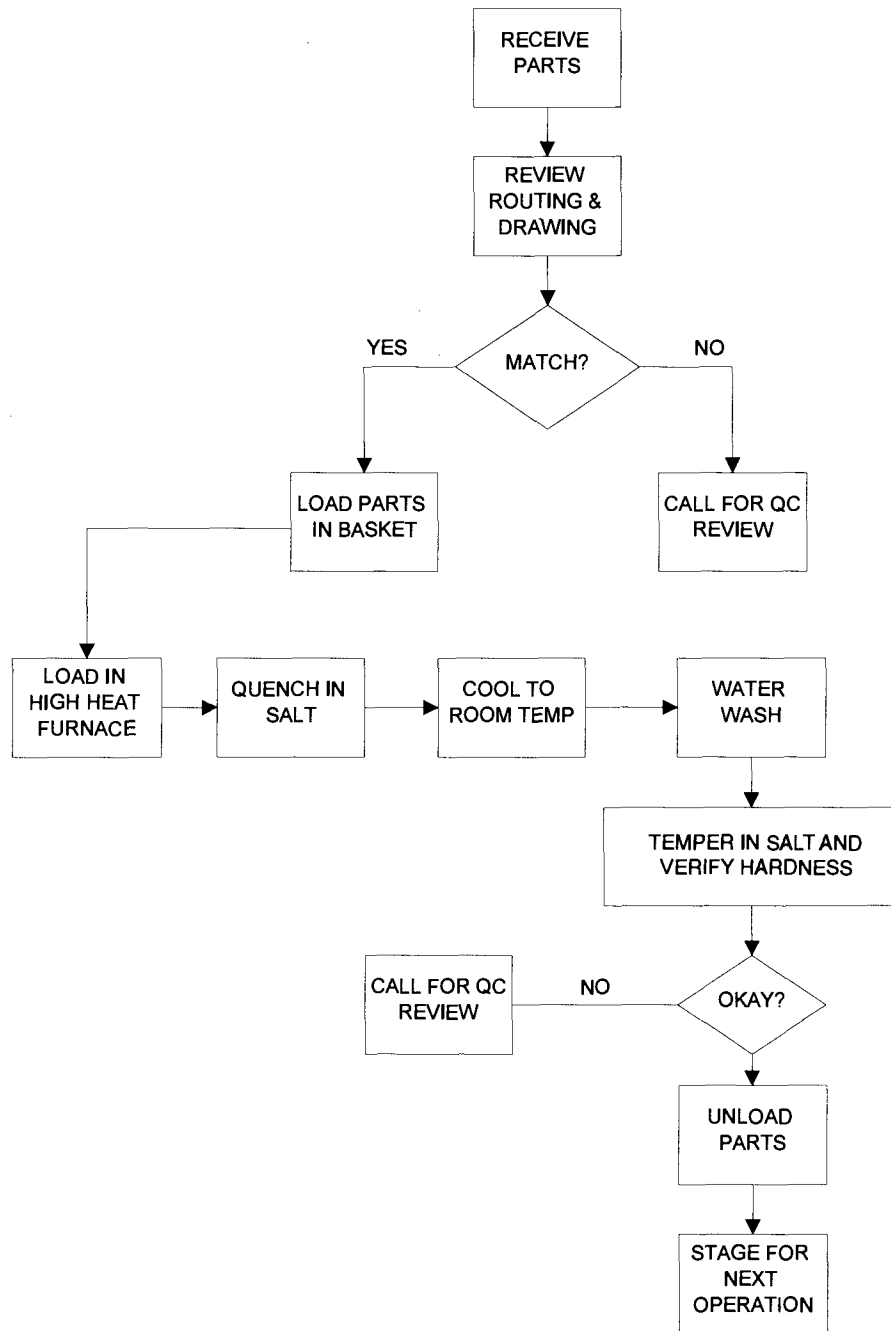


Figure 2-1—Basic salt bath heat treat process flow.

3. For “parts are positioned to minimize distortion,” the team gave a severity rating of 4 because failure to satisfy this requirement could result in a dimensional defect. The capability was 3 because of operator experience with the effects of incorrect positioning. The selection of 2 for detection was assigned because a double check of position prior to moving the parts to the high-heat furnace is performed by another operator.
4. For “parts have similar mass and cross-sectional area,” ratings of 4, 3, and 2 were assigned for severity, capability, and detection, respectively, based upon the quality history and experience of the operators involved.

This process is completed for each step in the process of salt heat treating. The end result is a compilation of values that allow’s management to prioritize the analyses and improvements to be made by the SPQP team. An example of the completed process flow analysis for salt heat treating is provided in Fig. 2-2. In this example, one can see that the SCD values (severity rank times the capability rank times the detection rank equals the SCD value) vary from one step to the other and within each step depending on the controlled characteristic.

Management must decide which controlled characteristics require further evaluation through a FMEA. Companies usu-

TABLE 2-1—Service/product quality plan—severity assessment guidelines.

Severity Assessment	The severity assessment rates the overall importance of each potential product nonconformance to the process and final customer.
5	<i>Safety related characteristic.</i> Failure to satisfy this requirement could result in unexpected and/or catastrophic failure, leading to personal injury or property damage.
4	<i>Critical characteristic.</i> Failure to satisfy this requirement could either result in a significant loss in performance or cause the end user to produce a product that does not conform to his or her customer's requirements or would prevent or significantly hamper a following operation from performing its function.
3	<i>Functional characteristic.</i> Failure to satisfy this requirement could prevent the product from being assembled and used as intended, lead to more variability in performance than is normally anticipated, could be perceived as poor quality by the final customer, or a subsequent operation would have some difficulty in its process due to the nonconformance.
2	<i>Nonfunctional characteristic.</i> Failure to satisfy this requirement will not have any appreciable impact on performance. Most cosmetic requirements shall be considered nonfunctional characteristics unless there is a history of customer complaints. Cosmetic requirements that have resulted in complaints will be considered a functional characteristic. Subsequent operations would see no appreciable difference in performance.
1	<i>Process characteristic.</i> Failure to satisfy this requirement has no impact on the finished product or the manufacturing process.

TABLE 2-2—Service/product quality plan—capability assessment guidelines.

Capability Assessment	For Manufacturing Processes with Documented Process Capability Data	For Manufacturing Processes Without Documented Process Capability Data
1	$Cpk > 2.0$	N/A
2	$1.67 < Cpk < 2.0$ or $Ppk < 2.0$	N/A
3	$1.33 < Cpk < 1.67$ or $1.67 < PPK < 2.0$	Although documented process capability data are not available, past experience with this process on similar products has been very positive.
4	$1.00 < Cpk < 1.33$ or $1.33 < Ppk < 1.67$	Very few known problems have occurred when using this process on similar products in the past.
5	$Cpk < 1.0$	This process has been known to be a source of scrap and/or discrepant material when used on similar products or there are no historical data for this process.

NOTE: This assessment uses the formula $\min \left[\frac{\bar{x} - LSL}{3\sigma}, \frac{USL - \bar{x}}{3\sigma} \right]$ for both Cpk and Ppk .

TABLE 2-3—Service/product quality plan—detection assessment guidelines.

Detection Assessment	The detection assessment rates the probability that the current inspection and SPC system will find a nonconformance should it occur.
1	A nonconformance will almost always be detected. Either the process automatically detects a failure or a high capability has been established and SPC is appropriate, understood, and used to run the process.
2	There is a good chance of detecting a nonconformance. SPC is generally understood and usually reacted to in a capable process, or some form of 100% inspection is used.
3	The current system may detect a failure. SPC is in place, but not fully understood and or reacted to, or sample inspections are done throughout the run.
4	A nonconformance will probably not be detected. Control charts are done incorrectly or are incomplete, or inspections are limited, such as setup only.
5	There is absolute certainty that a nonconformance will not be detected. No inspection is done.

NOTE: "Detection" must take place before reaching the next applicable process/customer. Inspection by the next process or final inspection is not appropriate in determining this rating.

TABLE 2-4—Load parts in basket.

Process Step	Controlled Characteristic	SCD	Severity	Capability	Detection
Load parts in basket	Paper work matches	9	3	3	1
	Parts are positioned to assure even heat transfer	24	4	3	2
	Parts are positioned to minimize distortion	24	4	3	2
	Parts have similar mass and cross-sectional area	24	4	3	2

ally do not have unlimited resources and must limit the number of projects through the use of Pareto analysis.

Before going further, I feel it beneficial to provide definitions of *Pareto analysis* and *Pareto chart*.

Pareto analysis: Analyses of the frequency of events described on a Pareto chart that contribute to an outcome. In the quality profession, outcomes could be rejects, scrap, and other contributors to cost of quality such as incorrect invoices, purchase orders, missing information, etc.

Pareto chart: A simple statistical tool that ranks contributing factors to an outcome according to either cost or frequency of occurrence. This allows for easy prioritization of contributing factors for analysis, thereby keeping cost of analysis low by focusing on the *vital few* and temporarily not analyzing the *trivial many*.

In our example, management decided to perform a FMEA on all controlled characteristics that had an SCD value that exceeded 50. The candidates for FMEAs are shown in Table 2-5. In general, management would also consider any controlled characteristic that had a 5 for either capability or detection regardless of the SCD's value rank.

Phase 3: FMEA

The FMEA is a document designed to accept change. It acts as a futuristic planning tool by identifying potential causes of failure that should be considered in the development of control plans. As new controls are implemented, the FMEA is revisited and revised to reflect new process capabilities. FMEAs can be developed for processes or products. In our example, we are creating a Process FMEA for the salt heat treating process. A FMEA is an analytical technique utilized to assure to the best of its ability that all potential concerns (failures) are identified and addressed through some control mechanism. The group best suited to develop a FMEA is manufacturing engineering or a similar group or individual that understands the process (manufacturing or service). The Process FMEA identifies failure modes, explores the effects of the failure on customers, determines the potential causes of those failures, looks at current controls to avoid or identify the failure, and suggests actions to improve control.

The team assigned to complete the FMEA should consist of those close to the process being evaluated. As mentioned earlier, for a manufacturing operation such as heat treating, the best person to lead the team is a manufacturing engineer. For our example, other potential members are the plant metallurgist, laboratory technician, furnace operator, and super-

visor of the heat treat department. An example of the FMEA format is shown in Fig. 2-3.

Let's work through an example of completing a FMEA. Each column contains information that leads to information/action for the subsequent column. Our team came up with the FMEA shown in Fig. 2-4 for Process Step 4: High Heat Furnace. The following logic is applied to fill the columns with information:

Process

In this column, list the process step that creates the controlled characteristic under analysis. For our example, the first entry in this column is High Heat Furnace. This process step is the first process step of the process flow analysis that had an SCD value that exceeded 50. To complete the FMEA, following in order, the next entries from Table 2-5 would be Cool, Temper, and Hardness Test.

Controlled Characteristics/Fail Mode

In this column, list the controlled characteristic and the anticipated failure mode. For the process step, High Heat Furnace, the controlled characteristic is Part Microstructure. The potential failure modes are: incorrect atmosphere, incorrect furnace temperature, and incorrect time at temperature.

Effects

In this column, list the effect the failure mode would have on the controlled characteristic. In the case of our example, all failure modes identified would cause the wrong microstructure, leading to product failure at a subsequent operation or in product application.

Likely Causes

At this juncture, we examine the likely cause(s) of the identified failure modes. The likely cause of incorrect atmosphere is contaminated salt. The likely cause for incorrect temperature is a defective furnace thermocouple. The likely cause of incorrect time at temperature is an incorrect setting of the furnace timer.

Current Control Methods

In this column, list the present method of controlling the likely cause(s) of the failure mode(s). In our example, the furnace salt is evaluated every six months by the chemical company that supplies the salt. The maintenance department changes the furnace thermocouples every two weeks. The removed thermocouples are returned to the thermocouple supplier to be calibrated and rebuilt as required for future

SERVICE / PRODUCT QUALITY PLAN

Phase I - Process Flow Analysis

Product Line: Salt Bath Heat Treat

Manufacturing Location: ABC Company

Original Issue Date: January 1994

Approved By: _____

Process Flow Diagram
1) Receive Parts
2) Review Routings and Drawings
3) Load Parts Into Rack or on Wire and Match Paperwork.
4) High Heat Furnace
5) Quench
6) Cool
7) Water Wash
8) Temper
9) Clean
10) Hardness Test
11) Unload Parts From Rack or Wire and Match Paperwork.
12) Stage For Subsequent Operations, Black Oxide or Further Processing.

Controlled Characteristics
1) Parts are ready for Heat Treat.
2) Parts match metallurgical requirements of the routing and drawing.
3) - Paperwork for each load match. - Parts are positioned to ensure even heat transfer - Parts are positioned to minimize distortion. - Parts have similar mass and cross sectional area.
4) Part microstructure
5) Part hardness Part microstructure.
6) Part microstructure.
7) Parts free of salt.
8) Part hardness Part microstructure.
9) Parts free of Heat Treat scale. Parts free of Heat Treat salts.
10) Meet part hardness requirement.
11) Parts are free from: - Damage - Distortion - Cracks - Salt - Paperwork matches parts in individual orders.
12) Parts are as represented.

Original			
S	C	D	S
e	a	e	C
v	p	t	D
e	a	e	C
r	p	t	D
i	a	t	D
t	b	i	D
y	i	t	D

Revised (9/30/93)			
S	C	D	S
e	a	e	C
v	p	t	D
e	a	e	C
r	p	t	D
i	a	t	D
t	b	i	D
y	i	t	D

---	---	---	---	4	3	1	12
---	---	---	---	---	---	---	---
4	3	4	48	5	3	2	30
---	---	---	---	---	---	---	---
3	3	1	9	3	3	1	9
3	3	3	27	4	3	2	24
4	3	4	48	4	3	2	24
3	3	3	27	4	3	2	24
---	---	---	---	---	---	---	---
---	---	---	---	5	3	5	75
---	---	---	---	3	3	5	45
---	---	---	---	5	3	5	75
---	---	---	---	---	---	---	---
2	3	1	6	3	4	2	24
---	---	---	---	---	---	---	---
---	---	---	---	5	5	3	75
---	---	---	---	5	3	5	75
---	---	---	---	---	---	---	---
2	3	2	12	3	3	1	9
---	---	---	---	---	---	---	---
---	---	---	---	3	4	2	24
---	---	---	---	---	---	---	---
4	3	2	24	5	5	3	75
---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---
---	---	---	---	3	3	2	18
---	---	---	---	3	4	4	48
---	---	---	---	5	3	3	45
---	---	---	---	3	4	2	24
---	---	---	---	4	3	1	12
---	---	---	---	---	---	---	---
---	---	---	---	3	3	1	9
---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---

(Salt-H1A)

Figure 2-2— Process flow analysis.

TABLE 2-5—Salt Bath Heat Treat Phase 1 Results: operations in the process that exceed 50 in the SCD rating.

Operation	Characteristic	SCD Rating
Step 4: High heat furnace	Part microstructure	75
Step 6: Cool	Part microstructure	75
Step 8: Temper	Part hardness	75
	Part microstructure	75
Step 10: Hardness test	Meet part hardness requirement	75

use. The furnace operators monitor the time at heat as indicated on the electronic furnace controller.

Responsibility (Resp. and Date)

In this column, list the person(s) held accountable for applying the current controls. For our example, the heat treat supervisor is held accountable for having the furnace salts evaluated every six months, the maintenance department is accountable for changing the furnace thermocouples every two weeks, and the furnace operators are accountable for monitoring the time at heat.

Recommended Actions

This column is used when the team identifies an opportunity for improvement on one of the current methods of control. In our example, the team felt that the six-week interval was too arbitrary and not based on historical data. This meant that during some six-month periods, the salt bath was out of control or specification and not known except by sporadic metallurgical failures. So the team decided to apply statistical process control (SPC) to the salt bath analysis. A program was established to analyze the bath every week and chart the main variables of the bath on an individual's chart. The bath could then be rejuvenated/replaced based on out-of-control data. In the long run the team felt that money could be saved using this approach by eliminating metallurgical rejections necessitating rework or scrap. The chemical supplier was providing the bath analysis free of charge and was more than happy to acquire statistical data on the life cycle of his chemicals for marketing purposes.

Date

In this column list the name of the individual responsible for the recommended action(s) and the date the action(s) are expected to be implemented or completed.

All FMEAs should be put on a review program to evaluate and ascertain the currentness of the document. One of the better methods is to put document numbers on the SPQP and add them to the company calibration software system. This way, a one year "calibration" cycle can be programmed, and the review process cannot be overlooked. The review does not require a team; all that is required is that the individual making the review be knowledgeable of the process under review. The individual can always solicit, as necessary, the council of others in the organization for expert or specific assistance.

Phase 4: Control Plan

The final phase of an SPQP is the development of a control plan. As with the FMEA, a control plan can be designed for

a process or for a product. The decision to make a process or product control plan is usually decided by the type of organization. An organization that provides a service, such as a machine shop manufacturing components for a larger manufacturer or a company that provides office cleaning services, would most likely employ a product control plan so that they are confident of satisfying all their customers' unique requirements. On the other hand, a manufacturer of standard ASTM A325M¹ structural bolts or a bank clearing customer checks would find the process control plan more apropos. In either case, the control plan format is the same and is shown in Fig. 2-5.

The control plan, as the FMEA, is divided into columns with headings to provide a natural sequence of events enabling users of the control plan a concise and clear guide for controlling the quality of the process or product. We will now work our way through a process control plan for heat treating an ASTM A325M structural bolt with a salt-bath furnace.

Process Point Control

This column contains the same information in the same sequence as the like column in the process flow analysis for the salt heat treat process. It is a listing of all steps required in the process of heat treating via this method in the exact order the steps are performed.

Controlled Characteristic

This column contains the same information in the same sequence as the like column in the process flow analysis for the salt heat treat process. All characteristics controlled at the process step in the same row must be listed in this column.

Control Methods/Sample Plan

In this column the method of controlling the characteristic along with the specified sampling method is detailed. Several methods of control are available including first article verification, in-process inspection to a sample plan based on lot size or production rate/hour, statistical process control, and 100% inspection. The method of control is based upon the capability of the process step to maintain design criteria.

Method of Evaluation

In this column we describe the process, equipment, or instrumentation used to evaluate each controlled characteristic. Methods may include visual inspection with or without a microscope, a metallograph, a pair of dial calipers, a scanning electron microscope (SEM), a hardness testing machine, etc. Of importance here is the requirement that for whatever method of evaluation we employ, an evaluation of the repeatability and reproducibility of that method be determined. One method of conducting an evaluation of the repeatability and reproducibility of an evaluation method is described in ASTM Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Nondestructive Testing (F 1469).

¹Specification for High-Strength Bolts for Structural Steel Joints [Metric].

SERVICE/PRODUCT QUALITY PLAN

Phase II - Failure Mode and Effects Analysis

Pg ___ of ___

Current Revision/Date: _____
 Approved By: _____

Product Line: _____
 Manufacturing Location: _____
 Original Issue Date: _____

Process	Controlled Characteristics/Fail Mode	Effects	Likely Causes	Current Control Methods	Resp. and Date	Recommended Actions	Date

Figure 2-3—Failure mode and effects analysis.

Phase II - Failure Mode and Effects Analysis

Pg 1 of 3

SERVICE/PRODUCT QUALITY PLAN

Product Line: Salt Heat Treat
 Manufacturing Location: ABC Company
 Original Issue Date: January 20, 1994
 Current Revision/Date: _____
 Approved By: _____

Process	Controlled Characteristics/Fail Mode	Effects	Likely Causes	Current Control Methods	Resp. and Date	Recommended Actions	Date
High Heat Furnace	Part Microstructure 1) Atmosphere Wrong 2) Temperature Wrong 3) Time Wrong	Wrong Microstructure Leading to potential product failure	1) Salt contaminated 2) Wrong control settings 3) Thermocouples defective.	1) Salt evaluated every 6 mths. 2) Operator monitors temp. & time on controller instruments for each furnace. 3) Thermocouples are changed every 2 weeks.	Supervisor Operator Maintenance	1) Evaluate salt analysis to determine optimum frequency of evaluation. Use control chart method take data weekly.	Supervisor Begin 02/14/94

Figure 2-4—Failure mode and effects analysis.

SERVICE/PRODUCT QUALITY PLAN

Phase III - Control Plan

Pg ___ of ___

Product Line: _____

Date: _____

Manufacturing Location: _____

Process Point Control	Controlled Character.	Control Methods/Sample Plan	Method of Evaluation	Resp.	Reaction of Plan to Out of Control or Specifications.

Figure 2-5—Control plan.

SERVICE/PRODUCT QUALITY PLAN

Phase III - Control Plan

Pg ___ of ___

Product Line: _____

Date: _____

Manufacturing Location: _____

Process Point Control	Controlled Character.	Control Methods/Sample Plan	Method of Evaluation	Resp.	Reaction of Plan to Out of Control Specifications.
Temper	Part Hardness Part Microstructure	x + R Chart, 5 pieces per furnace load per order. 1 coupon per shift/furnace/material grade is submitted to the metallurgical laboratory for analysis.	Newage Digital Hardness Machine. metallograph	Furnace Op. Laboratory Technicians	Implement Procedure QA 017 All parts processed after the last acceptable micro must be held for metallurgical evaluation. Any product found out of compliance is handled in accordance with procedure QA 017 and QA 018.

Figure 2-6—Control plan.

Responsibility

In this column, list the person(s) or department held accountable for evaluating the controlled characteristic. In the case of persons, avoid the use of personal names; instead, refer to the job title. This practice allows wider use of the control plan and eliminates the need for revisions when an individual is no longer performing the task detailed in the plan.

Reaction of Plan to Out of Control or Specifications

In this column we specify what to do if during the course of evaluation we find the characteristic either out of control or out of specification. This is an important consideration, and the team developing the control plan should be very specific so the person/department making the evaluation has clear instructions on how to handle the situation.

Failure to properly handle an out-of-control or out-of-specification characteristic could result in allowing the situation to continue or even permit a defective product to reach the customer. It is recommended that the team refer to standard operating procedures that describe in detail how to deal with these situations. Any referenced procedure should be available and completely understood by the individual/department that must act upon the problem.

A partially completed process control plan is shown in Fig. 2-6. So that we know how it is constructed, we will go through the process step, Temper.

The columns entitled Process Point Control and Controlled Character in the Phase III Control Plan shown in Fig. 2-6 list the process step and the controlled characteristics, respectively, for the temper operation. Two characteristics are affected by the temper operation: one is "part hardness," and the other is "part microstructure." A separate line is used for each of these characteristics.

In the Control Methods/Sample Plan column adjacent to Part Hardness, the team put the phrase "X & R Chart, 5 pieces per furnace per order." This lets the furnace operator or anyone viewing the control plan know the statistical process control is to be applied to this characteristic at this process step. It also specifies the type of chart and the frequency and size of subgroup sampling.

In the Method of Evaluation column, the team inserted the name of the instrument required to check part hardness, in this case, a Newage digital hardness machine.

In the column entitled Responsibility, the team inserted the job title, Furnace Operator. In all cases, when assigning

accountability for action, name the individual performing the task. With this directive comes responsibility from management. Management must assure that the person understands what is required and is properly trained to perform the task.

The column entitled Reaction of Plan to Out-of-Control Specification must provide enough information for the person named for responsibility to take appropriate action. In this case, the team chose to reference a procedure that details how to deal with nonconforming material.

The controlled characteristic, part microstructure, is addressed in similar manner. However, due to the time and cost involved in preparing metallurgical micromounts, the team decided to check this characteristic only once per shift/furnace/material grade. This action was made possible because the team earlier initiated more frequent check analyses of the salt bath when an opportunity for improvement was taken on the FMEA.

Although the SPQP program is very powerful, it does require a great deal of effort and resources to apply. This downside, however, is nothing compared to the business consequences of failing to plan for quality. Futuristic quality planning pays high dividends in terms of reduced scrap and rework. Other benefits include more satisfied customers both in terms of the sheer number of customers and in the degree to which your customers are satisfied. This alone should be enough incentive for the top executives of an organization to fully support such a program.

Once the full support of top management is acquired, the staff management should review their operations and make recommendations for application of the SPQP process. It is best to choose a process or product fairly well understood by all involved in the process flow and one that shows promise for improvement. By starting with a process or product that is going to show success, confidence in the program is instilled in those who participate and in those who are on the sidelines watching to see how it goes. After two or three successes, you will find a grass roots movement by others to apply this new technique to their own areas of responsibility.

The other three programs mentioned earlier in this chapter are best covered under *continuous improvement*, the topic of Chapter 3. In Chapter 3, we will discuss critical performance indicators (CPIs), and the plan, initiate, evaluate (PIE) processes for continuous improvement. These two programs include strategic methods for service and product improvement, employee involvement and education, and business systems.

Continuous Improvement

IN THE FIRST CHAPTER we discussed management's role in providing the leadership necessary for the company to meet its business objectives. One business objective of primary importance is *continuous improvement*. If a company is dedicated to continuous improvement, it will constantly improve its internal performance, customer service, and quality. Such improvement automatically strengthens the company's competitive position and its ability to respond to customer needs.

Continuous improvement begins with an understanding of where you are and where you want to be. Everyone wants to be the best in their field; however, our ambitions should be realistic and in line with our resources. Goals should be obtainable while providing enough challenge to allow employees the opportunity to extend their current abilities.

While moving along the path of continuous improvement, keep in mind that the journey never ends! The present is now and the future is only the next step along the way. You cannot stop because, if you do, someone will pass you by. There is a saying from the Great North: "If you're not the lead dog, the scenery never changes." This saying applies to a company's journey along the path of continuous improvement. If you're not the leader in your industry, you won't see future opportunities until your competitor has passed that point, leaving only the spoils for you.

So, where do we begin to move along this path of continuous improvement? Like any journey, we have to determine where we are and where we want to go. Most companies have a pretty good idea of where they are through historical data that provide a measure of how well they are meeting the needs of their customers. These data include ratings on customer quality system surveys, customer returns, the number of service requests, employee absentee rates, efficiency ratios, the ratio of quotes accepted to those given, employee turnover, customer certification awards, cost of quality, JIT delivery performance, lost time injuries, and hundreds, even thousands more.

The data include information from internal as well as external customers. The two cannot be separated, as both contribute to the strength of the company. In the first chapter, we talked about utilizing surveys to assess the current pulse of the company. This is a good place to begin.

Top management should form a steering committee to evaluate all the summary information available from the data acquired from this historical data mentioned earlier. From that information, intelligent questions can be formed to ask employees, customers, and suppliers in the form of a survey. The purpose of this survey is to discover your strengths and weaknesses.

Analysis of the survey results should identify the critical performance indicators (CPIs) that drive your organization. If you recall, we earlier defined CPIs as those measures that contribute to customer (internal and external) satisfaction. It may not be surprising to find such factors as on-time delivery and cost of quality among the concerns of your customers and employees.

Once you have identified your CPIs, you need to know how to track and measure these indicators so that you may find out whether your efforts toward continuous improvement are effective. This requires a structured and systematic approach and a few tools of statistics.

Structured and systematic means that procedures are established to assure that everyone knows what is expected and that they do things the same way. It is important that everyone work with the same set of data and that these data be factual. The statistical tools are basic problem-solving techniques employing the use of brainstorming, flow chart analysis, and cause and effect analysis. These are simple yet powerful techniques that anyone can apply. A more detailed study of these techniques is discussed in Chapter 7, Statistical Quality Control.

The next step is to flow chart the process that affects the CPI. An example of a flow chart was presented in Chapter 1, Fig. 1-3. A flow chart is simple to construct and can be done by the employees who do the processes that lead to the final output of that process. For example, let's say that one of our company CPIs was to ship the customer order on time. If we examine the processes (steps) that affect shipping the customer's order on time, we may find, depending on the size of the organization, that as many as 30 processes contribute to that CPI. For the sake of simplicity, let's cut the number of processes to a more manageable level for this example.

The first step is to assemble representatives from each department that have an influence on shipping the customer's order on time. In our fictional company, these representatives will come from the customer service, design engineering, manufacturing engineering, production control, purchasing, manufacturing, quality, and the shipping departments. The entire process is represented in Fig. 3-1.

Each of the steps in this Ship Customer Order On Time flow chart has flow charts of its own. For instance, the last step, Shipping Packs & Ships Order, requires several steps before the customer order is actually shipped out the door. Documents must be assembled, packing and shipping instructions read, boxes selected and assembled, labels prepared, the product containerized, and the method of transportation scheduled.

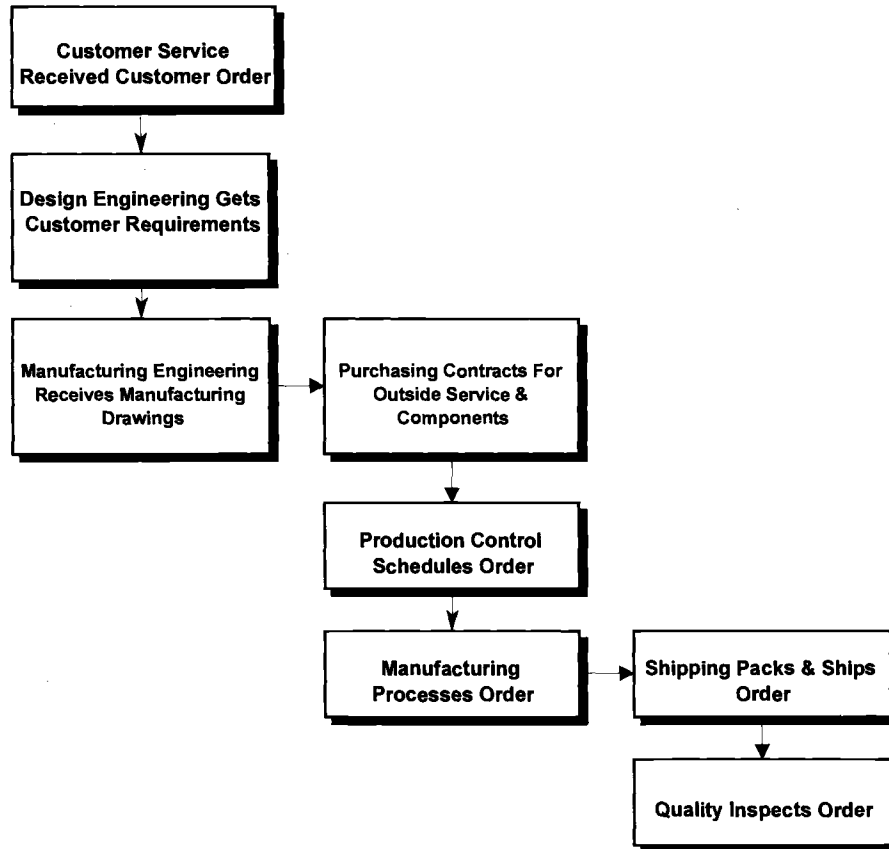


Figure 3-1—Flow chart for processing a customer order.

Every step requires time and employee input. Does each step contribute value to the product and is each step necessary? These basic questions must be answered by everyone along the process chain. If a step is required, the next questions center around the overall efficiency of that step. Throughout this analysis, the collection and evaluation of data should be observed by the employee team from the process. Some of the best methods of presenting data are the simplest. The run chart is very effective in tracking progress over time (Fig. 3-2).

The on time shipment chart in Fig. 3-2 shows improvement over a twelve-month period. The chart could very well have shown a downward or even a random pattern. It is important to know when to react to trends on run charts. It is a mistake to assign cause every time the chart makes a move in either the positive or negative direction. Normal forces of variation are ever present, and until a process is in control and control limits are calculated via statistical calculations of control chart data, reaction to movement should be with caution. More on control charts will be discussed in Chapter 7.

Through analysis of data collected, opportunities for improvement will become evident. Management must determine which opportunities to work toward first. These decisions are usually based upon cost effectiveness, quality improvement, or criticality of correcting an undesirable condition. Whatever the reasons for choosing a particular op-

portunity as a project for improvement, the process is the same.

The improvement process has been defined by more than one quality guru as the *plan, act, measure, and evaluate cycle*. I call the process PIE (plan, initiate, evaluate) (Fig. 3-3).

PLAN

The most important part of a project is the planning phase; this is certainly true for continuous improvement projects. The better the plan, the better the implementation and the results. When developing a plan, the team needs to consider all action steps in the process expected to lead to the improvement desired. Once all action steps are identified, the next step is to decide the sequence in which these steps should be implemented. After the sequence is determined, the time allotted to complete each step is calculated, and responsibility for each step is assigned.

This planning process can work only if a few basic guidelines are applied during this phase.

Planning Guidelines

- Obtain upper management commitment through sponsorship.
- Form the right combination for the team.

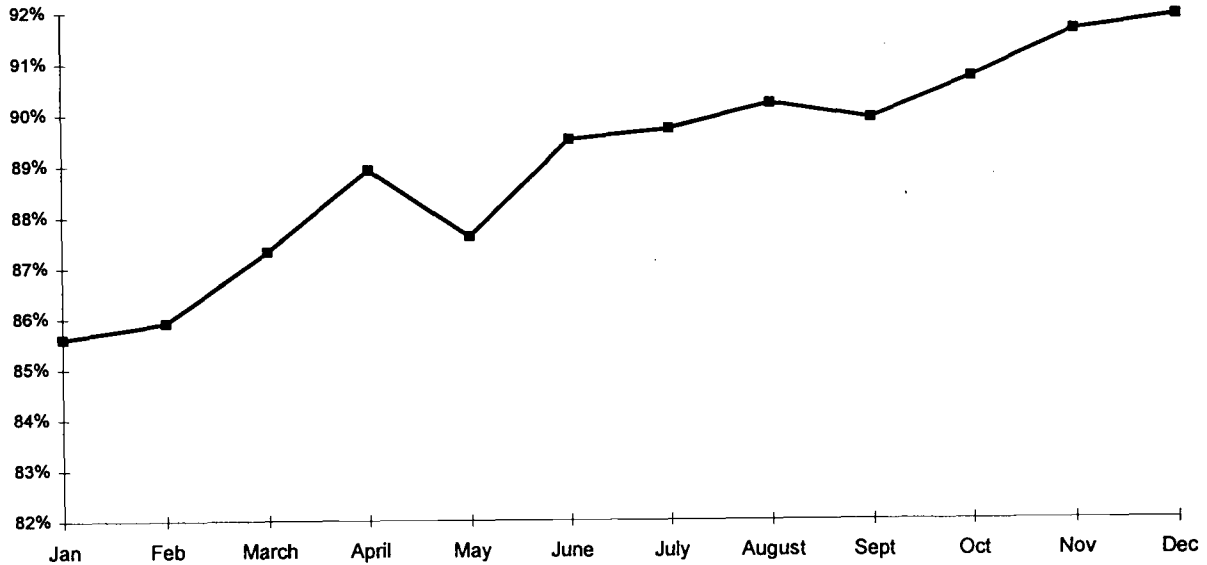


Figure 3-2—On-time-shipments trend chart.

- Develop a vision and a policy statement for the team.
- Develop objectives and guidelines.
- Review current programs and projects.

A closer study of each of these planning rules will make your planning easier.

Obtain Upper Management Commitment Through Sponsorship

Whenever a project is being considered, it is wise, indeed imperative, that the most senior member of the organization be firmly established as sponsor of that project. The project needs his endorsement and the understanding that his door is always open to discuss progress on the project.

Form the Team

This phase of planning should not be taken lightly. Picking names and then throwing these individuals together in a room does not create a team. Each function involved in the project should be represented, and these representatives should have a good working knowledge of the area they represent.

They must possess attributes that foster teamwork. These attributes include honesty, good communication skills, dependability, leadership, empathy, and a willingness to work with others and share.

Develop a Vision and a Policy Statement

The team needs to know when they have achieved their objective. The vision is where the organization wishes to be when all phases of the program are implemented and successful. The vision statement should be concise and easy to understand. It should be measurable and should fit with the organization's business policy. It becomes a policy statement when endorsed and signed by the senior manager at the facility.

Develop Objectives and Guidelines

The team must be provided with the objectives of their project and the guidelines to be followed to achieve those objectives. For instance, an objective may be to reduce the lead time in turning around a "request for quote" to a customer. A guideline (or restriction) may be that we are only interested at this point in reducing in-house lead time. We wish to tackle the outside sales and marketing function at another time.

Review Current Programs and Projects

After the team has been formed and several meetings have been held describing the project and its vision statement, policy statement, objectives, and guidelines, the team should thoroughly review the project. The objective of this review is to determine if the team has everything at their disposal to initiate the project and to successfully achieve the vision. A list of needs should be prepared and submitted to the senior manager for his consideration and action.

The two previous examples provide a good starting point for describing how we can work with CPIs and the PIE method to achieve continuous improvement. Management provides the resources for service and product improvement,

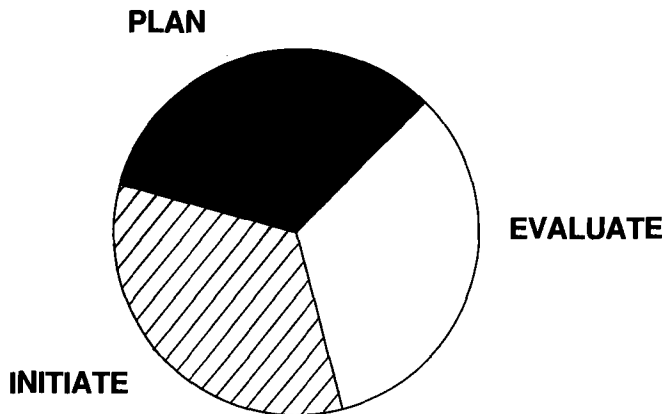


Figure 3-3—PIE.

employee involvement and education, and business systems, discussed in Chapter 2, to gain the fullest benefits of these terms as follows:

SERVICE AND PRODUCT IMPROVEMENT

Service and product improvement comes from initiating new programs or techniques and monitoring the CPIs associated with the process undergoing change. Advantages of service and product improvement are many and varied as shown below:

- Reduced scrap.
- Less rework.
- Improved capacity.
- Fewer returned goods.
- Less service calls.
- Improved earnings through lower cost of quality.
- Improved earnings through more efficient operations.
- Satisfied customers.
- Satisfied employees.
- Gaining a competitive advantage over your competition.

REASONS FOR EMPLOYEE INVOLVEMENT

Employee involvement and education is one of the main ingredients in creating continuous improvement and cannot be avoided when using the PIE methodology. The reasons for gaining employee involvement are described below:

- To bring, to the fullest extent possible, common values and procedures to the workplace.
- To produce the lowest-cost, highest-quality products and services for world markets and meet customer expectations.
- To put employees in the decision process to:
 - Provide capable systems and manufacturing processes.
 - Provide clear expectations in terms of operations and quality.
- Provide a means to measure progress.
- Provide a means to correct any situation not meeting expectations.
- Provide the environment for all employees to work together toward the accomplishment of organizational goals.
- To strive to achieve "total" commitment to quality and productivity by all employees.
- To have an action plan developed through representation of all employees.
- To desire all employees to have ownership of the process of continuous improvement and an understanding and commitment to the organization's goals.
- To have total commitment to customer service, whoever that customer may be.
- To create an interesting, challenging, enjoyable, and safe work environment.
- To develop a system of communication and feedback to solve organizational problems and to keep employees informed by:
 - Intra/inter department communications.
 - Management-level communications.

- Employee-to-employee communications.
- Horizontal and vertical.
- External and internal.
- To have sufficient knowledge of company operations, customer needs, and individual job responsibilities.
- For all employees to have a better or complete knowledge of the working part of the company's product or service to be a better judge of acceptable quality.

It is difficult to dispute the advantages employee involvement brings to an organization, yet many company executives still feel threatened by employees who "know too much." The truth of the matter is that the more employees know about their business contribution, the better they are able to contribute to the overall success of the organization.

New business systems are created and existing ones refined through the CPI and PIE programs. There has never been a business system that worked perfectly the first time, but how many times have you heard somebody say, "But we always did it like that!" Why are some people so afraid to change the way things are done? The answer lies in the company's management style. A management philosophy should embrace W. Edwards Deming's 14 Points of Management Obligations.¹ His 14 management obligations are paraphrased below:

1. Create constancy of purpose toward improvement of product and service with the aim to become competitive, stay in business and provide jobs.
2. Adopt the philosophy: We are in a new economic age created by global competition. A transformation of management style is necessary to halt the continued decline of industry.
3. Cease depending 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 alone. Purchasing must be combined with design of product, manufacturing, and sales when dealing with chosen suppliers. The aim is to minimize total cost, not just initial cost.
5. Improve constantly and forever every activity in the company to improve quality and productivity and thus constantly decrease costs.
6. Institute training and education on the job for everyone, including management.
7. Institute supervision. The aim of supervision should be to help people and machines do a better job.
8. Drive out fear so that everyone may work effectively for the company.
9. Break down barriers between departments. People in the research, design, sales, and production departments must work as a team to tackle usage and production problems encountered with the product or service.
10. Eliminate slogans, exhortations, and targets for the work force that ask for zero defects and new levels of productivity. Such exhortations only create adversarial relationships; the bulk of the causes of low quality and

¹"Out of the Crisis," Massachusetts Institute of Technology, Center for Advanced Engineering Studies, 1986.

low productivity belong to the system and lie beyond the power of the work force.

11. Eliminate work standards that prescribe numerical quotas for the day. Substitute aids and helpful supervision. (Such aids would be CPIs.)
- 12a. Remove the barriers that rob hourly workers of their right to pride of workmanship. The responsibility of supervisors is to change the goal from sheer numbers to quality of the product or service.
- 12b. Remove the barriers that rob people in management and in engineering of their right to pride of workmanship. This means, among other changes, abolition of the annual or merit rating and of management by objective.
13. Institute a vigorous program of education and retraining. New skills are required for changes in techniques, materials, and service.
14. Put everybody in the company to work in teams to accomplish the transformation.

Let's work through an example of how CPIs can be used to bring about awareness and thus improvement. Let's take another look at the run chart we created for on time shipments.

Our management team has decided that our on time shipment performance may not continue to improve unless a greater emphasis is placed on that goal. At a meeting that included all staff management, a decision was made to create an employee team to study and find ways to improve our on time shipment performance. A representative from the management team was selected to serve on this employee team as a facilitator. The management team also set objectives for the employee team. Among these were an overall improvement of on time shipments to 96%. The management team felt that, with a concerted effort by the employees and with full support of management, this goal was obtainable. During the last quarter, the company achieved an average of 91.4%, and the last two months nearly 92%. During the last twelve months, each month was an improvement over the previous month's performance with only two exceptions.

The goal of 96% represents a 5% improvement over the last quarter results. A 5% improvement can be significant or insignificant. It all depends on the time block during which management wishes this goal to be reached and on the level of difficulty of change to reach each milestone. As discussed earlier, by the time management has come up with the vision, most obstacles have been thought out and addressed, making it possible to reach that vision through the talent pool that makes up the improvement team. For our example, let's say the vision is to reach a level of 96% on time shipment in six months. The vision has been approved, and the general manager has affixed her signature to the vision statement securing her support and making it management policy.

With our team in place and the objectives and guidelines understood, responsibilities are established to carry out the project. It is important to point out that the team was made aware that, even though the goal is to improve on time shipments, there is a broader objective—to improve on time performance in each process step along the process chain from receiving the order from the customer to shipping the order out the door.

Even with this expanded objective, you can see that management put in some guidelines or restrictions. For this project, we are not concerned with the process chain between the customer's request for quote and the moment the customer receives our quote. Management, at this time, is also not interested in the process from the time the order leaves the facility to the time it reaches the customer's dock. These two process chains certainly contribute significant time to the overall process, but there is little this facility can do to influence these process steps, with the possible exception of design engineering the concept. Let's go back to the flow chart shown in Fig. 3-1 for processing a customer order.

The team formed to improve upon this process consists of talented employees from each of the departments represented in the process chain. Working together, they conclude that each department in the chain needs to track the amount of time an order spends in their area. This may differ for different departments. For example, the time spent in the quality department can be measured in hours, whereas the time spent in the manufacturing department should be measured in days. Also, it is clear that some departments require further breakdown in their contribution. For instance, in manufacturing there are possibly several cost centers that make up the entire department. In manufacturing an ASTM A325M² fastener, for instance, we could have wire annealing, wire draw, boltmaker, heat treat, and hot dip galvanizing all contributing time to the process. And let's not forget the queue time between operations; sometimes these delays take more time than value-added steps. Even these subprocesses need steps of their own to make them effective. Let's look at the boltmaker step in manufacturing the ASTM A325M fastener. Steps in this process may include gathering process drawings, tooling, and inspection gauging. All aspects of the process are under investigation when our task is to improve our on time shipment CPI.

At this point it is usually important to have each team member construct a detailed flow chart of their department's process. They may wish to enlist help from their department and form an ad hoc team to give a full evaluation of each process step performed in their department. They would be the ones closest to the action and should know the ins and outs of their operations better than anyone. The ad hoc team would try to identify opportunities for improvement and eliminate redundant or unnecessary steps. After a new section of the process is selected for evaluation, a CPI can be chosen and data collected and tracked. As a change is made to the process, it can be determined if that change has an effect by seeing a shift in the CPI.

Let's take a closer look at this example. Assume the team for the boltmaker department decided they would track how long it took the boltmaker operator to acquire tooling, gauging, and process drawings to run an order. They decide to do this for a six-month period to see if any one category might benefit from more attention. The results of their six-month study are shown in Fig. 3-4.

If we rearrange the above data to include only the CPIs and occurrences, it becomes evident that the time spent

²Specification for High-Strength Bolts for Structural Steel Joints [Metric].

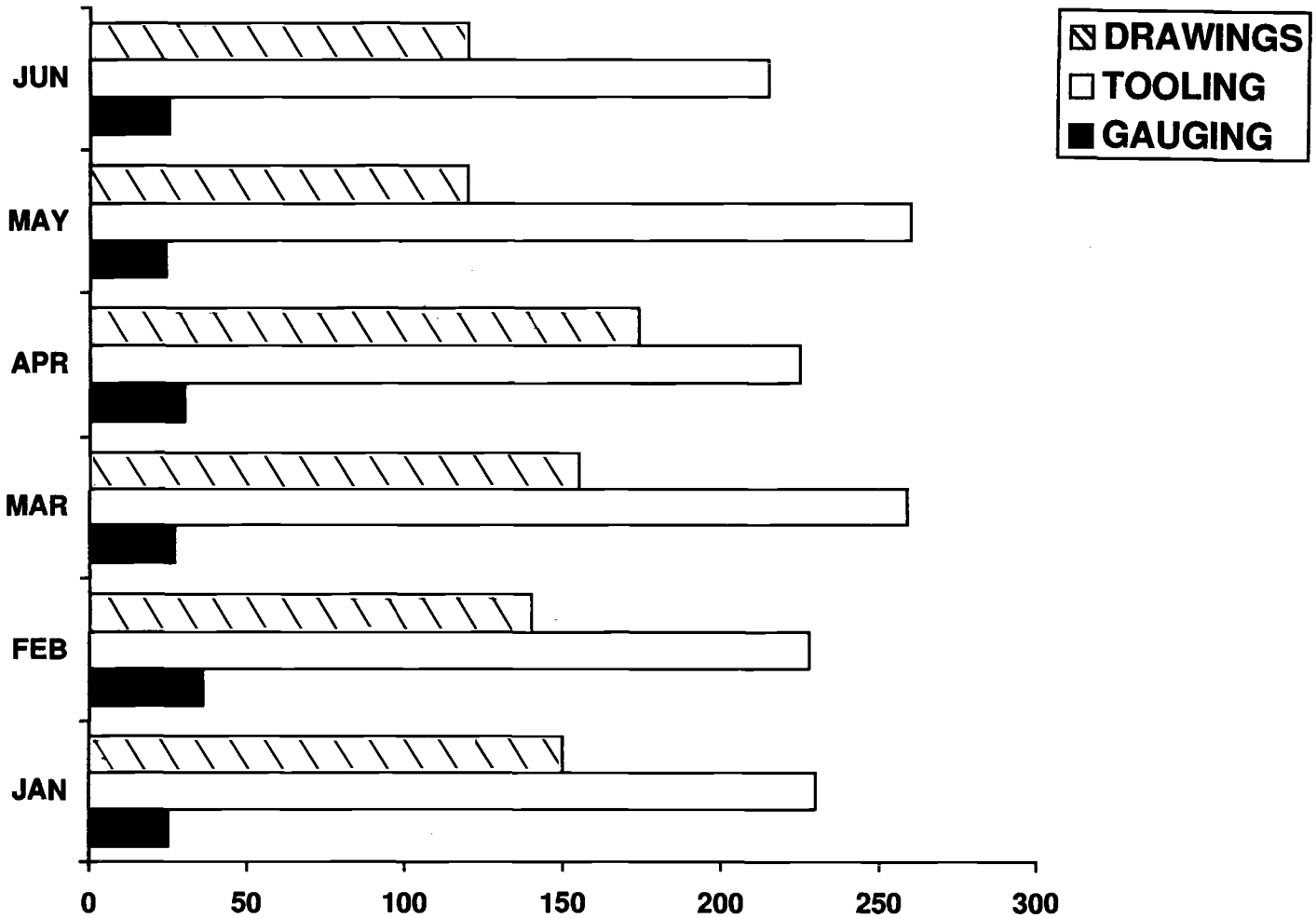


Figure 3-4—Set-up CPI analysis.

waiting for tooling is an opportunity for improvement. The result is Fig. 3-5.

Now the boltmaker team has an area of focus to isolate reasons for delays in getting tooling to the boltmaker. They will choose to select CPIs that contribute to having tooling available. Examples may be tool location, setup time, or tool availability. The process goes on until all causes are identified and presented to management for resolution.

There are times when an identified opportunity requires extra planning to initiate change. Let's look at another example. This one was identified by the quality department. The representative from that department found that orders were sometimes delayed at final inspection because the inspector on duty was not always familiar with the product or the inspection techniques necessary to determine if the product met requirements.

A separate employee involvement team was established to develop the plan to improve the knowledge of inspection techniques of the inspectors. The team was comprised of the inspection supervisor, several inspectors, a design engineer, and a quality engineer. After several brainstorming sessions, the team came up with a progression of steps that would lead to a well-informed and educated quality technician. Note that the team felt so strongly that the training to be

provided to the inspectors was so much beyond the current job description that a new job title had to be created. After all steps in the process were finalized, the team created a project timetable for developing quality technicians. The project timetable they came up with is shown in Fig. 3-6.

This project time table represents an overview of the project to train inspectors to be certified quality technicians through the American Society of Quality Control (ASQC), Milwaukee, WI. Each and every step in the process has its own project timetable detailing the progression necessary to complete that objective and the individual responsible to make it happen. Some of these activities may be only a few steps, such as Steps 5 and 6, while some may be as large and detailed as the overview, such as Step 7.

INITIATE

The next step in the PIE process is initiating actions identified in the planning phase. In my example for the planning phase, it was important to demonstrate how plans are initiated through the use of identifying and tracking CPIs. We also explored how to expand upon acquired data to further analyze avenues to improvement.

Six Month Sum for Boltmaker CPIs

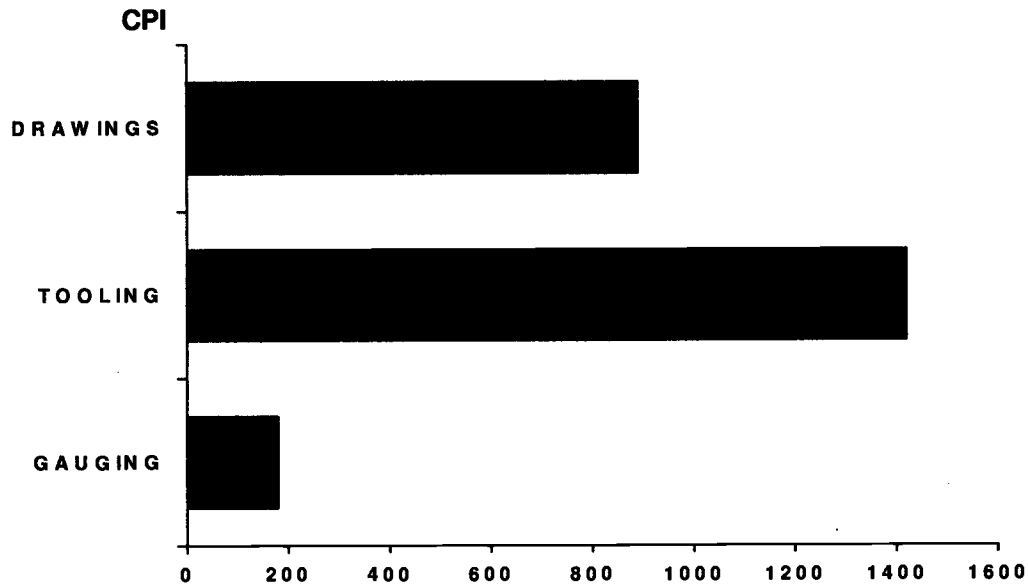


Figure 3-5—Six-month Pareto analysis for boltmaker CPIs.

What's important to remember in initiating action to act upon a plan is to involve the people who make things happen. It may be necessary to provide training for selected individuals or groups of individuals to prepare them to contribute to the success of the program. This investment in people is an investment in bottom line improvement, as detailed earlier in this chapter.

Involvement is a two-way street. In addition to involving employees, supervisors and managers must be active members of the action teams. Managers and supervisors make for good team facilitators to assure that the team stays the course. The teams must be ever mindful of the vision statement and plan objectives. Once the team has achieved the goals of the project, three steps should be taken.

First, the team should be congratulated, and depending on the significance of the achievement, rewards should be awarded. Second, the team should be disbanded; otherwise, teams could go on meeting forever with no agenda. This is not only a waste of resources, but prevents them from pursuing new opportunities for improvement. Third, the CPIs improved upon should be monitored for a period of time to assure that the gains are held.

EVALUATE

Total quality management is about measurement and evaluation. The only way to know if improvement is taking place is by measuring where we are and comparing it to where we were and where we want to be. If we develop a plan for improvement, initiate action to improve, and do not measure the outcome of our actions, we are unaware. We do not know if we are improving, remaining constant, or losing ground.

During the initiation phase of the improvement project, evaluation should be frequent, sometimes daily. As the program continues for six months or more, less frequent studies can be made on results. When a project is deemed complete, the frequency of evaluation will vary with the dynamics of the CPI. I recommend, at a minimum, that monthly summary reports be analyzed to look for changes due to business swings on first-tier CPIs.

This simple philosophy, when adopted by management, will almost always guarantee success: *Make continuous improvement a way of life in your organization*. This applies to all managers in the organization. Obviously, the most senior manager should share this philosophy, but so should all department heads and supervisors because their organizations are those who work for them.

Demonstrate to all members of your organization that you expect improvement. We need to demonstrate that we will not be satisfied with the status quo. Encourage your people to ask, "Why can't things be better?," "How can I improve this process?," etc.

When problems or issues arise, treat them as opportunities to improve upon the situation. Every solved problem contributes to improvement. We should be on the lookout for problems because we improve our competitive advantage by identifying and solving them.

Pay attention to W. Edwards Deming's point of driving out fear. At all levels of the organization, people should be able to discuss problems and mistakes. The messenger should never be shot. We are all human and subject to the actions of the systems in place. If there is a problem, chances are the system is at fault because the issue was never addressed or because a change has occurred external to the system.

To the fullest extent possible, base decisions on fact, not intuition. Look to data and assure that these data are true.

28 TOTAL QUALITY MANAGEMENT MANUAL

Quality Technician Development														
Issued by: Joe Quality														
Issue date: Jan. 5, 1994														
STEP	Process/Activity	Responsibility	J	F	M	A	M	J	J	A	S	O	N	D
1	Define job description for a Quality Tech.	Quality Manager	P											
2	Provide job desc. to the inspectors	Quality Supervisor		P										
3	Assess current skill level of inspectors	Quality Engineer				Δ								
4	Advise each inspector of their skill level	Quality engineer					Δ							
5	Consult with each inspector	Quality Supervisor					Δ							
6	Develop training modules-internal	QA Staff				Δ								
7	Develop training modules-external	Community college				Δ								
8	Commence training	Quality Staff & Community college						Δ						
9	Evaluate effectiveness of training	Quality Supervisor & Quality Engineer							Δ					
10	Certify inspectors as Quality Technicians	General Manager & Quality Manager							Δ					

Figure 3-6—Project time table.

Decisions based on intuition are almost always wrong at the operations level. For higher-level continuous improvement, intuition sometimes cannot be avoided and oftentimes is the basis for decisions that move an organization to the next level of achievement. Marketing sometimes must make decisions based on customer innuendo, but a shop foreman or office manager should rely on data.

Utilize statistical methods to evaluate and study processes.

Once processes are under statistical control, the need for extensive inspection is eliminated. You will still need to carry out audit inspections (or verifications), but total inspection time should be reduced. Concentrate on doing the job right the first time. Do not rely on inspecting quality into the job after it is complete. The process of quality by inspection only perpetuates the hidden "rework and remake" departments of your organization.

Part 2: Quality Organization Function

Quality Systems

QUALITY SYSTEMS are made up of the quality organization and the written guidelines used to define the quality organization as they relate to the rest of the organization. Quality systems are the result of the quality policy established by the executive management team. The two most important elements of quality systems are the quality manual and the organization's standard operating procedures. When developing the quality manual, it is recommended that attention be paid to following the guidelines established by the ANSI/ASQC Q9000-1, Q9001-1, Q9002-1, Q9003-1, and Q9004-1 standards. These are the American equivalents to the ISO 9000 series of quality standards. The ANSI/ASQC standards are available from the American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202 and from ASTM. Even if the organization has no intention of applying for ISO registration, the quality guidelines in the ANSI/ASQC Q9000-1 series of quality systems are among the best available to control quality.

To proceed further at this point without defining who in the organization is responsible for quality would possibly lead some down the wrong path when we discuss the contents of the quality manual and associated procedures that supplement implementation of manual policies. I don't want to start off with the notion that quality is the responsibility of the quality department. Nor do I want to simply state that quality is everybody's responsibility.

Let's look one more time at the definition of quality I provided in Chapter 2, which is: *Quality is achieved when we provide goods and services that meet or exceed customer requirements.*

To meet this definition, the part or service provided must conform to design or process requirements. The design or process must conform to its market requirements, and market requirements must conform to customer expectations. Therefore, three major groups with their necessary support groups are responsible for quality: marketing, engineering, manufacturing/operations, and their support groups. For the purposes of simplicity, I would like to call manufacturing/operations by the single term: *manufacturing*. This one word will mean either a facility that produces a part or a facility that provides a service. And I would like to use the term *product* to mean either a part or a service. The question of who is responsible for quality is now easier to define.

Responsibility for quality in an organization rests with marketing, engineering, and manufacturing along with the support groups that provide services to them. Each must be held accountable for their contribution to the overall effort. Marketing must make sure their concept of customer needs

and requirements is fully understood and that they convey this information to the engineering group. Engineering must assure that they fully translate the marketing requirements to designs and processes that allow manufacturing to produce the product. Manufacturing must assure that the end product they provide to the customer conforms to the facility's design engineering requirements.

You may be asking, "Where does the quality department fit into this picture?" First let me say that we must agree that the quality department or any of its people should not be held responsible for the quality of the product provided by the organization. How can they be if they did not market, design, or manufacture the product?

The quality department's function is to facilitate continuous improvement by providing services to marketing, engineering, manufacturing, and all their support groups. Their role is similar to that of another service group in the organization, the accounting department. I do not think I would find too many people who suggest that the accounting department is responsible for the organization's profit and loss statement. The results on this statement are only a report of what actually happened. So too with the quality department's role—they report on what took place. And, like the accounting department, the quality department provides assistance in identifying opportunities for improvement through measurement and communication. The quality department also has experts in the area of quality engineering and reliability, and technicians and inspection equipment to assist all other facility functions in their improvement projects.

The Quality Manual

With all this in mind, who is responsible for the quality manual and the standard operating procedures that augment it? In my opinion, the quality department. The quality department must work with all other departments within the organization to provide them with the guidelines they need to assure quality in their operations. Each individual department should have a hand in developing the quality manual, but the ultimate responsibility for writing and maintaining it rests with the quality function.

The guidelines for quality management and quality system elements are fully described in the ANSI/ASQC Q9004-1 document. I recommend that readers acquire and review this document when establishing their own quality system and manual. I provide, for convenience, in Fig. 4-1 the table of contents of the guidelines recommended in that standard.

The list of topics in Fig. 4-1 looks very much like the table

Contents

	Page
1 Scope	1
2 Normative references	1
3 Definitions	1
4 Management responsibility	2
5 Quality-system elements	5
6 Financial considerations of quality systems	7
7 Quality in marketing	8
8 Quality in specification and design	8
9 Quality in purchasing	11
10 Quality of processes	12
11 Control of processes	13
12 Product verification	15
13 Control of inspection, measuring, and test equipment	15
14 Control of nonconforming product	16
15 Corrective action	17
16 Postproduction activities	17
17 Quality records	18
18 Personnel	19
19 Product safety	20
20 Use of statistical methods	20
Annex	
A Bibliography	21

Figure 4-1—ANSI/ASQE Q9004-1-1994.

of contents to be found in the ANSI/ASQC 91, 92, and 93 standards, but the difference is that the Q9004-1 document describes the management philosophy behind each topic, whereas the Q9001-1, Q9002-1, and Q9003-1 documents describe the working systems. In Chapters 8, 9, and 10, I pro-

vide a sample quality manual for a manufacturing, a service, and a distributor organization, respectively.

Figure 4-2 represents the different levels of documentation required for ISO 9001 and 9002. The quality manual discussed earlier is called a Level 1 document and translates

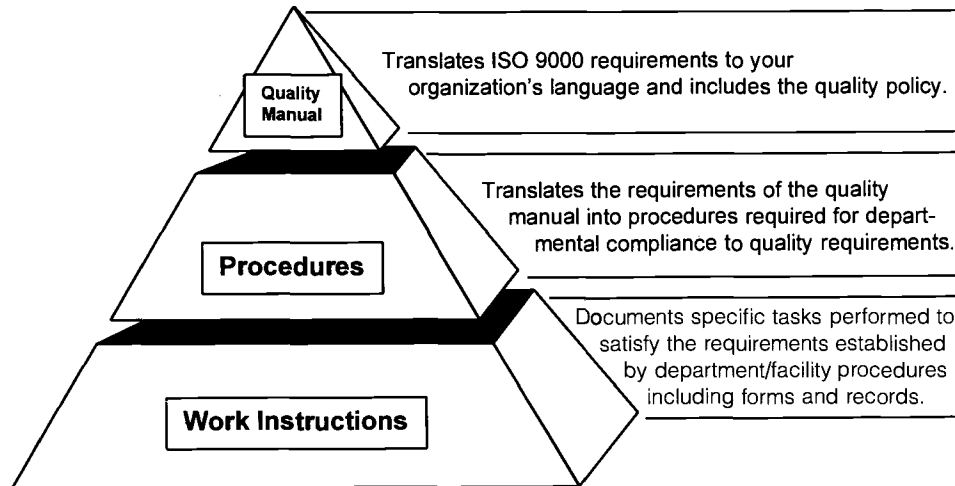


Figure 4-2—ISO documentation pyramid.

ISO 9000 requirements to the language of your organization. Management procedures are Level 2, and they document department (or division) requirements for compliance to the quality manual. Work instructions and forms are Level 3 and contain document-specific tasks necessary to complete an activity defined in the management procedures. Quality records are Level 4 documents and contain the necessary documentation or records of quality activities to meet the requirements of the quality manual. As you can deduce from the chart, the lower the level of documentation, the more detail is provided. The quality manual need not be as thick as the New York City telephone book, nor does it need as much detail as the instruction manual for the space shuttle. A well-developed quality manual need only contain between 20 and 50 pages depending on the size and complexity of the organization.

Procedures

Let's take a closer look at how management procedures and work instructions tie together. For an organization's metrology department (the area in which technicians apply the science of measurement to calibrate test and measuring equipment), management will have a procedure on how to calibrate and maintain gauges and measuring equipment, but in order for the facility to implement that procedure, there has to be a work instruction on how to calibrate each category of gauge and measuring instrument in use at the facility. In this case, one could have up to 25 work instructions to satisfy a single management procedure. I'll provide an example of each for clarification.

The first example is a management procedure on equipment calibration, and the second is a work instruction for calibrating a dial and vernier caliper.

STANDARD PROCEDURE

ANY COMPANY

SUBJECT: Certification Instructions Equipment Calibration

PROCEDURE NO.: ANY 11-01

REVISION: 1.0

PAGE: 1 OF 4

DATE: Insert date

PREPARED BY: Insert author

1.0 Purpose

- 1.1 The purpose of this procedure is to define the general conditions and requirements for implementing and maintaining a certified calibration program for our test equipment.
- 1.2 Compliance with this procedure will ensure through the consistent examination and control of measuring devices and accessories the means for manufacturing accuracy.

2.0 Application

- 2.1 This procedure shall apply to all equipment, whether privately or company owned, that is used or may be used for the appropriate measuring and/or judging of the manufactured products' conformance to specification.

3.0 Materials and Equipment

- 3.1 IBM PC computer and PQ systems Gage Pack® calibration software (or equivalent).
- 3.2 Test equipment serialization procedure, ANY 11-02.
- 3.3 Gauge Repeatability and Reproducibility Study work instruction ANY 11-01-01.

4.0 Procedure

- 4.1 All test equipment that is used or may be used to determine the acceptability of manufactured product must be certified as accurate by the metrology department.
 - 4.1.1 Employees must submit their test equipment to the metrology department for certification prior to use in manufacturing.
 - 4.1.2 New company purchased test equipment must be certified by the metrology department prior to use in manufacturing.
 - 4.1.3 All test equipment of new or unique design is subject to qualification through a Gage Repeatability and Reproducibility study in accordance with work instruction ANY 10-45.

- 4.2 All test equipment submitted for initial certification will be permanently marked, if possible, with an identification/serial number, in accordance with ANY 11-02.
- 4.3 Test equipment will be certified in accordance with appropriate Quality Assurance Work Instructions, and shall be tested against devices certified and traceable to the National Institute of Standards and Technology (NIST).
- 4.4 Test equipment determined to be accurate and reliable through examination by Metrology will be certified and the results of the examination recorded on the computer through application of the calibration software.
- 4.5 Certified test equipment then shall be released by Metrology for approved use within the limitations of the test equipment's intended application.
- 4.6 Test equipment determined to be inaccurate/unreliable through this process will be routed to an appropriate calibration or repair facility and the results of this action recorded.
- 4.7 All test equipment returned from calibration or repair facilities must be routed through Metrology for reexamination.
- 4.8 Following the initial examination and certification of each type of test equipment, subsequent test equipment examinations will be scheduled using the gauge calibration software system.
- 4.9 Test equipment due for examination and recertification will be printed out off the gauge calibration software on a weekly basis.
- 4.10 Metrology will exchange due test equipment with certified test equipment so as not to interrupt the manufacturing process.
- 4.11 Test equipment may be submitted to Metrology for additional examinations at any time, regardless of the scheduling program.
- 4.12 Test equipment found to be in use with expired certification tags or labels will be confiscated and/or prohibited from use until the appropriate recertification of the test equipment can be accomplished.
- 4.13 Test equipment examination intervals shall be scheduled on the basis of frequency of use, fragility, and the accuracy required of the test equipment.
- 4.14 Except for test equipment being returned for routine certification, rejection tags must be affixed to uncertified test equipment in inventory to prevent accidental reuse.
- 5.0 *Auditing Procedure*
 - 5.1 Metrology shall be responsible for conducting sporadic, unannounced shop-wide audits/inspections for the test equipment governed by this procedure.
 - 5.2 Audits shall evaluate the present condition of the test equipment audited versus the same test equipment at the last recorded Metrology examination.
 - 5.3 Audits will ensure control of measuring devices and accessories by requiring corrective action for any violations of this procedure.
 - 5.4 Test equipment found to be in violation of this procedure, or designated tolerances and parameters, through Metrology auditing, may be confiscated and/or prohibited from use until appropriate recertification of the test equipment can be accomplished.
 - 5.5 The auditor may grant an "operational deviation" for any equipment found to be in violation of this procedure or of the designated tolerances and parameters established for the test equipment.
 - 5.6 Test equipment cited with an "operational deviation" must be submitted to Metrology within five working days of the citation for examination and appropriate adjustment. Example: A gauge block is out of specification, but used to

complete an order. A correction factor is calculated to compensate for the error.

The preceding example is the system management procedure implemented to control test equipment calibration and certification. The method(s) by which the metrology department carries out this procedure is detailed in work instructions. For most organizations there are much more work instructions than management procedures simply because of the breadth of the area being managed. In our example for calibration, this procedure applies, as stated in 2.0, to application to all test equipment whether privately or company owned. There may be thousands of measuring devices covered by this definition. At least each category of measuring device should have a work instruction that details how it is to be certified. Here is an example of a work instruction that ties in with the calibration procedure presented as ANY 11-01.

ANY COMPANY

STANDARD WORK INSTRUCTIONS

SUBJECT: Calibration Procedure For Digital Calipers, Dial Calipers, and Vernier Calipers

Work Instruction No. 11-01-24

Page 1 of 2

Date Prepared	Insert Date
Prepared By:	Insert Name
Approved By:	Insert Name

1.0 *Purpose*

- 1.1 The following work instruction is for use by Quality Control in establishing accuracy requirements of digital, dial, and vernier calipers.

2.0 *Application*

- 2.1 This work instruction is applicable to all calipers which are either in use or may be used to measure and/or determine the manufactured product's conformance to specifications.

3.0 *Equipment*

- 3.1 Gauge blocks certifiable to NIST.
- 3.2 Calibration test stand.
- 3.3 Cleaning solvent.
- 3.4 Lint free towels.

4.0 *Documentation*

- 4.1 Calibration control software.
- 4.2 Test equipment calibration data sheet (form 11-01-90)

5.0 *Procedure*

- 5.1 Clean all surfaces of the caliper with cleaning solvent and lint-free towels.
- 5.2 Readings are taken at 0.500-in. (1.27 cm) and 1.000-in. (2.54 cm) intervals throughout the measuring range of the measuring device for outside measurements using gauge blocks.
- 5.3 Readings are taken in three random locations along the measurement range for inside and depth measurements using the calibration test stand.

6.0 *Acceptance Criteria*

- 6.1 All readings are to be within one graduation mark of true value to the nearest 0.001 in. (0.002 54 cm).
- 6.2 The caliper must repeat within ± 0.0005 in. (0.001 27 cm) on a second test at the same value.
- 6.3 Any caliper failing to pass all check points must be repaired before releasing for production.

- 6.3.1 All repaired calipers must be examined by Metrology and meet the requirements of this work instruction for acceptance.
- 6.3.2 Calipers not meeting the requirements after repair shall be removed from service.
- 6.4 All calipers meeting all criteria shall be certified and released to manufacturing.
- 7.0 *Records*
 - 7.1 Results of this examination shall be recorded on both the software system and on the calibration data sheet for hard copy backup.
 - 7.2 The data entered into the software system shall be backed up daily on a disk and on the main computer's hard drive. This provides for three records, one of which is offsite.
- 8.0 *Calibration Schedule*
 - 8.1 Calipers shall be recalled for calibration and certification every twelve months.

The work instruction provides information the metrology technician can follow so that the requirements of the management procedure can be satisfied. Work instructions should be prepared by someone in the department who is actually performing the task being defined. The reasons for this are many, but a very obvious one is that the only person who fully understands the actual procedure for doing the task is the one who performs it.

If we have the individual closest to the task prepare the work instruction, we must assure that he or she understands the content and intent of the management procedure that governs their responsibilities. Therefore, it is imperative to have involvement from the department task performers

when management procedures are prepared. The best way to accomplish this is to ask for assistance from the task performers when the procedures are going through phase one of their development.

If you take another look at the two example procedures, you will notice something else if you are familiar with the ISO standards. In ISO 9001, the table of contents has *Inspection, Measuring, and Test Equipment* listed in Section 11. The procedure number and the work instruction numbers both start with the number 11. This format of numbering will be of assistance to your employees and to outside auditors when reviewing your compliance to ISO requirements or to any quality system if you tailor your procedure topic numbers to coincide with the numbers in the table of contents of your quality manual.

Another worthwhile addition to your procedures and work instructions is to include a process flow chart. This allows for two advantages; one, the flow chart provides a graphic diagram of the steps necessary to comply with the procedure/work instruction; secondly, it allows the procedure to be short on words because a picture truly is worth a thousand words.

Organizing For Quality

Setting up the quality organization is as important a task as anything we have discussed earlier. However, titles in the quality organization are not as important as the job descriptions of the individuals assigned to assure that quality systems are followed. Medium to large organizations will find

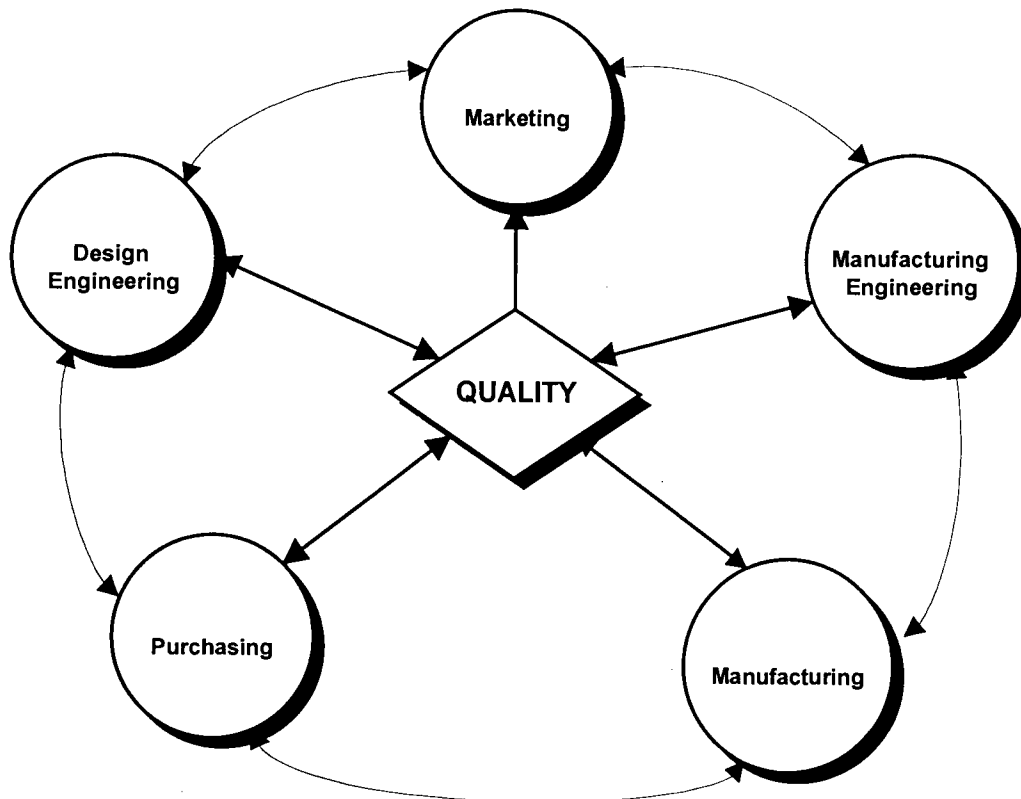


Figure 4-3—TQM interaction.

it beneficial to have a separate group in the organization responsible for maintaining the systems. Smaller companies will have many key individuals who perform multifunctional tasks.

Even if the quality organization is a separate group or is an individual who has other duties, the checks and balances should be in place. There should not, for instance, be conflict between producing the product and making the product to customer requirements. With this in mind, there are a few guidelines that should be observed. An individual responsible for assuring that the product is shipped on time is not always a good choice for quality manager. When organizing, conflicts of interest must be identified and avoided. Obviously this is easier to accomplish in medium to large companies than in smaller ones.

Before assigning responsibility for quality, look at what the primary duties are for those in the quality function. There are two main responsibilities. First and most important is preventing nonconforming products from reaching the customer. The second is finding ways to improve all functional activities.

Preventing nonconforming products from reaching the customer applies to both internal and external customers. Focusing on this responsibility not only satisfies those who purchase the product but, just as importantly, provides for efficiency of operations, reducing internal costs. A great deal can be saved by doing the job correctly the first time. Some estimates have put the cost of nonconformance as high as 35% of production costs. This cost is totally unacceptable and can be avoided through training and leadership.

The second function of a quality organization is to find methods of improvement. This function is carried out through measurement, analysis, evaluation, management reports, and participation on continuous improvement teams. These two functions do not necessarily fit in with other job functions whose task is to produce a product in a certain time period—they are even opposing. The quality department's role is not to expedite or "move" a product through the process chain—that responsibility rests solely with the group responsible for the process chain. If a job is held up by the quality department due to some nonconformance, it is not the responsibility of the quality department to find a solution to this problem. The quality department should assist, but the primary responsibility rests with the responsible group. To satisfy these two main functions, quality must be in a liaison with all other functions.

Figure 4-3 displays the interaction that must take place between quality and all other functions when seeking continuous improvement through the SPQP process. It also is a good example of an organization chart of interactions. All functions have a dotted line relationship with each other under the team management concept. All department managers in Fig. 4-3 ideally will report to the general manager or equivalent senior manager in the organization.

No matter what the organizational structure, what's important is that the quality manager is on a par with other department managers. And the quality manager usually needs a persuasive personality that can influence his peers in day-to-day interaction to make quality the number one objective.

Quality Reporting

CONTRARY TO SOME who believe that quality is free, I submit that customer satisfaction has costs associated with it. These costs are a legitimate business expense, and like all business expenses we would like a return on that investment. I like to think of the cost of quality as an investment in both the hard and soft technologies of the business. The hard technologies are office equipment, machinery, buildings, gauges, test equipment, and similar items. The soft technologies are the people and their interactions with the hard technologies.

COST OF QUALITY

The cost of quality is generally 5 to 20% of sales, and this accounts only for costs that can be quantified. Some costs cannot be determined, such as the price a company pays for dissatisfying a customer. Sure, we can count the cost of the returned item and the time we spend analyzing the complaint, but we cannot count the negative impression we made on our customer. Even when we look just at assignable costs, in a manufacturing facility this can amount to \$1500 to \$2500 per year per employee. This certainly gives management reason to study the cost of quality and find ways to reduce it. This figure can be reduced effectively through a well-managed cost-of-quality program. Experience with effective cost-of-quality programs has shown the return on investment to be approximately 5:1 to 10:1.

Now that we have demonstrated how valuable these costs can be to management, let us see how a good cost-of-quality program can be structured. First and foremost, the top executive management of the organization must support the program. The quality department and the accounting department become business partners in this management tool. Together they collect the data necessary to assemble the report for staff management. The output from the Cost of Quality Report are CPIs that can and should be displayed for employee awareness.

A few basic components are required to provide enough information to analyze accounting expenses and statistics. One needs certain pertinent data, such as cost of shipments (sales), cost of manufacturing (production), facility labor and overhead rates, rework hours, scrap costs, and cost of returns. These are broken down to: (1) *total prevention costs*, (2) *total appraisal costs*, (3) *total internal failures*, and (4) *total external failures*. Then, through analysis, we can arrive at our critical performance indicators. The CPIs as a minimum are: (1) total cost of quality (TCQ), (2) TCQ/product shipped, (3)

TCQ as a percent of manufacturing cost, and (4) scrap as a percent of total pieces produced.

The collection of these data, as you can see, requires information from both the quality and the accounting departments. The quality department usually has the information on customer returns, the number of pieces scrapped and reworked, and the number of items recalled due to nonconformance. The accounting department has all cost data associated with the data supplied by Quality, as well as information on labor, shipments, and overhead. A simple cost-of-quality report may look like the sample shown in Fig. 5-1.

To provide more visibly to the CPIs at lower levels in the organization, one can develop run charts that display the TCQ over time. This allows everyone the opportunity to see just how well the facility is performing. If the TCQ CPIs are exhibiting continuous improvement, the employees gain a sense of achievement for their efforts. If the trend is in the opposite direction for any given CPI, the employees can see where they must seek better ways. A run chart could look like Fig. 5-2.

In this example, both the percent scrap and the cost of quality show a continuous improvement curve. This information is vital to reinforce employee self-esteem and to give everyone in the organization direction for future efforts. The input for future direction comes from analysis of the various components that make up the cost of quality. Many of the largest gains in continuous improvement oftentimes come from departments outside of quality. This is what can be expected when the quality function and the other functions work as teams as I discussed in Chapter 4.

QUALITY SYSTEMS AUDITS

Another management tool is the quality systems audit. I have found this tool to be my most effective key to achieving continuous improvement. Properly applied, it gives an honest and candid appraisal of how your organization is following the established quality systems and how effective they are.

There are different levels of system audits, and most segments of the organization can find one that can be used for their own self-assessment. Quality systems audits can be conducted on top management all the way down the organization chart to the person doing the actual labor on any given task. All it takes is for someone to format the survey to fit the scope of the audited system. Everyone can benefit

**ANY COMPANY
COST OF QUALITY REPORT
FY 1994**

1.00 PERTINENT INFORMATION		January	February	March	1st. Qtr
1.1	Total Direct Labor Hours	45,580	46,425	46,245	138,250
1.2	Total Shipments Pcs	125,877	127,630	125,721	379,228
1.3	Ave. Mfg. Cost of Shipments	25.02	28.73	23.76	25.84
1.4	Scrap Pieces	1,546	1,285	1,115	3,946
1.5	Rework Pieces	1,865	1,279	1,042	4,186
1.6	Rework Hours	578	599	475	1652
1.7	Plant Overhead & Labor Rate	57.00	57.00	57.00	57.00
2.00 PREVENTION COSTS					
2.1	Plant Prevention Costs	20,553	19,975	19,575	
2.2	Miscellaneous				
2.3	Total Prevention Costs	20,553	19,975	19,575	60,103
3.00 APPRAISAL COSTS					
3.1	Quality Assurance Labor	49,345	48,321	48,222	145,888
3.2	Quality Assurance Expenses	35,754	34,227	34,875	104,856
3.3	Miscellaneous				
3.4	Total Appraisal Costs	85,099	82,548	83,097	250,744
4.00 INTERNAL FAILURE COSTS					
4.1	Scrap	38,681	36,918	26,492	102,091
4.2	Rework	32,946	34,143	34,143	101,232
4.3	Total Internal Failure Costs	71,627	71,061	60,635	203,323
5.00 EXTERNAL FAILURE COSTS					
5.1	Justified Customer Returns	9,100	8,975	10,100	28,175
5.2	Stock Recalls	875	0	500	1375
5.3	Miscellaneous				
5.4	Total External Costs	9,975	8,975	10,600	29,550
6.00 CRITICAL PERFORMANCE INDICATORS					
6.1	Total Cost of Quality (TCQ)	187,254	182,559	173,907	543,720
6.2	Plant Scrap Rate (% pcs)	1.21%	1.00%	0.88%	1.03%
6.3	TCQ / Product Shipped	1.49	1.43	1.38	1.43
6.4	TCQ / Manufacturing Costs	5.95%	4.98%	5.82%	5.55%

Figure 5-1—Cost of quality report.

from this exercise because no one can ignore themselves. Examples of systems that can be audited are numerous; I include a few here so one can appreciate the magnitude of scope: the quality manual, contract review, drawing control, calibration records, purchasing procedures, personnel train-

ing records, customer service procedures, manufacturing inspection procedures, invoicing procedures, and preventive maintenance schedules.

Some audits will be formal, while others can be informal. This depends on the management procedure on quality sys-

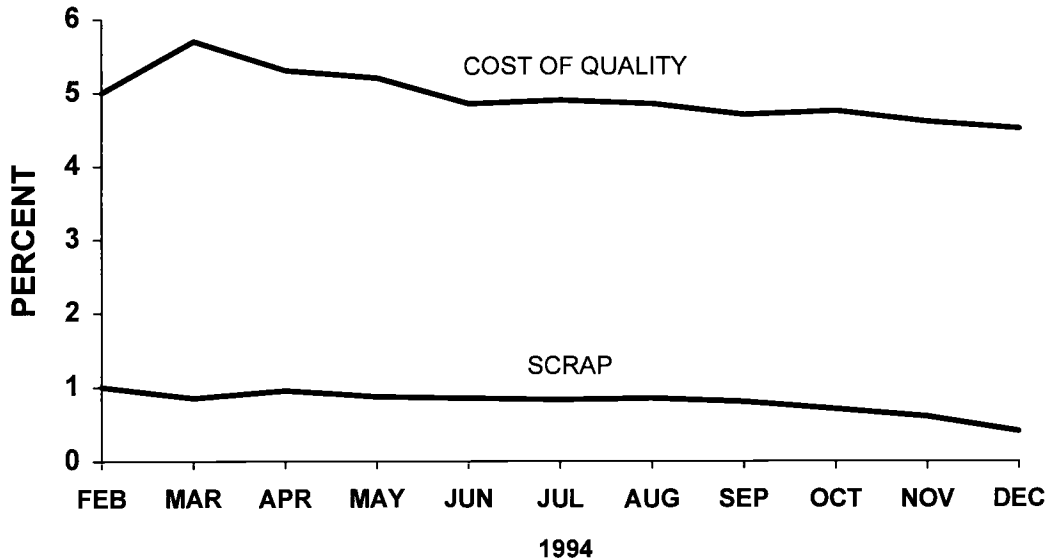


Figure 5-2—Percent scrap and percent cost of quality.

tem audits and on how each department develops its own work instructions to satisfy those requirements. Formal audits require documentation and follow-up corrective action on deficiencies discovered during the audit. Informal audits are usually management tools used to assess day-to-day operations. Reports as a result of informal audits are generally verbal and used as personnel development aids.

The structure of the survey used in formal system audits should follow in sequence the steps in the procedure or work instruction. For instance, if we were developing a system audit of the management procedure explained in Chapter 4 (ANY 11-01), there would be questions designed to assure that the requirement in Paragraphs 1.0 through 5.6 of the management procedure were being adhered to. A sample question for Paragraph 4.1.1 may be: "Is all employee-owned test equipment certified? Submit a list of all production employees that shows test equipment owned and the date of last certification. Are there any exceptions to being current?"

The formal quality systems audits should be conducted by a cross-functional team and contain no one from the system being audited. In other words, the audit must be conducted free of bias. As an example, if we were auditing purchasing procedures, we may have on our auditing team members from quality, engineering, and customer service. This auditing team would tour the purchasing department with the purchasing manager or supervisor.

Immediately after the survey, the team and the person representing the audited system should sit down and discuss the results, including any deficiencies. This is very important because disagreements can be resolved much easier then, instead of a week or two later when the request for corrective action is received.

This brings us to the next phase of the quality systems audit, the request for corrective action. Each deficiency requires a corrective action request to be sent to the department manager for resolution. The department manager should be given sufficient time to respond, but a response should be expected in a reasonable time frame. Usually 15 working days is provided unless the deficiency is a threat to customer satisfaction, which would demand immediate action.

The quality department along with the human resources department are responsible to assure that auditors are properly trained and qualified to conduct audits. Only personnel who have received and successfully completed the training should be permitted to conduct audits. Special attention is given to working in teams, understanding differences, and problem solving to assure constructive and positive audits.

Documentation of all formal audits is best channeled through the quality department for retention and follow-through. A system should be established to assure that corrective action identified on the Request for Corrective Action reports is in fact in place. Usually a member of the audit team from that area is given the responsibility to revisit the department and reaudit the deficient item after a sufficient amount of time has elapsed for the department to initiate corrective measures. This follow-through is only required on more serious problems.

What is important to understand is that quality systems audits are a look at your own operations and are intended to be constructive. Many times procedures are revised because systems audits find that deviation from original procedures result in an improvement. It is only natural for people to continually seek better methods to do their jobs.

Supplier Qualification

PARTNERSHIPS

ORGANIZATIONS that consider their suppliers to be part of their overall business strategy are going to be way ahead of their competition. Suppliers are an integral part of any organization's ability to operate in a cost-effective way. Companies who realize they are not always best at performing certain tasks and utilize the expertise and experience of suppliers will be rewarded with long-lasting business partnerships with selected suppliers. When developing a business partnership with a supplier, certain objectives need to be considered.

Objectives

One of the more important objectives is improved product quality. Business partners need to share information from the earliest stages of product development. I recommend that suppliers in a partnership relationship be permitted and encouraged to participate in your SPQP (service/product quality planning) process. Through this interaction, there may be processes or design changes identified that result in significant cost savings. Improved quality is also achieved through analysis of your supplier's quality systems. Through quality system audits, opportunities for supplier improvement are identified, and by working with the supplier to meet these challenges, both benefit. Meeting this objective is discussed later.

Another objective is to maintain or reduce costs associated with purchased material. In some organizations the material costs associated with purchased items can approach 100% in the case of companies whose value-added contribution to the end product is mainly to assemble/build that product. A similar situation exists with distributors; they rely solely on their supplier for product cost, as the value added comes from the service they can provide. Even in organizations whose purchased material costs are only 20%, there is considerable saving to be gained through a well-orchestrated supplier partnership.

To consider in a supplier partnership are blanket orders versus spot or single-purchase orders one lot at a time, value analysis through the SPQP process, and reduction in your supplier base.

Creating or maintaining outstanding supplier delivery performance is another objective. This objective is achieved by opening up those communications necessary in partner relationships. Much can be gained when purchaser and supplier meet on a regular basis. Weekly meetings are recom-

mended. Depending on the current order status, these meetings can be conducted as brief telephone conversations or as face-to-face meetings at either party's place of business. In addition, time should be devoted annually for an information seminar at your facility or off-site in which you present your business plan to all key suppliers. This will be discussed later in this chapter when we discuss supplier involvement.

Depending on the nature of your business, another major objective is maintaining and controlling confidential and/or proprietary information. Your business is your business; to survive in today's global economy, only those who have a common interest in your organization's goals and objectives should know the details of your journey to satisfy these objectives. Some common sensitive areas are: pricing, bid/quote information, process information, design specifications, company plans and goals, profit information, wage and salary scales, customer lists, supply sources, and supplier information.

Sourcing Considerations

There are three main considerations when selecting suppliers. One is the effectiveness of their quality systems, another is their process capability or capacity, and the other is their price. In a nutshell it comes down to *quality, delivery, and value*.

The key to assessing the expected quality performance of a future supplier is the Supplier Quality Systems Survey as part of the overall "partners in quality" concept. The survey should be designed to give objective analysis of the supplier's quality systems, management goals, drawing and change control, procurement methods, production control, fixture and gauge control, process control, product control, documentation and records, packaging and shipping methods, and employee awareness of these systems.

Supplier Measures

The Partners In Quality Program should also provide for methods of measuring a supplier's performance to established criteria, including such things as on-time performance, quality of supplied product, response to corrective action requests, cost containment, and meeting other value-added benefits. Many of these criteria are easily reported as CPIs and can be distributed to the supplier on a monthly or quarterly basis.

Examples of purchasing reports will now be discussed and

TABLE 6-1—Partner’s in quality supplier rating summary.

Supplier ¹	Survey Score ²	Audit Inspection ³	Supplier Status ⁴
A	91.10	100.00	Certified
B	90.00	100.00	Certified
C	90.00	97.00	Preferred
D	81.40	98.10	Preferred
E	79.60	99.80	Preferred
F	78.20	99.20	Preferred
G	77.70	99.40	Preferred
H	76.40	98.60	Preferred
I	72.90	100.00	Approved
J	72.50	98.50	Approved
K	72.10	98.30	Approved
L	71.40	100.00	Approved
M	67.10	100.00	Approved
N	55.40	91.60	Conditional
O	55.00	99.50	Conditional
P	48.60	99.20	Conditional
Q	26.40	94.70	Conditional
R	26.10	100.00	Conditional

¹Supplier code identifier.

²Score achieved on an on-site quality systems survey.

³Measure of incoming inspection results on a pieces received/accepted basis.

⁴Status of supplier based on composite of survey and audit scores.

displayed for information and suggestions. The three examples given are very powerful CPIs when shared with your suppliers. All key suppliers would receive monthly the report shown in Table 6-1, allowing them to observe their current performance as compared with other suppliers who share your partnership agreement. By coding the suppliers as A through R, no confidentiality is compromised, as the supplier knows only that he is A or Q and does not know what code applies to others.

Figure 6-1, the PIQ Rating Summary, allows the supplier to see how the overall performance of the supplier base is

meeting established goals. By knowing his individual score, he has a feel for how valuable his individual contribution is to that effort. If the supplier’s score is below the average, we can assume we are not getting as much value added as we would from a supplier who is above average. This assists your purchasing department at negotiation time.

Figure 6-2 is an overall picture of your ability to receive orders from suppliers on time, which in turn provides confidence to your own production scheduling department in your ability to manage the purchasing function.

SUPPLIER INVOLVEMENT

One of the better ways to cement a partnership and to show your suppliers you are serious is to sponsor a “supplier day” at your facility. If you don’t have adequate facilities, conduct the seminar off site at a local conference center. The objectives of the seminar are to review your company’s business plan and goals, to discuss your continuous improvement progress, to establish supplier goals and improvement objectives, and to encourage involvement and participation. One method for structuring a program such as this is detailed in the following paragraphs.

If you do not have a list of your top 20 or so suppliers, prepare one using criteria that provide some measure to identify supplier worth such as dollar volume or critical components. After you know your top suppliers, send them a letter telling them about the seminar and invite them to attend by enclosing an RSVP form and a self-addressed envelope. If you do not get a response from some of your key suppliers, you may wish to consider asking suppliers whom you want to develop as future top suppliers to assure full attendance.

After you receive responses and know which suppliers are

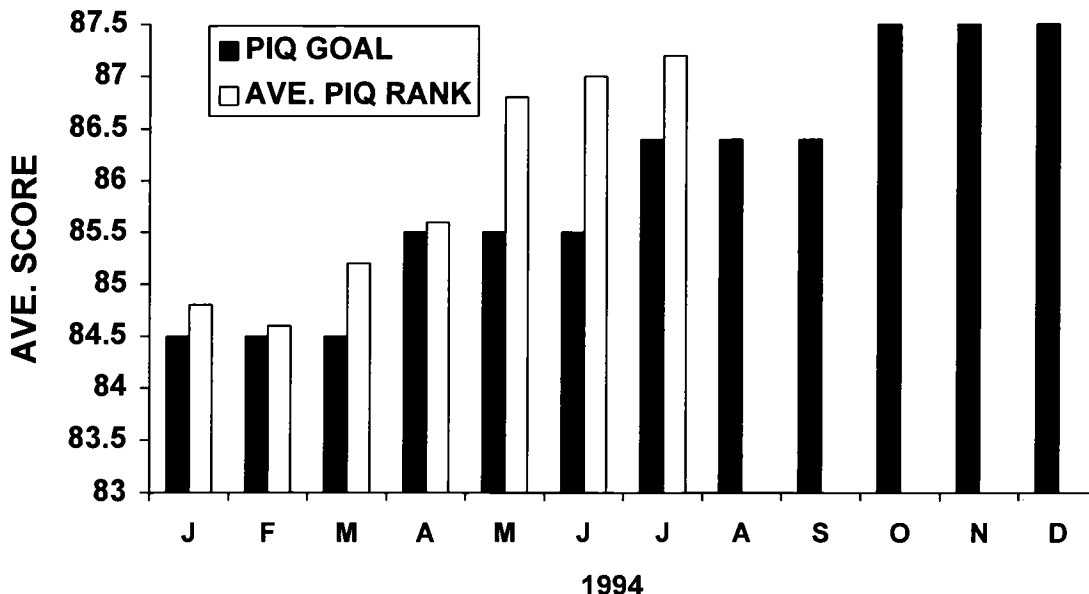


Figure 6-1—PIQ rating summary.

42 TOTAL QUALITY MANAGEMENT MANUAL

interested, send a follow-up letter with a simple survey for them to complete. The survey should be designed to allow your suppliers to appraise your company as a business partner. A sample survey is shown as Fig. 6-3.

The rating scale goes from 5 to 1, with 5 representing excellent and 1 meaning a very poor performance. The results of this survey should be analyzed carefully and shared with your suppliers. Where improvement is indicated, it should be pursued with a team approach including your suppliers whenever possible.

Shortly before the seminar, provide the attendees with an agenda for the program. This gives the attendees time to develop the frame of mind you are hoping they bring to the meeting. Included in the program should be a general business update by the top manager of the facility. This manager should also introduce the staff management and give a brief description of the continuous improvement programs underway. Each staff manager should give at least a 20-minute talk on the continuous improvement projects in their respective departments. This demonstrates to the audience that continuous improvement can be applied to any discipline. It's not just a quality thing. This should consume most of the morning. In the afternoon, devote attention to your purchasing department's quality improvement objectives for suppliers. This part of the program should be shared by the purchasing and quality managers. Leave an hour open for reviewing the supplier survey (Fig. 6-3) and for open discussion.

I have participated in several of these types of supplier involvement programs, and every one of them has been a success. When they are properly administered, both parties go away with a feeling of cooperation.

Supplier Quality Systems Survey

The Supplier Quality Systems Survey is a management tool that does many things for both the customer and the supplier. As the customer, you share with your supplier the quality philosophy your organization has chosen to apply to

your business. You also have a consistent measure by which you can evaluate each supplier against their systems and each supplier with their competition. The survey requires communication between organizational counterparts in quality, purchasing, and others in each organization and develops understanding and relationships. The supplier gains because the survey provides a critical look at how well he is doing business and to what extent he is satisfying the customer. All in all, the survey can serve both the customer and the supplier as they journey along the path of continuous improvement.

It is recommended that the quality systems survey be developed to follow closely your own quality manual since this survey will transfer your quality philosophy to your supplier. As an aid, I have prepared a model survey that follows the quality manual I present in Chapter 8. The Supplier Quality Systems Survey is in Appendix D.

When setting up the parameters of the supplier quality survey, special attention should be focused on assessing the supplier's management and their attitude toward teamwork and continuous improvement. Control systems to be assessed include document and change control, materials control, fixture and test equipment control, process control, product control, auditing methods, and quality reporting.

Let us look at each of these elements in detail beginning with supplier management.

Supplier Management

A sense of the attitude carried by management in regard to TQM principles has to be gained through the survey. We discussed these at length in Chapter 1. Is the management committed to team-oriented management and activities? Is there a customer focus that includes internal as well as external customers? Are there programs in place and planned for the future that assure the continued upgrading of employees through training? Does the management utilize the inherent job knowledge of their employees through empowerment and involvement of the workforce? And, is there a

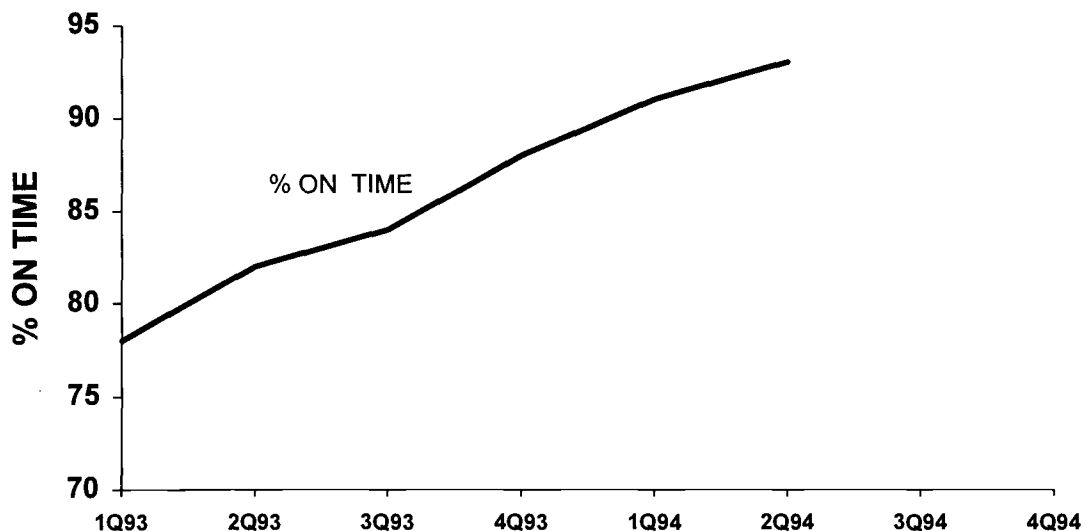


Figure 6-2—Supplier on-time performance.

SUPPLIER SURVEY FORM

	5	4	3	2	1
Requests for quotation are clear and complete.					
Blueprints and job specifications are accurate and legible.					
Satisfactory follow-up is given if a contract is not awarded on a quote.					
Purchase order format is clear.					
Purchase order information is accurate.					
Invoices are paid according to stated terms and conditions.					
Purchase orders are issued within stated leadtimes.					
Adequate planning information is provided beyond your leadtime horizon.					

Our company provides the following information on a regular basis.

- Production plans
- Current supplier delivery and quality ratings
- Quarterly and annual financial summaries
- Significant personnel changes

We communicate the level of quality that is required for our products.					
You are notified within a reasonable period of time after shipment that material does not meet specification.					
Returned material is properly packaged and identified.					
We communicate sampling and inspection plans for our product.					
Purchasing / Quality Assurance employees are cooperative and respond to requests for information on a timely basis.					

In the following space, or on additional paper please list any questions or issues you want us to discuss at our seminar.

Figure 6-3—Supplier survey form.

measurement system in place to track progress, such as CPIs?

Document and Change Control

There must be a system in place to assure that current documents and procedures are available to all users at the supplier's facility. It should also be established that obsolete documents and procedures are not available to those who are not aware of possible revisions. Finally, the documents under control should be available at all locations where operations essential to the effective functioning of the quality system are performed.

Materials Control

There should be a system in place to assure that material, either purchased or produced, that is in inventory is identified as to inspection status and part identification. There should be a procedure for controlling suppliers, nonconforming material, corrective action, receiving inspection, packaging, and shipping. Work instructions for those who perform these functions should also be available.

Fixture¹ and Test Equipment Control

Periodic calibration of test equipment and fixturing are essential for control and verification of product quality. Controlled master standards shall be maintained and traceable to either national standards or manufacturer's standards. Key elements of a successful fixture and test equipment program are:

- Calibration and certification of analytical equipment used to determine physical, chemical, or mechanical properties.
- Repeatability and reproducibility studies for equipment used to collect variable data.
- Equipment history and inventory data.
- Records that include location, method of calibration, date of next certification, and current status.
- Marking system to identify equipment and its due date for certification.
- Procedures/work instructions for disposition of nonconforming equipment and fixturing.

Process Control

The supplier should have systems in place that provide a plan for production and identification of product. Better sys-

¹This applies only if fixtures are used as a final acceptance inspection device.

tems assign production to process proven to be capable of achieving high levels of quality and output. This requires an analysis of the process through statistical methods discussed in Chapter 7. As a minimum, a supplier's system should provide for:

- Documented work instructions.
- Compliance with the quality manual.
- Monitoring and controlling process parameter and product critical characteristics during production and assembly.
- Workmanship acceptance criteria via work standards or samples where possible.
- A safe, clean, and well-organized work environment.

Product Control

Product inspection and quality should be controlled to the fullest extent possible by the individual doing the job. I call this *point of control responsibility*; where it can be applied, it is the most effective method of assuring product quality. The supplier's elements of product control should include:

- Receiving inspection.
- First article inspection.
- Measurement system verification.
- In-process inspection to statistical sampling plans that specify zero defects.
- Final product audits.

Auditing Methods

Procedures must be in place to assure that all quality systems are functioning as written. This is carried out through quality system audits as discussed in Chapter 5. These audits should be scheduled according to the current status and importance of the activity. Results of the audits must be documented and deficiencies noted. All identified deficiencies require documented corrective action. Management responsible for the activity under evaluation should initiate and assure effective corrective action.

Quality Reporting

The supplier should have a cost-of-quality report in place that, at a minimum, tracks rework and scrap. The report should be distributed to appropriate management that can effect process and product improvements.

When all eight criteria described above are in place and effectively implemented, one can be confident in the supplier's ability to satisfy your requirements and provide quality products.

Part 3: Statistical Quality Control

Statistical Quality Control

ONE OF THE MORE effective tools available to organizations that apply total quality management (TQM) is found in the applications of statistical quality control (SQC). The more common applications in use today include:

- Pareto analysis.
- Frequency distribution analysis.
- Multivari analysis.
- Measurement error analysis.
- Control charts.
- Cause and effect diagrams.
- Process capability analysis.
- Correlation analysis.
- Design of experiments.
- Acceptance sampling.

Some of these applications can be used by nonstatisticians, and others require in-depth knowledge of statistical theory. The point is that everyone in the organization from top management to employee can use at least some or all of these techniques to improve their effectiveness.

As discussed in earlier chapters, the commitment and understanding of upper management must be present for any program to succeed; this is especially true with a statistical quality control program. More often than not, when we apply statistical tools such as process capability and process control, we find out more about the process than we may have expected. We may find that our fixturing is not capable of positioning our part piece to assure precise contact with the tool or die. This may require significant expense to remedy. Unless there is commitment from upper management, the decision more often than not is: Do the best you can, we'll sort any defects if necessary.

It is not my intent to present a complete study on statistical methods. Primarily, this is a book on TQM; however, it is important to provide a brief overview on the subject so those in upper management understand how SQC came to be and how some of the applications are applied to propel practitioners along the path of continuous improvement.

QUALITY CONTROL

Quality control has been with us for thousands of years, but it was not until about 200 years ago, at the beginning of the Industrial Revolution, that we began to drift away from the craftsman method of assuring quality. The craftsman's method of controlling quality was a very personal one. He made sure that whatever he produced was, to his way of thinking, acceptable for commerce. It met his standards.

When the industrial revolution began, other influences arose that determined the quality of a product, the market, or the end user. In the beginning of this period, factories were small and located in the "industrial" cities. It was difficult to move commerce across the landscape, so industries served local communities. This provided for small lot sizes and screening (100% inspection) as a method to control quality.

During the 1920s and into the 1940s the pace of manufacturing changed from small production lots to larger and larger production runs. Included with this increase in production were advances in engineering, which led to more complex design and assemblies. It was during this period that lot-by-lot inspection gained wide acceptance by management. During the 1940s and 1950s, lot-by-lot inspection was the only way quality control personnel (i.e., inspectors) could keep up with production because screening slowed the process too much.

However, it was not long before everyone realized that lot-by-lot inspection, although fast, had serious shortcomings, not the least of which was the possibility of accepting a lot containing nonconforming parts simply because the sample taken was free of these parts. Thus, the customer or end user would receive a percentage of parts that were either useless, or worse yet, dangerous.

During the 1960s and 1970s, the shortcomings of both screening (time consuming and ineffective) and lot-by-lot inspection (not fully acceptable to the customer) encouraged management to develop what came to be known as *in-process inspection*. In-process inspection was usually accomplished by an inspector who patrolled the manufacturing floor checking on equipment, materials, methods, people, and output. In-process inspection was also sometimes carried out by the machine operator responsible for a particular phase of the manufacturing process. For example, a machine operator may measure a few pieces every hour during the production run to make sure the parts are within engineering specifications, or a plater may check the coating thickness on a fastener on one or two pieces every tenth barrel or rack to assure conformance.

In-process inspection coupled with lot-by-lot inspection was much more acceptable from the consumers' point of view because they were assured of a better chance of receiving a product to their requirements. But it still had its shortcomings:

- There was no way of knowing what went on between visits by the inspector.
- Lot-by-lot inspection still permitted nonconforming parts

to be shipped, even with zero as the acceptance number for rejects.

- When nonconforming parts were discovered, it caused production delays that were unplanned.
- The costs of scrap and rework for the manufacturer were very high.
- The system bred mistrust between inspector and machine operator.

The ineffectiveness of screening, lot-by-lot inspection, and in-process inspection along with a business climate that demanded both increased profits and consumerism led management to an increased interest in modern SQC methods.

STATISTICAL APPLICATIONS

The need to better understand our manufacturing processes led to application of statistics and statistical process control (SPC). Management saw the use of SPC as a means of providing a better product for their customers while at the same time reducing the overall cost of quality. When implementing an effective SPC program, organizations needed to work under many of the philosophies found in W. Edwards Deming’s 14 Points of Management (see Chapter 3). These 14 points, although meant for management, have wide application for all employees once upper management is applying TQM principles throughout the organization.

DESCRIPTIVE STATISTICS

Variation is present in all “like” things in the universe. There have never been any two things that are exactly alike. No two people are exactly alike, no two grains of sand, no two metal stampings, and so on. As long as we have the

means, we can examine and analyze until we find a difference. This is an important concept to understand because variation is the cornerstone of our foundation for SPC.

In any industry, variation is caused by common and special causes that are present in any process stream. Figure 7-1 represents a typical process stream made up of raw materials, people, methods, equipment, and the environment surrounding the process. All or any one of the elements of a process stream may contain variation that could affect the output. By accepting variation as a fact of any process, we can deal with it in a scientific manner as statisticians.

The variation one can encounter in this process stream may be common or special:

- *Common cause variation*—a source of chance variation that is always present; part of the natural variation inherent in the process itself.
- *Special cause variation*—a source of variation that is intermittent, unpredictable, and unstable. It is signaled by an out-of-control condition on a control chart.
- *Control chart*—a graphic representation of the output of a process showing plotted values of some statistic gathered from that output, a central line, and one or more control limits. It is used to detect special causes of variation.

In the process stream, materials are expected to have certain properties, and the elements that contribute and define those properties are a source of variation. When the process making the material contains only common causes of variation, the process is said to be in control. If one of the properties should exhibit a new trait or characteristic, it may be a source of special variation. This must be evaluated carefully so as not to identify this variance as special when it may be common—we just did not see this side of the material before. Many sources of special variation can be influenced by the person running the process and to some extent

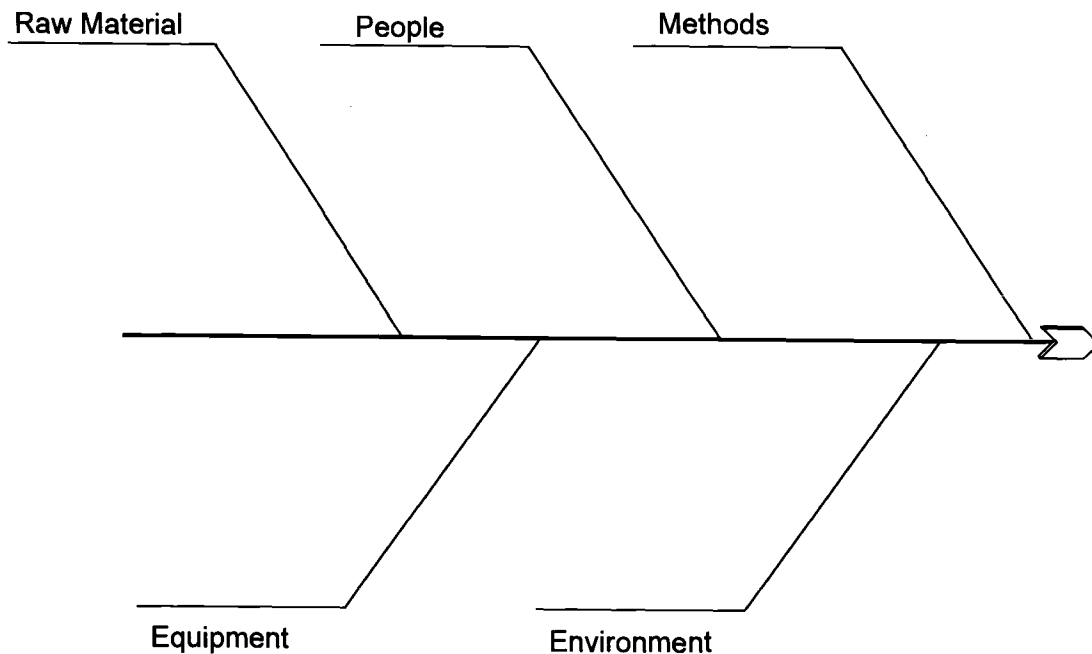


Figure 7-1—Typical process stream.

Hardness Data

36	35	35	34	36
34	37	36	36	37
35	35	36	36	37
36	37	35	37	38
36	35	35	34	36
34	37	36	36	37
35	35	36	36	37
36	37	35	37	38
38	37	35	37	38
36	36	37	37	38
36	38	37	35	36
36	35	34	38	39
37	36	38	35	37
36	37	36	35	36

Figure 7-2—Histogram of 70 hardness tests.

can be overcome. The sources of common variation are not controllable by the process operator. They are present and will influence the process no matter what the person running it attempts to do to overcome that influence. Only a change in the process stream will change the variation inherent in the process.

We could look at each of the other elements of the process stream—people, environment, methods, and equipment—and see the same dilemma. They all contain variation—some we can control and some we cannot. A heat-treating process has all kinds of elements that contribute to the successful end of meeting all the mechanical properties specified in the engineering specification.

Let us look at an example of the hardness of an ASTM A 490¹ bolt heat treated to a specified core hardness of HRC (Hardness Rockwell C-Scale) 33/39. Data were collected on

¹Specification for Heat-Treated, Steel Structural Bolts, 150 ksi (1035 MPW) Tensile Strength. ASTM Committee F16 on Fasteners.

a 50-piece sample and the following values were observed as shown in Fig. 7-2.

A statistician could describe these data in the form of a histogram as shown in Fig. 7-3.

When one looks at the two methods of describing the hardness data, it becomes obvious that the histogram provides a much clearer view than the table of values for the same data. When we look at the table, it is not readily apparent what the range of values is, what the most common value is, what data are in specification, or how the data are distributed. By having the same data in histogram format, we see at a glance that the range of values is from HRC 34 to 38; we see HRC 36 as the most common value; we see the values of all fall within the HRC 33-39 specification; and we know that the values are evenly distributed about the midpoint of the specified range.

It would be useful to further evaluate the data in Fig. 7-2 and learn a little more about the central tendency. There are three measures of central tendency that find application in statistical analysis; they are the mean, the median, and the mode. The *mean* is the numerical average calculated by adding all numbers in the set of data and dividing the sum by the number of Individual values in the data set. The *median* is the middle value in a set of data arranged from the smallest to the largest. The *mode* is the most frequently occurring value in a data set.

A small set of data (Fig. 7-4) will serve to illustrate these definitions. In this set of data, the mean is $(33 + 36 + 35 + 37 + 37) \div 5$ or 35.6. The median value is 36, and the mode is 37. To the industrial user of statistics, the mean, usually referred to as the average, is the most used statistic from a set of data. The average along with measures of dispersion is used to further define how the process is performing. There are two terms that relate to dispersion; they are *range* and *standard deviation*. The range is defined simply as the difference between the highest and lowest values in a set of data. The range of the data in Fig. 7-2 is 5, the difference between the high value of 39 and the low value of 34.

There are many ways to define *standard deviation*, but the one generally used in classic examples for SPC is: *standard*

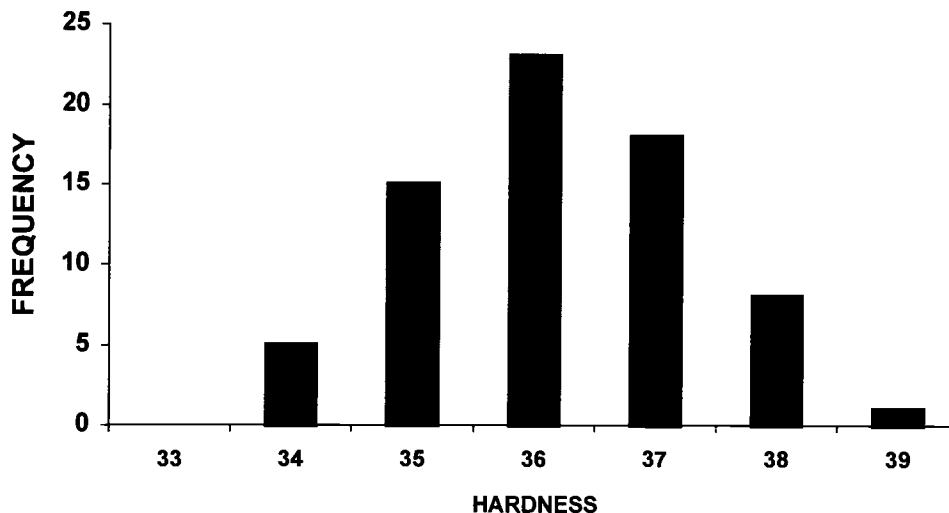


Figure 7-3—Hardness data.

Test Data

33	36	35	37	37
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Figure 7-4—Test data.

deviation—a measure of the dispersion of a series of data around their average (mean), expressed as the square root of the quantity obtained by summing the squares of the deviations from the average of the results and dividing by the number of data points minus one. This looks more complicated than it is. Today, the calculation of the standard deviation (σ) is accomplished with only an understanding of the basic mathematical skills of addition, subtraction, multiplication, and division. And if we are lucky, it can all be handled by a simple computer macro command once the raw data are entered. For the sake of completing the example, the standard deviation for the data in Fig. 7-2 is: $\sigma = 1.178\ 723$, or rounded off to two significant figures, 1.18, the mean is 36.28, the median is 36, and the mode is 36.

This technique is useful when studying raw data collected from a larger population of data and has application to both office and laboratory analysis. Better techniques are available to industrial applications that not only provide the descriptive statistics presented above, but that also give the analyst an idea of what the process is doing and capable of doing. This is called *statistical process control* or SPC.

SPC

SPC is a method of studying a process through the use of control charts. A control chart is a tool for the operator of a process, the manufacturing engineer when evaluating the process, or anyone else who has an interest in the process. Control charts are based upon data. The data must be collected in such a manner as to remove as much bias as possible. This requires the evaluation of devices used to measure the characteristics that become data. There are two definitions of data:

- **Variable data**—Characteristics that can be measured and expressed in values from a continuous scale. This type of data must be collected through a gauge or test device.
- **Attribute data**—Characteristics that can be defined as either pass/fail, yes/no, conforming/nonconforming, etc. A gauge or test device may be used as well as acceptance criteria.

For example, the hardness values in Fig. 7-2 are variable data because the values are from a continuous scale (i.e., 20 to 70 on a C-scale of a hardness tester). If we were determining what data in Fig. 7-4 are less than 36 because any value less than 36 was defective, we are working with attribute data in the form of conforming/nonconforming. In this case, there are two values nonconforming and three values conforming.

Typical gauges used in the collection of variable data would include: micrometers, calipers, dial indicators, coordinate measuring machines (CMMs), electronic testers, hardness testers, etc. Gauges for attribute data include go/no-go fixtures, color charts, thread ring gauges, etc. Regard-

less of the type gauge used in evaluating the object under investigation, the gauge must have repeatability and reproducibility. There are several tests to apply to determine an instrument's repeatability and reproducibility (R&R); the one provided for you in Appendix A is ASTM F 1469, Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Nondestructive Testing. This standard describes fully how to conduct the test and how to interpret the results. It also contains an example for the user to follow.

Briefly, when we evaluate for repeatability we are analyzing the instrument's precision, bias, and accuracy. In evaluating reproducibility, we are determining the instrument's ability to produce the same measurement on the same piece between two or more operators. There are several reasons one should conduct a gauge R&R. Among them are:

- To provide a criterion to accept new measuring devices.
- To compare one measuring device against another.
- To compare measuring devices before and after calibration or repair.
- To provide a basis for evaluating a measuring device suspected of being deficient.
- To provide a reliable measuring device for collecting data for SPC.

Variable Gauge Analysis

The variable gauge analysis is conducted with two or three operators and k test parts of different values. Each of the two or three operators measures each test part in such a manner as to prevent operator bias in evaluation. It is advisable to have a third or fourth party participate in the study by collecting data from the operator's measurements. This way neither operator will know what the other got for a measurement until all data are collected.

All data are listed on a work sheet, and the necessary calculations are performed to complete the analysis. In most cases, a gauge error of 10% of the specification tolerance, or less, is considered an acceptable variance for statistical control. If the error is greater than 10%, the device must either be improved or replaced with one that is acceptable. More detail is provided in ASTM F 1469.

There is also a study for attribute data one can apply to test devices that provide a go or no-go evaluation of the test part. The study is not as scientific as the one for variable type equipment, but it provides for some assurance of the measuring system.

Attribute Gauge Analysis

The attribute gauge analysis is conducted with two operators that each evaluate 20 test parts against two standards of known value, one conforming and the other nonconforming. In conducting this evaluation, it is desirable that some of the parts being tested be either slightly above or below the specification limits so as to truly test the measurement system. The test is run twice by each operator, and the results are recorded on the analysis work sheet. A sample attribute gauge analysis work sheet is provided in Appendix E. As with the variable gauge analysis, it is recommended that a third party be involved so as to lessen operator bias.

The measurement system is considered acceptable if all

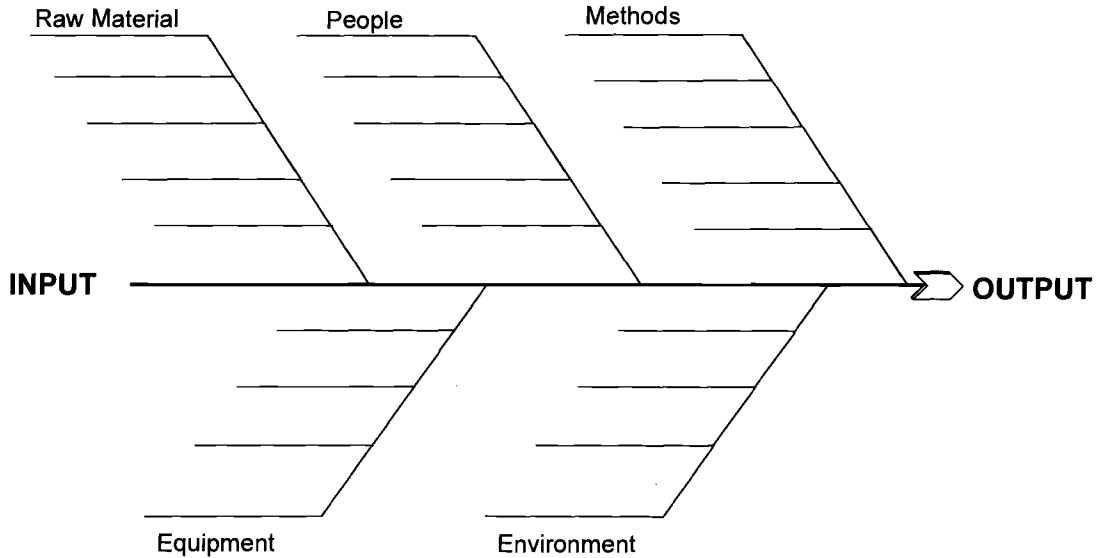


Figure 7-5—Cause and effect diagram.

evaluation decisions are in agreement with each other. If any of the evaluations disagree, the system must be improved and then reevaluated for effectiveness. If the measuring system cannot be improved, it is considered unacceptable and an alternate measuring system must be developed.

Understanding variability, data, the process, and gauge R&R are requisites to evaluating the process through the use of control charts. There are many control charts available to study processes. There are variable and attribute control charts.

Variable Control Charts

We can apply variable control charts whenever we are able to collect variable type data. The more common variable control charts are:

- \bar{X} & R chart—Control chart for averages and range.
- \bar{X} & s chart—Control chart for averages and sigma (σ).
- Median chart—Control chart for median and range.
- Chart for individuals—Control chart for a moving range.

We apply attribute charts whenever we are collecting data that have only two options, right or wrong, yes or no, etc. The more common attribute control charts are:

- p-chart—Control chart for fraction defective.
- np-chart—Control chart for number defective.
- c-chart—Control chart for defects per unit (constant subgroup).
- u-chart—Control chart for defects per unit (variable subgroup).

All of the above control charts have unique characteristics that render them useful under given conditions. I will not

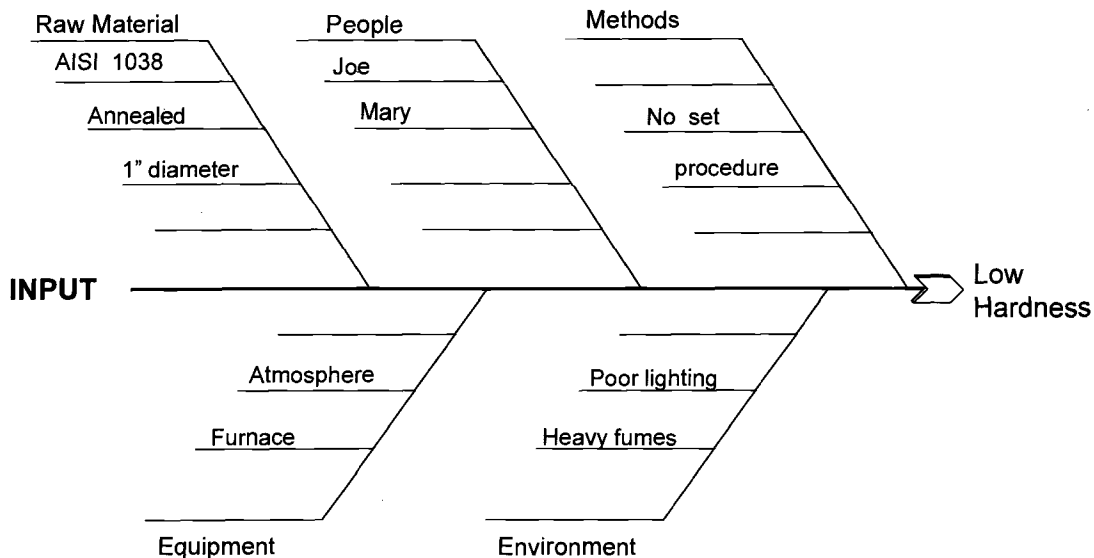


Figure 7-6—Cause and effect diagram.

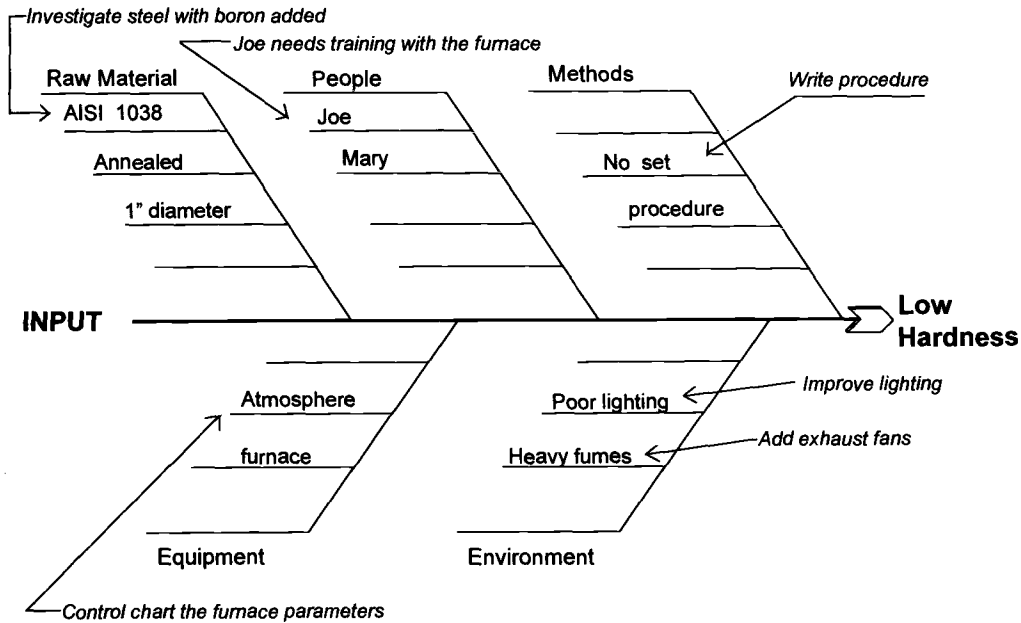


Figure 7-7—Cause and effect diagram.

attempt in this study to provide a step-by-step method for constructing the eight charts listed above, but I will provide some basic guidelines that should be followed regardless of the type chart selected to monitor a process. There are two books I recommend for the reader who is interested in learning more about the control charts and their construction. The first is *Understanding Statistical Control*,² and the second is *Recommended Practices for Statistical Process Control*.³

Guidelines for Control Charting

- **Management training**—Management must understand the value of SPC and the basics of application. They must drive fear from the corporate culture so that accurate reporting can occur. Employees must be permitted to concentrate on quality, not numbers. Management must understand that SPC will identify opportunities for improvement that may require capital investment in the process.
- **Employees training**—Employees need to be trained in basic SPC. They need to know how to determine when a subgroup is out of control. They need to be able to recognize trends and runs for sequential subgroups. They need to realize that all opportunities identified for improvement may not be addressed in the short term due to the need for capital expenditures. They need to understand what they can control and what must be changed by management in a process.
- **Understand the process**—Flow chart the process to understand how and where part characteristics are affected during the process stream. Determine all contributing elements from the process stream: material, methods, people, equipment, and environment. Ask what each contributes to

the characteristics being evaluated during the charting process.

- **Choose the characteristics for charting**—Base your decisions on need for improvement. Do not attempt to chart every characteristic a process produces. Paretoize to determine which ones have the most effect on changing the output. Use the SPQP process to characterize characteristics as to their importance in satisfying the customer and chart high achievers from that list.
- **Choose your method of measurement**—Determine the test and measuring equipment by choosing ones that measure to at least 10% of the characteristic's stated tolerance and one that has a gauge R&R \leq 10%.
- **Remove sources of variation**—When the process is studied, find ways to remove as many sources of variation as possible. The end result should leave only common causes of variation in the process stream to the greatest extent possible. As the process is charted, management should evaluate the results to find ways to reduce the common causes from the system by changing the process.
- **Process capability analysis**—Prior to allowing the operator to chart the process, one should first evaluate the process

TABLE 7-1—Pareto analysis.

	1st week	2nd week	3rd week	4th week	5th week	6th week
Missing B/P	35	37	25	30	27	23
B/P clarification	60	58	42	52	75	50
Service	65	78	60	88	79	72
Off-load	15	12	20	18	5	10
Priority	5	8	7	6	8	5
Tooling/fixtures	30	25	20	11	21	15
System down	3	5	0	0	3	4

²Wheeler, D. J. and Chambers, D. S., *Understanding Statistical Control*, Statistical Process Controls, Inc., Knoxville, TN, 1986.

³Compilation from contributing authors, "Recommended Practices for Statistical Process Control," Industrial Fastener Institute, Cleveland, OH, 1991.

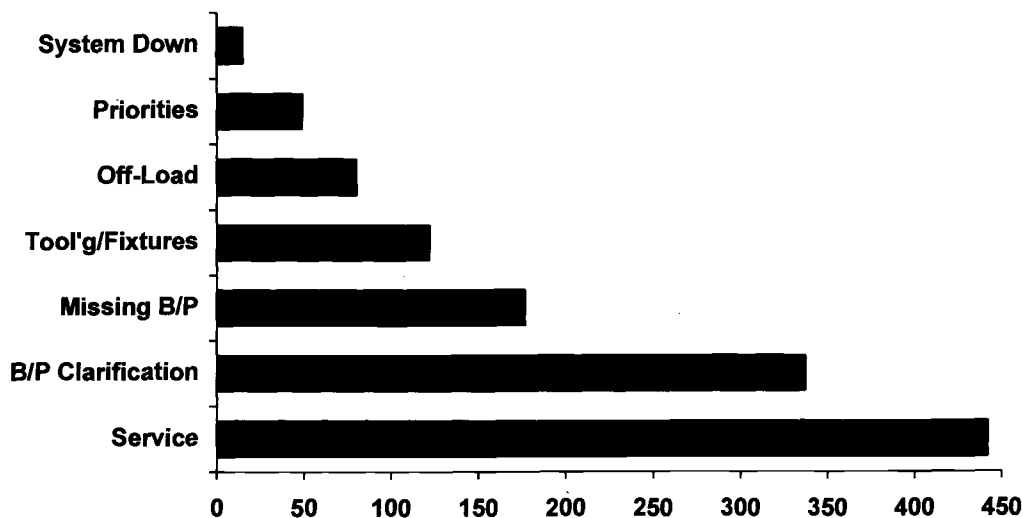


Figure 7-8—Pareto Chart 1.

for process capability. The first thing a process capability study will tell us is if the process is in a state of statistical control. There is no point in going further with charting until this state has been achieved. This gives management a starting point in determining how well the process will answer the call to produce product within engineering specifications. A method to conduct process capability analysis is provided in ASTM F 1503, Standard Practice for Machine/Process Potential Study Procedures.⁴ For your convenience, this standard is reproduced in Appendix A.

Cause and Effect Diagrams

A very simple yet powerful tool is the cause and effect diagram, or fishbone analysis. This tool utilizes the process stream model with a few modifications. A typical cause and effect diagram starts off as shown in Fig. 7-5.

You can see why it is sometimes referred to as a fishbone diagram. This tool has its greatest potential when a team is assembled to brainstorm a process. It would be good at this point to provide an example of how this tool is used. We will assume we have a team pulled together to evaluate the heat-treating process for ASTM A 325 bolts. The hardness requirement is HRC 25-32, and we are having difficulty meeting this specification on a consistent basis. Some thoughts the team might come up with are shown in Fig. 7-6.

The next step would be to find ways to improve the system or to remove variables that contribute to the undesirable output, low hardness. Our team found many areas in the present system that needed improvement. Not all would contribute to resolving the low hardness problem, but even those contribute to quality of work life, so it was decided to recommend all improvements to management for action. The team's recommendation is represented as Fig. 7-7.

Pareto Analysis

It is sometimes useful to group data in descending order to determine what inputs have the most impact on the data or situation. The tool used to accomplish this is called Pareto analysis, named after the Italian economist, Pareto. His theory was that to gain the most from our resources we should concentrate on the vital few, and not worry about the useful many. There are many applications for this theory when opportunities for improvement are so numerous that full-scale analysis cannot be done on them all. We can focus on the vital few that account for 80% or more of the total opportunities.

A case study of an application of the Pareto principle would serve as a good example. At Kennametal, Inc. in Solon, Ohio, we knew we had an opportunity to improve our on-time performance to customer ship dates if we could reduce the lead time in our process engineering department.

We established a team from the process engineering department to flow chart the process. After the process was fully identified, we asked the team to find ways to reduce road blocks to doing their job in an efficient manner. Several items were identified as contributing to their failure to process an order. These were: missing blueprints, unclear blueprints, service, off-loading, priorities, tooling/fixturing availability, and system problems. An explanation is required here to make you aware of what each category represented. We process an order through Process Engineering by working on a job packet from Customer Service. The job packet contains: part blueprints, promised delivery date, special customer requirements, and the number of pieces required. It is the job of Process Engineering to develop a process routing to manufacture the order.

Off-loading means the job could not be run on the equipment originally scheduled for processing. *Service* is when a process engineer is called to clarify process instructions for an operator on a machine or when the engineer needs to call Customer Service or Design Engineering for clarification. *Priorities* are jobs that interrupt the job they are currently

⁴ASTM Committee F16 on Fasteners.

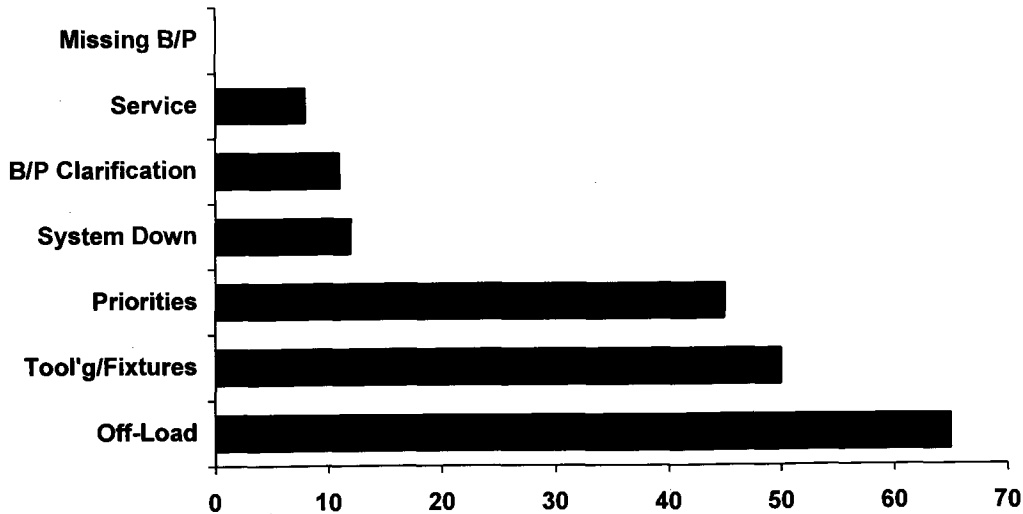


Figure 7-9—Pareto Chart 2.

working on. System problems represented those times when the CAD/CAM program was down. The other categories are self-explanatory.

This list became our CPIs, and systems were put in place to track the number of occurrences for each of these indicators. We tracked results for six weeks and paretoized the data to identify opportunities for improvement. The accumulated data are shown in Table 7-1.

To make the data more meaningful and to present it in a fashion that would instantly define opportunities for improvement, we put the data in the form of a Pareto chart (Fig. 7-8).

From the analysis, service had the greatest number of occurrences, blueprint clarification had the second most, and missing blue prints were next in number of occurrences. These three categories represented 79% of all reasons for delay. The next step was to develop an action plan to reduce the occurrences of these three factors. The strategies employed included cross training between design and process engineers and creating product-specific teams of design and process engineers, customer service representatives, and machine operators.

Several opportunities were identified as the result of this exercise. Through better tolerancing of our product (based on capability) we reduced tooling costs, programming costs, and manufacturing costs. By utilizing geometric dimension-

ing and tolerancing (GD&T), we improved our processing capabilities. Through a better understanding of our CAD geometric features and through silo tumbling we were able to utilize features of our standard parts on our custom-engineered parts.

The results of this project included reduced service and blueprint clarification occurrences, better communications between departments, better quality programming, and better efficiencies.

After six months had passed, another Pareto analysis was performed and other opportunities were identified. The problems identified in the first analysis were all but eliminated as causes of delay (see Fig. 7-9).

The team now had a new set of challenges for continuous improvement, and they set about finding ways to reduce delays due to off-loading and the unavailability of tooling and fixtures and dealing more effectively with priorities.

The other statistical tools listed in the beginning of this chapter require a broader knowledge of statistics than covered in this book. Information on multi-vari analysis, correlation analysis, and design of experiments should be pursued in text books dedicated to those subjects. The effort would be well worthwhile as these tools are very effective in defining the root causes of variance, which in turn should lead to better efficiencies.

Part 4: The Quality Assurance Manual

Introduction to Part IV: The Quality Assurance Manual

THE DEVELOPMENT of the quality assurance manual is a task that requires close coordination between all members of the management team. The written quality assurance manual describes how the quality systems are applied to each operating unit in the organization. As King Ramses of Egypt (he was one of the eleven kings of Egypt, B.C.) said, "So it is written, so it shall be." This is how auditors will interpret the contents of your manual. It is how your top management should convey the written document to the entire organization.

The quality assurance manual should be formatted after guidelines that satisfy organizational goals, customer requirements, and international standards on quality. This is a huge task and not the sole responsibility of the quality department. It becomes necessary for all department and operating unit managers to supply input to the quality department as they formulate the document.

The model quality assurance manuals I provide in this book satisfy only national and international quality requirements. It is not possible to include organizational goals or customer requirements as they are dependent upon particular and unique demands. However, those requirements can be integrated where necessary throughout the models.

The models are formatted to satisfy the quality requirements specified in ANSI/ASQC Q9000-1994 (the United

States equivalent to ISO 9000). For the manufacturing model in Chapter 8, I use ANSI/ASQC Q9001-1994 and ASME FAP-1. For the service industry model in Chapter 9 (heat treaters, platers, contract machine shops, etc.), I use ANSI/ASQC Q9002-1994, for the distributor's model in Chapter 10, I use ANSI/ACQC Q9003-94 and ASME FAP-1.

To provide more understanding with regard to the referenced standards, they are defined as follows:

ASME FAP-1 is Quality Assurance Program Requirements for Fastener Manufacturers and Distributors.¹

ANSI/ASQC Q9000-94 is Quality Management and Quality Assurance Standards—Guidelines for Selection and Use.²

ANSI/ASQC Q9001-1994 is Quality Systems—Model for Quality Assurance in Design/Development, Production, Installation and Servicing.²

ANSI/ASQC Q9002-1994 is Quality Systems—Model for Quality Assurance in Production and Installation.²

ANSI/ASQC Q9003-1994 is Quality Systems—Model for Quality Assurance in Final Inspection and Test.²

¹The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017, 1990.

²American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202, 1987.

Manufacturing Company Quality Assurance Manual

MANUFACTURING COMPANY QUALITY ASSURANCE MANUAL

Table of Contents

1.0	Management Responsibility
2.0	Quality System
3.0	Order Review
4.0	Product Design and Development Control
5.0	Document Control
6.0	Purchasing Control
7.0	Customer Supplied Product
8.0	Product Identification and Traceability
9.0	Process Control
10.0	Inspection and Testing
11.0	Inspection, Measuring and Test Equipment
12.0	Inspection and Test Status
13.0	Control of Non-Conforming Product
14.0	Corrective Action
15.0	Handling, Storage, Packaging and Delivery
16.0	Quality Records
17.0	Internal Quality Audits
18.0	Training
19.0	Servicing
20.0	Statistical Methods
21.0	Quality Improvement Program

1.0 Management Responsibility

- 1.1 Company management is responsible for communicating the Company's Corporate Quality Policy throughout the organization. Corporate and facility management are responsible for assuring that this policy is understood and implemented.
- 1.2 Corporate and facility Quality Assurance is organized to be independent of production. Quality Assurance, working in conjunction with facility management, has the responsibility and authority to:
 - 1.2.1 Initiate action to prevent the occurrence of product nonconformity;
 - 1.2.2 Identify and record any product quality problems;
 - 1.2.3 Initiate, recommend, or provide solutions through designated channels;
 - 1.2.4 Verify the implementation of solutions; and
 - 1.2.5 Control further processing, shipment, or installation of nonconforming product until the deficiency or unsatisfactory condition has been corrected.
- 1.3 The quality system outlined in this manual is reviewed annually by Corporate Management and revised or reaffirmed as appropriate. Compliance is evaluated

through quality system audits in accordance with documented procedures. Audits are performed by trained personnel independent of the function being audited.

- 1.4 The Corporate Quality Assurance Manager functions as the management representative and has the responsibility and authority for assuring that the requirements of this manual are implemented and maintained. Facility Quality Assurance Managers act as management representatives for their facilities.

2.0 Quality System

- 2.1 Company's Quality system is documented and implemented through the following documents:
 - 2.1.1 *Corporate Quality Manual*—Defines the scope of the corporation's Quality System and provides overall direction to the development of corporate and facility procedures.
 - 2.1.4 *Corporate Procedures*—Provides direction to help manufacturing facilities comply with the Quality Manual by defining specific corporate requirements or providing general technical guidance.
 - 2.1.5 *Facility Procedures*—Defines the standard operating practices at each manufacturing facility. Facility procedures satisfy corporate procedure requirements and the Corporate Quality Manual.
 - 2.1.6 *Company Facility Work Instructions*—Provides specific directions for the completion of tasks affecting quality.

3.0 Order Review

- 3.1 New products are reviewed for manufacturability and to assure that adequate production capacity and tooling are available for product introduction.
- 3.2 After an item becomes a standard stocked item, the company's primary interface occurs between the manufacturing facility's production and inventory control (P&IC) department and the production scheduler in the company's distribution facilities. The interface between manufacturing P&IC and the distribution facilities is defined in written procedures.
- 3.3 Requests for customer special products may be entered to our manufacturing facilities from our distribution centers, field sales, or direct from the customer. Written procedures describe the order review process and ensure order completeness and manufacturability. Discrepancies are resolved before manufacturing begins.
- 3.5 Each facility maintains records of quotations, purchase orders, engineering drawings, and other documentation in accordance with written procedures.

4.0 Product Design and Development Control

- 4.1 The design and/or development of new standard products is the responsibility of corporate product engineering. Quality system requirements for the design and development of standard products are documented in their Procedures Manual.

- 4.2 The design of customer specials may be performed within the product engineering department at the manufacturing facilities. Customer specials are defined as nonstandard products, unique to a specific customer request or application.
- 4.3 Engineering functions at the manufacturing facilities maintain procedures that explain how:
 - 4.3.1 Design work is completed and verified in a manner which assures that all specified requirements are met.
 - 4.3.2 Design activities are assigned to qualified personnel.
 - 4.3.3 Customer design requirements which are incomplete, ambiguous, or do not comply with internal engineering guidelines are reviewed with the customer for clarification and final approval before design documentation is released for manufacture.
 - 4.3.4 Designs comply with appropriate regulatory and safety requirements where such requirements exist.
 - 4.3.5 Design characteristics and tolerances are reviewed for manufacturability and contain or reference acceptance criteria, as appropriate.
- 4.4 Engineering maintains procedures to assure proper review, documentation, and approval of all design revisions.

5.0 Document Control

- 5.1 Manufacturing facilities maintain procedures which describe the approval process for all product drawings generated within their facility. These procedures also cover the approval of drawing revisions.
- 5.2. Plant drawing control procedures describe how and where drawings are maintained throughout the facility and the method used to collect and dispose of outdated drawings.
- 5.3 Procedural controls are documented and assure that:
 - 5.3.1 Procedures are reviewed by those affected and any suggestions resolved before the procedure is approved by authorized personnel and issued;
 - 5.3.2 Distribution is controlled and documented so that all recipients are notified of procedural changes;
 - 5.3.3 Revisions to a procedure are reviewed and approved by the originating author or function, and the nature of the change is documented where practical;
 - 5.3.4 Procedures are reviewed periodically to assure they are still current.
- 5.4 Unless otherwise stipulated, the Quality Assurance department is responsible for the control and issue of all procedures which impact product quality. Quality Assurance also maintains a current procedures index.

6.0 Purchasing Control

- 6.1 The purchase of raw materials, supplies, components, finished products or services is performed in accordance with written procedures which ensure that:
 - 6.1.1 Purchasing documents clearly identify the product or service being purchased, including information regarding type, style, class, or grade, where such information is appropriate;
 - 6.1.2 Special requirements, such as specifications, drawings, reference standards, technical data, or quality system/certification requirements are stated on the purchase order;
 - 6.1.3 Purchase orders are reviewed for completeness and approved prior to release; and

- 6.1.4 An approved supplier list is used to select suppliers. The selection of suppliers for inclusion on the approved supplier list is dependent upon the type and criticality of product or service provided. Supplier evaluations may be based on their participation in the company's "Partners In Quality" supplier certification program or previously demonstrated capability and performance.

- 6.2 The company's customers may conduct source inspection at a manufacturing facility when stipulated in the purchase order. The company retains responsibility for quality regardless of such inspection.
- 6.3 Incoming audits may be initiated by Quality Assurance to assure conformance to dimensional, metallurgical, marking, and cosmetic requirements.

7.0 Customer Supplied Product

- 7.1 Products provided by customers for use or processing at our company (e.g., special gauges or templates) are controlled in accordance with written procedures. Standard processing, inspection, and test procedures are used unless otherwise specified.
- 7.2 Product which is lost, damaged, or scrapped is reported to the customer and returned to him if possible.

8.0 Product Identification and Traceability

- 8.1 Incoming raw materials are identified with a unique batch or heat number as appropriate in accordance with written procedures.
- 8.2 Company facilities identify each order or batch of product with a unique traceability code and maintain such code throughout all stages of manufacture.
- 8.3 Finished product and/or finished product packaging is marked with the traceability code and/or a date code in accordance with written procedures.
- 8.4 The degree of traceability required for a given product or product component is based on the item's criticality to the final customer as well as any physical limitations which would prohibit product marking.

9.0 Process Control

- 9.1 Company facilities plan and control production through the use of manufacturing routings. Routings specify the raw materials required, the sequence of operations necessary to produce the product, and the applicable drawing, including revision level. Individual facilities may include additional information with the routing to facilitate manufacturing. Routings are developed in accordance with written procedures.
- 9.2 Documentation is required for those aspects of manufacturing where the absence of such would adversely affect product quality. Documentation may consist of procedures, work instructions, control plans, reference standards, or Product/Service Quality Plans.
- 9.3 Processes are controlled through the monitoring of appropriate product or process characteristics. The method used to control the process is documented in written procedures, work instructions, or control plans. Where appropriate, statistical process control (SPC) is utilized to monitor manufacturing processes, reduce sources of variation, and identify opportunities for improvement. SPC is implemented in accordance with written procedures or accepted industry standard practice.
- 9.5 New processes or equipment are reviewed to assure compliance with specified requirements. When appropriate, new equipment is subject to process qualification tests in accordance with written procedures.

10.0 Inspection and Testing

- 10.1 Quality Assurance is responsible for approving inspection and test procedures to assure outgoing quality. In-

spection and test will normally consist of the following elements:

10.1.1 *Receiving Inspection*

10.1.1.1 Quality Assurance is responsible for implementing adequate controls at receiving inspection. These controls may include 100% incoming inspections, audits, or reviews of supplier certification reports. Quality records of incoming inspections, tests, or certifications are retained in accordance with established record retention procedures.

10.1.1.2 Except as noted below, manufacturing follows procedures which prevent the use of incoming materials until all receiving inspection requirements are met.

10.1.1.3 Quality Assurance may release material for production before incoming inspections or material evaluations are completed. If this is done and subsequent receiving inspections identify a discrepant condition, production is halted and any suspect material is quarantined for further review and disposition.

10.1.2 *In-Process Inspection*

10.1.2.1 In-process inspections are performed by inspection and/or production personnel in accordance with approved product quality plans, internal procedures, work instructions or control plans. To the extent necessary, inspection documents define sampling requirements, the method of measurement used, a reaction plan if nonconforming material is found and qualitative standards for visual/cosmetic requirements.

10.1.3 *Final Inspection*

10.1.3.1 Final inspection is conducted, as required, in accordance with approved Product Quality Plans, internal procedures, work instructions, or control plans.

10.1.4 *Certification Inspection*

10.1.4.1 Product certifications are completed by Quality Assurance in accordance with specific customer requests and requirements.

10.1.4.2 Certificates of conformance must be approved by the plant QA Manager or his designate.

10.1.5 Nonconforming product found during inspection is identified, segregated from normal production, and placed on hold pending further review and disposition.

10.1.6 Critical in-process inspection and test results are documented. Inspection results are retained and are traceable to the order.

11.0 Inspection, Measuring and Test Equipment

11.1 Quality Assurance is responsible for the control and calibration of measurement and test equipment and fixtures, including employee owned gauges, which are used to verify product quality.

11.2 Quality Assurance may select, or participate in the selection of, new gauging and test equipment and ensures that the gauging is of the proper type, accuracy, and repeatability for the intended measurement.

11.3 Calibrations are performed at prescribed intervals, using certified measurement standards traceable to the National Institute of Standards and Technology (NIST) or equivalent. Where standards do not exist, the basis or method for verifying accuracy is documented.

11.4 Calibration procedures are written which describe the frequency and method of calibration, the required equipment, whether or not an outside service is employed, records to be retained, applicable acceptance standards, and the actions to be taken when results are unsatisfactory.

11.5 Quality Assurance maintains a gauge identification and calibration scheduling system at each manufacturing location. The gauge scheduling system includes the type and serial number of the gauge to be calibrated, its physical location within the plant, and the date when the next calibration is due. Records of all calibrations are maintained.

11.6 Quality Assurance maintains metrology laboratory facilities for gauge, fixture, and test equipment calibration. Metrology facilities provide adequate security, environmental controls, and appropriate storage facilities to safeguard gauge masters, gauges under calibration, and gauging not currently in use.

12.0 Inspection and Test Status

12.1 The inspection and/or test status of product is identified by tag, marking, authorization stamp, or other suitable means in accordance with written procedures.

12.2 All required tests, inspections, and documentation must be complete before the product can be released for shipment. Inspection documentation may be retained with order packet, or in various Quality Assurance databases as deemed appropriate. Inspection records must provide actual inspection results or a signoff (e.g., approval tags, employee signature or number, approval stamp, etc.) which verifies that the inspection was completed.

12.3 Inspection records identify the individual(s) responsible for releasing conforming product.

13.0 Control of Nonconforming Product

13.1 Products which do not conform to specified requirements are segregated from normal production and clearly identified with the reason for rejection in accordance with approved procedures. Final disposition of nonconforming product may involve rework or repairs to comply with product specifications, scrapping the product under review, or requesting a waiver (concession) from specification.

13.2 Quality Assurance and production review significant nonconformances to determine root cause and to make final disposition on the product in question.

13.3 Requests for waivers are initiated by Quality Assurance and approved by the appropriate product engineering personnel in accordance with approved waiver procedures.

13.3.1 Waivers to deviate from customer requirements on special products must be approved by the customer.

13.4 Product which is reworked or repaired is reinspected in accordance with approved procedures.

14.0 Corrective Action

14.1 Corrective action procedures are used to identify, analyze, and eliminate conditions which adversely affect product or service quality.

14.2 Requests for corrective action may be initiated as the

result of recurring customer complaints, scrap, rework, poor service quality, or any other issue where improvement is required.

14.3 Corrective action procedures consist of the following elements:

14.3.1 A clear, concise description of the problem or concern.

14.3.2 Appropriate containment actions as required to prevent the further processing, shipment, or sale of suspect material.

14.3.3 An analysis of the problem for the purpose of determining root cause. Problem analysis may include a review of individual processes or process flows, Product/Service Quality Plans, failure mode and effects analyses, scrap, rework, customer returns data, quality records, or other pertinent information.

14.3.4 Development and implementation of permanent corrective actions to prevent a recurrence.

14.3.5 Provisions for followup to assure that corrective actions are implemented and effective.

14.4 Quality Assurance documentation, such as procedures, work instructions, Product/Service Quality Plans, or control plans, are updated as appropriate to reflect implemented improvements.

15.0 Handling, Storage, Packaging and Delivery

15.1 Manufacturing follows procedures which protect product from damage, contamination or deterioration during storage and manufacture.

15.2 Raw materials and scrap awaiting shipment for disposal or reprocessing are controlled and stored in accordance with written procedures.

16.0 Quality Records

16.1 Quality records are retained and maintained for the time periods specified in written corporate procedures.

16.2 Quality records consist of documentation generated during purchase, manufacture, or testing which demonstrates that the required quality levels were met or that the quality system in place was effective.

16.3 Quality records are stored in a manner which assures legibility and facilitates sorting. Adequate storage facilities are provided which prevent deterioration or loss.

17.0 Internal Quality Audits

17.1 Corporate Quality Assurance conducts periodic audits at manufacturing facilities to ensure conformance to the Quality Manual and selected procedures. In addition, Corporate Quality Assurance conducts periodic product audits on material in inventory in accordance with approved Corporate Quality Assurance procedures.

17.2 Manufacturing facilities conduct internal quality system audits to assure conformance to relevant Corporate and plant procedures. Quality system audits are conducted in accordance with written procedures.

17.3 Manufacturing facilities conduct final product audits in accordance with approved audit procedures.

17.4 Audit results are reported to appropriate levels of management for review. Management personnel in the department audited are responsible for corrective action responses in a timely manner.

18.0 Training

18.1 The company maintains procedures for identifying training needs and provides for the training of personnel performing activities affecting quality.

18.2 Training records and job requirements are documented and retained by the department manager or the Human Resources function.

18.3 Individuals assigned specific tasks which impact quality are qualified based on education, training, or experience, as appropriate.

19.0 Servicing

19.1 Where applicable, the company establishes and maintains procedures for providing appropriate levels of service to customers.

19.2 The company is responsible for direct customer service. Corporate Quality Assurance provides technical support to the manufacturing facilities, as well as analysis and disposition of performance related customer returns.

20.0 Statistical Methods

20.1 Statistical methods are employed, as appropriate, to facilitate problem identification and analysis and the control, improvement, or qualification of processes or systems.

20.2 When employed, statistical methods are conducted in accordance with internal procedures or accepted standard practice.

20.3 Management is responsible for providing adequate training for those employees using or interpreting statistical results.

20.4 Statistical methods may include, but are not limited to:

- 20.4.1 Pareto analysis
- 20.4.2 Process capability analysis
- 20.4.3 Statistical process control
- 20.4.4 Design of experiments
- 20.4.5 Regression analysis

21.0 Quality Improvement Program

21.1 Corporate and facility management are responsible for developing the company's Quality Improvement Program. The Quality Improvement Program consists of a three-year strategic plan, as well as detailed annual quality improvement projects. This plan is submitted to the Board of Directors for final approval. Quarterly updates are issued to management to monitor progress.

21.2 Cost of Quality reports are issued by each facility.

21.3 Where appropriate, quality improvement plans include provisions for advanced quality planning for significant new product developments.

Service Industry Quality Assurance Manual

SERVICE INDUSTRY QUALITY ASSURANCE MANUAL

Table of Contents

1.0	Management Responsibility
2.0	Quality System
3.0	Contract Review
4.0	Document Control
5.0	Purchasing
6.0	Purchaser Supplied Gauging & Test Equipment
7.0	Product Identification and Traceability
8.0	Process Control
9.0	Inspection and Testing
10.0	Inspection, Measuring, and Test Equipment
11.0	Inspection and Test Status
12.0	Control of Nonconforming Product
13.0	Corrective Action
14.0	Handling, Storage, Packaging, and Delivery
15.0	Quality Records
16.0	Internal Quality Audits
17.0	Training
18.0	Statistical Techniques

1.0 Management Responsibility

- 1.1 It is the policy of the company to market and provide products of such quality that they will reliably perform their intended function so that the company is recognized as a quality leader in the industry. It is the responsibility of company senior management to communicate the corporate quality policy throughout the company.
- 1.2 The company's Quality Assurance is organized to be independent of production. Quality Assurance, working in conjunction with company management, has the responsibility and authority to:
 - 1.2.1 Initiate action to prevent the occurrence of product nonconformity;
 - 1.2.2 Identify and record any product quality problems;
 - 1.2.3 Initiate, recommend, or provide solutions through designated channels;
 - 1.2.4 Verify the implementation of solutions; and
 - 1.2.5 Control further processing, shipment, or installation of nonconforming product until the deficiency or unsatisfactory condition has been corrected.
- 1.3 The quality system outlined in this manual is reviewed annually by company management and revised or reaffirmed as appropriate. Compliance is evaluated through quality system audits in accordance with documented procedures. Audits are performed by trained personnel independent of the function being audited.

- 1.4 The company's Quality Assurance Manager functions as the management representative and has the responsibility and authority for assuring that the requirements of this manual are implemented and maintained.

2.0 Quality System

- 2.1 The company's quality system is documented and implemented through the following documents:
 - 2.1.1 *Quality Manual*—Defines the scope of the company's quality system and provides overall direction to the development of the company's procedures.
 - 2.1.4 *Procedures*—Provides direction to help the production facility comply with the Quality Manual by defining specific company requirements or providing general technical guidance.
 - 2.1.6 *Work Instructions*—Provides specific directions for the completion of tasks affecting quality.

3.0 Order Review

- 3.1 All orders are reviewed to assure that adequate instructions exist to fully understand the customer's requirements.
- 3.2 A thorough review of the requirements is made to compare them with existing requirements from the same customer. Quality plans are modified as required.
- 3.3 The company will assure that we have the necessary capacity to perform the job in the time requested on the order.
- 3.4 Records of quotations, purchase orders, engineering drawings, and other documentation will be maintained in accordance with written procedures.

4.0 Document Control

- 4.1 The company shall maintain procedures which describe the approval process for all product drawings procedures and specifications received by customers and regulatory agencies. These procedures also cover the approval of revisions to these documents.
- 4.2 Company drawing control procedures describe how and where drawings are maintained throughout the facility and the method used to collect and dispose of outdated drawings.
- 4.3 Procedural controls are documented and assure that:
 - 4.3.1 Procedures are reviewed by those affected and any issues resolved before the procedure is approved by authorized personnel and issued;
 - 4.3.2 Distribution is controlled and documented so that all recipients are notified of procedural changes;
 - 4.3.3 Revisions to a procedure are reviewed and approved by the originating author or function, and the nature of the change is documented where practical;
 - 4.3.4 Procedures are reviewed periodically to assure they are still current.
- 4.4 Unless otherwise stipulated, the Quality Assurance department is responsible for the control and issue of all procedures which impact product quality.

- 4.5 Quality Assurance maintains an index of all procedures that affect the quality of our production and service to the customer.

5.0 Purchasing Control

- 5.1 The purchase of raw materials, supplies, components, finished products or services is performed in accordance with written procedures which ensure that:
- 5.1.1 Purchasing documents clearly identify the product or service being purchased, including information regarding type, style, class, or grade, where such information is appropriate;
 - 5.1.2 Special requirements, such as specifications, drawings, reference standards, technical data, or quality system/certification requirements are stated on the purchase order;
 - 5.1.3 Purchase orders are reviewed for completeness and approved prior to release; and
 - 5.1.4 An approved supplier list is used to select suppliers. The selection of suppliers for inclusion on the approved supplier list is dependent upon the type and criticality of product or service provided. Supplier evaluations may be based on their participation in the company's "Partners In Quality" supplier certification program or previously demonstrated capability and performance.
- 5.2 The company may conduct source inspection at a supplier's facility when stipulated in the purchase order. The supplier retains responsibility for quality regardless of such inspection.
- 5.3 Incoming audits may be initiated by Quality Assurance to assure conformance to dimensional, metallurgical, marking, and cosmetic requirements.

6.0 Customer Supplied Product

- 6.1 Products provided by customers for use or processing at our company (e.g., special gauges or checking fixtures) are controlled in accordance with written procedures. Standard processing, inspection, and test procedures are used unless otherwise specified.
- 6.2 Product which is lost, damaged, or scrapped is reported to the customer and returned to him if possible.

7.0 Product Identification and Traceability

- 7.1 Incoming raw materials are identified with a unique batch or heat number as appropriate in accordance with written procedures.
- 7.2 Each order or batch of product is identified with a unique traceability code which is maintained throughout all stages of production.
- 7.3 Finished orders and/or finished order packaging is marked with the traceability code and/or a date code in accordance with written procedures.
- 7.4 The degree of traceability required for a given order is based on the item's criticality to the customer as well as any physical limitations which would prohibit marking.

8.0 Process Control

- 8.1 The company plans and controls production through the use of production routings. Routings specify the raw materials required, the sequence of operations necessary to complete the order, and the applicable drawing, including revision level. Routings are developed in accordance with written procedures.
- 8.2 Documentation is required for those aspects of production where the absence of such would adversely affect product quality. Documentation may consist of procedures, work instructions, control plans, reference standards, or Product/Service Quality Plans.
- 8.3 Processes are controlled through the monitoring of appropriate product or process characteristics. The

method used to control the process is documented in written procedures, work instructions, or control plans. Where appropriate, statistical process control (SPC) is utilized to monitor manufacturing processes, reduce sources of variation, and identify opportunities for improvement. SPC is implemented in accordance with written procedures or accepted industry standard practice.

- 8.5 New processes or equipment are reviewed to assure compliance with specified requirements. When appropriate, new equipment is subject to process qualification tests in accordance with written procedures.

9.0 Inspection and Testing

- 9.1 Quality Assurance is responsible for approving inspection and test procedures to assure outgoing quality. Inspection and test will normally consist of the following elements:

9.1.1 Receiving Inspection

9.1.1.1 Quality Assurance is responsible for implementing adequate controls at receiving inspection. These controls may include 100% incoming inspections, audits, or reviews of supplier certification reports. Quality records of incoming inspections, tests, or certifications are retained in accordance with established record retention procedures.

9.1.1.2 Except as noted below, production follows procedures which prevent the use of incoming materials until all receiving inspection requirements are met.

9.1.1.3 Quality Assurance may release material for production before incoming inspections or material evaluations are completed. If this is done and subsequent receiving inspections identify a discrepant condition, production is halted and any suspect material is quarantined for further review and disposition.

9.1.2 In-Process Inspection

9.1.2.1 In-process inspections are performed by inspection and/or production personnel in accordance with approved product quality plans, internal procedures, work instructions or control plans. To the extent necessary, inspection documents define sampling requirements, the method of measurement used, a reaction plan if nonconforming material is found and qualitative standards for visual/cosmetic requirements.

9.1.3 Final Inspection

9.1.3.1 Final inspection is conducted, as required, in accordance with approved Product Quality Plans, internal procedures, work instructions, or control plans.

9.1.4 Certification Inspection

9.1.4.1 Product certifications are completed by Quality Assurance in accordance with specific customer requests and requirements.

9.1.4.2 Certificates of conformance must be approved by the plant Quality Assurance Manager or his designate.

- 9.1.5 Nonconforming product found during inspection is identified, segregated from normal production,

and placed on hold pending further review and disposition.

- 9.1.6 Critical in-process inspection and test results are documented. Inspection results are retained and are traceable to the order.

10.0 Inspection, Measuring and Test Equipment

- 10.1 Quality Assurance is responsible for the control and calibration of measurement and test equipment and fixtures, including employee owned gauges, which are used to verify product quality.
- 10.2 Quality Assurance may select, or participate in the selection of, new gauging and test equipment and ensures that the gauging is of the proper type, accuracy, and repeatability for the intended measurement.
- 10.3 Calibrations are performed at prescribed intervals, using certified measurement standards traceable to the National Institute of Standards and Technology (NIST) or equivalent. Where standards do not exist, the basis or method for verifying accuracy is documented.
- 10.4 Calibration procedures are written which describe the frequency and method of calibration, the required equipment, whether or not an outside service is employed, records to be retained, applicable acceptance standards, and the actions to be taken when results are unsatisfactory.
- 10.5 Quality Assurance maintains a gauge identification and calibration scheduling system. The gauge scheduling system includes the type and serial number of the gauge to be calibrated, its physical location within the company, and the date when the next calibration is due. Records of all calibrations are maintained.
- 10.6 Quality Assurance maintains metrology laboratory facilities for gauge, fixture, and test equipment calibration. Metrology facilities provide adequate security, environmental controls, and appropriate storage facilities to safeguard gauge masters, gauges under calibration, and gauging not currently in use.

11.0 Inspection and Test Status

- 11.1 The inspection and/or test status of an order is identified by tag, marking, authorization stamp, or other suitable means in accordance with written procedures.
- 11.2 All required tests, inspections, and documentation must be complete before the order can be released for shipment. Inspection documentation may be retained with order packet, or in various Quality Assurance databases as deemed appropriate. Inspection records must provide actual inspection results or a signoff (e.g., approval tags, employee signature or number, approval stamp, etc.) which verifies that the inspection was completed.
- 11.3 Inspection records identify the individual(s) responsible for releasing conforming product.

12.0 Control of Nonconforming Product

- 12.1 Products which do not conform to specified requirements are segregated from normal production and clearly identified with the reason for rejection in accordance with approved procedures. Final disposition of nonconforming product may involve rework or repairs to comply with product specifications, scrapping the product under review, or requesting a waiver (concession) from specification.
- 12.2 Quality Assurance and production review significant nonconformances to determine root cause and to make final disposition on the product in question.
- 12.3 Requests for waivers are initiated by Quality Assurance and approved by the appropriate management personnel in accordance with approved waiver procedures.

- 12.3.1 Waivers to deviate from customer requirements must be approved by the customer.

- 12.4 Product which is reworked or repaired is reinspected in accordance with approved procedures.

13.0 Corrective Action

- 13.1 Corrective action procedures are used to identify, analyze, and eliminate conditions which adversely affect product or service quality.
- 13.2 Requests for corrective action may be initiated as the result of recurring customer complaints, scrap, rework, poor service quality, or any other issue where improvement is required.
- 13.3 Corrective action procedures consist of the following elements:
- 13.3.1 A clear, concise description of the problem or concern.
- 13.3.2 Appropriate containment actions as required to prevent the further processing, shipment, or sale of suspect material.
- 13.3.3 An analysis of the problem for the purpose of determining root cause. Problem analysis may include a review of individual processes or process flows, Product/Service Quality Plans, failure mode and effects analyses, scrap, rework, customer returns data, quality records, or other pertinent information.
- 13.3.4 Development and implementation of permanent corrective actions to prevent a recurrence.
- 13.3.5 Provisions for follow-up to assure that corrective actions are implemented and effective.
- 13.4 Quality Assurance documentation, such as procedures, work instructions, Product/Service Quality Plans, or control plans, is updated as appropriate to reflect implemented improvements.

14.0 Handling, Storage, Packaging and Delivery

- 14.1 Production follows procedures which protect product from damage, contamination, or deterioration during storage and manufacture.
- 14.2 Raw materials and scrap awaiting shipment for disposal or reprocessing are controlled and stored in accordance with written procedures.

15.0 Quality Records

- 15.1 Quality records are retained and maintained for the time periods specified in written corporate procedures.
- 15.2 Quality records consist of documentation generated during purchase, production, or testing which demonstrates that the required quality levels were met or that the quality system in place was effective.
- 15.3 Quality records are stored in a manner which assures legibility and facilitates sorting. Adequate storage facilities are provided which prevent deterioration or loss.

16.0 Internal Quality Audits

- 16.1 The company conducts periodic audits of operations to ensure conformance to the Quality Manual and selected procedures. In addition, the company conducts periodic product audits on material in inventory in accordance with approved Quality Assurance procedures.
- 16.2 The Quality Assurance manager conducts internal quality system audits to assure conformance to relevant company procedures. Quality system audits are conducted in accordance with written procedures.
- 16.3 Audit results are reported to appropriate levels of management for review. Management personnel in the department audited are responsible for corrective action responses in a timely manner.

17.0 Training

- 17.1 The company maintains procedures for identifying training needs and provides for the training of personnel performing activities affecting quality.
- 17.2 Training records and job requirements are documented and retained by the department manager or the Human Resources function.
- 17.3 Individuals assigned specific tasks which impact quality are qualified based on education, training, or experience, as appropriate.

18.0 Statistical Methods

- 18.1 Statistical methods are employed, as appropriate, to facilitate problem identification and analysis and the control, improvement, or qualification of processes or systems.

18.2 When employed, statistical methods are conducted in accordance with internal procedures or accepted standard practice.

18.3 Management is responsible for providing adequate training for those employees using or interpreting statistical results.

18.4 Statistical methods may include, but are not limited to:

- 18.4.1 Pareto analysis
- 18.4.2 Process capability analysis
- 18.4.3 Statistical process control
- 18.4.4 Design of experiments
- 18.4.5 Regression analysis

Distributor Industry Quality Assurance Manual

INTRODUCTION

IN MY OPINION the ANSI/ASQC Q9003-1994 and ISO 9003 standards fall short when specifying quality system requirements for final inspection and test facilities that typically are the general description of 80% of the distributor industry.

In reviewing the use of the standard guidelines in Q9000-1994, Q94 recommends they use Q9003-1994 when conformance to specified requirements are to be assured by the supplier solely at final inspection and test. One would apply Q92 when conformance to specified requirements is to be assured by the supplier during production and installation. Very few distributors get involved in production (i.e., machining or installation). However, many are involved in services such as metallic coatings and parts kitting (the practice of combining two or more different parts to make a whole, such as making a kit consisting of five M20 by 2.5 by 80-mm heavy hex structural bolts, five M20 by 2.5 heavy hex nuts, and five hardened washers). Therefore, I included sections in the quality manual that provide for the control of these activities.

DISTRIBUTORSHIP QUALITY ASSURANCE MANUAL

Table of Contents

1.0	<i>Management Responsibility</i>
2.0	<i>Quality System</i>
3.0	<i>Order Review</i>
4.0	<i>Document Control</i>
5.0	<i>Purchasing</i>
6.0	<i>Product Identification and Traceability</i>
7.0	<i>Inspection and Testing</i>
8.0	<i>Inspection, Measuring, and Test Equipment</i>
9.0	<i>Inspection and Test Status</i>
10.0	<i>Control of Nonconforming Product</i>
11.0	<i>Corrective Action</i>
12.0	<i>Handling, Storage, Packaging, and Delivery</i>
13.0	<i>Quality Records</i>
14.0	<i>Internal Quality Audits</i>
15.0	<i>Training</i>
16.0	<i>Statistical Techniques</i>

1.0 Management Responsibility

- 1.1 It is the policy of the company to market and provide products of such quality that they will reliably perform

their intended function so that the company is recognized as a quality leader in the industry. It is the responsibility of company senior management to communicate the corporate quality policy throughout the company.

- 1.2 The company's Quality Assurance is organized to be independent of production. Quality Assurance, working in conjunction with company management, has the responsibility and authority to:
 - 1.2.1 Initiate action to prevent the shipment of nonconforming product;
 - 1.2.2 Identify and record any product quality problems;
 - 1.2.3 Initiate, recommend, or provide solutions through designated channels;
 - 1.2.4 Verify the implementation of solutions; and
 - 1.2.5 Control further acceptance or shipment, of nonconforming product until the deficiency or unsatisfactory condition has been corrected.
- 1.3 The quality system outlined in this manual is reviewed annually by company management and revised or reaffirmed as appropriate. Compliance is evaluated through quality system audits in accordance with documented procedures. Audits are performed by trained personnel independent of the function being audited.
- 1.4 The company's Quality Assurance Manager functions as the management representative and has the responsibility and authority for assuring that the requirements of this manual are implemented and maintained.

2.0 Quality System

- 2.1 The company's quality system is documented and implemented through the following documents:
 - 2.1.1 *Quality Manual*—Defines the scope of the company's quality system and provides overall direction to the development of the company's procedures.
 - 2.1.4 *Procedures*—Provides direction to help the operating departments comply with the Quality Manual by defining specific company requirements or providing general technical guidance.
 - 2.1.6 *Work Instructions*—Provides specific directions for the completion of tasks affecting quality.

3.0 Order Review

- 3.1 All orders are reviewed to assure that adequate instructions exist to fully understand the customer's requirements.
- 3.2 A thorough review of the requirements is made to compare them with existing requirements from the same customer. Quality plans are modified as required.
- 3.3 Records of quotations, purchase orders, engineering drawings, customer specifications and other documentation will be maintained in accordance with written procedures.

4.0 Document Control

- 4.1 The company shall maintain procedures which describe the approval process for all product drawings proce-

dures and specifications received by customers and regulatory agencies. These procedures also cover the approval of revisions to these documents.

- 4.2 Company document control procedures describe how and where documents are maintained throughout the facility and the method used to collect and dispose of outdated documents.
- 4.3 Procedural controls are documented and assure that:
 - 4.3.1 Procedures are reviewed by those affected and any issues resolved before the procedure is approved by authorized personnel and issued;
 - 4.3.2 Distribution is controlled and documented so that all recipients are notified of procedural changes;
 - 4.3.3 Revisions to a procedure are reviewed and approved by the originating author or function, and the nature of the change is documented where practical;
 - 4.3.4 Procedures are reviewed periodically to assure they are still current.
- 4.4 Unless otherwise stipulated, the Quality Assurance department is responsible for the control and issue of all procedures which impact product quality.
- 4.5 Quality Assurance maintains an index of all procedures that affect the quality of our distribution and service to customers.

5.0 Purchasing Control

- 5.1 The purchase of supplies, components, finished products or services is performed in accordance with written procedures which ensure that:
 - 5.1.1 Purchasing documents clearly identify the product or service being purchased, including information regarding type, style, class, or grade, where such information is appropriate;
 - 5.1.2 Special requirements, such as specifications, drawings, reference standards, technical data, or quality system/certification requirements are stated on the purchase order;
 - 5.1.3 Purchase orders are reviewed for completeness and approved prior to release; and
 - 5.1.4 An approved supplier list is used to select suppliers. The selection of suppliers for inclusion on the approved supplier list is dependent upon the type and criticality of product or service provided. Supplier evaluations may be based on their participation in the company's "Partners In Quality" supplier certification program or previously demonstrated capability and performance.
- 5.2 The company may conduct source inspection at a supplier's facility when stipulated in the purchase order. The supplier retains responsibility for quality regardless of such inspection.
- 5.3 Incoming audits may be initiated by Quality Assurance to assure conformance to dimensional, metallurgical, marking, and cosmetic requirements.

6.0 Product Identification and Traceability

- 6.1 Incoming materials are identified with a unique batch or lot number as appropriate in accordance with written procedures.
- 6.2 Each order or batch of product is identified with a unique traceability code which is maintained throughout all stages of storage through shipping.
- 6.3 Finished orders and/or finished order packaging is marked with the traceability code and/or a date code in accordance with written procedures.

7.0 Inspection and Testing

- 7.1 Quality Assurance is responsible for approving inspection and test procedures to assure incoming and outgo-

ing quality. Inspection and test will normally consist of the following elements:

7.1.1 Receiving Inspection

7.1.1.1 Quality Assurance is responsible for implementing adequate controls at receiving inspection. These controls may include 100% incoming inspections, audits, or reviews of supplier certification reports. Quality records of incoming inspections, tests, or certifications are retained in accordance with established record retention procedures.

7.1.1.2 Except as noted below, the warehouse and distribution functions follow procedures which prevent the storage or shipment of incoming materials until all receiving inspection requirements are met.

7.1.1.3 Quality Assurance may release material for inventory before incoming inspections or material evaluations are completed. If this is done and subsequent receiving inspections identify a discrepant condition, the material must be quarantined for further review and disposition.

7.1.3 Final Inspection

7.1.3.1 Final inspection is conducted, as required, in accordance with approved Product Quality Plans, internal procedures, work instructions, or control plans.

7.1.4 Certification Inspection

7.1.4.1 Product certifications are completed by Quality Assurance in accordance with specific customer requests and requirements.

7.1.4.2 Certificates of conformance must be approved by the facility Quality Assurance Manager or his designate.

7.1.5 Nonconforming product found during inspection is identified, segregated from normal process flows, and placed on hold pending further review and disposition.

7.1.6 Inspection and test results are documented. Inspection results are retained and are traceable to the order.

8.0 Inspection, Measuring and Test Equipment

- 8.1 Quality Assurance is responsible for the control and calibration of measurement and test equipment and fixtures, including employee owned gauges, which are used to verify product quality.
- 8.2 Quality Assurance may select, or participate in the selection of, new gauging and test equipment and ensures that the gauging is of the proper type, accuracy, and repeatability for the intended measurement.
- 8.3 Calibrations are performed at prescribed intervals, using certified measurement standards traceable to the National Institute of Standards and Technology (NIST) or equivalent. Where standards do not exist, the basis or method for verifying accuracy is documented.
- 8.4 Calibration procedures are written which describe the frequency and method of calibration, the required equipment, whether or not an outside service is employed, records to be retained, applicable acceptance standards, and the actions to be taken when results are unsatisfactory.

- 8.5 Quality Assurance maintains a gauge identification and calibration scheduling system. The gauge scheduling system includes the type and serial number of the gauge to be calibrated, its physical location within the company, and the date when the next calibration is due. Records of all calibrations are maintained.
- 8.6 Quality Assurance maintains metrology laboratory facilities for gauge, fixture, and test equipment calibration. Metrology facilities provide adequate security, environmental controls, and appropriate storage facilities to safeguard gauge masters, gauges under calibration, and gauging not currently in use.
- 9.0 Inspection and Test Status**
- 9.1 The inspection and/or test status of an order is identified by tag, marking, authorization stamp, or other suitable means in accordance with written procedures.
- 9.2 All required tests, inspections, and documentation must be complete before the order can be released for shipment. Inspection documentation may be retained with order packet, or in various Quality Assurance databases as deemed appropriate. Inspection records must provide actual inspection results or a sign-off (e.g., approval tags, employee signature or number, approval stamp, etc.) which verifies that the inspection was completed.
- 9.3 Inspection records identify the individual(s) responsible for releasing conforming product.
- 10.0 Control of Nonconforming Product**
- 10.1 Products which do not conform to specified requirements are segregated from the normal process flow and clearly identified with the reason for rejection in accordance with approved procedures. Final disposition of nonconforming product may involve rework or rejection to the supplier to comply with product specifications, scrapping the product under review, or requesting a waiver (concession) from specification.
- 10.2 Quality Assurance reviews significant nonconformances with the supplier to make final disposition on the product in question.
- 10.3 Requests for waivers are initiated by the supplier's Quality Assurance representative and reviewed with our customer by our quality assurance management in accordance with approved waiver procedures.
- 10.3.1 Waivers to deviate from customer requirements must be approved by the customer.
- 10.4 Product which is reworked is reinspected in accordance with approved procedures.
- 11.0 Corrective Action**
- 11.1 Corrective action procedures are used to identify, analyze, and eliminate conditions which adversely affect service quality.
- 11.2 Requests for corrective action may be initiated as the result of recurring customer complaints, poor service quality, or any other issue where improvement is required.
- 11.3 Corrective action procedures consist of the following elements:
- 11.3.1 A clear, concise description of the problem or concern.
- 11.3.2 Appropriate containment actions as required to prevent further instances of the problem.
- 11.3.3 An analysis of the problem for the purpose of determining root cause. Problem analysis may include a review of individual processes or process flows, Service Quality Plans, failure mode and effects analyses, customer returns data, quality records, or other pertinent information.
- 11.3.4 Development and implementation of permanent corrective actions to prevent a recurrence.
- 11.3.5 Provisions for follow-up to assure that corrective actions are implemented and effective.
- 11.4 Quality Assurance documentation, such as procedures, work instructions, Service Quality Plans, or control plans, are updated as appropriate to reflect implemented improvements.
- 12.0 Handling, Storage, Packaging, and Delivery**
- 12.1 All processes follow procedures which protect product from damage, contamination, or deterioration during product receipt, storage, and packaging.
- 12.2 Product awaiting shipment for disposal or reprocessing are controlled and stored in accordance with written procedures.
- 13.0 Quality Records**
- 13.1 Quality records are retained and maintained for the time periods specified in written procedures.
- 13.2 Quality records consist of documentation generated during purchase, rework or testing which demonstrates that the required quality levels were met or that the quality system in place was effective.
- 13.3 Quality records are stored in a manner which assures legibility and facilitates sorting. Adequate storage facilities are provided which prevent deterioration or loss.
- 14.0 Internal Quality Audits**
- 14.1 The company conducts periodic audits of all processes to ensure conformance to the Quality Manual and selected procedures. In addition, the company conducts periodic product audits on material in inventory in accordance with approved Quality Assurance procedures.
- 14.3 Audit results are reported to appropriate levels of management for review. Management personnel in the department audited are responsible for corrective action responses in a timely manner.
- 15.0 Training**
- 15.1 The company maintains procedures for identifying training needs and provides for the training of personnel performing activities affecting quality.
- 15.2 Training records and job requirements are documented and retained by the department manager or the Human Resources function.
- 15.3 Individuals assigned specific tasks which impact quality are qualified based on education, training, or experience, as appropriate.
- 16.0 Statistical Methods**
- 16.1 Statistical methods are employed, as appropriate, to facilitate problem identification and analysis and the control, improvement, or qualification of processes or systems.
- 16.2 When employed, statistical methods are conducted in accordance with internal procedures or accepted standard practice.
- 16.3 Management is responsible for providing adequate training for those employees using or interpreting statistical results.
- 16.4 Statistical methods may include, but are not limited to:
- 16.4.1 Pareto analysis
- 16.4.2 Gauge and test equipment repeatability and reproducibility studies
- 16.4.3 Statistical process control

Part 5: Fastener Quality Assurance Act

Public Law 101-592

ON 16 Nov. 1990, President George Bush signed into law HR-3000, enacting Public Law 101-592 (hereafter referred to as the Fastener Quality Act, or FQA). The FQA was necessary in large part because there exists in the fastener industry those who are more interested in making money in fraudulent ways than in conducting business in an ethical manner. The business practices of these individuals included supplying fasteners with false certifications, unauthorized material substitutions, head marks inconsistent with performance levels, and other deviations from the standards they represented.

This phenomenon surfaced during the mid-1980s, and because of the seriousness of the consequences of applying substandard fasteners, the U.S. Government became involved. The results of misapplied fasteners included: loss of life, human injury, equipment failure—including military tanks, and millions of dollars in costs associated with these losses.

All of this could have been avoided if those who purchased the fraudulent fasteners had applied TQM principles. The fastener industry could have escaped becoming a regulated industry with all the added costs to the industry and to the American taxpayer if good business practices had existed. Many in the industry are bitter, and who can blame them? From a quality professional's point of view, I am both elated and disappointed by the result. On balance, however, I am more disappointed because the absence of continuous improvement in operations resulted in unnecessary costs. The added costs will affect the American taxpayer more than the fastener industry. As I read the FQA, I see easy compliance for those companies who follow the TQM guidelines discussed in this book. The vast majority of companies in the fastener industry are well positioned to comply with the FQA, with minor corrections to their operating practices. The minority contains a mix of companies willing to change their operating philosophy to comply, as well as those who will still attempt to circumvent compliance.

A brief summary of the FQA would be appropriate and beneficial to those not familiar with its provisions.

To date, the FQA is not in effect. There are still recommended amendments under consideration before the U.S. Senate. These amendments were recommended to Congress by a group of industry experts appointed to the Fastener Advisory Committee (FAC) by the Commerce Department. The FAC includes members from fastener manufacturers, distributors, users, testing laboratories, and standards organizations. The group is diverse and, as should be expected, did not always agree on what the FQA should contain. However,

in spite of their differences they were able to reach consensus on many of their original points of contention. The FAC introduced three amendments to the House of Representatives. The three areas of concern were: (1) chemical testing, (2) sale of fasteners with minor deviations from standard, and (3) lot segregation.

CHEMICAL TESTING

The way the FQA is now prepared, it is necessary to conduct a chemical analysis on each shipping lot of fasteners covered by the FQA. The industry practice has been to apply the certified mill test report of chemistry to all lots of fasteners manufactured from the heat of steel applicable to that mill certification. This has been accepted by both manufacturers and users because fastener manufacturing has no affect on the original material's chemistry. If the requirement of providing a chemistry test on each shipping lot was imposed, it is estimated by the FAC that this would add between \$100 million and \$266 million to the cost of doing business.

MINOR DEVIATIONS

Many fastener specifications and standards now permit the use of fasteners that may contain minor deviations. Provisions exist within the standard or specification that require full disclosure from the seller to the buyer. This makes good economic sense when the deviation would have absolutely no impact on form, fit, or use for the fastener's intended application. The FQA as currently written would not allow the sale of fasteners with deviations from standard. It does not make sense for a Governmental body who knows nothing about fasteners or the engineered application of fasteners to have final judgment as to acceptance. This decision should be left to the fastener manufacturer and his customer! The FAC estimates the cost of this change of practice to the industry to be between \$200 million and \$1 billion.

LOT SEGREGATION

This area of the FQA has perhaps generated the most polarity among the FAC. At the present time, distributors commingle lots of like grades (property classes) of fasteners. This could mean different lots from the same manufacturer or

74 TOTAL QUALITY MANAGEMENT MANUAL

that lots from different fastener manufacturers could be supplied to users under the present system. This practice removes all traceability when records are not maintained with proper documentation by the distributor. Some distributors apply good sound business systems for commingling, while others do not. So as not to place an unnecessary burden on all distributors, the FAC has recommended that the provision for lot traceability be made voluntary for distributors. While fasteners offered for sale would be from accepted lots meeting the specification/standard requirements, a distributor could commingle fasteners from different lots. If required by an application, a customer could go to a distributor who maintains lot control to obtain fasteners from segregated lots.

The first two recommendations were accepted by the House. The Senate approved all three recommendations on 16 March 1994. The battle continues as of this writing on 10 July 1994 over inclusion of the voluntary lot segregation provision as recommended by the FAC.

What fasteners are affected by the FQA? NIST (National Institute of Standards and Technology) estimates that as it is now written 25% of the fastener market is affected. This represents \$1.5 billion worth of fasteners a year! The fasteners included are:

- A screw, nut, bolt, or stud having internal or external threads and load-indicating washers, made of metal, that is required by specification or standard to be through-hardened and is 5 mm or greater in terms of the metric system or a quarter inch or greater in terms of the British system.
- Screws, nuts, bolts, or studs having internal or external threads that bear a grade or property class identification marking required by a standard or specification, and washers if subject to this standard or specification.
- Any fasteners added from time to time by the Secretary of Commerce, as necessity dictates.

One major change the fastener industry must adjust to is the use of accredited laboratories for testing and inspection. This provision has resulted in a whole new industry for NIST. Under the FQA, NIST must approve and accredit laboratories for inspection and testing of fasteners covered by the FQA. This activity will be administered through NVLAP (National Voluntary Laboratory Accreditation Program). NVLAP held a workshop in February 1993 to gather information from the fastener industry on inspection and test methods and requirements. In August 1993 another workshop was held describing the contents of a handbook that contained administration, operational, and technical requirements for fastener inspection and testing laboratories.

The FQA will be implemented 180 days after the Secretary of Commerce issues final regulations on testing and certification, and a system has been established to register manufacturers and private label insignias for the purpose of traceability if at that time there are enough NVLAP-approved testing laboratories. If there are not, provisions exist for a six-month delay to the effective date of the FQA. Implementation of the FQA will probably occur no sooner than the third quarter of 1995.

This should not be a license for the fastener industry to fail to prepare for implementation. Some things should be considered now to prepare to comply with the FQA, and I

list some of them here. A full list can not be prepared at this time due to the uncertainty of the status of the FQA's provisions. Let us begin at the beginning of the process chain.

FASTENER MANUFACTURERS

- Apply TQM principles to your organization.
- Establish total lot control and traceability.
- Apply this to all fasteners regardless if they are or are not covered by the FQA.
- Know your suppliers and establish supplier qualification procedures.
- Register your logo or manufacturer's identification mark with NIST.
- Maintain original test records for ten years.
- Establish effective in-house testing criteria.
 - Use IFI-139 as a guide. A copy of IFI-139 is in Appendix B.
 - Apply this standard to your outside testing laboratory as well.
- Purchase steel that is specially designed for the unique requirements of fastener manufacturing.
 - Use IFI-140 as your steel standard. A copy of IFI-140 is in Appendix B.
- Apply the quality system requirements of ISO 9000 and ASME-FAP-1 to your operations.
- Name someone to be responsible and accountable for compliance.

TESTING LABORATORIES

- Apply TQM principles to your organization.
- Become familiar with the following standards:
 - IFI-139.
 - ISO/IEC Guide 25, General Requirements for Competence of Calibration and Testing Laboratories.
- Study NVLAP certification requirements now.
- Apply for NVLAP certification as soon as you are ready.
- Maintain original test records for ten years.
- Test records must include:
 - A description of the fastener.
 - Product specification and lot identification.
 - The sampling standard utilized.
 - The production lot size and sample size tested.
 - A statement of conformance or nonconformance.
 - It must be tamper resistant.
 - It must be written in English.
- Apply the quality system requirements of ISO 9003 (ANSI/ASQC Q9003-1994) to your operations.

FASTENER DISTRIBUTORS

- Apply TQM principles to your organization.
- Establish lot control and lot traceability procedures.

- Set procedures to provide traceability to customers who request it.
- Know your suppliers and establish supplier qualification systems.
- Understand the product standards/specifications for the fasteners you distribute.
- Maintain original test records for ten years.
- Apply the quality system requirements of ISO 9003 (ANSI/ASQC Q9003-1994) to your operations.
- Name someone to be responsible and accountable for compliance.
- Verify that your suppliers are registered in compliance with Section 8 of the FQA.
- Verify that the test report comes from an accredited NVLAP laboratory.
- Understand your rights under the FQA.
- Apply the appropriate fastener standard/specification for your application.
- Apply the quality system requirements of ISO 9000 (ANSI/ASQC Q9000-1994) to your organization.

A central theme that applies to the entire fastener industry and market is to apply total quality management principles and establish quality systems that comply with the ISO 9000 and ASME-FAP-1 standards. Application of these systems will provide for accountability, responsibility, and traceability for any fastener supplied through these systems and will assure ease of compliance with the FQA.

A copy of the Fastener Quality Act, Public Law 101-592, is provided for the reader in Appendix C. As provided, it does not contain the proposed amendments now before the U.S. Senate. The reader should stay informed and acquire the final version of the FQA as it becomes available.

FASTENER USERS

- Apply TQM principles to your organization.
- Know your suppliers and establish supplier qualification systems.
- Purchase only from suppliers certified through ISO 9000 or ASME-FAP-1.

APPENDICES

**Appendix A: ASTM Standards F 1469, F 1470,
and F 1503**



Standard Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Nondestructive Testing¹

This standard is issued under the fixed designation F 1469; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 This guide describes the steps required to conduct a complete repeatability and reproducibility (RR) study on nondestructive test equipment. This guide is a manual (use of calculator) method. Other methods may utilize the application of computer driven software.

1.2 This guide can be used to evaluate all test equipment that provides variable measuring data.

2. Terminology

2.1 Definitions:

2.1.1 *repeatability*—the variation in the values of measurements obtained when one operator uses the same gage for measuring identical characteristics of the same parts.

2.1.2 *reproducibility*—the variation in the average of measurements made by different operators using the same parts.

3. Significance and Use

3.1 This guide is recommended for the purpose of evaluating test equipment that may be utilized in statistical process control, testing laboratories, and for in-process control of manufacturing operations.

3.2 Ask the question: What effect does the operator have on the measurement process? If possible, the operators who normally use the test equipment should be included in the study. If operator calibration of the equipment is likely to be a significant cause of variation, then the operator should recalibrate the equipment prior to each group of readings.

3.3 The test equipment should provide direct readings in which the smallest digit is no larger than one tenth of the tolerance of the characteristic being evaluated.

3.4 It is recommended that a test equipment repeatability and reproducibility study be a mandatory part of all test equipment purchases and that acceptance criteria be $<10\%$ for certification and statistical process control (SPC) use.

4. Equipment Certification

4.1 Test equipment shall be certified through use of certified standards as accurate to the manufacturer's/user's calibration systems with certified standards before a repeatability and reproducibility study is performed.

4.2 Certifications must be traceable to the National Institute of Standards and Technology (NIST), or recognized

equivalent, and shall be current to the test equipment's calibration schedule.

5. Procedure

5.1 Although the number of operators, trials, and parts may be varied, the following guidelines represent the optimum conditions for conducting a study using the forms in Figs. 1a to 1d.

5.2 Select three operators and identify them as Operators *A*, *B*, and *C*.

5.3 Calibrate the test equipment with a certified standard.

5.4 Select ten parts for measurements and number them from 1 to 10, such that the numbers are not visible to the operators.

5.5 Allow Operator *A* to inspect all ten parts in a sequential order and enter the results in the 1st trial column for Operator *A* of the Repeatability and Reproducibility Data Sheet (Fig. 1a). Part number identification and associated data entry shall be performed by an observer.

5.6 Repeat 5.5 with Operators *B* and *C* and enter the results in the corresponding 1st trial column for each operator.

5.7 Repeat 5.5 and 5.6 using a random selection of the ten parts. Enter data in the 2nd trial column for each operator. If three trials are needed, repeat the cycle and enter data in the corresponding 3rd trial column for each operator.

5.8 Steps 5.5, 5.6, and 5.7 may be changed to the following when large part size or simultaneous availability of parts is not possible:

5.8.1 Allow Operators *A*, *B*, and *C* to measure the first part and record their readings in the corresponding 1st trial columns for each operator.

5.8.2 Allow Operators *A*, *B*, and *C* to remeasure the first part and record their readings in the corresponding 2nd trial columns for each operator. If three trials are to be used, repeat the cycle and enter the results in the corresponding 3rd trial columns for each operator.

5.9 If the operators are not available at the same time, the following method may be used. Allow Operator *A* to measure all ten parts at once and enter the results in the 1st trial column for Operator *A*. Repeat the measurements in a different order and enter the results in the corresponding 2nd and 3rd trial columns for Operator *A*. Do the same with Operators *B* and *C*, as soon as they are available entering their data in their corresponding 1st, 2nd, and 3rd trial columns.

5.10 Make all necessary calculations on the Repeatability and Reproducibility Data Sheet (Fig. 1a) and Repeatability and Reproducibility Report (Fig. 1b). For clarity, Figs. 1c and 1d are provided as examples.

¹ This guide is under the jurisdiction of ASTM Committee F-16 on Fasteners and is the direct responsibility of Subcommittee F16.93 on Quality Assurance Provisions for Fasteners.

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Sample #	Operator A				Operator B				Operator C			
	1st Trial	2nd Trial	3rd Trial	Range	1st Trial	2nd Trial	3rd Trial	Range	1st Trial	2nd Trial	3rd Trial	Range
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
Totals												

$\bar{R}, A =$ <input style="width: 80%;" type="text"/> $\Sigma A =$ <input style="width: 80%;" type="text"/> $\bar{X}, A =$ <input style="width: 80%;" type="text"/>	$\bar{R}, B =$ <input style="width: 80%;" type="text"/> $\Sigma B =$ <input style="width: 80%;" type="text"/> $\bar{X}, B =$ <input style="width: 80%;" type="text"/>	$\bar{R}, C =$ <input style="width: 80%;" type="text"/> $\Sigma C =$ <input style="width: 80%;" type="text"/> $\bar{X}, C =$ <input style="width: 80%;" type="text"/>
---	---	---

\bar{R}, A \bar{R}, B \bar{R}, C $\Sigma \bar{R}, A, B, C$ $\bar{R} =$	$\bar{R} \times D-4 = UCL-R^*$	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th># Trials</th> <th>D-4</th> </tr> </thead> <tbody> <tr> <td>2</td> <td>3.27</td> </tr> <tr> <td>3</td> <td>2.58</td> </tr> </tbody> </table>	# Trials	D-4	2	3.27	3	2.58	\bar{X}, A \bar{X}, B \bar{X}, C $\text{Max } \bar{X}$ $\text{Min } \bar{X}$ $\bar{X} \text{ dif}$
# Trials	D-4								
2	3.27								
3	2.58								

Reference : The D-4 Constant is obtained from the table of Factors for X-Bar, R charts, page 12, Western Electric Statistical Quality Control Handbook.

Notes :

FIG. 1a Gage Repeatability and Reproducibility Data Sheet

Operator A					Operator B				Operator C			
Sample #	1st Trial	2nd Trial	3rd Trial	Range	1st Trial	2nd Trial	3rd Trial	Range	1st Trial	2nd Trial	3rd Trial	Range
1	35.6	35.7		0.1	36.3	36.1		0.2	35.7	35.8		0.1
2	35.5	35.5		0	35.8	35.7		0.1	35.9	36.0		0.1
3	36.1	35.9		0.2	35.9	36.1		0.2	36.1	35.9		0.2
4	36.3	36.2		0.1	36.0	35.8		0.2	35.8	35.5		0.3
5	36.2	36.2		0	36.3	36.2		0.1	36.3	36.3		0
6	35.9	36.0		0.1	35.6	35.5		0.1	36.2	36.0		0.2
7	36.2	36.1		0.1	35.7	35.7		0	35.5	35.7		0.2
8	35.8	35.7		0.1	36.4	36.3		0.1	35.8	36.0		0.2
9	35.8	35.8		0	36.2	36.3		0.1	36.0	36.1		0.1
10	35.9	36.1		0.2	36.0	36.0		0	35.7	35.7		0
Totals	359.3	359.2	0	0.9	360.2	359.7	0	1.1	359	359	0	1.4

$\bar{R}, A = 0.09$ $\Sigma A = 718.5$ $\bar{X}, A = 35.925$	$\bar{R}, B = 0.11$ $\Sigma B = 719.9$ $\bar{X}, B = 35.995$	$\bar{R}, C = 0.14$ $\Sigma C = 718$ $\bar{X}, C = 35.9$
--	--	--

\bar{R}, A	0.09
\bar{R}, B	0.11
\bar{R}, C	0.14
$\Sigma \bar{R}, A, B, C$	0.34
$\bar{R} =$	0.113333

\bar{R}	×	D-4	=	UCL-R*
0.113333	×	3.27	=	0.3706

# Trials	D - 4
2	3.27
3	2.58

Reference : The D-4 Constant is obtained from the table of Factors for X-Bar, R charts, page 12, Western Electric Statistical Quality Control Handbook.

\bar{X}, A	35.925
\bar{X}, B	35.995
\bar{X}, C	35.9
Max \bar{X}	35.995
Min \bar{X}	35.9
$\bar{X} \text{ dif}$	0.095

Notes:

FIG. 1b Gage Repeatability and Reproducibility Data Sheet

Part Name : _____
 Part Number : _____
 Characteristic : _____

Gage Name : _____
 Gage No. : _____
 Specification : _____

Date : _____
 Performed By : _____
 File Name : _____

From Date Sheet : $\bar{R} =$

\bar{X} dif = Tolerance :

Measurement Unit Analysis								
Repeatability - Equipment Variation (E.V.)								
E.V. =	$(\bar{R}) \times (K - 1)$							
=	$() \times ()$							
=	<input type="text"/>	<table border="1"> <tr> <th>Trial#</th> <td>2</td> <td>3</td> </tr> <tr> <th>K-1</th> <td>4.56</td> <td>3.05</td> </tr> </table>	Trial#	2	3	K-1	4.56	3.05
Trial#	2	3						
K-1	4.56	3.05						
Reproducibility - Appraiser Variation (A.V.)								
A.V. =	$\sqrt{[(\bar{X} \text{ dif}) \times (K - 2)]^2 - [(E.V.)^2 / (n \times r)]}$							
=	$\sqrt{[(10 \times 0)^2 - (0^2 / (10 \times 0))]}$							
=	<input type="text"/>	<table border="1"> <tr> <th>Operator#</th> <td>2</td> <td>3</td> </tr> <tr> <th>K-2=</th> <td>3.65</td> <td>2.7</td> </tr> </table>	Operator#	2	3	K-2=	3.65	2.7
Operator#	2	3						
K-2=	3.65	2.7						
n = # parts r = # trials								
Repeatability and Reproducibility (R & R)								
R & R	$\sqrt{(E.V.)^2 + (A.V.)^2}$							
=	$\sqrt{()^2 + ()^2}$							
=	<input type="text"/>							
<p>* Guidelines for acceptance are referenced in "Measurement System Analysis" by A.I.A.G., 1990, page 46. All calculations are based upon predicting 5.15 sigma (99.0% of the area under the normal distribution curve). A.V. -- if a negative value is calculated under the square root sign, the appraiser variation (A.V.) defaults to Zero (0).</p>								

% Tolerance Analysis	
% E.V. =	$100 [(E.V.) / (Tol)]$
=	$100 [() / ()]$
=	<input type="text"/>
% A.V. =	$100 [(E.V.) / (Tol)]$
=	$100 [() / ()]$
=	<input type="text"/>
% R&R	$\sqrt{(\% E.V.)^2 + (\% A.V.)^2}$
=	$\sqrt{()^2 + ()^2}$
=	<input type="text"/>
<p>* Guidelines for acceptance are: Under 10% error - gage system O.K. 10% - 30% error - may be acceptable based on importance of application, cost of gage, cost of repairs, etc. Over 30% error - Gage system needs improvement. Make every effort to identify the problems and have them corrected.</p>	

FIG. 1c Gage Repeatability and Reproducibility Data Sheet

Part Name : 1/2 - 13 x 4 A490
 Part Number : A490 - 15
 Characteristic : Hardness

Gage Name : Rockwell Tester
 Gage No. : XYZ
 Specification : HRC 33 - 38

Date : 03/11/92
 Performed By : _____
 File Name : _____

From Date Sheet : $\bar{R} =$

\bar{X} dif = Tolerance :

Measurement Unit Analysis								
Repeatability - Equipment Variation (E.V.)								
E.V. =	$(\bar{R}) \times (K - 1)$							
=	$(0.113333) \times (4.56)$							
=	<input type="text" value="0.5168"/>	<table border="1"> <tr> <th>Trial#</th> <td>2</td> <td>3</td> </tr> <tr> <th>K-1</th> <td>4.56</td> <td>3.05</td> </tr> </table>	Trial#	2	3	K-1	4.56	3.05
Trial#	2	3						
K-1	4.56	3.05						
Reproducibility - Appraiser Variation (A.V.)								
A.V. =	$\sqrt{[(\bar{X} \text{ dif}) \times (K - 2)]^2 - [(E.V.)^2 / (n \times r)]}$							
=	$\sqrt{[(0.0095) \times (2.7)]^2 - [(0.5168)^2 / (10 \times 2)]}$							
=	<input type="text" value="0.228994"/>	<table border="1"> <tr> <th>Operator#</th> <td>2</td> <td>3</td> </tr> <tr> <th>K-2=</th> <td>3.65</td> <td>2.7</td> </tr> </table>	Operator#	2	3	K-2=	3.65	2.7
Operator#	2	3						
K-2=	3.65	2.7						
n = # parts r = # trials								
Repeatability and Reproducibility (R & R)								
R & R	$\sqrt{(E.V.)^2 + (A.V.)^2}$							
=	$\sqrt{(0.5168)^2 + (0.228994)^2}$							
=	<input type="text" value="0.565261"/>							
<p>* Guidelines for acceptance are referenced in "Measurement System Analysis" by A.I.A.G., 1990, page 46. All calculations are based upon predicting 5.15 sigma (99.0% of the area under the normal distribution curve). A.V. -- if a negative value is calculated under the square root sign, the appraiser variation (A.V.) defaults to Zero (0).</p>								

% Tolerance Analysis	
% E.V. =	$100 [(E.V.) / (Tol)]$
=	$100 [(0.5168) / (5)]$
=	<input type="text" value="10.34"/>
% A.V. =	$100 [(E.V.) / (Tol)]$
=	$100 [(0.2289938) / (5)]$
=	<input type="text" value="4.58"/>
% R&R	$\sqrt{(\% E.V.)^2 + (\% A.V.)^2}$
=	$\sqrt{(10.34)^2 + (4.58)^2}$
=	<input type="text" value="11.3 %"/>
<p>* Guidelines for acceptance are: Under 10% error - gage system O.K. 10% - 30% error - may be acceptable based on importance of application, cost of gage, cost of repairs, etc. Over 30% error - Gage system needs improvement. Make every effort to identify the problems and have them corrected.</p>	

FIG. 1d Gage Repeatability and Reproducibility Data Sheet

6. Analysis of Results

6.1 Evaluate the data following the steps on the data sheets to determine if the test equipment is acceptable for its intended application. The criteria for acceptability is dependent upon the percentage of part tolerance that is consumed by the test equipment error. Acceptability is based upon the following criteria

6.1.1 Test equipment with a repeatability and reproducibility percentage of 10 % or less is fully capable and may be used for certification testing.

6.1.2 Test equipment with a repeatability and reproduc-

ibility percentage between 10 and 30 % shall be reviewed by a qualified technician. If possible, the testing system should be improved or replaced; however, the system may continue to be used as is until an improvement is found.

6.1.3 Test equipment with a repeatability and reproducibility percentage greater than 30 % is unacceptable. Take immediate corrective action to replace or improve the testing system.

7. Keywords

7.1 repeatability; reproducibility; statistical process control; test equipment

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.



Standard Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection¹

This standard is issued under the fixed designation F 1470; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

^{ε1} NOTE—Title was corrected editorially in November 1993.

INTRODUCTION

Throughout this guide the terms *detection* and *prevention* apply to quality control systems. A brief description of both is provided to assist the purchaser in the application of this guide.

The *detection system* relies on inspection as the primary means of controlling the quality of furnished material. Methods include in-process and final inspection. In-process inspection is typically performed by the individual performing the process and generally includes a first-piece inspection by someone other than the operator. Quality-control inspection may perform audit inspections on the process output during the course of the production run. In addition, a final inspection is performed by quality control inspectors according to a prescribed sample plan. The other sample plans utilize zero defects as their acceptance criteria.

The *prevention system* uses advanced quality planning in addition to many of the techniques used in the detection system. Quality planning incorporates a systems approach to quality control that focuses on defect prevention and continual improvement. In addition, Statistical Process Control (SPC) is usually applied to control the process, thereby reducing the variability of the output.

The ISO 9000 standards describe quality system models and either their use or those of the ASQC 90 series (ISO 9000 equivalent) are prevention-based quality systems.

1. Scope

1.1 This guide provides sampling methods for determining how many fasteners to include in a random sample in order to determine the acceptability of a given lot of fasteners.

1.2 This guide is for mechanical properties, physical properties, coating requirements, and other quality requirements specified in the standards of ASTM Committee F-16. Dimensional and thread criteria sampling plans are the responsibility of ASME Committee B18. Therefore, unless otherwise specified in this guide, dimensional and thread fit sampling shall be in accordance with ANSI/ASME B18.18.3M.

1.3 This guide provides for two sampling plans: one designated the "detection process," as described in 3.1.3, and one designated the "prevention process," as described in 3.1.8.

2. Referenced Documents

2.1 ANSI Standards:

- ASME/ANSI B18.18.2M Inspection and Quality Assurance for High-Volume Machine Assembly²
- ASME/ANSI B18.18.3M Inspection and Quality Assurance for Special Purpose Fasteners²
- ASME-FAP-1 Quality Assurance Program Requirements for Fastener Manufacturers and Distributors²
- ANSI/ASQC Q90 Quality Management and Quality Assurance Standards—Guidelines for Selection and Use²
- ANSI/ASQC Q91 Quality Systems—Model for Quality Assurance in Design/Development, Production, Installation, and Servicing²
- ANSI/ASQC Q92 Quality Systems—Model for Quality Assurance in Production and Installation²
- ANSI/ASQC Q93 Quality Systems—Model for Quality Assurance in Final Inspection and Test²
- ANSI/ASQC Q94 Quality Management and Quality System Elements—Guidelines²

2.2 ISO Standards:

- ISO 9000 Quality Management and Quality Assurance Standards—Guidelines for Selection and Use²
- ISO 9001 Quality Systems—Model for Quality Assurance in Design/Development, Production, Installation and Servicing²

¹ This guide is under the jurisdiction of ASTM Committee F-16 on Fasteners and is the direct responsibility of Subcommittee F16.93 on Quality Assurance Provisions for Fasteners.

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² Available from the American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

- ISO 9002 Quality Systems—Model for Quality Assurance in Production and Installation²
- ISO 9003 Quality Systems—Model for Quality Assurance in Final Inspection and Test²
- ISO 9004 Quality Management and Quality System Elements—Guidelines²

3. Terminology

3.1 Definitions:

3.1.1 *assembly lot*—an assembly lot may consist of a combination of different products. As long as the products that make up the assembly are in accordance with 3.1.6, the quantity of assemblies determine the sample size. Example: ten assemblies consisting of a bolt, nut, and a washer would have a lot size of ten if the bolts, nuts, and washers meet the criteria of 3.1.6. However, if any of the components in the assembly are not in accordance with 3.1.6 then the ten assemblies will have to be separated into lots that meet all the requirements of 3.1.6.

3.1.2 *common cause*—common cause variation affects all the individual values of the process output being studied. In control chart analysis, it appears as part of the random process variation.

3.1.3 *detection process*—a past-oriented strategy of quality control that attempts to identify the nonconforming product after it has been produced, and then to separate it from the conforming product.

3.1.4 *in-process sampling inspection*—a random sample of product drawn from prescribed points to the processing stream (usually characteristic sensitive) and performing specific inspections and tests to determine conformance of the product at that point of the processing stream.

3.1.5 *inspection*—process of measuring, examining, testing, gaging, or using other procedures to ascertain the quality or state of, detect errors or defects in, or otherwise appraise materials, products, services, systems, or environments to a preestablished standard.

3.1.6 *lot*—a quantity of product of one part number that has been processed essentially under the same conditions from the same heat treatment lot and produced from one mill heat of material and submitted for inspection at one time.

3.1.7 *lot sampling inspection*—a random sample drawn from a lot and performing specified inspections and tests to determine the acceptability of the lot.

3.1.8 *prevention process*—a future-oriented strategy that improves quality through continuous improvement activities by directing analysis and action toward correcting the process itself. Prevention utilizes statistical process control and other statistical techniques.

3.1.9 *process flow*—the current or anticipated sequential process steps required to produce a fastener.

3.1.10 *random sampling*—when every fastener in the lot has an equal and independent chance of being chosen for the sample. The sample may be returned to the lot if it has not been altered or destroyed during the inspection/test upon completion of sampling.

3.1.11 *special cause*—special cause variation is intermittent, unpredictable, and unstable. In control chart analysis, it is signaled by a point beyond the control limits, a run, or

some other nonrandom pattern of points within the control limits.

3.1.12 *statistical control*—exists when all special causes of variation have been eliminated from a process and only common causes remain.

3.1.13 *test*—an element of inspection that generally denotes the determination by technical means of the properties or elements of supplies, or components thereof, and involves the application of established scientific principles and procedures.

4. Significance and Use

4.1 Sampling shall be selected in a random manner, ensuring that any unit in the lot has an equal chance of being chosen. Sampling should not be localized by selections being taken from the top of a container or from only one container of multi-container lots.

4.2 The purchaser should be aware of his supplier's quality assurance system. This can be accomplished by auditing the supplier's quality system, if qualified auditors are available, or by third-party assessment certification, such as provided by ASME's Fastener Accreditation Program (FAP).

5. Ordering Information

5.1 The purchaser shall specify at the time of order inquiry the specification number, issue date, and sampling plan (detection process or prevention process) required from the supplier.

5.2 Guidelines for sampling plan selection are provided in Section 9.

6. Acceptance Criteria

6.1 The acceptance criteria for Table 1 is to accept the lot if zero nonconforming parts are detected, and reject the lot if at least one nonconforming part is detected.

7. Disposition of Nonconforming Lots

7.1 *Supplier's Options*—The supplier has the following options in dispositioning nonconforming lots:

7.1.1 Lots may be scrapped.

TABLE 1 Sample Size

NOTE—The acceptance number in all cases is zero defects.

Lot Size	Sample Size			
	A	B	C	D
2 to 15	3	2	1	A
16 to 25	4	3	1	A
26 to 50	5	4	1	A
51 to 90	6	5	2	1
91 to 150	7	6	2	1
151 to 280	10	7	2	1
281 to 500	11	9	3	2
501 to 1200	15	11	3	2
1201 to 3200	18	13	3	2
3201 to 10 000	22	15	4	3
10001 to 35 000	29	15	4	3
35001 to 150 000	29	15	5	3
150001 to 500 000	29	15	6	4
500001 and over	29	15	7	5

^A Suppliers shall furnish certified test results from which the shipping lots originated. If certified test reports are not available, then the supplier must default to Sample Size C and conduct the tests required.

7.1.2 Lots may be 100 % sorted and all nonconforming parts removed.

7.1.3 Lots may be reworked or reprocessed to correct the nonconforming characteristic(s), if permitted by specification. See 7.3.

7.1.4 Lots may be “used-as-is” providing the purchaser is informed of the rejectable items and written approval is obtained. This disposition shall be documented with each shipment, including appropriate signatures and dates authorizing the release.

NOTE 1—Caution should be exercised when applying the option to “use-as-is.” In the interest of safety and quality, all “use-as-is” condi-

tions should have no effect on the fastener’s intended application or end use.

7.2 *Purchaser’s Options*—The purchaser has the following options in dispositioning nonconforming lots:

7.2.1 Lots may be rejected and returned to the supplier.

7.2.2 Lots may be accepted. If nonconforming lots are accepted, the responsibility for the lot is borne by the purchaser, provided the purchaser issues a written deviation to the supplier relieving him of responsibility for the nonconforming product.

7.3 *Reinspection*—When rework or reprocessing is performed to correct a nonconforming item, that lot shall be reinspected on completion of all rework or processing, using

TABLE 2 Sampling Level for the Detection Process

NOTE—Legend: WA—Where Applicable.
NA—Not Applicable.

Characteristic	Sample Level ^A	Description of Control			
		Internally Threaded Parts	Externally Threaded Parts	Non-threaded	Washers
Adhesion (coating)	C	WA	WA	WA	WA
Bend (body, nails)	A	NA	NA	WA	NA
Bend (notched bolts)	B	NA	WA	NA	NA
Body bend (track spikes)	C	NA	NA	WA	NA
Breaking strength (eyebolts)	C	NA	WA	NA	NA
Carbide precipitation	C	WA	WA	WA	WA
Case depth/decarburization	C	WA	WA	WA	WA
Chemistry ^B	—	WA	WA	WA	WA
Compression (washer direct tension)	B	NA	NA	NA	WA
Cone proof	C	WA	NA	NA	NA
Drive test	A	WA	WA	NA	NA
Elongation—Machined specimen	C	NA	WA	WA	NA
Extension at failure	C	NA	WA	WA	NA
Grain size ^C	—	WA	WA	WA	WA
Hardness ^D	B	WA	WA	WA	WA
Head bend (track spikes)	C	NA	NA	WA	NA
Humidity	B	WA	WA	WA	WA
Hydrogen embrittlement	B	WA	WA	WA	WA
Impact	C	NA	WA	WA	NA
Lubrication	B	WA	WA	WA	WA
Magnetic permeability	B	WA	WA	WA	WA
Packaging ^E	—	WA	WA	WA	WA
Plating/coating thickness (weight)	A	WA	WA	WA	WA
Product identification marking ^F	—	WA	WA	WA	WA
Proof load—Full size	C	WA	WA	NA	NA
Reduction of area—Machined specimen	C	NA	WA	WA	NA
Rivet bend	B	NA	NA	WA	NA
Rivet flattening	B	NA	NA	WA	NA
Rotational capacity	C	WA	WA	NA	WA
Salt spray ^G	B	WA	WA	WA	WA
Shear strength	C	NA	WA	WA	NA
Stress corrosion	B	WA	WA	WA	WA
Surface discontinuities	B	WA	WA	WA	WA
Surface roughness	B	WA	WA	WA	WA
Tensile strength—Full size ^H	C	NA	WA	WA	NA
Tensile strength—Machined specimen	C	NA	WA	WA	NA
Torque ^I (prevailing)	C	WA	WA	NA	NA
Torque (torsional strength)	C	WA	WA	NA	NA
Yield strength—Full size	C	NA	WA	NA	NA
Yield strength—Machined specimen	C	NA	WA	NA	NA

^A Quantity of samples is in Table 3, Sample Size.

^B A certified copy of the material producer’s chemical analysis shall be furnished with each shipping lot, and the shipping lot shall have documentation providing traceability to this chemical analysis. It is required that the purchaser of the raw material (used to manufacture) shall verify that the material is the material specified on the purchase order.

^C Grain size shall be included with the material producer’s chemical analysis report.

^D Surface or core, or both, as applicable.

^E All packaging requirements shall be in conformance with the applicable packaging standard.

^F Visual inspection for conformance.

^G Continuous monitoring of salt spray performance in accordance with the recommendation of Table B in Appendix 1 of ASME/ANSI B18.18.2M constitutes compliance with the requirements for salt spray testing outlined in this table.

^H Wedge angle or axial test as applicable.

^I Prevailing torque test includes thread start, all specified torque requirements, and retention of locking feature, when applicable.

the same sample plan as used in detecting the nonconformance. The sample shall be inspected for the corrected criteria and any other criteria affected by the rework. The acceptance level shall be in accordance with 6.1.

8. Selection of Sampling Plans

8.1 Except as specified in 8.2, the detection process sampling level in accordance with Table 2 shall be applied.

8.2 If the purchaser knows through documented evidence that his supplier conforms with ASME/ANSI B18.18.3M,

ASQC/ANSI 90, 91, 92, 93, or 94, or ISO 9000, 9001, 9002, 9003, or 9004, the purchaser may specify the prevention process in accordance with Table 3.

9. Keywords

9.1 detection systems; fasteners; inspection for mechanical properties; performance requirements; prevention systems; quality requirements; sampling plans; selection and size; statistical process control

TABLE 3 Sampling Level for the Prevention Process

NOTE—Legend: WA—Where Applicable.
NA—Not Applicable.

Characteristic	Description of Control				
	Sample Level ^{A,B}	Internally Threaded Parts	Externally Threaded Parts	Non-threaded	Washers
Adhesion (coating)	D	WA	WA	WA	WA
Bend (body, nails)	B	NA	NA	WA	NA
Bend (notched bolts)	C	NA	WA	NA	NA
Body bend (track spikes)	D	NA	NA	WA	NA
Breaking strength (eyebolts)	D	NA	WA	NA	NA
Carbide precipitation	D	WA	WA	WA	WA
Case depth/decarburization	D	WA	WA	WA	WA
Chemistry ^C	—	WA	WA	WA	WA
Compression (washer direct tension)	C	NA	NA	NA	WA
Cone proof	D	WA	NA	NA	NA
Drive test	B	WA	WA	NA	NA
Elongation—Machined specimen	D	NA	WA	WA	NA
Extension at failure	D	NA	WA	WA	NA
Grain size ^D	—	WA	WA	WA	WA
Hardness ^E	C	WA	WA	WA	WA
Head bend (track spikes)	D	NA	NA	WA	NA
Humidity	C	WA	WA	WA	WA
Hydrogen embrittlement	C	WA	WA	WA	WA
Impact	D	NA	WA	WA	NA
Lubrication	C	WA	WA	WA	WA
Magnetic permeability	C	WA	WA	WA	WA
Packaging ^F	—	WA	WA	WA	WA
Plating/coating thickness (weight)	B	WA	WA	WA	WA
Product identification marking ^G	—	WA	WA	WA	WA
Proof load—Full size	D	WA	WA	NA	NA
Reduction of area—Machined specimen	D	NA	WA	WA	NA
Rivet bend	C	NA	NA	WA	NA
Rivet flattening	C	NA	NA	WA	NA
Rotational capacity	D	WA	WA	NA	WA
Salt spray ^H	C	WA	WA	WA	WA
Shear strength	D	NA	WA	WA	NA
Stress corrosion	C	WA	WA	WA	WA
Surface discontinuities	C	WA	WA	WA	WA
Surface roughness	C	WA	WA	WA	WA
Tensile strength—Full size ^I	D	NA	WA	WA	NA
Tensile strength—Machined specimen	D	NA	WA	WA	NA
Torque ^J (prevailing)	D	WA	WA	NA	NA
Torque (torsional strength)	D	WA	WA	NA	NA
Yield strength—Full size	D	NA	WA	NA	NA
Yield strength—Machined specimen	D	NA	WA	NA	NA

^A Final inspection of a characteristic may be carried out at any stage of manufacture, provided the characteristic is not subject to change in any further manufacturing or processing operation. Therefore, the testing of those samples may be deducted from the sample level specified.

^B Quantity of samples is in Table 3, Sample Size.

^C A certified copy of the material producer's chemical analysis shall be furnished with each shipping lot, and the shipping lot shall have documentation providing traceability to this chemical analysis. It is required that the purchaser of the raw material (used to manufacture) shall verify that the material is the material specified on the purchase order.

^D Grain size shall be included with the material producer's chemical analysis report.

^E Surface, core, or both, as applicable.

^F All packaging requirements shall be in conformance with the applicable packaging standard.

^G Visual inspection for conformance.

^H Continuous monitoring of salt spray performance in accordance with the recommendation of Table B in Appendix 1 of ASME/ANSI B18.18.2M constitutes compliance with the requirements for salt spray testing outlined in this table.

^I Wedge angle or axial test as applicable.

^J Prevailing torque test includes thread start, all specified torque requirements, and retention of locking feature, when applicable.

 **F 1470**

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Standard Practice for Machine/Process Potential Study Procedure¹

This standard is issued under the fixed designation F 1503; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the proper method for establishing process potentials for new or existing processes.

2. Referenced Documents

2.1 *ASTM Standard:*

F 1469 Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Non-Destructive Testing²

2.3 *ASME Standard:*

ASME-FAP-1 Quality Assurance Program Requirements for Fastener Manufacturers and Distributors³

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *bilateral specifications*—specifications that have both upper and lower values.

3.1.2 *Pp*—process capability index defined as $Z/6\sigma$.

3.1.3 *Ppk*—process capability index defined as $Z_{\min}/3\sigma$.

3.1.4 *process parameters*—combination of people, equipment, materials, methods, and environment that produce output.

3.1.5 *unilateral specifications*—specifications that have only upper or lower values.

3.1.6 *Z*—number of standard deviation units from the process average to a value of interest such as an engineering specification. When used in capability assessment, Z_{usl} is the distance to the upper specification limit; Z_{isl} is the distance to the lower specification limit; and Z_{min} is the distance to the nearest specification limit.

3.1.7 σ —an estimate of the standard deviation of a process characteristic.

4. Summary of Practice

4.1 A process potential study is conducted to provide a level of confidence in the ability of a machine/process to meet engineering specification requirements. This is accomplished through statistical process control techniques as defined in this practice.

4.2 For new equipment purchases, the purchaser's manufacturing engineering department, or equivalent discipline, shall have primary responsibility for ensuring that the requirements of this practice are met. The purchaser's

quality assurance department shall be available to assist on an as-requested basis.

4.3 New manufacturing processes will not be accepted for use in production with *Pp* values less than 1.67. If a manufacturing process must be conditionally accepted, a process improvement/product control plan must be developed.

4.3.1 The process improvement/product control plan shall identify specific process improvement activities, which will be implemented to make the process fully capable as well as an interim inspection plan to ensure that nonconforming product is not shipped to a customer.

4.4 *Product Specifications:*

4.4.1 Prior to any process potential study, the product specifications (nominal dimension and tolerances) must be identified, and an appropriate method of variables type inspection selected.

4.4.2 This practice is limited to bilateral specifications whose distributions can be expected to approximate a normal curve. This practice should not be applied to unilateral specifications (flatness, concentricity, minimum tensile, maximum hardness, etc.).

4.5 *Gage Capability Analysis:*

4.5.1 All gaging systems used to evaluate product must have documentation for a gage repeatability and reproducibility study in accordance with Guide F 1469 before the process study is conducted.

4.5.1.1 Gaging systems which consume $\leq 10\%$ of the applicable product tolerance are considered acceptable.

4.5.1.2 Gaging systems which consume over 10 to 30 % of the applicable product tolerance are generally considered to be unacceptable. However, users of this guide may authorize their use depending on factors such as the criticality of the specification in question, the cost of alternative gaging systems, and so forth.

4.5.1.3 Gaging systems which consume more than 30 % of the product tolerance are unacceptable and must be replaced.

4.5.2 All gaging systems must be certified as accurate using standards traceable to NIST.

4.6 *Process Parameter Selection:*

4.6.1 For studies conducted at the equipment vendor's facility, all process parameters (for example, infeed rates, coolant, dies, pressures, fixtures, etc.) must be established and documented prior to the process qualification test so the requirements of 9.5 can be met.

4.6.1.1 Process parameters may not be changed once a process qualification test has begun.

4.6.1.2 All process adjustments made during the process qualification study must be documented and included with information required in Section 10 of this practice.

¹ This practice is under the jurisdiction of ASTM Committee F-16 on Fasteners and is the direct responsibility of Subcommittee F16.93 on Quality Assurance Provisions for Fasteners.

Current edition approved Feb. 15, 1994. Published April 1994.

² *Annual Book of ASTM Standards*, Vol 15.08.

³ Available from American Society of Mechanical Engineers, 345 E. 47th Street, New York, NY 10017.

		MATERIAL				SAMPLE SIZE/FREQUENCY				PART NO.				CHART NO.											
PART NAME (PRODUCT)						OPERATION (PROCESS)						SPECIFICATION LIMITS													
OPERATOR				MACHINE				GAGE				UNIT OF MEASURE		ZERO EQUALS											
DATE																									
TIME																									
SAMPLE MEASUREMENTS	1																								
	2																								
	3																								
	4																								
	5																								
SUM																									
AVERAGE, \bar{X}																									
RANGE, R																									
NOTES																									
		1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25																							

FIG. 1 Variables Control Chart (\bar{X} and R)

NOTE—Process adjustments are defined as those adjustments made by the process due to internal process gaging (or other sources of feedback control), or by the operator as part of the normal operation of process.

4.6.2 The selection of process parameters is the responsibility of the purchaser's manufacturing engineering or equivalent discipline, or, in some cases, the machine supplier depending on preestablished contractual agreements.

4.6.2.1 The process parameters selected must be consistent with those intended to be used in production.

4.6.3 Process parameters may be systematically varied after a study is completed and additional process qualification studies performed for process optimization purposes.

5. Significance and Use

5.1 This practice is designed to evaluate a machine or process isolated from its normal operating environment. In its normal operating environment, there would be many sources of variation that may not exist at a machine builder's facility; or put another way, this study is usually conducted under ideal conditions. Therefore, it should be recognized that the results of this practice are usually a "best case" analysis, and allowances need to be made for sources of

variations that may exist at the purchaser's facility.

5.2 Further comment on the significance of statistical analysis and capability studies can be found in ASME FAP-1.

6. Material Selection

6.1 Material (for example, steel slugs, bar, wire, pre-finished parts, etc.) used for process qualification studies shall be selected at random. The variability of material used for process qualification studies should be consistent with the variability of material the machine is likely to see in production.

6.2 Presorting of material is not permissible for process qualification purposes.

6.3 In some cases, process potential results may be influenced by the specific product specifications selected for the study. The specific product selected for qualifying a new manufacturing process should be based on that which will yield the most conservative results. If the relationship between specific product specifications and process potential is unknown, two or more distinct studies should be performed with different products to qualify and accept the new process.

out-of-control condition is identified and corrected, new control limits may be calculated by excluding the out-of-control points. A second study is not required.

7.2.3.2 In some instances, control chart analysis may reveal out-of-control conditions that are inherent to the process. Trends due to tool wear or grinding wheel wear are typical examples. If the cause of the out-of-control condition is known, the out-of-control condition is both repeatable and predictable, and the condition cannot be eliminated, the process potential study may be considered acceptable and Pp and Ppk values calculated in accordance with 8.1 through 8.3.

8. Calculating Results

8.1 Estimate the process standard deviation as follows:

$$\sigma = \bar{R}/d_2$$

where:

d_2 = constants for sample size 2 to 10, see Table 2.

8.2 Calculate Pp by dividing the total product tolerance by 6σ .

8.3 Calculate Ppk as follows:

$$Ppk = \text{minimum of } (USL - \bar{X})/3\sigma \text{ or } (\bar{X} - LSL)/3\sigma$$

where:

USL = upper specification limit, and

LSL = lower specification limit.

9. Analysis of Results

9.1 The qualification of a manufacturing process shall be based on a review of the statistical parameters Pp and Ppk . Pp and Ppk are both numerical indexes that provide a measure of a process's variability relative to predefined product specifications. Pp considers the tolerance range only, whereas Ppk considers both the tolerance range as well as how close the process average was to the nominal specification. Pp and Ppk will have the same numerical value when the process average is centered around nominal. As the

process average moves away from nominal, Ppk will decrease.

9.2 The decision to accept or qualify a manufacturing process shall be based on the following criteria:

9.2.1 *Accept*— Ppk equals 1.67 or greater. Process is capable of consistently producing product within specification, if controlled properly, using statistical process control (SPC) techniques.

9.2.2 *Conditional Acceptance*— Ppk equals 1.33 to 1.67. Process is marginally capable. SPC techniques may be used; however, special care must be taken to ensure that the process average is as close to nominal as possible. Occasional 100 % sorting of product may be required.

9.2.3 *Reject*— Ppk equals less than 1.33. Process is incapable of producing product within specification. This will require 100 % sorting by the machine operator.

9.3 A process with $Ppk < 1.33$ may also be accepted if both of the following conditions exist.

9.3.1 $Pp \geq 1.67$, and

9.3.2 The process is such that the process average can be controlled by the machine operator through normal process adjustments.

9.3.3 The requirements identified in 4.3 shall be imposed on any process that receives conditional acceptance.

9.4 In many cases, capability may vary depending on the degree of control exercised during the study (that is, the type and frequency of adjustments made). The purchaser is responsible for reviewing all adjustments made during the study and ensuring that the same level of control can/will be used in production.

9.5 If the original process potential study is conducted at the equipment vendor's facility, a follow-up study must be performed after the process is set up and running in the appropriate manufacturing facility to confirm results.

10. Documentation

10.1 Documentation of each gage repeatability/reproducibility study and process qualification analysis conducted must be forwarded to the purchaser's quality assurance department for review.

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Appendix B: IFI Standards IFI-139 and IFI-140

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1.0 SCOPE

This standard establishes requirements for quality assurance systems and guidelines for technical competency of fastener testing laboratories.

1.1 REFERENCE DOCUMENTS

1.1.1 SPECIFICATIONS AND STANDARDS The following specifications and standards served in part as resources in the creation of this IFI-139 standard:

- MIL-STD-45662 - Calibration Systems Requirements
- MIL-STD-1312 - Fasteners, Test Methods
- MIL I 45208 - Inspection System Requirements
- MIL Q 9858 - Quality Program Requirements
- ASTM E 548 - Practice For Preparation of Criteria For Use In The Evaluation of Testing Laboratories And Inspection Bodies
- ISO Guide 25 - General Requirements For The Technical Competence of Testing Laboratories
- ISO 9000: Quality Management and Quality Assurance Standards – Guidelines for Selection and Use
- ISO 9003: Quality Systems: Model for Quality Assurance in Final Inspection and Test
- ISO 9004: Quality Management and Quality System Elements – Guidelines
- ASTM F606 - Standard Test Methods For Conducting Tests To Determine The Mechanical Properties Of Externally And Internally Threaded Fasteners, Washers, And Rivets
- SAE J429 - Mechanical and Material Requirements For Externally Threaded Fasteners
- ANSI/ASME B18.8.2 - Taper Pins, Dowel Pins, Straight Pins, Grooved Pins, and Spring Pins Including The Double Shear Testing
- IFI 100/107 - Prevailing-Torque Type Steel Hex and Hex Flanged Nuts
- IFI 124 - Test Procedure for the Locking Ability Performance of Non-Metallic Locking Element Type Prevailing-Torque Lock Screws

IFI 125

- Test Procedure for the Locking Ability Performance of Chemical Coated Lock Screws

1.2 DEFINITIONS

1.2.1 MECHANICAL FASTENER A mechanical device designed specifically to hold, join, couple, assemble, or maintain equilibrium of single or multiple components. Common families of fasteners include nuts, bolts, rivets, screws, pins, washers, and special parts.

1.2.2 FASTENER TESTING LABORATORY An organization that performs testing and/or inspection of dimensional, mechanical, chemical, metallurgical, and performance characteristics of mechanical fasteners and meets the requirements of this standard.

1.2.3 INSPECTION Inspection of a fastener is the activity to evaluate and measure the required characteristics and properties which, by way of drawings, standards, or specifications, constitute the fastener's engineering definition.

1.2.4 INSPECTION PLAN A pre-established combination of inspection and testing to be performed including frequency, sample size, method, and acceptance criteria.

1.2.5 FASTENER QUALITY Fastener quality is conformance of a fastener or fastener lot within its specified tolerances, limits, and requirements. Any fastener manufactured completely within its specified limits, regardless of how narrow or broad, is a "quality" fastener.

1.2.6 FASTENER PRECISION The narrowness of its specified limits establishes whether or not it may be considered a "precision" fastener. Quality should not be confused with precision, which is the result of being manufactured to close tolerances.

1.2.7 FASTENER LABORATORY ACCREDITATION Formal recognition that a laboratory has demonstrated capabilities to meet or exceed the requirements of this standard. This capability will be verified by the completion of an on-site survey by a recognized laboratory accreditation body or agency.

1.2.8 STANDARDS/SPECIFICATIONS Fastener standards/specifications define the requirements for a mechanical fastener. These may include, as applicable, the dimensional, chemical, metallurgical, mechanical, and performance characteristics.

IFI STANDARD	QUALITY ASSURANCE REQUIREMENTS FOR FASTENER TESTING LABORATORIES	IFI-139 Page 1 of 5
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1.2.9 CERTIFICATION The procedure by which written assurance is given that the chemistry, dimensional characteristics, mechanical properties, metallurgical properties, and performance characteristics conform to applicable standards and/or specifications and that data exists to assure those statements.

1.2.10 EQUIPMENT CALIBRATION All testing equipment, measuring devices and gages used to inspect fasteners for conformance to standards/specifications shall be controlled and, at specified periods, checked to assure maintenance of accuracy within specified limits. All checks and calibrations shall be traceable to applicable national or international standards.

1.2.11 LOT OF FASTENERS A lot is a quantity of a fastener product having a single lot number produced consecutively at the initial operation from a single mill heat of material and processed essentially at one time by the same process in the same manner so that statistical sampling is valid.

1.2.12 FASTENER TEST An activity during which chemical, mechanical, physical, metallurgical, or performance characteristics are evaluated to determine if they conform to the requirements of the standard, specification or purchase order.

1.2.13 TEST REPORT A fastener test report is a record including those characteristics which relate to the standards and/or specifications of manufacture. These items may include, as applicable, material certification, heat analysis, heat number, mechanical properties, metallurgical characteristics, performance requirements, surface discontinuities, and dimensions.

1.2.14 DIMENSIONAL INSPECTION Actual measurement of product dimensions and/or geometry using as appropriate micrometers, dial indicators, comparators, functional gages, or other devices suitable for measurement or size conformation.

1.2.15 MECHANICAL TESTING Verifies the mechanical properties which identify the reaction of a fastener to applied loads. These properties are the result of the manufacturing methods and metallurgical treatments employed for a given material. Typical mechanical tests are tensile (axial/wedge), yield, hardness, proofload, torsional strength, creep, stress rupture, shear, and ductility.

1.2.16 PERFORMANCE TESTING Tests conducted to verify that the functional design features of the fasteners which satisfy the specification requirements are present. Performance properties of the fastener may include, but are not limited to, fatigue, corrosion resistance, torque-tension, locking, drilling, thread forming, and sealing.

1.2.17 METALLURGICAL EXAMINATION The evaluation of metallurgical characteristics imparted to fasteners through material selection, forming, and heat treatments. The evaluation may include such items as chemistry, grain size, microstructure, decarburization, effective case depth, and through-hardness.

1.2.18 PHYSICAL PROPERTY TESTING These properties are inherent in the basic raw material and generally are unchanged or only slightly altered in the fastener following manufacture. Such properties are typically electrical resistivity, thermal conductivity, density, coefficient of thermal expansion, and magnetic susceptibility.

1.2.19 VISUAL EXAMINATION Macroscopic examinations are those which are used to examine general workmanship and the presence of surface discontinuities such as quench cracks, forging cracks, bursts, shear bursts, seams, folds, voids, tool marks, nicks, and gouges.

2.0 ORGANIZATION

The fastener laboratory shall be able to demonstrate technical competency for those tests for which it seeks accreditation.

A fastener testing laboratory shall have an organization/structure, functional responsibilities, levels of authority, and lines of communication for activities affecting quality. This shall be documented.

The quality assurance manager shall report to the highest operating officer in the company, division or organization, and have autonomy from influences by persons responsible for production.

A description of the history of the organization, the type of users served and geographic areas served shall be available.

3.0 STAFF

3.1 There shall be a written job description for each technical position in the laboratory. The description

IFI STANDARD	QUALITY ASSURANCE REQUIREMENTS FOR FASTENER TESTING LABORATORIES	IFI-139 Page 2 of 5
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shall detail necessary education, training, technical knowledge and experience.

3.2 A file shall exist for each employee which summarizes education, training and experience. Additionally, the file shall include evidence of the capability of each employee to perform specific tests, inspections and measurements.

4.0 TRAINING

Training for personnel involved in fastener evaluation shall be organized to reflect disciplines of fastener inspection and testing which are: dimensional, mechanical, performance, chemical and metallurgical. Where personnel certification is required, evidence of that certification shall be made available to the auditor.

5.0 QUALITY SYSTEM

5.1 QUALITY ASSURANCE DOCUMENTATION The quality system shall be fully documented in a quality assurance manual or an appropriate set of documents. The elements of this manual or these documents shall include but not be limited to:

- organization structure
- organizational chart
- quality organizational chart
- facilities
- scope of operation
- outside services
- statement of quality policy, authority, and frequency of review
- proficiency testing
- duties and responsibilities of personnel
- personnel qualification and training
- test procedures
- document and change control
- equipment list
- calibration procedures
- environment
- control of test samples
- procedure to handle technical complaints and/or discrepant test results
- equipment repair and maintenance
- control of subcontractors
- audit procedure
- fraud and falsification control

5.2 STANDARDS AND SPECIFICATIONS There shall be evidence that all fasteners are evaluated in

accordance with the applicable requirements of the related standards, specifications, or purchase order for conformance.

6.0 FASTENER LABORATORY INSPECTION EQUIPMENT AND PROCEDURES

6.1 MINIMUM REQUIRED TEST CAPABILITY

A fastener laboratory must have appropriate measuring and testing equipment or access to that equipment and must be able to conduct the inspections or tests according to the applicable specifications. This includes the following measuring and testing capabilities.

Fastener geometry	Decarburization/ carburization
Proof load	Coating thickness
Surface hardness	Core hardness
Thread acceptability	Surface discontinuities
Tensile strength	

Equipment required shall at least include for applicable characteristics:

Characteristic	Equipment
Dimensional Measurements	Gage Blocks Outside Micrometers Inside Micrometers Calipers
Hardness	Thread Gaging Rockwell, Vickers, or Brinell Tester
Tensile and Proof	Tensile Tester

Decarburization/ Carburization	Microscopic or micro-hardness
Coating thickness	Microscopic, magnetic, columetric
Surface discontinuities	Per specification

Machining capability shall be in place to prepare test specimens.

6.2 PROFICIENCY TESTING Accreditation of a laboratory will require participation in an approved fastener proficiency testing program that verifies the laboratory's ability to achieve consistently accurate test results on standardized fasteners.

6.3 SUBCONTRACTING INSPECTION: CERTIFICATION REQUIREMENT For fasteners to be certified, they must meet chemical, mechanical and dimensional requirements as designated in the

IFI STANDARD	QUALITY ASSURANCE REQUIREMENTS FOR FASTENER TESTING LABORATORIES	IFI-139 Page 3 of 5
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standards and/or the engineering drawings to which they were manufactured. A laboratory may be accredited even if it does not have all equipment required by the product standard to inspect fasteners, provided it uses exclusively a laboratory accredited in the subcontracted test or measurement. The laboratory ultimately issuing the fastener certification, and doing the majority of the tests is liable for the validity of that entire certification even if it subcontracts part of the inspection. The issuer of the certification is responsible for using only accredited laboratories.

Inspection equipment and specific procedure requirements are determined, at least to a degree, by the specifications governing the fasteners being inspected and tested. For this reason, the laboratory must have a defined procedure to analyze the fastener specifications and demonstrate capabilities to inspect and test to fulfill the requirements of the applicable specifications.

6.4 ADDITIONAL TESTING CAPABILITIES It is recognized that at least 52 separate tests for fasteners exist based on current specification requirements. A list of these tests are included for reference in Appendix A. A summary of mechanical fastener inspection including Item for inspection, equipment commonly used and related specifications is in Appendix B.

7.0 CALIBRATION OF EQUIPMENT

A documented equipment calibration system is required for testing laboratories which test or evaluate fasteners.

7.1 Each piece of measuring and testing equipment shall have a unique identification and be calibrated as appropriate prior to being put into service.

7.2 The calibration system shall be designed to assure that measurement results are traceable as applicable to national standards and/or international standards. Where applicable national or international standards do not exist, the testing laboratory shall establish and perform tests to prove accuracy of equipment.

7.3 Reference standards shall be calibrated and be traceable to national or international standards. Reference or traceable standards used for calibration shall not be used for other purposes.

7.4 Measuring and test equipment and measurement standards shall be calibrated at periodic intervals established on the basis of stability, purpose and degree of usage. Calibration intervals shall be defined for each type of measuring or testing equipment or measurement standard and documented in written procedures. Calibration intervals shall be reviewed and modified as required based on the evidence of previous calibrations. A program for recalibrating measuring and testing equipment shall be developed. Operational checks of testing equipment prior to use should be made between recalibrations.

7.5 Calibration records shall be maintained. The records shall identify the schedules and procedures followed. The records shall include a suitably identified individual file of calibration listing at least a description of the testing equipment or measuring system, the calibration interval, date and results of last calibration.

7.6 Testing equipment or measuring systems which require certification of calibrations shall have a calibration report or certificate which identifies it as such.

8.0 ENVIRONMENT IN THE LABORATORY

8.1 Measuring and testing equipment and measurement standards shall be calibrated and used in a controlled environment as applicable. Temperature, humidity, vibration, fumes, dust, illumination and other controllable factors potentially affecting precision measurements shall be identified and controlled. When applicable, compensating corrections shall be applied to calibration results obtained in an environment different from standard conditions.

8.2 Adequate storage facilities for equipment, standards and records shall be provided. Adequate steps shall be taken to ensure good housekeeping in the testing laboratory.

9.0 HANDLING TEST SAMPLES

A system for identifying the items to be tested shall be used to ensure that no confusion regarding identity occurs during testing. Each item shall be maintained by manufacturing lot number or a unique number assigned by the testing laboratory traceable to a manufacturing lot number.

IFI STANDARD	QUALITY ASSURANCE REQUIREMENTS FOR FASTENER TESTING LABORATORIES	IFI-139 Page 4 of 5
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There shall be a written policy regarding receipt, retention and disposal of samples tested.

10.0 RECORDS

A system shall be in place to record the dimensional, mechanical and performance testing event by date, equipment and operators. Each event shall be traceable to the manufacturer's lot number or purchase order. Records shall be legible, identifiable and retrievable and shall be retained for ten years. All records and test reports shall be maintained in such manner as to preserve their confidential nature. Adequate steps shall be taken so that test reports, certificates and other records are preserved and protected against loss and damage.

11.0 CERTIFICATIONS AND TEST REPORTS

11.1 TEST REPORTS

Testing laboratory data shall be included in a report which accurately, clearly, and without prejudice presents the recorded parameters, the actual test results, and all other relevant information. This report shall identify the standards and specifications applicable to the particular lot being tested and the number of pieces tested, and, in those cases where the importer or private labeled distributor assumes the responsibility for inspection and testing, a letter from the manufacturing source indicating the standards or specifications to which the lot was manufactured.

11.2 Each fastener test report shall include at least the following information:

11.2.1 SAMPLE TEST REPORT

- name and address of testing laboratory
- unique identification of report and of each page of the report
- name and address of the client
- description and identification of the tested item, including manufacturer's name and address which shall be furnished by the source requesting the testing
- manufacturer's lot number
- a statement to the effect that the test results relate only to the items tested

- identification of the product specification and test conducted
- any deviations, additions to or exclusions from the test specification, and any other information relevant to a specific test
- disclosure of any non-standard test method or procedure utilized
- statement of conformance or non conformance to applicable specifications
- listing of range of actual test results for given lot samples including the number of samples examined (all actual test results on file)
- name and title of person(s) accepting technical responsibility for the test report and the date of issue
- a statement that the report shall not be reproduced in part or in full without the approval of the testing laboratory, or alternately a system shall be in place to prevent unauthorized test report reproduction.

11.2.2 **LOT CERTIFICATION** For lot certification the report shall include all of the information in paragraph 11.2.1 and information which includes lot number, lot size and sample test size and the basis of that sample selection.

11.3 Particular care and attention shall be paid to the arrangement of the test report, especially with regard to presentation of the test data and ease of assimilation by the reader. The format shall be carefully and specifically designed for each type of test carried out, but the headings shall be standardized as far as possible.

11.4 Corrections or additions to a test report after issue shall be made only by a further document suitably marked, e.g. "Supplement to test report serial number...(or otherwise identified)," and shall meet the relevant requirements of the preceding paragraphs.

11.5 Certifications - The laboratory shall issue a written statement of assurance that the test report is complete and valid, and shall disclose the approved accrediting body in accordance with Section 6 of Public Law 101-592 applicable to its accreditation including its date of its expiration.

IFI STANDARD	QUALITY ASSURANCE REQUIREMENTS FOR FASTENER TESTING LABORATORIES	IFI-139 Page 5 of 5
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APPENDIX A
FASTENER TESTING

- | | |
|--|--|
| I. Dimensional | 25.) Macro Etch |
| II. Mechanical and Performance Testing | 26.) Inclusions |
| 1.) Shear | 27.) Kesternich |
| 2.) Proof Load | 28.) Humidity |
| 3.) Widening | 29.) Salt Spray |
| 4.) Tensile | 30.) Magnetic Particle |
| a.) Wedge | 31.) Liquid Penetrant |
| b.) Axial | 32.) X-ray |
| 5.) Hardness | 33.) Ultrasonic |
| a.) Macro | 34.) Eddy Current |
| b.) Micro | 35.) Adhesion |
| 6.) Impact | 36.) Chemical Stripping |
| 7.) Torsional | 37.) Chemical Drop |
| 8.) Torque/Tension | 38.) Creep |
| 9.) Ductility | 39.) Rotational Capacity |
| 10.) Fatigue | 40.) Vibration |
| 11.) Drive | 41.) Drill Screw |
| 12.) Elongation | 42.) Chemical Analysis |
| 13.) Stress Rupture | 43.) Case Depth |
| 14.) Hydrogen Embrittlement | 44.) Decarburization/
Carburization |
| 15.) Proof Torque | 45.) Grain Size |
| 16.) Torque - To Clamp Ratio | 46.) Minimum Tempering
Temperature |
| 17.) Pull Through | 47.) Yield |
| 18.) Push Out | 48.) Magnetic Permeability |
| 19.) Twist | 49.) Reduction of Area |
| 20.) Compression | 50.) Part Elongation |
| 21.) Clamp Load Torque | 51.) Thread Laps |
| 22.) Breakaway Torque | 52.) Thread Forming |
| 23.) Prevailing Torque | |
| 24.) Flow Lines | |

APPENDIX B

MECHANICAL FASTENER INSPECTION

I. Minimum Requirements

A. DIMENSIONAL INSPECTIONS

Feature	Equipment	Specification
Threads	Indicating Type Ring Gages	ANSI B1.3M FED-STD-H28/20 MIL-S-7742 MIL-STD-8879
Linear Measurements	Gage Blocks Outside Micrometers Inside Micrometers Calipers Plug Gages Tri-Micrometers	MIL-STD-120
Angle and Radii	Optical Comparators Functional Gages Radius Charts	MIL-STD-120
Thread Runout	Functional Gages	
Hex Socket Size Wall Thickness Hex Socket Depth	Functional Gages Fixture and Dial Indicator Dial Indicator	ANSI/ASME B18.3 ANSI/ASME B18.3 ANSI/ASME B18.3

B. PHYSICAL TESTING

Test	Equipment	Specification
Hardness	Rockwell Tester	ASTM-E18 MIL-STD-1312-6
Micro-Hardness	Micro-Hardness Tester Preparation Equipment	ASTM-E92 ASTM-E384 MIL-STD-1312-6 ASTM-E3
Tensile and Proof including specimens	Tensile Tester	ASTM-F606 SAE-J429 SAE-J995 MIL-STD-1312-8
Discontinuities	Macro-etch Microscope Magnetic Particle Liquid Penetrant	ASTM F788 ASTM F812 SAE-J122 SAE-J123 MIL-STD-1949 MIL-STD-6866 ASTM-E340 ASTM-E709 ASTM-E165
Stress Durability (Hydrogen Embrittlement)	Torque Wrenches Test Plates Test Washers	MIL-STD-1312-5 ASTM F606
Decarburization/ Carburization	Macro-etch Microhardness	SAE J419 ASTM A574 ASTM F606

C. CHEMICAL ANALYSIS

Material	Equipment	Specification
Steel	Carbon Determiner Spectrometer	ASTM-E30

II. Additional Requirements (when applicable)

A. DIMENSIONAL

Feature	Equipment	Specification
Recesses	Recess Penetration Recess Wobble	ANSI/ASME B18.6.4
Straightness	Straightness Gage	IFI-136 ANSI/ASME B18.3 ANSI/ASME B18.2.1
Thread Runout	Thread Runout Gage	IFI-136 ANSI/ASME B18.2.1
Flat Head Protrusion	Protrusion Gage	ANSI/ASME B18.6.4 ANSI/ASME B18.6.2
Hex Head Height (across corners)	Gaging Ring	ANSI/ASME B18.6.4
Slotted Nut	Slot Gage	ANSI/ASME B18.2.2
Coating/Plating Thickness	Various Microscopic	MIL-STD-1312-12 ASTM-B487
	Magnetic Tester	ASTM-499
	Coulometric Tester	ASTM-B504

B. PHYSICAL TESTING

Test	Equipment	Specification
Shear	Tensile Tester Universal Tester Hydraulic Press	ASTM-F606 MIL-STD-1312-13 MIL-STD-1312-28 MIL-STD-1312-20
Double Shear	Shear Block and Support Block or Fixture	ANSI/ASME B18.8.2
Impact	Impact Tester	ASTM-A540 ASTM-A370
Magnetic Permeability	MU Gage	MIL-STD-17214 ASTM A-342
Torsional Strength	Torque Wrench Torque Fixture	ANSI/ASME B18.6.4 ASTM-F738
Hex Socket Strength	Torque Wrench Fixture	ASTM-F880 ASTM-F912
Recess Torsional Strength	Torque Wrench Fixture	MIL-B-87114 MIL-STD-1312-25

Test	Equipment	Specification
Ductility	Ductility Block	SAE-J78 SAE-J81 IFI-112 IFI-113
Salt Spray	Salt Spray Cabinet	ASTM-B117 MIL-STD-1312-1
Cas Depth	Macro-etch Microhardness	SAE-J423
Torque-Tension	Torque Wrenches Load Cells	SAE-J174 IFI-101 MIL-STD-1312-15
Tensile (elevated temp)	Tensile Tester w/heater	MIL-STD-1312-28
Double Shear (elevated temp)	Tensile Tester or Hydraulic Press w/heater	MIL-STD-1312-18
Humidity	Humidity Cabinet	MIL-STD-1312-3
Vibration	Vibration Tester	MIL-STD-1312-7
Fatigue	Fatigue Tester	MIL-STD-1312-11
Drill Drive Testing	Drill-Drive Tester	SAE-J78 IFI-113
Thread Forming	Torque Wrench & Test Block	SAE-J81
Clamp Load Torque	Test Nut, Test Washer, Load Measuring Device Torque Measuring Device	IFI-124
Break Away Torque	Test Nut Torque Wrench	IFI-125
Prevailing Torque	Test Bolt Hardened Washer Torque Measuring Device Test Washer	IFI-100/107
Metallographic Analysis: Grain Size Flow Lines Microstructure	Metallographic Equipment	
Plating Adhesion		ASTM-B571
Panel Fastener Tests: Push-out Tensile Torque-out Shear Pull-up		MIL-STD-1312-22 MIL-STD-1312-23 MIL-STD-1312-24 MIL-STD-1312-26 MIL-STD-1312-27
Fastener Sealing		MIL-STD-1312-19
Stress Relaxation		MIL-STD-1312-17

Test	Equipment	Specification
Stress Corrosion		MIL-STD-1312-9
Blind Rivet Tests		SAE-J1200 IFI-114 IFI-116 IFI-117 IFI-119

C. CHEMICAL

Material	Equipment	Specification
Aluminum and Alloys		ASTM-B316 ASTM-E34 ASTM-E101 ASTM-B211
Brass & Bronze		ASTM-E54
Copper & Copper Alloys		ASTM-E53 ASTM-E62 ASTM-E75 ASTM-E76 ASTM-E478
Stainless Steel		ASTM-E353
Titanium		AMS-4928 AMS-4967 AMS-4971
Coating Type	X-Ray	ASTM-B568

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INTRODUCTION

Forming is the primary manufacturing operation in the fastener industry and the term includes heading, upsetting, extruding and forging. These formed parts are produced at very high speeds by metal flow due to machine-applied pressure. The primary forming operation self-inspects the quality of the raw material and imperfections such as seams, laps, and internal pipe which may not be visible are revealed when the material is upset. The absence of bursts, forging cracks and open seams is strong evidence that the quality of material selected was that intended for the severe upsets of today's fastener manufacturing.

RODS & BARS.

While standard steel grades for rods and bars have been in existence for many years, and have, with modifications or restrictions of one or more elements, long been used for cold forming, this IFI-140 presents a distinct selected series of twenty steel grades for cold forming. These have been jointly developed by steel producers and cold heading and forging users under the aegis of the Industrial Fasteners Institute. These twenty grades are designated IFI steel grades and the ranges and limits for the thirteen carbon steel grades for carbon, manganese, phosphorus, and sulfur are shown in Table 1. Maximum residual limits for copper, nickel, chromium, molybdenum and tin are specified in paragraph 6.4. Silicon ranges and limits are shown in Table 3. The chemical limits for the seven alloy steel grades are shown in Table 4.

A significant area of improvement is in the decarburization control and measurement for cold heading rods and bars. A method to measure based upon the location of the worst decarburization position is described in paragraph 8.0 and shown in Drawing Number 1. The average

total affected depth which may not be exceeded is found in Table 6. Free ferrite should not exceed the maximum depth of free ferrite at the worst location.

To prepare a material for cold forming it is often spheroidized, which is an annealing treatment that transforms the microstructure of steel to its softest condition with maximum formability. In the hot rolled or normalized condition, steels containing less than 0.80% carbon consist of the microconstituents pearlite and ferrite. Pearlite, the harder of the two constituents, causes the steels to resist deformation. The harder pearlite is comprised of alternating thin layers or shells of ferrite and cementite (iron carbide), a very hard substance. In spheroidize annealing, the cementite layers are caused by time and temperature to collapse into spheroids or globules of cementite. This globular form of cementite tends to facilitate cold deformation in such processes as cold heading, cold rolling, forming and bending.

Plate 1 displays variations in the transformation of pearlite to spheroidized cementite. Temperature variations within a charge or inadvertent heating either slightly below or slightly above the optimum temperature may produce a departure from the ideally spheroidized structure. Plate 1 displays material treated at a lower than ideal temperature exhibiting a granular structure and is shown at G1 through G5. Material treated at a higher than ideal temperature will exhibit a lamellar structure and is shown as L1 through L5. Latent energy from cold work will allow drawn wire to transform more readily to a higher degree of spheroidization than will hot rolled rod or bar. The degree of spheroidization is normally evaluated at 1,000X magnification.

When spheroidize annealed, Cold Heading Rods or Cold Heading Bars shall meet a maximum rating of G-2 or L-2 in Plate 1.

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 1 of 23
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While a fully spheroidized microstructure is desired for forming, material is rarely used in the "as spheroidized annealed" condition. Such material can cause processing difficulties because of its poor coil configuration, the formation of a "shear lip" during shearing, or result in undesirable bending of the fastener shank during cold heading. For these reasons almost all material is given a light wire drawing reduction after the thermal treatment either by the wire producer or in front of the fastener heading operation. Spheroidized structures are also known to retard austenization during short cycle heating, such as induction heating, in a subsequent hardening operation. Additional time may be required to dissolve the spheroidized cementite into the austenite at the heating temperature.

The tolerances for rod and bar are reduced for IFI grades, reflecting the committee consensus that this feature would significantly improve control of cold working. Out-of-round material may cause localized die wear showing up as wear rings in the drawing die. The elliptical material cross section produces non-uniform cold work stresses around the circumference of the drawn cross section which contributes to distortion of the product and causes hardness variation across the section. Thus, serious efforts are anticipated now and in the future to bring about reasonable economic tolerance improvement.

Rods and bars are subject to mill testing and inspection to provide material soundness and freedom from detrimental surface imperfections. These features are required to assure satisfactory performance of the wire produced from rods and bars. Thermal treatment as a part of wire mill processing is very important in the higher carbon grades of steel. Wire "direct drawn" from low carbon and medium low carbon steel wire rods is sometimes successfully used for simple two-blow

upsets or for standard trimmed hexagon head cap screws.

As upsetting becomes progressively more demanding, wire drawn from annealed or spheroidize annealed rods is more appropriate. For demanding applications, annealed-in-process or spheroidized annealed-in-process wire is required. For thermally treated in process wire, the final drawing operation may be performed by the wire supplier or incorporated into the cold heading operation by drawing in tandem with that operation.

Cold Heading Rods and Bars will not necessarily result in successful production of recess head and socket head quality wire. Wire mills desiring to produce recess head and socket head wire should consult steel manufacturers to secure material with additional restrictive requirements.

In the production of rods for heading, forging or cold extrusion in killed steels over 0.13% carbon, both austenitic grain size and decarburization are important features. Such steels can be produced either "fine" or "coarse" austenitic grain as required depending upon the type of heat treatment and application. Table 6 shows decarburization limits for the maximum permissible depth of free ferrite and the average total affected depth of decarburization. The examination is conducted as outlined in paragraph 8.0 of this Standard. If decarburization limits closer than those shown in Table 6 are required in a given manufactured product, it is sometimes appropriate for the purchaser to incorporate means for carbon restoration in his manufacturing process.

In cases of disagreement in the testing for decarburization, it is customary to make heat treatment tests of the finished product to determine suitability for the particular application.

<p>IFI STANDARD</p>	<p>CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS</p>	<p>IFI-140 Page 2 of 23</p>
<p>Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.</p>		<p>Issued: April 20, 1993</p>

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Rods and bars should be reasonably free from detrimental surface imperfections including seams, voids, pits, scratches and laps. Material, suitably thermally treated when appropriate, which bursts or splits when upset or formed, and having imperfections deeper than the greater of 0.003" or 0.5% of D (where D is the finished diameter in inches of material), is normally rejectable.

Samples requiring assessment of such surface imperfections shall be prepared by careful metallographic technique, suitably etched, and the depth of imperfection measured radially from the surface at a magnification of 100X.

Mechanical properties for thermally treated rods and bars are shown in Table 7.

Rod size tolerances are shown in Table 9.

Bar size tolerances are shown in Table 10.

A selected series of steel grades has been developed for carbon steel rods and bars for cold heading and cold forging. See Table 1.

WIRE.

Wire for cold heading and forging is produced from bars or rods featuring closer than normal control of: chemical composition, size tolerances, decarburization limits, freedom from detrimental surface imperfections, and when appropriate, specified mechanical properties for thermally treated material, see Table 7; and when spheroidized, a maximum rating of G2 or L2, see Plate 1.

Thermal treatment of wire involves heating and cooling the steel in such a manner as to achieve desired properties or structures.

Annealing is the general term applied to a variety of thermal treatments for the purpose

of softening the wire. Annealing commonly involves heating the material to temperature near or below the critical temperature. A number of processes are employed which influence the surface finish obtained. If a particular finish is required on wire annealed at final size, the producer should be consulted.

Regular Annealing, sometimes called pot annealing, is performed by heating coils of wire in a furnace followed by slow cooling without an attempt to produce a specific microstructure or a specific surface finish.

Spheroidize Annealing involves prolonged heating at a temperature near or slightly below the lower critical temperature, followed by slow cooling, with the object of producing a globular (spheroidal) condition of the carbide to obtain maximum softness.

Annealed in Process Wire is a term normally associated with cold heading wire. The product is manufactured by drawing rod or bar to a size larger than the finished diameter wire, and regular annealing to relieve the stresses of cold work and obtain softening. This is followed by cleaning, coating with a suitable lubricant, and redrawing to finished size, usually with an area reduction of between 7% to 20% depending upon wire size and application. See Table 7 for expected tensile strengths.

Spheroidize Annealed in Process Wire is another term normally associated with cold heading wire. The product is manufactured by drawing rod to a size larger than the finished diameter wire, followed by spheroidize annealing to obtain maximum softness and to create a spheroidal structure as shown in Plate 1. The wire is then cleaned, coated with a suitable lubricant and redrawn to finished size, usually with an area reduction of between 7% to 20% depending upon wire size and application.

<p>IFI STANDARD</p>	<p>CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS</p>	<p>IFI-140 Page 3 of 23</p>
<p>Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.</p>		<p>Issued: April 20, 1993</p>

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Decarburization tests are made by the microscopic method described in paragraph 8.0. Table 6 shows the decarburization limits for the maximum depth of free ferrite and the maximum average total affected depth. The limits shown apply to wire made from killed steel over 0.13% carbon. When closer limits are required, it is sometimes appropriate for the purchaser to incorporate means for carbon restoration in his finished product.

Finishes or coatings are designed to provide proper lubrication for the header dies. With modern developments in cold heading technique, the role of wire finishes has assumed much greater importance. In addition to performing the required upset in the dies, the cold heading operations may now include single or double extrusion, slotting, punching, trimming, pointing, etc. The wire coatings or finishes must have both the necessary lubricating quality and adherence to prevent galling or undesirable die wear. This necessitates special control of the various types of lubricants that are used and the correct amount of coatings for the type of heading operation involved.

While lime-soap finishes are widely employed, phosphate finishes are frequently used for the more demanding forming applications.

Phosphate coated wire finishes are produced from material which has been chemically cleaned, coated with zinc phosphate, and suitably neutralized. The stock may be coated with lime or borax as a carrier if the lubricant is to be applied in the die box. The wire lubricant may be applied by immersing the phosphate coated coils in a dilute soluble soap bath, by pickup of a dry lubricant in the drawing die box, or by a combination of both methods. The drawn finish so produced is particularly beneficial in many severe cold working applications, especially those involving backward extrusion.

Thermally treated wire can also be supplied cleaned and lime coated or cleaned and phos-

phate coated at ordered size. Wire phosphate coated at ordered size can be furnished with or without suitable lubricant coatings for subsequent drawing into smaller sizes or for direct use in cold formers. A drawn phosphate finish as discussed in the preceding paragraph, provides a more effective lubrication during cold forming than phosphate coated at finished size.

Solid die heading machines, especially those used for extrusion heading, require a coating of special consistency, whereas with open or split die heading machines a light coating will perform satisfactorily. Cold heading finishes are varied considerably even for the same type of heading, in order to meet individual cold heading requirements. Those coatings are individual in character and involve manufacturing techniques that differ markedly from conventional wire mill practice when the only consideration is the provision of lubrication essential for the wire drawing operation.

Size tolerances for wire for cold heading and cold forging are shown in Table 8.

Mechanical properties for selected steel grades of wire for cold heading and cold forging when thermally treated are shown in Table 7. Whereas it is appropriate to establish mechanical properties for selected compositions of thermally treated carbon steel rods and bars, mechanical properties of wire drawn directly from rods or bars are substantially influenced by the amount of reduction in drawing the wire. The reduction is dependent on the incremental availability of nominal rod and bar sizes as well as the influence of size tolerances. Accordingly no values are included in Table 7 for wire drawn from annealed or spheroidize annealed rods or bars. Certain steel grades are available with differences in deoxidation practices. Suitable allowances for aluminum killed steel and rimmed steel are incorporated in the footnote to Table 7. The amount of reduction prior to thermal treatment, the size tolerance of the intermediate thermally treated wire, and the required percent

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Page 4 of 23
		Issued: April 20, 1993

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reduction to final size which progressively increases as the final wire size decreases, influence the mechanical properties. An appropriate adjustment in values for annealed in process and spheroidize annealed in process wire as a function of size is included in the footnote to Table 7.

Chemical compositions particularly suited to wire for cold heading and cold forging have been developed. For carbon steels these are included in Table 1 and for alloy steels in Table 4.

Cold Heading and Cold Forging Wire have five application variations as follows:

- Cold Heading
- Recessed Head
- Socket Head
- Scrapless Nut
- Tubular Rivet

Each of these variations is intended to be well suited to the fabrication of a particular fastener type and fastener manufacturing method.

Fastener fabrication includes a wide variety of methods and complexity of machines and tooling. The simplest is a single die, single blow machine, common to the nail machines, but also used for simple shapes such as certain rivets. Single die, two blow machines which first gather stock, then rotate the die, and strike again, are widely used for larger headed rivets and most machine screws and tapping screws. By partitioning the cold work in two separate die cavities, progressively and selectively deforming the raw material, it is thus possible to produce larger overall deformations or upsets, of more complex shapes, without fracture.

Two die three blow machines permit extruding of the shank, thereby utilizing a larger diameter starting raw material, accommodating the production of larger heads without as much upsetting; or permitting the use of hard drawn wire where annealed material would otherwise have been required. Progressive headers can

include six or more stations permitting the cold forged production of very complex configurations which otherwise would require machining or a combination of forming and machining for their manufacture. Accordingly, it is not appropriate to merely examine the geometry of a finished fastener to establish the appropriate raw material, e.g., hard drawn, wire drawn from annealed rod or bar, or spheroidize annealed in process wire. The method of manufacture is also required information, as is the steel processing for a particular application. Communication between the steel supplier and the fastener producer is therefore of paramount importance to avoid the use of raw material which is unnecessarily costly on the one hand or inadequately processed on the other.

Cold Heading Wire is produced by specially controlled manufacturing practices to provide satisfactory quality for heading, forging and roll threading. The wire is subject to mill tests and inspection for internal soundness, control of chemical composition and freedom from detrimental surface imperfections.

In many cases, the threads of bolts, screws, studs, etc., are cold formed by an operation known as roll threading. This consists of rolling the shank between rolling dies to provide the particular thread form required. Experience has shown that detrimental internal imperfections and detrimental surface imperfections in the wire will result in a crushed condition or imperfect thread which renders the product unfit for use. Therefore, particular care is required in the manufacture of the wire to provide freedom from detrimental imperfections. Precautions are also required of the fabricators in setting up and adjusting roll threading equipment. Faulty set-up or adjustment can produce defective threads even when the wire is of proper quality.

Hard drawn low carbon and medium low carbon steel wire is sometimes successfully used for simple two-blow upsets or for standard trimmed hexagon head cap screws. As upsetting

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Page 5 of 23
		Issued: April 20, 1993

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becomes progressively more demanding, wire drawn from annealed or spheroidized annealed rods is more appropriate. For demanding applications, annealed in process or spheroidize annealed in process wire is required. For thermally treated in process wire, the final drawing operation may be performed by the wire supplier or incorporated into the cold heading operation by drawing in process in tandem with that operation. Cold Heading wire is not appropriate for recessed head or socket head application.

Recessed Head Wire is employed when screw heads incorporate a recess configuration such as a crossed or square recess. This wire involves more exacting precautions and controls than Cold Heading wire, such as improved surface quality and special wire processing. Exacting precautions and controls are necessary in the selection and internal soundness of the steel and in the preparation of billets for surface quality. Special attention to rod rolling and to inspection of the rods is essential. In order to provide wire that will be soft enough to withstand the very severe cold forming operations, wire for all types of recess head screws is generally spheroidize annealed in process or spheroidize annealed at finished size, with the final drawing incorporated into the heading operation by drawing in process in tandem with that operation. When spheroidize annealed at finish size wire is so employed, the fastener producer should ensure that the final reduction is not excessive.

Socket Head Wire is similar to Recessed Head wire but is intended for the deep sockets attendant with hexagon and Torx™ and similar internal drives, requiring still more exacting processing and controls to accommodate the substantially heavier deformation.

Scrapless Nut Wire is produced by closely controlled manufacturing practices, and sub-

jected to mill tests and inspection designed to provide internal soundness and freedom from detrimental surface imperfections, thus providing satisfactory cold heading, cold expanding, cold punching, and thread tapping characteristics.

This wire is produced for the manufacture of various shaped nuts, which are made in continuous operation on heading machines. The cold heading operation in the production of scrapless nuts is very severe, and the wire is specially prepared for that purpose.

Low and medium low carbon hard drawn wire or wire drawn from annealed rods or bars is employed, depending on the severity of deformation. Medium carbon wire is normally drawn from annealed or spheroidize bars or rods, or produced annealed in process. For nuts not requiring a final heat treatment, the attainment of minimum required nut proof loads is partially dependent on the raw material, the selection of an appropriate steel grade, and the amount of wire reduction.

Tubular Rivet Wire is suitable for cold heading and backward extruding the hole in the shank during cold heading. In order to obtain the properties essential for the production of tubular rivets, the wire is spheroidize annealed in process but with a final redrawing operation somewhat heavier than normal to prevent buckling in the extruding operations. Accordingly, the mechanical properties shown in Table 7 may not always be appropriate for spheroidize annealed in process tubular rivet wire. Wire may also be furnished spheroidize annealed at finished size with the final drawing incorporated into the heading operation by drawing in tandem with that operation. Wire finish to accommodate the individual conditions of severe cold extruding and cold heading is an important consideration. Tubular Rivet wire is normally produced from low carbon aluminum killed steel.

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 6 of 23
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Issued: April 20, 1993

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SUMMARY.

This IFI Standard has been developed by a joint effort of cooperation between the fastener manufacturer, the raw material manufacturer, and other important fastener industry suppliers.

Following IFI approvals and subsequent publication, and in its traditional role of issuing IFI standards, it is intended that IFI-140 will be introduced into the National Consensus Standards process.

The IFI Raw Materials Study Committee

includes:

<u>NAME</u>	<u>COMPANY</u>
Ian Park, Chairman	Consultant
Edward Kottcamp, Jr., Past Chmn.	SPS Technologies
John Asimou	American Steel & Wire Corporation
Edward Frederick	Bethlehem Steel
Bill Darm	Brainard Rivet
James Fox	Charter Steel
Daniel Bosko	Cuyahoga Bolt & Screw
John Williams	Cuyahoga Bolt & Screw
Jeff Easter	Elco Industries, Inc.
John Herron	Herron Testing Laboratories, Inc.
Arthur Lukowicz	HI-Temp Inc.
Larry Mercer	Huck International, Inc.
Michael Starozhitsky	Illinois Tool Works Inc.
Anton Tendler	Ivaco Steel Mills Ltd.
Edward Bueche	USS/Kobe Steel Company
Ron Fullington	USS/Kobe Steel Company
Munekazu Tsuji	USS/Kobe Steel Company
Joe McAuliffe	Lake Erie Screw Corp.
Bryan Burgy	Medalist Industrial Fastener Division
Christopher Wackrow	MNP Corporation
Greg Johnson	Nucor Fastener
Peter Kasper	Nucor Fastener
Dick Adams	Raritan River Steel Co.
Brian Murkey	RB&W Corporation
Richard Nebiolo	Republic Engineered Steels, Inc.
Dick Hadden	Sidbec-Dosco Inc.
Rick Nishizaki	Sidbec-Dosco Inc.
Craig Hagopian	Stelco Fastener & Forging Co.
Geoffrey Boal	Stelco Inc.
Geoffrey Palmer	Stelwire
Ron Ceselli	A Unit of Stelco Inc.
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	Walker Wire & Steel Co.
	Wrought Washer Mfg., Inc.

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Page 7 of 23
		Issued: April 20, 1993

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1.0 Scope.

1.1 This specification includes the physical, mechanical and metallurgical requirements for carbon and alloy steel wire, rods and bars in coils intended for the manufacture of mechanical fasteners which include: bolts, nuts, rivets, screws, washers and special formed parts manufactured cold.

1.2 Wire size range includes 0.062 inches to 1.375 inches.

1.3 Rod size range usually includes 7/32 inches to 47/64 inches and generally offered in 1/64th increments.

1.4 Bar size range includes 3/8 inches to 1½ inches.

1.5 Sizes for wire, rod and bar outside the ranges of paragraphs 1.2, 1.3 and 1.4 may be ordered by agreement between purchaser and supplier.

1.6 Material is furnished in five application variations. The Steel Industry uses the term "quality" to designate characteristics of a material which make it particularly well suited to a specific fabrication and/or application and does not imply "quality" in the usual sense. The purchaser should advise the supplier regarding their manufacturing process and finished product application as appropriate. The five application variations are:

- Cold Heading
- Recessed Head
- Socket Head
- Scrapless Nut
- Tubular Rivet

1.6.1 Wire is furnished to all five application variations.

1.6.2 Rod and bar are furnished to the single application variation; Cold Heading.

1.7 Conformance of all test data shall be determined in accordance with ASTM E29.

1.8 Heat treating terms not defined in this Standard are included in SAE J415.

2.0 Referenced Documents.

2.1 ASTM Specifications:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking and Loading Methods for Steel Products for Domestic Shipment

E 10 Test Method for Brinell Hardness of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification

E 30 Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

E 112 Test Methods for Determining Average Grain Size

E 1077 Standard Test Methods for Estimating the Depth of Decarburization of Steel Specimens

2.2 SAE Standards:

J403 Chemical compositions of SAE carbon steels

J404 Chemical compositions of SAE alloy steels

J406 Methods of Determining Hardenability of Steels

J415 Definitions of Heat Treating Terms

2.3 IFI Standards:

IFI Spheroidization Rating — Plate 1

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 8 of 23
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Issued: April 20, 1993

All standards and specifications are advisory only. Their use by anyone is entirely voluntary. Reliance thereon for any purpose by anyone is at the sole risk of that person or the user of the product, and the IFI is not responsible for any loss, claim or damage arising therefrom. In formulating and approving standards and specifications, the IFI has not investigated and will not investigate patents which may apply to the subject matter. Prospective users of the standards and specifications are responsible for advising themselves of and protecting themselves against any patent infringement liability which may arise out of such use. © 1993 Industrial Fasteners Institute.

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3.0 Definitions.

3.1 Carbon Steel: Steel is considered to be carbon steel when no minimum content is specified or required for chromium, molybdenum and nickel, or any other element added to obtain a desired alloying effect; or when the maximum content specified for manganese does not exceed 1.65%. When specified, boron may be added to killed carbon steel with a maximum allowable of 0.003%.

3.2 Alloy Steel: Steel is considered to be alloy steel when the maximum of the range given for Manganese exceeds 1.65% or in which a definite range or definite minimum quantity for any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels; chromium, molybdenum, and nickel or any other alloying element added to obtain a desired alloying effect.

3.3 Annealing: Annealing is a process of heating to and holding steel at a given temperature for a given time and then cooling at a given rate, used to soften and/or produce changes in the microstructure of the steel to enhance formability and reduce tensile strength.

3.4 Spheroidizing: Spheroidizing, a form of annealing, involves prolonged heating at temperatures near the lower critical temperature, followed by slow cooling, with the object of forming spheroidal metallic carbides that have a higher degree of formability.

3.5 Wire: Wire is produced from hot rolled or annealed rods or bars by cold drawing for the purpose of obtaining desired size, dimensional accuracy, surface finish and mechanical properties. Wire is furnished in the following conditions; direct drawn (DD); drawn from annealed rod or bar (DFAR or DFAB); drawn from spheroidized annealed rod or bar (DFSR or DFSB); drawn to size and spheroidized (SAFS); drawn, annealed in process, and finally lightly drawn to size (AIP);

and drawn, spheroidize annealed in process, and finally lightly drawn to size (SAIP). Wire size tolerances are shown in Table 8. Sizes include those specified in paragraph 1.2.

3.6 Spheroidize annealed-at-finish size wire (SAFS) is wire that has been spheroidize annealed after final cold reduction. One or more annealing treatments may precede the final cold reduction.

3.7 Annealed-in-Process (AIP) or Spheroidize Annealed-in-Process (SAIP) wire is produced as drawn carbon or alloy steel wire. In producing AIP and SAIP wire, rods or bars are drawn to wire and thermal treatment (followed by a separate cleaning and coating operation) is done prior to final drawing to produce a softer and more ductile wire for applications in which direct drawn wire would be too hard. Thermal treatment may also be employed when controlled mechanical properties are required for a specific application.

3.8 Rods: Rods are produced from hot rolled or cast billets, usually rolled in a multiple strand mill to a round cross section then coiled into one continuous length to size tolerances shown in Table 9. Rods are furnished as-rolled, annealed or spheroidize annealed in sizes found in paragraph 1.3.

3.9 Bars: Bars are produced from hot rolled or cast billets, or blooms rolled single strand into coils. Bars have a greater precision in cross section than rods. Size tolerances are shown in Table 10. Bars are furnished as-rolled, annealed, or spheroidize annealed and in sizes found in paragraph 1.4.

3.10 A lot is defined as a quantity of raw material of one size and heat number submitted for testing at one time.

3.11 Seams: A longitudinal discontinuity extending radially into wire, rod or bar. Seams in raw material used for the manufacture of fas-

<p align="center">IFI STANDARD</p>	<p align="center">CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS</p>	<p align="center">IFI-140 Page 9 of 23</p>
<p>Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.</p>		<p align="center">Issued: April 20, 1993</p>

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teners or formed parts may lead to the formation of bursts.

3.12 Voids: A shallow pocket or hollow on the surface of the material.

3.13 Laps: A longitudinal surface discontinuity extending into rod, bar, or wire caused by doubling over of metal during hot rolling.

4.0 Manufacture.

4.1 Melting practice: The steel typically is melted in a basic oxygen or electric furnace process.

4.2 Casting practice: Steel may be either ingot cast or strandcast.

4.3 Deoxidation practice and grain size:

4.3.1 Silicon killed fine grain: Ordinarily produced with aluminum for grain refinement. When vanadium or columbium are used for grain refinement, agreement by the material purchaser is required.

4.3.2 Silicon killed coarse grain

4.3.3 Silicon killed coarse grain practice

4.3.4 Aluminum killed fine grain

4.3.5 Rimmed (grain size not specified)

4.4 Thermal treatment:

4.4.1 Material may be furnished without thermal treatment, but when required and depending upon end use, material may be ordered as follows:

4.4.1.1 Annealed

4.4.1.2 Spheroidized

4.4.1.3 Drawn from annealed rod or bar

4.4.1.4 Drawn from spheroidize annealed rod or bar

4.4.1.5 Spheroidized at finished size wire

4.4.1.6 Annealed-in-process wire

4.4.1.7 Spheroidize annealed-in-process wire

5.0 Ordering Information

5.1 Wire orders shall state the following:

5.1.1 Quantity

5.1.2 Wire diameter

5.1.3 Steel grade

5.1.4 Deoxidation practice and grain size

5.1.5 Application variation per paragraph 1.5

5.1.6 Thermal treatment

5.1.7 Surface coating

5.1.8 Coil weight

5.1.9 Coil i.d. and o.d. as required

5.1.10 Packaging

5.1.11 Tagging

5.1.12 Mill certification as required

5.1.13 Special requirements, e.g., steel making method and practice, special shipping instructions, single heat, etc.

Example: 40,000 lbs., IFI-140, 0.250 inches, carbon steel wire, IFI-1022A, silicon killed

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**CARBON AND ALLOY STEEL WIRE,
RODS AND BARS FOR
MECHANICAL FASTENERS**

IFI-140

Page 10 of 23

Issued: April 20, 1993

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coarse grain, Recessed Head, spheroidize annealed-in-process, phosphate and lube, 1500 lb. coils, 28 inch coil i.d., on 18 inch tubular carriers, three bands per carrier, one metal tag per coil, mill certification, do not ship Fridays.

5.2 Rod orders shall state the following:

- 5.2.1 Quantity
- 5.2.2 Rod diameter
- 5.2.3 Steel grade
- 5.2.4 Deoxidation practice and grain size
- 5.2.5 Cold Heading
- 5.2.6 Thermal treatment
- 5.2.7 Surface coating
- 5.2.8 Coil weight
- 5.2.9 Coil i.d., o.d., as required
- 5.2.10 Packaging
- 5.2.11 Tagging
- 5.2.12 Mill certifications as required
- 5.2.13 Special requirements, e.g., descaling practice, steelmaking method and practice, special shipping instructions, etc.

Example: 200,000 lbs., IFI-140, 21/64 inches, carbon steel rod, IFI-1022B, silicon killed fine grain, Cold Heading, spheroidize annealed, pickled and lamed, 3,000 lb. coils, 48 inch coil i.d., compacted and unitized in packages of two, banded with three steel straps per coil, two metal tags per coil attached to lead end on inside of bundle, put separators between coils.

5.3 Bar orders shall state the following:

- 5.3.1 Quantity
- 5.3.2 Bar diameter
- 5.3.3 Steel grade
- 5.3.4 Deoxidation practice and grain size
- 5.3.5 Cold Heading
- 5.3.6 Thermal treatment
- 5.3.7 Surface coating
- 5.3.8 Coil weight
- 5.3.9 Coil i.d., o.d., as required
- 5.3.10 Packaging
- 5.3.11 Tagging
- 5.3.12 Mill certification as required
- 5.3.13 Special requirements, e.g., steelmaking method and practice, special shipping instructions, single heat, etc.

Example: 90,000 lbs., IFI-140, 0.610 inches, carbon steel bars, IFI-1038, silicon killed coarse grain, spheroidize annealed, Cold Heading, phosphate & lime, 5,400 lb. coils, 54 inch coil i.d., three bands per coil, one metal tag per coil, lead end of each coil paint red.

6.0 Chemical Requirements.

6.1 Standard carbon steel compositions are found in standards such as SAE J403 and alloy steel compositions in SAE J404. A number of compositions particularly appropriate to the cold forging industry processes have been developed in a joint producer/user effort and are included in this Standard as IFI designated steel grades.

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 11 of 23
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Issued: April 20, 1993

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The chemical composition range of these IFI grades may not necessarily be identical to those of SAE J403 or SAE J404.

6.2 Cast or Heat Analysis (Formerly Ladle Analysis) — An analysis of each cast or heat shall be made by the producer to determine the percentage of the elements specified. The analysis shall be made from a test sample(s), preferably taken during the pouring of the cast or heat. The chemical composition shall be reported, if required, to the purchaser or his representative.

6.3 Product Analysis (Formerly Check Analysis) — A product analysis may be made by the purchaser. The analysis is not used for a duplicate analysis to confirm a previous result. The purpose of the product analysis is to verify that the chemical composition is within specified limits for each element, including applicable permissible variations in product analysis. The results of analyses taken from different pieces of a heat may differ within permissible limits from each other and from the heat or cast analysis. The results of the product analysis obtained, shall not vary both above and below the specified range.

6.3.1 Rimmed or capped steels are characterized by a lack of uniformity in their chemical composition, especially for the elements carbon, phosphorus, and sulfur, and for this reason product analysis is not technologically appropriate unless misapplication is clearly indicated.

6.3.2 For referee purposes, Method ASTM E30 shall be used.

6.4 Residual Limits: Material grades defined in this Standard shall conform to the following residual limits to provide optimum formability and tool life during the cold forming operation:

Residual limits for Carbon and Alloy Steels

Cu	=	0.20 max.
Ni	=	0.10 max.
Cr	=	0.10 max. (note 1)
Mo	=	0.04 max. (note 2)
Sn	=	0.02 max.

Note 1: Cr may be present to 0.20 max. if so specified.

Note 2: Mo may be present to 0.06 max. if so specified.

6.5 IFI Engineered Steel Grades: The carbon steel chemical ranges and limits are shown in Table 1. Permissible variations for product analysis of carbon steel are as shown in Table 2. The silicon limits as influenced by the deoxidation practice are shown in Table 3. The alloy steel chemical ranges and limits are shown in Table 4. Permissible variations for product analysis of alloy steel are shown in Table 5.

7.0 Metallurgical Structure.

7.1 When a coarse austenitic grain size is specified, the steel shall have a grain size number of 1 to 5 inclusive, as determined in accordance with Test Methods E112. Conformance to this grain size of 70% of the grains in the area examined shall constitute the basis of acceptance. One test per heat shall be made. A. Grain size requirements do not apply to material ordered to "coarse grain practice."

7.2 When a fine austenitic grain size is specified, the steel shall have a grain size number of 5 or higher as determined in accordance with Test Methods E112. Conformance to this grain size of 70% of the area examined shall constitute the basis of acceptance. One test per heat shall be made unless the provision of 7.2.1 is exercised.

7.2.1 When aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.020% total aluminum or, alternately, 0.015% acid soluble aluminum. The aluminum content shall be reported. The grain size test specified in 7.2 shall be the referee test.

7.2.2 If specified on the order, one grain size test per heat shall be made and the austenitic

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 12 of 23
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Issued: April 20, 1993

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grain size of the steel, as represented by the test, shall be number 5 or higher.

7.2.3 By agreement between purchaser and supplier, columbium or vanadium or both may be used for grain refining instead of or with aluminum. The maximum contents shall be:

Cb 0.05 max.
V 0.08 max.
Cb + V 0.06 max.

The content of the elements shall be reported with the heat analysis and the austenitic grain size test shall be required.

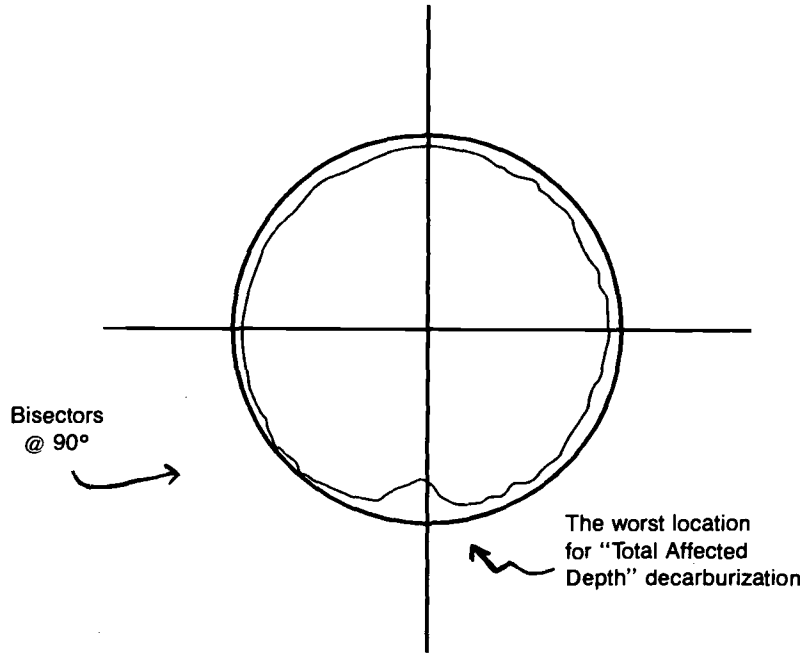
7.3 Spheroidize annealed material shall meet a maximum rating of G2 or L2 in the IFI spheroidization rating — Plate 1.

8.0 Decarburization.

Using the basic procedures of ASTM E1077, the entire periphery of a sample prepared of the rod, wire or bar shall be examined for decarburization at a magnification of 100 diameters, unless otherwise agreed to. Free ferrite shall not exceed the maximum depth shown in Table 6. The worst location shall be used to draw perpendicular bisectors, and the depth of decarb at the points where the bisectors intersect the circumference, shall be measured and the four (4) readings averaged as shown in Drawing No. 1.

That average shall not exceed the limits for total affected depth shown in Table 6.

Drawing No. 1



IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 13 of 23
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Issued: April 20, 1993

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9.0 Hardenability.

Hardenability shall be determined in accordance with SAE J406: Methods of Determining Hardenability of Steels. The Appendix A or B of that standard may be used upon agreement between producer and purchaser.

10.0 Mechanical Properties.

10.1 Tensile strength is determined using the test methods of ASTM A-370. Values for tensile strength are included in Table 7 for the following conditions:

- ▶ annealed or spheroidize annealed rod & bar
- ▶ spheroidize annealed at finish size wire
- ▶ annealed-in-process or spheroidize annealed-in-process wire

Material which has not been thermally treated is not usually produced to a specific tensile strength.

The values listed in Table 7 are designed to provide optimum headability and tool life in the cold forming process. Modifications to those limits require agreement between producer and purchaser. Table 7 shows only maximum tensile strengths, however, minimum tensile requirements may be stipulated by agreement between producer and purchaser.

10.2 Percent reduction in area is determined by the test method included within ASTM A370. Values for minimum percentages are included in Table 7.

10.3 Yield Strength/Percent Elongation: Used for special applications when agreed upon between purchaser and manufacturer. Method of determination shall be in accordance with ASTM A370.

10.4 Hardness: May be used as an option when agreed to between producer and purchaser in lieu of tensile/reduction of area testing of wire or bar over 1" in diameter. Test method shall be in accordance with ASTM E10.

10.5 No individual test value shall be out of specification, and for steels with a maximum specified carbon content over 0.30%, the maximum of the range shall not exceed the minimum by more than 10% in any lot.

$$\text{e.g.: } \frac{(80 \text{ KSI} - 74 \text{ KSI}) \times 100}{74 \text{ KSI}} = 8.1\% \text{ accept}$$

Test one sample per coil/bundle on at least 20% of randomly selected coils/bundles in the lot, with no fewer than two (2) tests and no more than five (5) tests. Other sampling plans may be employed as agreed upon between the purchaser and the supplier.

10.6 Traceability shall include the mill order and steel heat number with all specified mechanical data on mill test certification.

10.7 Tensile/reduction in area equipment shall be calibrated and verified in accordance with ASTM A370, and operated by personnel with documented qualifications.

11.0 Size Tolerance.

Reducing diameter variability increases control of both the physical and mechanical properties during the forming process. Less variability permits engineering for reduced tool wear and consistent product quality.

11.1 Wire tolerances are shown in Table 8.

11.2 Rod tolerances are shown in Table 9.

Note: Inherent mill design of rod mills does not permit the same control of size as bar mills.

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 14 of 23
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Issued: April 20, 1993

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11.3 Bar tolerances are shown in Table 10.

12.0 Mill Scale/Surface Condition.

Material purchased as a hot rolled product shall have mill scale (surface oxides) as light as possible and be readily removable by an acid pickling or mechanical descaling process.

The surface shall be free from excessive dirt or contaminants which would impede pickling or contaminate an acid pickle bath.

13.0 Coatings.

Material coatings are generally used for two purposes: as a vehicle for the drawing compound used to draw wire or as a lubricant for cold heading or forming.

Typical coatings for hot rolled bars and wire rods include: pickle and lime dip; zinc phosphate and lime dip; and zinc phosphate and reactive or non-reactive lube dip. Common coatings for cold drawn wire comprise those base coatings plus the drawing compound used in the wire drawing operations.

The supplied coatings for all materials are specified by the purchaser based upon the individual requirements of the purchaser. Adequate care should be taken during handling and transit to maintain the integrity of the coating. Extreme variation in temperature may adversely affect the applied coatings.

14.0 Workmanship, Finish and Appearance.

Bar, rod and wire, shall be reasonably free from detrimental surface imperfections including seams, voids, pits, scratches and laps. Material, suitably thermally treated when appropriate,

which bursts or splits when upset or formed, and having imperfections deeper than the greater of 0.003 in. or 0.5% of D (where D is finished diameter in inches of material) shall be rejectionable. Samples requiring assessment of such surface imperfections shall be prepared by careful metallographic technique, suitably etched and the depth of imperfection measured radially from the surface at a magnification of 100X.

Wire shall be substantially free from rust, shall not be kinked or tangled, and for wire drawn last, shall be properly cast. No welds are permitted, unless otherwise specified.

15.0 Identification/Tagging.

A tag(s) shall be attached to each coil or banding as specified by the purchaser and shall include as a minimum the following information:

15.0.1 Supplier's name or trademark

15.0.2 Grade of steel

15.0.3 Heat number or traceable code

15.0.4 Diameter

When specified, the following may be added:

15.0.5 Purchaser's name

15.0.6 Purchase order number

15.0.7 Mill order number

15.0.8 Secondary process description and source if applicable

15.0.9 Bar coding (optional). It is suggested that bar coding in accordance with AIAG B-5 be used.

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 15 of 23
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Issued: April 20, 1993

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16.0 Packaging and Loading.

Unless otherwise specified, rod coils shall be wound counterclockwise which provides a right hand pitch to facilitate handling and uncoiling. Winding of bar coils varies and the direction of winding should be specified. The nature of compacting, banding and protection, shall be specified by purchaser.

16.1 The purchaser shall specify the method of packaging and loading for shipment. A recommended procedure for packaging and loading for shipment is found in ASTM A-700.

17.0 Certification and Test Reports.

When specified in the purchase order, a producer's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this Specification and has been found to meet the requirements as specified. Test results shall be retained by the producer for a minimum period of ten (10) years. A test report shall be furnished which will meet the consumer's requirements for chemical analysis of the mill heat including the identification and the results of the chemical analysis of the primary steel melter.

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 16 of 23
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Issued: April 20, 1993

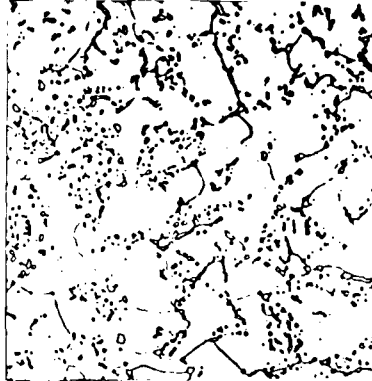
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PLATE 1

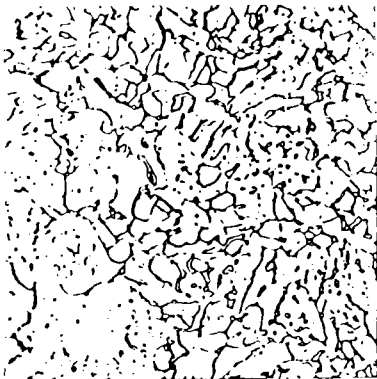
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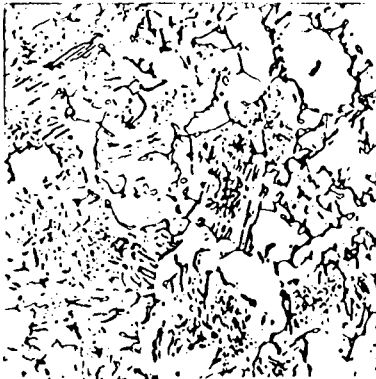
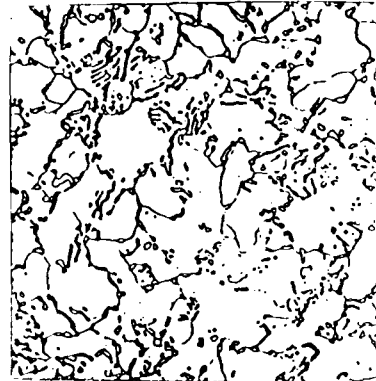
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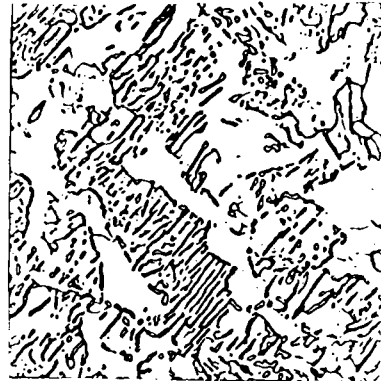
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RODS AND BARS FOR
MECHANICAL FASTENERS**

IFI-140

Page 17 of 23

Issued: April 20, 1993

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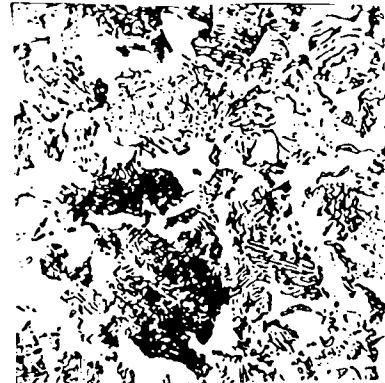
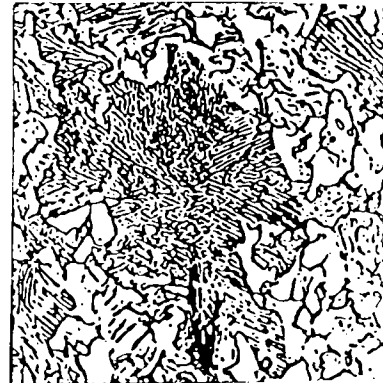


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**CARBON AND ALLOY STEEL WIRE,
RODS AND BARS FOR
MECHANICAL FASTENERS**

IFI-140

Page 18 of 23

Issued: April 20, 1993

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Table 1 Carbon Steels, Chemical Ranges and Limits

Conditions Furnished	IFI Steel Grade Designation	Carbon		Manganese		Phosphorus	Sulfur	Silicon
		Min.	Max.	Min.	Max.	Max.	Max.	
AIK	IFI-1006	—	0.08	0.25	0.40	0.020	0.020	S e e T a b l e 3
R, AIK, SiFg, SiCg	IFI-1008	—	0.10	0.30	0.50	0.020	0.020	
R, AIK, SiFg, SiCg	IFI-1010	0.08	0.13	0.30	0.60	0.020	0.020	
AIK, SiFg, SiCg	IFI-1018	0.15	0.19	0.65	0.85	0.020	0.020	
AIK, SiFg	IFI-10B21	0.19	0.23	0.80	1.10	0.020	0.020	
AIK, SiFg, SiCg	IFI-1022/A	0.18	0.21	0.80	1.00	0.020	0.020	
AIK, SiFg, SiCg	IFI-1022/B	0.20	0.23	0.90	1.10	0.020	0.020	
AIK	IFI-1033	0.31	0.36	0.70	0.90	0.020	0.020	
AIK, SiFg, SiCg	IFI-1035	0.33	0.38	0.70	0.90	0.020	0.020	
AIK, SiFg, SiCg	IFI-1038	0.35	0.42	0.70	0.90	0.020	0.020	
SiFg	IFI-10B38	0.35	0.42	0.70	1.00	0.020	0.020	
SiFg	IFI-1541/A	0.36	0.41	1.35	1.60	0.020	0.020	
SiFg, SiCg, CgP	IFI-1541/B	0.38	0.43	1.35	1.60	0.020	0.020	

NOTE: Carbon steels which have added boron use a B designation between the first and last two digits of the grade designation. A boron steel has a minimum boron content of 0.0005% and a maximum of 0.003%.

AIK = Aluminum killed
R = Rimmed
SiFg = Silicon killed fine grain
SiCg = Silicon killed coarse grain
CgP = Coarse grain practice

Table 2 Permissible Variations from Specified Chemical Ranges, and Limits for Carbon Steel

Element	Limit or Max. of Specified Range %	Variation % Over Max Limit or Under Min Limit
Carbon	To 0.25 incl	0.02
	Over 0.25 to 0.55 incl	0.03
Manganese	To 0.90 incl	0.03
	Over 0.90 to 1.65 incl	0.06
Phosphorus	Over max only	0.008
Sulfur	Over max only	0.008
Silicon	To 0.30 incl	0.02
Copper	Over max only	0.03
Tin	Over max only	0.01
Nickel	Over max only	0.03
Chromium	Over max only	0.03
Molybdenum	Over max only	0.01
Vanadium	Over max only	0.01
Boron		N/A ¹

NOTE 1: Unless misapplication is indicated.

IFI STANDARD	CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS	IFI-140 Page 19 of 23
Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.		Issued: April 20, 1993

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Table 3 Silicon Limits for Four Deoxidation Practices

IFI Steel Grade Designation	DEOXIDATION PRACTICE							
	Silicon Killed Fine Grain		Silicon Killed Coarse Grain & Coarse Grain Practice		Aluminum Killed Fine Grain		Rimmed	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
IFI-1006	0.10	0.20	0.10	0.25	0.10	0.10	0.10	0.02
IFI-1008	0.10	0.20	0.10	0.25	0.10	0.10	0.10	0.02
IFI-1010	0.10	0.20	0.10	0.25	0.10	0.10	0.10	0.02
Boron Grades	0.10	0.30	N/A	N/A	N/A	N/A	N/A	N/A
All Other Grades	0.15	0.30	0.15	0.30	0.10	0.10	0.10	N/A

NOTES:

1. Fine Grain — Normally Si/Al killed or aluminum killed. Vanadium or Columbium (niobium) can be used upon agreement between raw material supplier and user (purchaser).
2. The values listed in this table are designed to provide optimum headability and tool life in the cold forming process. Modifications to these limits require agreement between producer and purchaser.

Table 4 Chemical Ranges and Limits for Alloy Steels

IFI Steel Grade Designation	Carbon		Manganese		Nickel		Chromium		Molybdenum		Phosphorus		Sulfur	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
IFI-1335	0.33	0.38	1.60	1.90	—	—	—	—	—	—	0.020	0.020	0.020	0.020
IFI-4037*	0.35	0.40	0.70	0.90	—	—	—	—	0.20	0.30	0.020	0.020	0.020	0.020
IFI-4042	0.40	0.45	0.70	0.90	—	—	—	—	0.20	0.30	0.020	0.020	0.020	0.020
IFI-4118	0.18	0.23	0.70	0.90	—	—	0.40	0.60	0.08	0.15	0.020	0.020	0.020	0.020
IFI-4140	0.38	0.43	0.75	1.00	—	—	0.80	1.10	0.15	0.25	0.020	0.020	0.020	0.020
IFI-5140	0.38	0.43	0.70	0.90	—	—	0.70	0.90	—	—	0.020	0.020	0.020	0.020
IFI-8637	0.35	0.40	0.75	1.00	0.40	0.70	0.40	0.60	0.15	0.25	0.020	0.020	0.020	0.020

*NOTE: Furnished in AIK or SiFg or SiCg or CgP
All other grades in SiFg — Fg only

IFI STANDARD
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CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS

IFI-140
Page 20 of 23
Issued: April 20, 1993

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Table 5 Permissible Variation from Specified Chemical Ranges and Limits for Alloy Steels

Element	Limit or Max of Specified Range, %	Variation, %, Over Max Limit or Under Min Limit
Carbon	To 0.30 incl	0.01
	Over 0.30 to 0.75 incl	0.02
Manganese	To 0.90 incl	0.03
	Over 0.90	0.04
Phosphorus	Over Max only	0.005
Sulfur	Over Max only	0.005
Silicon	To 0.40 incl	0.02
Nickel	To 1.00 incl	0.03
Chromium	To 0.90 incl	0.03
	Over 0.90	0.05
Molybdenum	To 0.20 incl	0.01
	Over 0.20 to 0.40 incl	0.02
Vanadium	Over Max. only	0.01
Copper	Over Max only	0.03

Table 6 Decarburization Limits for Killed Steels With Carbon Content Exceeding 0.13%

Diameter (Inches)	Free Ferrite Depth Max. Inches	Total Average Affected Depth Max. Inches
through 25/64	0.0015	0.005
over 25/64 through 5/8	0.0015	0.006
over 5/8 through 55/64	0.0015	0.007
over 55/64 through 1	0.0015	0.008
over 1 through 1½	0.0015	0.010

NOTES:

1. For purposes of determining conformance with this Standard, all specified limits are absolute as defined in ASTM E29.
2. Test conducted in accordance with paragraph 80 of this Standard.

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**CARBON AND ALLOY STEEL WIRE,
RODS AND BARS FOR
MECHANICAL FASTENERS**

IFI-140

Page 21 of 23

Issued: April 20, 1993

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Table 7 Mechanical Properties Carbon and Alloy Steels

Steel Grade	Rod/Bar Properties				Spheroidize Annealed at Finished Size Wire Properties				Annealed in Process and Spheroidized Annealed in Process Finished Wire Properties			
	Annealed		Spheroidize Annealed		SAFS		AIP		SAIP			
	Max. Tensile* KSI	Min. R/A %	Max. Tensile* KSI	Min. R/A %	Max. Tensile* KSI	Min. R/A %	Max. Tensile* KSI	Min. R/A %	Max. Tensile* KSI	Min. R/A %		
CARBON												
IFI-1006	55	62	53	65	51	70	62	60	60	62	62	
IFI-1008	56	62	54	65	52	70	63	60	61	62	62	
IFI-1010	58	62	55	65	54	70	65	60	62	62	62	
IFI-1018	68	62	65	65	63	68	76	60	68	62	62	
IFI-1022/A	72	62	67	65	65	68	81	60	72	62	62	
IFI-1022/B	73	62	69	65	67	68	82	60	73	62	62	
IFI-1033	80	58	74	60	72	64	89	56	82	58	58	
IFI-1035	81	58	75	60	73	64	90	56	83	58	58	
IFI-1038	82	58	76	60	74	64	91	56	84	58	58	
IFI-1541A	92	53	85	57	82	61	98	51	92	55	55	
IFI-1541B	93	53	86	57	83	61	99	51	93	55	55	
BORON												
IFI-10B21	75	62	71	64	69	68	84	60	75	62	62	
IFI-10B38	88	56	82	58	80	62	97	52	90	56	56	
ALLOY												
IFI-1335	93	53	85	55	82	59	100	51	92	53	53	
IFI-4037	86	55	80	57	78	60	95	53	85	55	55	
IFI-4042	88	55	82	57	80	60	97	53	87	55	55	
IFI-4118	76	60	71	61	68	64	84	58	76	59	59	
IFI-4140	92	55	85	57	82	59	102	53	90	55	55	
IFI-5140	92	55	85	57	82	59	102	53	90	55	55	
IFI-8637	92	53	85	55	82	57	102	51	92	53	53	

* For aluminum killed steel, subtract 3 KSI and add 1% R/A
 For rimmed steel, subtract 5 KSI and add 2% R/A
 For AIP and SAIP wire under 0.200", add 50 psi for every 0.001" under 0.200"

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 Published and issued by the Industrial Fasteners Institute of Cleveland, Ohio.

**CARBON AND ALLOY STEEL WIRE,
 RODS AND BARS FOR
 MECHANICAL FASTENERS**

IFI-140
 Page 22 of 23
 Issued: April 20, 1993

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Table 8
Wire Size Tolerances and Out of Round

Diameter	Diameter ± Tolerance	Out of Round Max.
Inch	Inch	Inch
< 0.076	0.0010	0.0010
0.076 < 0.500	0.0015	0.0015
≥ 0.500	0.0020	0.0020

Table 9
Rod Size Tolerances

Diameter	Diameter ± Tolerance	Out of Round Max.
Inch	Inch	Inch
7/32 - 47/64	0.012	0.018

Table 10
Bar Size Tolerances

Diameter	Diameter ± Tolerance	Out of Round Max.
Fractional Diameter in Inches	Inch	Inch
7/16 to 5/8	0.006	0.009
>5/8 to 7/8	0.007	0.011
>7/8 to 1	0.008	0.012
>1 to 1-1/8	0.009	0.014
>1-1/8 to 1-1/4	0.010	0.015
>1-1/4 to 1-3/8	0.011	0.017
>1-3/8 to 1-1/2	0.013	0.020

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CARBON AND ALLOY STEEL WIRE, RODS AND BARS FOR MECHANICAL FASTENERS

IFI-140

Page 23 of 23

Issued: April 20, 1993

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**Appendix C: Public Law 101-592—Fastener
Quality Act**

Public Law 101-592
101st Congress

An Act

To require that certain fasteners sold in commerce conform to the specifications to which they are represented to be manufactured, to provide for accreditation of laboratories engaged in fastener testing, to require inspection, testing, and certification, in accordance with standardized methods, of fasteners used in critical applications to increase fastener quality and reduce the danger of fastener failure, and for other purposes.¹

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,*²

SECTION 1. SHORT TITLE.

This Act may be cited as the "Fastener Quality Act".

SEC. 2 FINDINGS AND PURPOSE.

- (a) Findings - The Congress finds that -
- (1) the American economy uses billions of fasteners each year;
 - (2) millions of mismarked, substandard, counterfeit, and other nonconforming fasteners have been sold in commerce to end-users in the United States, and their use has dramatically increased the risk of equipment and infrastructure failures;
 - (3) both the military and civilian sectors of the economy have encountered unnecessary, unwarranted, and dangerous equipment and construction failures, as well as extraordinary expenses, as a result of the use of nonconforming fasteners;
 - (4) the sale in commerce of nonconforming fasteners and the use of nonconforming fasteners in numerous critical applications have reduced the combat readiness of the Nation's military forces, endangered the safety of other Federal projects and activities, and cost both the public and private sectors large sums in connection with the retesting and purging of fastener inventories;
 - (5) the purchase and use of nonconforming fasteners stem from material misrepresentations about such fasteners made by certain manufacturers, importers, and distributors engaged in commerce;
 - (6) current fastener standards of measurement evaluate bolts and other fasteners according to multiple criteria, including strength, hardness, and composition, and provide grade identification markings on fasteners to make the characteristics of individual fasteners clear to purchasers and users;

¹ Nov. 16, 1990 (H.R. 3000)

² Fastener Quality Act. Consumer protection. 15 USC 5401 note. 15 USC 5401

(7) current tests required by consensus standards, designed to ensure that fasteners are of standard measure, are adequate and appropriate for use as standards in a program of high-strength fastener testing;

(8) the lack of traceability by lot number of fasteners sold in commerce is a serious impediment to effective quality control efforts; and

(9) the health and safety of Americans is threatened by the widespread sale in commerce of mismarked, substandard, and counterfeit fasteners, a practice which also harms American manufacturers, importers, and distributors of safe and conforming fasteners, and workers in the American fastener industry.

(b) Purpose - In order to protect public safety, to deter the introduction of nonconforming fasteners into commerce, to improve the traceability of fasteners used in critical applications, and generally to provide commercial and governmental customers with greater assurance that fasteners meet stated specifications, it is the purpose of this Act to create procedures for the testing, certification, and distribution of certain fasteners used in commerce within the United States.

SEC. 3. DEFINITIONS.

As used in this Act, the term -

(1) "alter" means to alter -

(A) by through-hardening,

(B) by electroplating of fasteners having a minimum tensile strength of 150,000 pounds per square inch, or

(C) by machining;

(2) "consensus standards organization" means the American Society for Testing and Materials, American National Standards Institute, American Society of Mechanical Engineers, Society of Automotive Engineers, or any other standard-setting organization determined by the Secretary to have comparable knowledge, expertise, and concern for health and safety in the field for which such organization purports to set standards;

(3) "container" means any package of fasteners traded in commerce;

(4) "Director" means the Director of the National Institute of Standards and Technology;

(5) "fastener" means -

(A) a -

(i) screw, nut, bolt, or stud having internal or external threads, or

(ii) a load-indicating washer,

with a nominal diameter of 5 millimeters or greater, in the case of such items described in metric terms, or ¼ inch or greater, in the case of such items described in terms of the English system of measurement, which contains any quantity of metal and is held out as meeting a standard or specification which requires through-hardening,

(B) a screw, nut, bolt, or stud having internal or external threads which bears a grade identification marking required by a standard or specification,

- (C) a washer to the extent that it is subject to a standard or specification applicable to a screw, nut, bolt, or study described in subparagraph (B), or
- (D) any item within a category added by the Secretary in accordance with section 4(b),

except that such term does not include any screw, nut, bolt, or study that is produced and marked as ASTM A 307 Grade A;

(6) "grade identification marking" means any symbol appearing on a fastener purporting to indicate that the fastener's base material, strength properties, or performance capabilities conform to a specific standard of a consensus standards organization other person;

(7) "importer" means a person located within the United States who contracts for the initial purchase of fasteners manufactured outside the United States for resale of such person's use within the United States;

(8) "Institute" means the National Institute of Standard and Technology;

(9) "lot" means a quantity of fasteners of one part number fabricated by the same production process from the same coil or heat number of metal as provided by the metal manufacturer and submitted for inspection and testing at one time;

(10) "manufacturer" means a person who fabricates fasteners, or who alters any items so that it becomes a fastener;

(11) "original equipment manufacturer" means a person who uses fasteners in the manufacture or assembly of its products and sells fasteners to authorized dealers as replacement or service parts for its products;

(12) "private label distributor" means a person who contracts with a manufacturer for the fabrication of fasteners bearing the distributor's distinguishing insignia;

(13) "Secretary" means the Secretary of Commerce;

(14) "standards and specifications" means the provisions of a document published by a consensus standards organization, a government agency, or a major end-user of fasteners which defines or describes dimensional characteristics, limits of size, acceptable materials, processing, functional behavior, plating, baking, inspecting, testing, packaging, and required markings of any fastener; and

(15) "through-harden" means heating above the transformation temperature followed by quenching and tempering.

SEC. 4. SPECIAL RULES FOR FASTENERS.³

(a) Waiver Requirements. - If the Secretary determines that any category of fastener is not used in critical applications, the Secretary shall waive the requirements of this Act with respect to such category.

(b) Additional Item. - If the Secretary determines that -

(1) a category of screw, nut, bolt, or stud which is not described in section 3(5)(A)(i) or (B),

(2) a category of item which is associated with a fastener described in section 3(5)(A), (B), or (C), or

(3) a category of item which serves a function comparable to that served by a fastener so described

³ 15 USC 5403

is used in critical applications, the Secretary may include such category under section 3(5)(D) and therefore within the definition of fasteners under this Act.

(c) Notice and Opportunity for Comments. - The Secretary shall provide advance notice and the opportunity for public comments prior to making any determination under subsections (a) and (b) and shall act through the Director in making any such determination.

SEC. 5. TESTING AND CERTIFICATION OF FASTENERS.⁴

(a) Requirement. - (1) No fastener shall be offered for sale or sold in commerce unless it is part of a lot which -

(A) conforms to the standards and specifications to which the manufacturer represents it has been manufactured; and

(B) has been inspected, tested, and certified as provided in subsections (b) and (c) of this section.

(2)(A) Paragraph (1)(B) of this subsection shall not apply to fasteners which are part of a lot of 50 fasteners or less if, within 10 working days after the delivery of such fasteners, or as soon as practicable thereafter -

(i) inspection, testing, and certification as provided in subsections (b) and (c) is carried out; and

(ii) written notice detailing the results of such inspection, testing, and certification is sent (I) to all purchasers of such fasteners, except retail sellers and retail consumers, and (II) to any retail seller or retail consumer who, prior to delivery, requests such written notice.

(B) If a fastener is sold under this paragraph, each purchaser of such fastener, except for retail sellers and retail consumers unless such retail sellers and retail consumers request such notice in advance, shall be provided, contemporaneously with each sale and delivery, written notice stating that such fastener has not yet been inspected, tested, and certified as required by this Act.

(b) Inspection and Testing. - (1) The manufacturer of a lot of fasteners shall cause to be inspected and tested a representative sample, as provided in paragraph (2) of this subsection, of the fasteners in such lot to determine whether the lot conforms to the standards and specifications to which the manufacturer represents it has been manufactured. Such inspection and testing shall be performed by a laboratory accredited in accordance with the procedures and conditions specified by the Secretary under section 6. The standards and specifications to which the manufacturer represents such lot has been manufactured shall be disclosed by the manufacturer to the laboratory at the time the lot is submitted for inspection and testing under this paragraph. The manufacturer of a lot may perform the inspection and testing required by this paragraph in a laboratory which it owns or with which it is otherwise affiliated, if such laboratory is accredited in accordance with the procedures and conditions specified by the Secretary under section 6; unless the Secretary finds that, as to a specific type of fastener and as to a specific type of inspection or testing, a

⁴ 15 USC 5404

ban on manufacturer ownership or affiliation with the accredited laboratory would increase the protection of health and safety of the public or industrial workers.

(2) The size, selection, and integrity of the sample to be inspected and tested under paragraph (1) shall be governed -

(A) by the standards and specifications to which the manufacturer represents the fasteners in the sample have been manufactured; or

(B) if such standards and specifications do not provide for the size, selection, or integrity of the sample, by sampling procedures prescribed by the Secretary, who shall to the extent practicable use consensus testing standards and related materials.

Nothing in this paragraph shall prohibit a purchaser from requiring the inspection and testing of a greater number of fasteners from a lot than is specified in the applicable standards and specifications or in the applicable sampling procedures prescribed by the Secretary.

(c) Laboratory Report of Testing. - If a laboratory performing the inspection and testing under subsection (b)(1) determines, as to the characteristics selected under the sampling procedures prescribed by the secretary and based on the sample examined, that a lot conforms to the standards and specifications to which the manufacturer represents it has been manufactured, the laboratory shall provide to the manufacturer a written inspection and testing report with respect to such lot. The report, which shall be in a form prescribed by the Secretary by regulation, shall -

(1) state the manufacturer's name, the part description, and the lot number and note the grade identification mark and insignia found on the fastener;

(2) reference the standards and specifications disclosed by the manufacturer with respect to such lot under subsection (b)(1) or, where applicable, certified by the manufacturer under section 7(c)(1);

(3) list the markings and characteristics selected under the Secretary's procedures for testing, such as the chemical, dimensional, physical, mechanical, and any other significant characteristics required by the standards and specifications described in paragraph (2) and specify the results of the inspection and testing under subsection (b)(1);

(4) state whether, based on the samples provided as representative of the lot, such lot has been found after such inspection and testing to conform to such standards and specifications; and

(5) bear the original signature of a laboratory employee or officer determined by the Secretary to be responsible for the accuracy of the report and of the inspection and testing to which it relates.

SEC. 6. LABORATORY ACCREDITATION.⁵

⁵ 15 USC 5405

(a) Establishment of Accreditation Program. - (1) Within 180 days after the date of enactment of this Act, the Secretary, acting through the Director, shall issue regulations which shall include -

(A) procedures and conditions, including sampling procedures referred to in section 5, for the accreditation by the Institute of laboratories engaged in the inspection and testing of fasteners under section 5;

(B) procedures and conditions (which shall be consistent with the procedures and conditions established under subparagraph (A)), using to the extent practicable the requirements of national or international consensus documents intended to govern the operations of accreditation bodies, under which private entities may apply for approval by the Secretary to engage directly in the accreditation of laboratories in accordance with the requirements of this Act; and

(C) conditions (which shall be consistent with the procedures and conditions established under subparagraph (A)), under which the accreditation of foreign laboratories by their governments or organizations recognized by the Director shall be deemed to satisfy the laboratory accreditation requirements of this section.

(2) Upon establishing a laboratory accreditation program under paragraph (1), the Secretary shall publish a notice in the Federal Register stating that the Secretary is prepared to accept applications for accreditation of such laboratories.

(3) No accreditation provided under the terms of this subsection shall be effective for a period of greater than 3 years.

(b) Laboratory Accreditation Procedures. - Existing Institute accreditation procedures stated in part 7 of title 15, Code of Federal Regulations, as in effect on the date of enactment of this Act, supplemented as the Secretary considers necessary, shall be used to accredit laboratories under the accreditation program established under subsection (a).

(c) Ensuring Compliance. - (1) The Secretary shall ensure that -

(A) private entities accrediting laboratories under procedures and conditions established under subsection (a))(1)(B) comply with such procedures and conditions, and

(B) laboratories accredited by such private entities, or by foreign governments pursuant to subsection (a)(1)(C), comply with the requirements for such accreditation.

(2) The Secretary may require any such private entity or laboratory to provide all records and materials that may be necessary to allow the Secretary to carry out this subsection.

(d) Operation of Laboratory Accreditation Program. - (1) The Director may hire such contractors as are necessary to carry out the accreditation program established under subsection (a).

(2) Costs to the Institute and to the Secretary for the establishment and operation of the accreditation program under this section shall be fully reimbursable to the Institute or to the Secretary, as appropriate, through fees or other charges for accreditation services under such program.

(e) Recommendations to Consensus Standards Organizations. - The Director shall periodically transmit to appropriate consensus standards organizations any

information or recommendations that may be useful in the establishment or application by such organizations of standards and specifications for fasteners.

SEC. 7. SALE OF FASTENERS SUBSEQUENT TO MANUFACTURE.⁶

(a) Domestically Produced Fasteners. - It shall be unlawful for a manufacturer to sell any shipment of fasteners (except fasteners for which the Secretary has waived the requirements of this Act pursuant to section 4) which are manufactured in the United States unless the fasteners are accompanied, at the time of delivery, by a written certificate by the manufacturer certifying that -

(1) The fasteners have been manufactured according to the requirements of the applicable standards and specifications and have been inspected and tested by a laboratory accredited in accordance with the procedures and conditions specified by the Secretary under section 6; and

(2) an original laboratory testing report described in section 5(c) is on file with the manufacturer, or under such custody as may be prescribed by the Secretary, and available for inspection.

(b) Fasteners of Foreign Origin. - (1) Except as provided in paragraph (2) of this subsection, it shall be unlawful -

(A) for any person to sell to any importer, and

(b) for any importer to purchase,

any shipment of fasteners which are manufactured outside the United States unless delivery of such shipment to such importer is accompanied by a manufacturer's certificate as described in subsection (a), an original laboratory testing report described in section 5(c), with respect to each lot from which such fasteners were taken, and any other relevant lot identification information.

(2) The requirement under paragraph (1) of this subsection that the delivery of such a shipment to such importer be accompanied by an original laboratory testing report shall not apply in the case of fasteners imported into the United States -

(A) as products manufactured within a nation which is party to a congressionally-approved free trade agreement with the United States that is in effect, so long as the Secretary certifies that satisfactory arrangements have been reached by which purchasers within the United States can readily gain access to an original laboratory testing report for such fasteners; or

(B) as Canadian-origin products under the United States - Canada Automobile Pact for use as original equipment in the manufacturer of motor vehicles.

(c) Option for Importers and Private Label Distributors. - (1) Notwithstanding section 5(a) and subsections (a) and (b) of this section, delivery of a lot, or portion of a lot, of fasteners may be made to an importer or private label distributor without the required original copy of the laboratory testing report if -

(A) the manufacturer provides to the importer or private label distributor a manufacturer's certificate certifying that the fasteners have been manufactured according to the requirements of the applicable standards and specifications; and

(B) the importer or private label distributor assumes responsibility in writing for the inspection and testing of such lot or portion by a laboratory accredited in

⁶ 15 USC 5406

accordance with the procedures and conditions specified by the Secretary under section 6.

(2) If the importer or private distributor assumes the responsibility in writing for the inspection and testing of such lot or portion, the provisions of section 5(a) and subsections (a) and (b) of this section shall apply to the importer or private label distributor in the same manner and extent as to a manufacturer; except that the importer or private label distributor shall provide to the testing laboratory the manufacturer's certificate described under paragraph (1) of this subsection.

(d) Alterations Subsequent to Manufacture - (1) Any person who significantly alters a fastener so that such fastener no longer conforms to the description in the relevant certificate issued under section 5(c), and who thereafter offers for sale or sells such altered fastener, shall be treated as a manufacturer for purposes of this Act and shall cause such altered fastener to be inspected and tested under section 5 or this section as though it were newly manufactured, unless delivery of such fastener to the purchaser is accompanied by a written statement noting the original lot number, disclosing the subsequent alternation, and warning that such alteration may affect the dimensional or physical characteristics of the fastener.

(2) Any person who knowingly sells an altered fastener and who did not alter such fastener shall provide to the purchaser a copy of the statement required by paragraph (1).

(e) Commingling. - (1) Subject to paragraph (2), it shall be unlawful for any manufacturer or any person who purchases any quantity of fasteners for resale at wholesale to commingle like fasteners from different lots in the same container; except that such manufacturer or such person may commingle like fasteners of the same type, grade, and dimension from not more than two tested and certified lots in the same container during repackaging and plating operations: *Provided*, That any container which contain like fasteners from two lots shall be conspicuously marked with the lot identification numbers of both lots.

(2) Paragraph (1) does not apply to sales by original equipment manufacturers to their authorized dealers for use in assembling or servicing products produced by the original equipment manufacturers.

(f) Subsequent Purchaser. - (1) It shall be unlawful for any person to sell fasteners, of any quantity, to any person who purchases such fasteners -

(A) for sale at wholesale, or

(B) for assembling components of a product or structure for sale,

unless the container of fasteners sold is conspicuously marked with the number of the lot from which such fasteners were taken, except that this requirement shall not apply to sales by original equipment manufacturers to their authorized dealers for use in assembling or servicing products produced by the original equipment manufacturer.

(2) If a person who purchases fasteners for purposes other than those described in paragraph (1) (A) and (B) so requests either prior to the sale or at the time of sale, the seller shall conspicuously mark the container of fasteners with the lot number from which such fasteners were taken.

(g) Regulations. - The secretary may issue such regulations as may be necessary to ensure compliance with the provision of this section.

SEC. 8. MANUFACTURERS' INSIGNIAS.⁷

(a) General Rule. - No fastener which is required by the standards and specifications to which it was manufactured to bear a raised or depressed insignia identifying its manufacturer or private label distributor shall be offered for sale or sold in commerce unless the manufacture or private label distributor of such fastener has complied with the requirements prescribed by the Secretary in connection with the program established under subsection (b) of this section.

(b) Recordation. - The Secretary shall establish, by regulation, a program to provide for the recordation of the insignias of manufacturers and private label distributors described in subsection (a), to ensure the traceability of a fastener to its manufacturer or private label distributor.

SEC. 9. REMEDIES AND PENALTIES.⁸

(a) Civil Remedies. - (1) The Attorney General may bring an action in an appropriate United States district court for appropriate declaratory and injunctive relief against any person who violates this Act or any regulation under this Act.

(2) An action under paragraph (1) may not be brought more than 10 years after the date on which the cause of action accrues.

(b) Civil Penalties. - (1) Any person who is determined by the Secretary, after notice and an opportunity for a hearing, to have violated this Act or any regulation under this Act shall be liable to the United States for a civil penalty of not more than \$25,000 for each violation.

(2) The amount of the penalty shall be assessed by the Secretary by written notice. In determining the amount of the penalty, the Secretary shall consider the nature, circumstances, and gravity of the violation and, with respect to the person found to have committed the violation, the degree of culpability, and history of prior violations, the effect on ability to continue to do business, any good faith attempt to achieve compliance, ability to pay the penalty, and such other matters as justice may require.

(3) Any person against whom a civil penalty is assessed under paragraph (2) of this section may obtain review thereof in the appropriate court of the United States by filing a notice of appeal in such court within 30 days from the date of such order and by simultaneously sending a copy of such notice by certified mail to the Secretary. The findings and order of the Secretary shall be set aside by such court if they are found to be unsupported by substantial evidence, as provided in section 706(2) of title 5, United States Code.

(4) The Secretary may compromise, modify, or remit, with or without conditions, any civil penalty which is subject to imposition or which has been imposed under this section prior to referral to the Attorney General under paragraph (5).

(5) A civil penalty assessed under this subsection may be recovered in an action brought by the Attorney General on behalf of the United States in the appropriate district court of the United States. In such action, the validity and appropriateness of the final order imposing the civil penalty shall not be subject to review.

(6) For the purpose of conducting any hearing under this section, the Secretary may issue subpoenas for the attendance and testimony of witnesses and the production of relevant papers, books, and documents, and may administer oaths. Witnesses summoned shall be paid the same

⁷ 15 USC 5407

⁸ 15 USC 5408

fees and mileage that are paid to witnesses in the courts of the United States. In case of contempt or refusal to obey a subpoena served upon any person pursuant to this paragraph, the district court of the United States for any district in which such person is found, resides, or transacts business, upon application by the United States and after notice to such person, shall have jurisdiction to issue an order requiring such person to appear and give testimony before the Secretary or to appear and produce documents before the Secretary, or both, and any failure to obey such order of the court may be punished by such court as a contempt thereof.

(c) Criminal Penalties. - (1) Whoever knowingly certifies, marks, offers for sale, or sells a fastener in violation of this Act or a regulation under this Act shall be fined under title 18, United States Code, or imprisoned not more than 5 years, or both.

(2) Whoever intentionally fails to maintain records relating to a fastener in violation of this Act or a regulation under this Act shall be fined under title 18, United States Code, or imprisoned not more than 5 years, or both.

(3) Whoever negligently fails to maintain records relating to a fastener in violation of this Act or a regulation under the Act shall be fined under title 18, United States Code, or imprisoned not more than 2 years, or both.

SEC. 10. RECORD KEEPING REQUIREMENTS.⁹

(a) Laboratories. - Laboratories which perform inspections and testing under section 5(b) shall retain for 10 years all records concerning the inspection and testing, and certification of fasteners under section 5.

(b) Manufacturers, Importers, Private Label Distributors, and Persons who Make Significant Alteration. - Manufacturers, importers, private label distributors, and persons who make significant alterations shall retain for 10 years all records concerning the inspection and testing, and certification, of fasteners under section 5, and shall provide copies of any applicable laboratory testing report or manufacturer's certificate upon request to any subsequent purchaser of fasteners taken from the lot to which such testing report or manufacturer's certificate relates.

SEC. 11. RELATIONSHIP TO STATE LAWS.¹⁰

Nothing in this Act shall be construed to preempt any rights or causes of action that any buyer may have with respect to any seller of fasteners under the law of any State, except to the extent that the provisions of this Act are in conflict with such State law.

SEC. 12. CONSTRUCTION.¹¹

Nothing in this Act shall be construed to limit or otherwise affect the authority of any consensus standards organization to establish, modify, or withdraw any standards and specifications under any other law or authority in effect on the date of enactment of this Act.

SEC. 13. REGULATIONS.¹²

The Secretary shall within 180 days after the date of enactment of this Act issue such regulations as may be necessary to implement this Act.

SEC. 14. ADVISORY COMMITTEE.¹³

Within 90 days after the date of enactment of this Act, the Secretary shall appoint an advisory committee consisting of representatives of fastener manufacturers, importers,

⁹ 15 USC 5409

¹⁰ 15 USC 5410

¹¹ 15 USC 5411

¹² 15 USC 5412

¹³ 15 USC 5413

distributors, end-users, independent laboratories, and standards organizations. The Secretary and Director shall consult with the advisory committee -

- (1) prior to promulgating any regulations under this Act; and
- (2) in such other matters related to fasteners as the Secretary may determine.

SEC. 15. APPLICABILITY.¹⁴

The requirements of this Act shall be applicable only to fasteners fabricated 180 days or more after the Secretary issues final regulations required under sections 5, 6, and 8, except that the Secretary may extend such time period if the Secretary determines that an insufficient number of laboratories have been accredited to perform the volume of inspection and testing required. Upon any such extension, and every 6 months thereafter during such extension, the Secretary shall submit a report to the Congress explaining the reasons for such extension and the steps being taken to ensure the accreditation of a sufficient number of laboratories.

Approved November 16, 1990.

LEGISLATIVE HISTORY - H.R. 3000

HOUSE REPORTS: No. 101-211, Pt. 1 (Comm. on Science, Space, and Technology) and
Pt. 2 (Comm. on Energy and Commerce).

SENATE REPORTS: No. 101-388 (Comm. on Commerce, Science, and Transportation)

CONGRESSIONAL RECORD:

Vol. 135 (1989): Sept. 19, considered and passed House.

Vol. 136 (1990): Oct. 26, considered and passed Senate, amended. House concurred
in Senate amendment.

¹⁴ 15 USC 5414

Appendix D: Supplier Quality Systems Survey

SUPPLIER QUALITY SURVEY

SURVEY NO. _____
SURVEY DATE _____

SUPPLIER NAME AND ADDRESS

PRODUCT / SERVICE SUPPLIED

RATING LAST SURVEY _____

DATE LAST SURVEY _____
CURRENT SURVEY _____

SUPPLIER STATUS

CERTIFIED SUPPLIER

All elements are present and operational in the supplier's system they meet the requirements for certification status.

PREFERRED SUPPLIER

The supplier has met our requirements for preferred status, and has planned commitments to obtaining certification status.

APPROVED SUPPLIER

The supplier displays the organization and future direction to achieve the requirements of certified status, and meets the requirements of approved supplier.

CONDITIONAL SUPPLIER

The supplier has not been surveyed, is in the process of being surveyed, or as a result of the survey has not obtained minimum criteria for a supplier rating

Supplier Representatives:

Survey Team:

SUPPLIER QUALITY SURVEY	RATING*	COMMENTS
<p>A. MANAGEMENT</p> <ol style="list-style-type: none"> 1. Does the supplier management share the philosophy of partnership with its customers: to provide high quality products or service at competitive pricing with timely delivery in return for technical and quality support as well as a long term business relationship with (COMPANY NAME)? 2. Are there active programs or plans to facilitate participation in Continuous Quality Improvement? 3. Are programs for employee education and training present? <p>B. ORGANIZATION</p> <ol style="list-style-type: none"> 1. Does the vendor have a clearly defined and documented Quality Control function? (Supply organization chart.) 2. Does the Quality Control function have clear and documented authority to act on quality and non-quality issues through disposition of product? 3. Is the Quality Control structure oriented for prevention instead of detection? <p>C. FIXTURE AND TEST EQUIPMENT CONTROL (METROLOGY)</p> <ol style="list-style-type: none"> 1. Is there a separate unit dedicated to metrology? 2. Is there a documented procedure for calibration of all equipment (including analytical equipment) 3. Are capability studies performed and documented prior to use in production? (Repeatability and Reproducibility Studies?) 4. Are calibration records maintained which include fixture and test equipment identification, location, method of calibration and certification, results, date of current and next calibration, and current status? 5. Are fixtures and test equipment clearly marked with an identification, date of last calibration and date of next calibration? 6. Is there a clear definition of dispositioning non-certifiable fixtures and test equipment? <p>D. INSPECTION</p> <ol style="list-style-type: none"> 1. Is there a system to assure the quality of purchased materials, which may involve: <ol style="list-style-type: none"> a. incoming inspection b. vendor certification program c. source inspection 2. Is there a system to assure product conformance to specifications at the initial setup phase of product manufacture? 3. In the absence of SPC, is there a system with documentation to verify that product conforms to specification prior to shipment? 4. Is there a system which provides lot traceability through each process and includes traceability of all raw materials used during manufacture? 		

SUPPLIER QUALITY SURVEY	RATING *	COMMENTS				
<p>5. Is there a system that measures the effectiveness of the total quality systems through an evaluation of packaged, ready to ship product? (Final Product audit)</p> <p>6. Is there a system with supporting documentation that assures non-conforming product is removed from the normal process flow and clearly marked for disposition?</p> <p>7. Are inspection plans documented and do they include the following:</p> <ul style="list-style-type: none"> a. sample size b. sample frequency c. acceptance criteria d. significant characteristics e. product disposition <p>8. Are inspection plans designed for zero defects?</p> <p>E. PROCESS CONTROL</p> <p>1. Is statistical process control utilized to optimize processes and systems?</p> <p>2. Does SPC include the following programs:</p> <ul style="list-style-type: none"> a. process capability studies? b. significant characteristic selection? c. reports to top management for action on noncapable processes? <p>3. Are there documented process instructions for manufacturing and non-manufacturing jobs?</p> <p>4. Are critical process parameters monitored?</p> <p>5. Are critical and functional part characteristics monitored and documented during processing?</p> <p>F. QUALITY SYSTEMS AND ANALYSIS</p> <p>1. Are cost of quality reports generated and provided to management?</p> <p>2. Is there a system for problem identification and resolution that looks for root causes?</p> <p>3. Is there a documented system to provide and control changes to product and product specifications and processing?</p> <p>4. Is there a documented system to address customer returns ensuring prompt response to corrective action inquiries?</p>						
<p>survey points scored:</p> <p>survey points possible:</p> <p>survey score:</p>	<table border="1" style="width: 100%; height: 100%;"> <tr><td style="height: 20px;"></td></tr> <tr><td style="height: 20px;"></td></tr> <tr><td style="height: 20px;"></td></tr> <tr><td style="height: 20px;"></td></tr> </table>					
<p><i>*See supplement entitled Quality Survey - EXPLANATION OF SCORING SYSTEM.</i></p>						

Explanation of Quality Survey Scoring System

Each survey question will be rated on the basis of the following point system:

rating	explanation
10	This element is present, documented, and successfully operational in the Supplier's/Subcontractor's quality system and displays a history of consistent application and continuous improvement.
9	This element is present, documented, and successfully operational in the Supplier's/Subcontractor's quality system.
6	This element is included in the Supplier's/Subcontractor's quality system; however, documentation is incomplete and/or additional development is required.
4	This element is included in the Supplier's/Subcontractor's quality system; however, documentation is inadequate and additional development is required.
2	This element is included in the Supplier's/Subcontractor's quality plan, but has no present application and requires substantial development.
0	This element is not included in the Supplier's/Subcontractor's quality plan.

Appendix E: Attribute Gauge Analysis Form

N	OPERATOR A			OPERATOR B	
	1st Evaluation	2nd Evaluation		1st Evaluation	2nd Evaluation
1					
2					
3					
4					
5					
6					
7					
8					
8					
9					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

FOR THE SYSTEM TO BE ACCEPTABLE, ALL EVALUATIONS PER LINE ITEMS MUST AGREE.

GAUGE TYPE	GAUGE NO.	DATE
OPERATOR A	OPERATOR B	

ATTRIBUTE GAUGE ANALYSIS

Subject Index

- A**
Annealing, 109
ANSI/ASME B18.8.2, 97
ANSI/ASQC Q90, 86
ANSI/ASQC Q91, 86
ANSI/ASQC Q92, 86
ANSI/ASQC Q93, 86
ANSI/ASQC Q94, 86
ANSI/ASQC Q9000-1994, 57, 75
ANSI/ASQC Q9001-1994, 57
ANSI/ASQC Q9002-1994, 57
ANSI/ASQC Q9003-1994, 57, 74–75
ANSI/ASQC Q9004-1-1994, 31–32
ASME/ANSI B18.18.2M, 86
ASME/ANSI B18.18.3M, 86
ASME-FAP-1, 57, 74–75, 86, 91
ASTM A-325, 15, 53
ASTM A-370, 114, 120
ASTM A-490, 49
ASTM A-700, 114
ASTM E-10, 114, 120
ASTM E-29, 114
ASTM E-30, 114, 118
ASTM E-112, 114, 118
ASTM E-548, 97
ASTM E-1077, 114, 119
ASTM F-606, 97
ASTM F-1469, 15, 50, 81–85, 91
ASTM F-1470, 86–90
ASTM F-1503, 53, 91–94
Attribute gauge analysis, 50–51, 155
Autocratic management, 3
- C**
Cause and effect diagrams, 51–53
Chemical testing, Fastener Quality Assurance Act, 73
Coatings, IFI-140, 121
Communication, management role, 8
Continuous improvement, 21–28
 employee involvement, reasons for, 24–26
 evaluation, 27–28
 initiating actions, 26–27
 planning, guidelines, 22–24
 service and product improvement, 24
 structured and systematic approach, 21
Control charting, guidelines, 52–53
Control plan, 15, 18–20
Costs
 of nonconformance, 36
 of quality, 37–39
Critical performance indicators, 21
Customers, 5
- D**
Decarburization
 IFI-140, 119
- tests, 110–111
Distributor industry, quality assurance manual, 67–69
- E**
Employees
 involvement in continuous improvement, 24–26
Employee survey, 5–6
Evaluation, 27–28
- F**
Failure mode and effects analysis, 13, 15–17
Fastener
 distributors, Fastener Quality Assurance Act and, 74–75
 inspection, 103–106
 manufacturers, Fastener Quality Assurance Act and, 74
 testing, 102
 users, Fastener Quality Assurance Act and, 75
Fastener Quality Assurance Act, 73–75, 133–143
 advisory committee, 142–143
 applicability, 143
 chemical testing, 73
 construction, 142
 definitions, 134–135
 findings and purpose, 133–134
 laboratory accreditation, 137–139
 lot segregation, 73–74
 manufacturers' insignias, 141
 minor deviations, 73
 record keeping requirements, 142
 regulations, 142
 relationship to state laws, 142
 remedies and penalties, 141–142
 sale of fasteners subsequent to manufacture, 139–140
 special rules, 135–136
 testing and certification, 136–137
Flow chart, 10–11
 analysis, 10–15
- H**
Hardenability, IFI-140, 120
- I**
IFI 100/107, 97
IFI 124, 97
IFI 125, 97
IFI-139, 74, 97–106
IFI-140, 74, 107–129
 certification and test reports, 122
- chemical requirements, 117–118
coatings, 121
decarburization, 119
definitions, 115–116
hardenability, 120
identification/tagging, 121
manufacture, 116
mechanical properties, 120
metallurgical structure, 118–119
mill scale/surface condition, 121
ordering information, 116–117
packaging and loading, 122
rods and bars, 107–109
size tolerance, 120–121
wire, 109–112
workmanship, finish and appearance, 121
- Initiation, actions, 26–27
In-process inspection, 47–48
Inspection
 in-process, 47–48
 lot-by-lot, 47–48
 mechanical fastener, 103–106
ISO 9000, 74–75, 86, 97
ISO 9001, 32, 35, 86
ISO 9002, 32, 87
ISO 9003, 74–75, 87, 97
ISO 9004, 87, 97
ISO/IEC Guide 25, 74, 97
- L**
Lot-by-lot inspection, 47–48
Lot segregation, Fastener Quality Assurance Act, 73–74
- M**
Management
 commitment through sponsorship, 23
 role, 3–8
 autocratic management, 3
 communication, 8
 customer focus, 4–5
 empowerment and involvement, 6
 leadership commitment, 3
 measurement, 6–7
 recognition and rewards, 7–8
 silos, 3
 team management, 3–4
 training, 5–6
Manufacturing, 31
 quality assurance manual, 59–62
Materials control, suppliers, 44
Measurement, management's role, 6–7
Mechanical properties, IFI-140, 120
MIL I 45208, 97
MIL Q 9859, 97
MIL-STD-1312, 97
MIL-STD-45662, 97

Off-loading, 53

O

P

Pareto analysis, 53–54
Partners In Quality Program, 40–41
Planning, guidelines, 22–24
Process control, suppliers, 44
Product improvement, 24
Public Law 101-592 (see Fastener Quality Assurance Act)

Q

Quality
cost of, 37–39
definitions, 9, 31
Quality assurance manual
distributor industry, 67–69
manufacturing company, 59–62
service industry, 63–66
Quality control, 47–48
Quality manual, 31–33
Quality policy, 9
Quality reporting, 37–39
suppliers, 44
Quality systems, 31–36
audits, 37–39
organizing for quality, 35–36
procedures, 33–35

R

Recessed head wire, 112
Recognition, by management, 7–8
Repeatability, 50
Reproducibility, 50

Rewards, by management, 7–8
Rods, IFI-140, 107–109

S

SAE J403, 114, 117–118
SAE J404, 114, 117–118
SAE J406, 114, 120
SAE J415, 114
SAE J429, 97
Scrapless nut wire, 112
Service and product improvement, 24
Service industry, quality assurance manual, 63–66
Service/product quality plan
capability assessment guidelines, 12
detection assessment guidelines, 12
severity assessment guidelines, 12
suppliers in, 40
Silo, 3
Socket head wire, 112
Standard deviation, 49–50
Statistical process control, 50–54
attribute gauge analysis, 50–51
cause and effect diagrams, 51–53
pareto analysis, 53–54
variable control charts, 51–53
variable gauge analysis, 50
Statistical quality control, 47–54
applications, 48
descriptive statistics, 48–50
(see also Statistical process control)
Strategic planning, 9–20
control plan, 15, 18–20
failure mode and effects analysis, 13, 15–17
flow chart, 10–11

analysis, 10–15
reaction of plan to out of control or specifications, 20
Suppliers, 40–44
auditing methods, 44
document and change control, 44
fixture and test equipment control, 44
involvement, 41–44
management, 42, 44
materials control, 44
measures, 40–41
objectives, 40
partnerships, 40–41
process control, 44
product control, 44
quality reporting, 44
quality systems survey, 42, 44, 147–151
sourcing considerations, 40
survey, 42–43

T

Team management, 3–4
Testing laboratories, Fastener Quality Assurance Act and, 74
TQM interaction, 35–36
Training, 5–6
Tubular rivet wire, 112

V

Variable control charts, 51–53
Variable gauge analysis, 50

W

Wire, IFI-140, 107–112

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Jack P. Pekar is a graduate of Ohio University with a Bachelor of Science in Education, majoring in mathematics. He currently serves as Manager of Quality Services for Kennametal's Cleveland facility in Solon, Ohio.

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