CHAPTER 2

BASIC QUALITY CONCEPTS

“Well! I've often seen a cat without a grin, but a grin without a cat! It's the most curious thing I ever seen in all my life.”

Alice

BASIC QUALITY CONCEPTS

1.0 THE NATURE OF VARIATION

While standing on a street corner observing the passing traffic, two cars of the same make and model stop at a traffic light. Both cars are the same color, have Goodyear tires and have a luggage rack on the trunk. At first glance, the cars seem identical. Upon closer observation, differences are detected. Both cars have Goodyear tires, but are the tires the same size? Are the radios the same? Is the upholstery the same? There are many characteristics for comparison.

The closer an item is examined, the more differences are found. No two objects are exactly alike. All things differ by some degree. Some variation may be obvious, but other variation may require precise measuring equipment to detect.

All manufactured parts exhibit variation. It is the concept of variation that forms the basis of probability, statistics and quality control. Consider a part that is produced by a punch press. As raw material is fed into the press, the machine punches out the parts. Eventually the press will produce a large number of similar parts. A visual check of the diameters may reveal no differences among the parts. If the diameter is measured with a scale, some differences will be found. If the measurements are made with a micrometer, a greater number of differences will be detected. Each level of comparison or method of measurement reveals a greater amount of variation.

As the measurements increase in precision, the differences among the parts become greater and greater until ultimately none of the parts would be the same. As the level of comparison becomes more precise, the concept that no two objects are exactly alike is realized.

2.0 QUALITY

The word quality is often used indiscriminately for many different meanings. Quality can be defined as “fitness for use,” “customer satisfaction,” “doing things right the first time,” or “zero defects.” These definitions are acceptable because quality can refer to degrees of excellence. Webster’s dictionary defines quality as “an inherent characteristic, property or attribute.” QReview will define quality as a characteristic of a product or process that can be measured. Quality control is the science of keeping these characteristics or qualities within certain bounds.

In a manufacturing or service environment, there are two major categories of quality: quality of design and quality of conformance. A poorly designed product will not function properly regardless of how well it meets its specifications. Conversely, a product that does not conform to excellent design specifications will not properly perform its intended function.

2.1 Design Quality

Design quality refers to the level of characteristics that the designers specify for a product. High-grade materials, tight tolerances, special features and high performance are characteristics associated with the term, high quality product.

An example of design quality may be shown by the comparison between an expensive automobile and an economy model. A Ferrari and a Ford Escort are compared. Both cars will perform the same basic function of getting from point A to point B. Each will generally conform to its design specification. The owners in both cases may be satisfied with the way their cars are put together. However, that is where the similarity ends. The Escort owner does not expect his car to go 150 mph, have leather seats and have twelve coats of paint, or be highly responsive. The Ferrari owner expects these characteristics or qualities.

The cost of making a product will usually rise as more characteristics are specified to increase product performance, improve comfort, improve ease of use and make the product look better. High-grade materials usually command a premium price. However, in many cases, increased competition creates an atmosphere of finding ways to make better and less expensive designs. This is true for products such as computers, VCRs and televisions.

The reliability of a product must be considered in the design stage. Reliability is the probability that a product will perform its intended function, without failure, for a specified length of time. Reliability is dependent on the basic design, the quality of materials and the quality of components that go into the final product. To achieve the required reliability, designers may need to specify higher priced components. This may translate to higher prices but also higher value for the consumer.

Many products command a premium price because they provide value to the consumer. Others may be expensive because of their role as status symbols. Expensive products do not always contribute to better product performance or customer satisfaction. This is particularly true in the software industry. Many low priced applications work just as well and sometimes better than expensive ones.

The designer may receive input from various sources when determining the level of design quality. In addition to the designer’s own ideas, input concerning product performance, materials to be used and various product characteristics may be received from management, marketing, sales, other engineering organizations or directly from customers. The final design specification may or may not be what the designer had in mind.

Although some quality engineers and other quality professionals get involved with product design, their time and effort is usually spent in designing and maintaining systems to measure and control process and product characteristics after the design is complete. A challenge to quality engineers is to implement the statistical techniques used in manufacturing during the design stage. The goals would be to enhance product design by eliminating problems early in the design process to ensure the ease of manufacturing.

2.2 Conformance Quality

After the level of design quality has been determined, the product characteristics are formed into drawings and specifications. The manufacturing engineers will use the drawings and specifications to develop manufacturing specifications and design the operations necessary to produce the product. This includes the floor layout, machinery, test sets, tools and other equipment. A plan for the number of employees required may also be included. The quality engineer works with the manufacturing engineer to make the quality system and maintenance of conformance quality an integral part of the manufacturing process. Any product checks, process checks or quality improvement activities should be an inherent part of the process. Conformance quality may be defined as the degree of adherence of the product characteristics to the design drawings and specifications. The objective of a quality program is to have a system that will measure and control the degree of product and process conformance in the most economical way.

The quality engineer will determine what product or process characteristics are to be checked. The quality engineer will also determine the type of data to be collected, the corrective actions required, and the statistical tools or other techniques to be used.

3.0 QUALITY SYSTEMS

A quality system is a mechanism that coordinates and maintains the activities needed to ensure that the characteristics of products, processes or services are within certain bounds. A quality system involves every part of an organization that directly or indirectly affects these activities. Typically, the quality system is documented in a quality manual and in the associated documents that specify procedures and standards.

3.1 Basic Elements in a Quality System

There are three basic elements in a quality system: Quality Management, Quality Control, and Quality Assurance.

- ***Quality Management:*** Quality management is the means of implementing and carrying out quality policy. They perform goal planning and manage quality control and quality assurance activities. Quality management is responsible for seeing that all quality goals and objectives are implemented and that corrective actions have been achieved. They periodically review the quality system to ensure effectiveness and to identify and review any deficiencies.

- ***Quality Control:*** The term quality control describes a variety of activities. It encompasses all techniques and activities of an organization that continuously monitor and improve the conformance of products, processes or services to specifications. Quality control may also include the review of processes and specifications and make recommendations for their improvement. Quality control aims to eliminate causes of unsatisfactory performance by identifying and helping to eliminate or at least narrow the sources of variation. Quality control has the same meaning as variation control of product characteristics.

The objective of a quality control program is to define a system in which products meet design requirements and checks and feedback for corrective actions and process improvements. Quality control activities should also include the selecting and rating of suppliers to ensure that purchased products meet quality requirements.

- ***Quality Assurance:*** The term quality assurance describes all the planned and systematic actions necessary to assure that a product or service will satisfy the specified requirements. Usually this takes the form of an independent final inspection. The distinction between quality control and quality assurance is stated in an ANSI/ASQ standard: “Quality control has to do with making quality what it should be, and quality assurance has to do with making sure quality is what it should be.” The quality assurance function should represent the customer and be independent of the quality control function, which is an integral part of the manufacturing operation.

3.2 The Quality Audit

A quality audit is an independent assessment comparing the various management and quality activities to a standard. The word independent implies that the person performing the audit is not associated with the activity being audited. There are two general types of audits: management and quality system audits and product specific audits.

The types of quality audits:

- Management and Quality System Audit - Manufacturing
- Management and Quality System Audit - Software
- Management and Quality System Audit - Service
- Product Specific Audit - Manufacturing
- Product Specific Audit - Software
- Activity Specific Audit - Service

Companies use first-party audits to evaluate their own performance. Second-party audits are conducted by a customer on a supplier. Audits conducted by completely separate companies, with no personal stake in the audited company, are labeled third-party audits. Auditors in a third-party audit are usually registrars that audit to international standards such as the ISO 9000 series.

A customer will usually combine a quality system audit with a product-specific audit. Third-party audits are usually reviews of the management and quality system and not product specific.

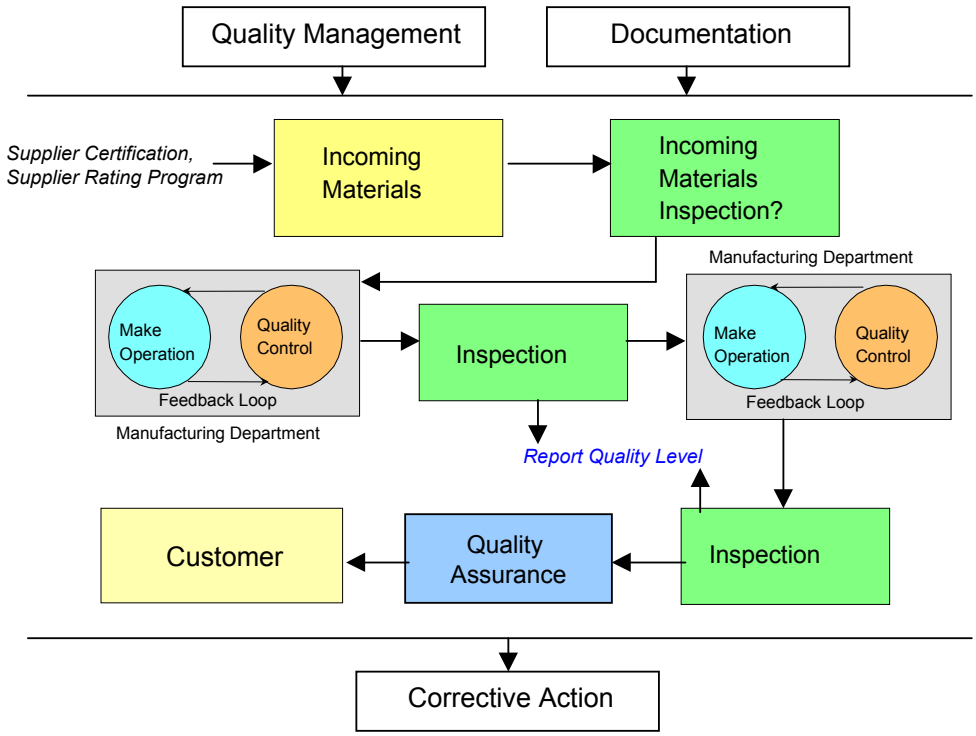
Quality audits assess that:

- Quality plans and procedures are in place
- Documents are controlled to avoid misuse
- Standards and regulations are being followed
- The data system provides accurate and adequate information
- Problems are addressed and corrective action is taken
- Products conform to requirements

Audits should be conducted on a scheduled basis. There should be no surprises to the organization being audited. This policy enables all those involved to organize their

workloads and assign personnel to assist in the audit. The audit should not disrupt any processes or work being done.

3.3 Quality Systems Diagram



4.0 QUALITY SYSTEMS STANDARDS

4.1 The International Organization for Standardization (ISO)

The International Organization for Standardization (ISO) was founded in 1946 to develop a common set of manufacturing, trade, and communications standards. It is based in Geneva, Switzerland. ISO promotes standards to facilitate international trade. The American Standards Institute (ANSI) is the United States representative to ISO. ISO has a full time staff plus technical committees, subcommittees, working groups and ad hoc groups. ISO receives input from governments, industry and other interested parties. ISO develops and promotes but does not implement or enforce international standards.

Quality systems or quality programs in one form or another have existed since the beginning of factories. Companies developed and implemented a quality system that worked for them. Although there was an abundance of literature on quality system elements, quality tools and statistical techniques, a standard did not exist until 1987. In that year, an ISO technical committee developed and published the ISO 9000 series of standards that define the minimum requirements for an adequate quality system. The ISO 9000 series standards were revised in 1994 and 2000.

The ISO 9000:2000 series and the joint ANSI/ISO/ASQ Q9000-2000 series of standards are used as a tool to establish whether companies are using a quality system that will ensure their ability to meet product quality and service performance requirements. The ISO 9000 series and the ANSI/ISO/ASQ Q9000-2000 series of standards are technically identical.

The ISO 9000 series standards are intended to assure that a company has at least a minimum adequate management and quality system in place. These generic standards provide quality management guidance as well as quality assurance guidance and requirements that apply to all types and sizes of companies. An ISO registration does not necessarily mean that a company produces products that always meet their design intent. The ISO audit is an assessment of the management and quality system and does not address product issues. There are no standards for product quality in the ISO 9000 series standards.

Over eighty countries have adopted the ISO 9000 series as a national standard. All standards developed by ISO are voluntary. There are no legal requirements to adopt them. However countries and companies often adopt and attach legal requirements to ISO standards. Each member country has an accreditation board that adopts the ISO 9000 series standards and certifies independent registrars. The Registrar Accreditation Board (ANSI/RAB) is the USA-recognized accreditation board.

Registrars are third party companies that evaluate quality systems for conformity to ISO 9000 standards. The registrars conduct audits and issue certificates to organizations that conform to the standards. The audit will involve most departments and functions in an organization. The focus of the audits is on documentation, implementation and effectiveness. Organizations are certified by the registrars and not by ISO or an accreditation board. ISO-conforming companies are allowed to display the registrar's mark on advertising and stationary as evidence of registration. Unfortunately, not all registrars are created equal so there may be significant differences in the way audits are conducted and findings assessed.

The ANSI/RAB sets standards and specifies training for registrars but does not maintain a list of registered companies. There are private companies that maintain lists with voluntary information provided by registrars.

4.2 The ISO 9000:2000 (ANSI/ISO/ASQ Q9000-2000) Series Standards

The ISO 9000 Standards Year 2000 Revision consists of:

- **ISO 9000**: Quality management systems - Fundamentals and vocabulary
- **ISO 9001**: Quality management systems - Requirements
- **ISO 9004**: Quality management systems - Guidelines for performance improvements

ISO 9001 registration provides confidence to customers and potential customers that an adequate quality system is in place and that quality and service requirements will likely be met. An ISO auditor will gather preliminary information on the company to be audited and then determine if the company is actually doing what it has documented.

The ISO 9000 Standards have been aligned with ISO 14001:1996 the environmental management standard.

4.3 ISO 9001:2000

A brief outline of the management system requirements per ISO 9001:2000 are listed below. For a complete list of requirements, please refer to the standard.

Quality Management System (Paragraph 4)

The organization shall establish, document, implement and maintain a quality management system and continually improve its effectiveness. The quality management system documentation shall include documented statements of a quality policy and quality objectives, a quality manual and records.

Documents required by the quality management system shall be controlled. Records are a special type of document and shall be established and maintained to provide evidence of conformity to requirements and of the effective operation of the quality management system. Records shall remain legible, readily identifiable and retrievable.

Management Responsibility (Paragraph 5)

Top management shall provide evidence of its commitment to the development and implementation of the quality management system and continually improving its effectiveness by communicating to the organization the importance of meeting customer as well as statutory and regulatory requirements. Management shall ensure that customer requirements are determined and are met with the aim of enhancing customer satisfaction. Management shall ensure that the quality policy is appropriate to the purpose of the organization, is reviewed for continuing suitability and is communicated and understood within the organization. Quality objectives, including those needed to meet product requirements are to be established for relevant functions and levels within the organization.

Top management shall appoint a member of management who, irrespective of other responsibilities, shall have responsibility and authority for the quality system

Resource Management (Paragraph 6)

The organization shall determine and provide the resources needed to implement and maintain the quality management system and continually improve its effectiveness, and to enhance customer satisfaction by meeting customer requirements. The necessary competence for personnel performing work affecting product quality shall be determined and training provided or other actions taken to satisfy these needs.
Appropriate records of education, training, skills and experience shall be maintained.

The infrastructure needed to achieve conformity to product requirements shall be determined and established. Infrastructure includes, buildings, workspace, associated utilities, process equipment (both hardware and software), and supporting services.

Product Realization (Paragraph 7)

The organization shall plan and develop the processes needed for product realization. In planning product realization, quality objectives and requirements for the product shall be determined. Where product requirements are changed, the organization shall ensure that relevant documents are amended and that relevant personnel are made aware of the changed requirements. The design and development of product shall be controlled. The organization shall determine the design and development stages, the review, verification and validation that are appropriate to each stage, and the responsibilities and authorities involved. Systematic reviews of design and development shall be performed per planned arrangements.

The organization shall ensure that purchased product conforms to specified purchasing requirements. Suppliers shall be evaluated and selected based on their ability to supply product in accordance with the organization's requirements. Purchasing information shall describe the product to be purchased.

Where appropriate, product shall be identified by suitable means throughout product realization. Product status shall be identified with respect to monitoring and measurement requirements. Where traceability is a requirement, the organization shall control and record the unique identification of the product. Care of customer property shall be exercised while it is under the organization's control.

Where necessary to ensure valid results, measuring equipment shall be calibrated or verified at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards. Where no such standards exist, the basis used for calibration or verification shall be recorded;

Measurement, Analysis and Improvement (Paragraph 8)

The organization shall plan and implement the monitoring, measurement, analysis and improvement processes needed to demonstrate conformity of the product, to ensure conformity of the quality management system, and to continually improve the effectiveness of the quality management system. The organization shall conduct internal audits at planned intervals to determine whether the quality management system conforms to the planned arrangements.

The management responsible for the area being audited shall ensure that actions are taken without undue delay to eliminate detected nonconformities and their causes. Follow-up activities shall include the verification of the actions taken and the reporting of verification results. Suitable methods for monitoring and, where applicable, measurement of the quality management system processes shall be applied. These methods shall demonstrate the ability of the processes to achieve planned results. When planned results are not achieved, corrective action shall be taken to ensure conformity of the product. Product characteristics shall be monitored and measured to verify that product requirements have been met. Product which does not conform to product requirements is to be identified and controlled to prevent its unintended use or delivery.

The controls and related responsibilities and authorities for dealing with nonconforming product shall be defined in a documented procedure.

Appropriate data shall be determined and collected to demonstrate the suitability and effectiveness of the quality management system and to evaluate where continual improvement of the quality management system can be made. The organization shall continually improve the effectiveness of the quality management system through the use of the quality policy, quality objectives, audit results, analysis of data, corrective and preventive actions and management review.

Action shall be taken to eliminate the cause of nonconformities in order to prevent recurrence. Corrective actions shall be appropriate for the nonconformities encountered.

5.0 FUNDAMENTAL PRINCIPLES

5.1 Statistical Quality Control and Statistical Process Control

Statistical quality control (SQC) and statistical process control (SPC) are scientific methods for analyzing data and keeping the process within certain boundaries. Many statistical tools, such as control charts, Pareto analysis, design of experiments, regression analysis and acceptance sampling may be used. SQC methods can be applied to anything that is possible to express in the form of numbers. SQC is concerned with product characteristics and SPC is concerned with process characteristics.

The word statistical means having to do with numbers, or more specifically, with drawing conclusions from numbers. The word quality means much more than the goodness or defectiveness of the product. It refers to the qualities or characteristics of the product or process being studied. The word control means to keep something within boundaries or to regulate it so that its outcome may be predicted with some degree of accuracy. In a manufacturing operation, conformance quality characteristics are to be kept within certain bounds. Taken together, the words Statistical Quality Control or Statistical Process Control mean:

Statistical - With the help of numbers or data,

Quality or Process - The characteristics of a product or process are studied,

Control - To make them behave the way they are intended to behave.

The most important element in statistical quality control is the feedback loop between the quality control function and the make operation. In statistical process control, the feedback loop is between the process control function and the device that regulates the process or the person responsible for adjustments. Continuous feedback and the appropriate corrective action drive statistical quality control and statistical process control to achieve the desired results. Both SQC and SPC seem to work best when the checks and feedback loops are automated and human intervention is minimized.

5.2 The Law of Large Numbers

The law of large numbers is a mathematical concept that says: Individual occurrences are unpredictable and group occurrences are predictable. The number of marriages, births and deaths in the United States next year can be predicted with some degree of accuracy, but exactly who will get married, who will be born or who will die cannot be predicted. This concept can be applied to a manufacturing process. For example, a statistical study can determine that products from a certain process are on average two percent defective. However, in any sample, the specific parts that will be defective cannot be predicted.

5.3 Central Limit Theorem

The central limit theorem states that a group of averages of sample size 4, 5 or 6 units always tends to follow the pattern of a normal distribution. If the population distribution leans to one side or the other, the distribution of sample averages from that population will tend to be symmetrical and have normal variation. The central limit theorem is what legitimizes the use of variables control charts regardless of the actual population distribution. The normal distribution and control charts will be reviewed in a subsequent chapter.

5.4 Data

Webster's dictionary defines the word data as a plural noun portraying factual information such as measurements or statistics used as a basis for reasoning, discussion, or calculation. Data are categorized in two ways: attribute data and variables data. Data classified as good/bad, pass/fail, go/no-go, etc., are called attribute or discrete data. When actual measurements are taken and recorded, the data are called variables or continuous data. In many cases (but not all cases), variables data will be distributed in a symmetrical bell-shaped curve called the normal curve. The known areas under the curve allow for inferences to be made about the process with relatively small amounts of information. By using the known areas under the curve, the fraction of measurements that will lie between, above, or below certain values can be predicted with a high degree of accuracy.

5.5 Distributions

Because of variation between measurements of individual parts, data when plotted will form a distribution. A distribution model describes how the data are dispersed. A plot of the distribution will show a center value and the range of measurements. The variation between data values will usually be quite small and follow a natural pattern. Large variation indicates that the pattern is unnatural. This may be attributed to external or assignable causes. When a pattern is unnatural, the cause should be investigated and eliminated. Statistical techniques such as control charts are used to identify the unnatural patterns. A plot of the actual data showing the data values versus the number of occurrences is called a histogram. A mathematical estimate of the shape of the histogram is called a frequency distribution. Distributions are formed because everything in the world that can be measured exhibits variation. If the measuring instrument is very precise, it will be discovered that like the snowflake, no two measurements are exactly the same.

5.6 Precision and Accuracy

In addition to the objects that are measured, the measuring instrument itself has variability. Two different instruments may measure the same parts and yield different results. In many cases, measuring parts a second time with the same instruments will give a different result. A low value of the instrument's standard deviation indicates greater precision. When an instrument is accurate but not precise, the measurements are distributed about the true value within the acceptable range. When an instrument is precise but not accurate, the measurements are clustered close together but at a distance from the true value. When an instrument is both accurate and precise, the data are clustered close together around the true value.

5.7 Statistical Techniques

Many statistical techniques are used in quality control and inspection. Listed below are the most widely used statistical methods.

- Histograms
- Statistical Inference
- Hypothesis Testing
- Decision Errors
- Statistical Process Control
- Control Charts
- Acceptance Sampling
- Process Capability Analysis
- Reliability
- Regression & Correlation
- Design of Experiments
- Pareto Analysis

Basic probability is the foundation of statistical methods. Its importance cannot be understated. To really understand statistical methods, an understanding of probability concepts is essential.

It must be stressed that the application of statistical techniques alone will not fix any problems or improve product or process quality. Statistical techniques are tools to identify problems and provide data for decisions. For problems to be fixed or improvements to be made, some action must be taken. The action may be automated or conducted by humans, but nevertheless, action must be taken. Automated actions work best in manufacturing situations.

The chapters that follow cover the essential elements of the various statistical techniques. *QReview* presents the material from an engineering point of view and assumes that the student has some previous background in statistical concepts and methodology. Mathematical derivations and in-depth explanations are not included. These are tasks for textbooks on mathematical statistics. The subject of metrology and calibration is covered in chapter twelve.

6.0 HUMAN FACTORS

Human factors focuses on human beings and how they interact with equipment, products, environments, other people and day to day activities. The goal of human factors in a company is to match the workplace and management approach to the capabilities, needs and limitations of people. The part of human factors addressing human and machine interactions is called ergonomics.
The first thrust of human factors was to study the workplace and design the environment

and machinery to better accommodate the person doing the job. This goal has been expanded to include the way management manages and the involvement of employees in the decision making process.

In the 1930s, a study was conducted at Western Electric's Hawthorne Works in Chicago, Illinois. Employees complained of bad lighting in an assembly area. New lighting was installed that brightened the area. The employees seemed to be much happier and as expected, productivity increased. It was decided to increase the light intensity and measure productivity. As the intensity increased, productivity increased. The first assumption was that brighter lights contribute to employee morale and higher productivity. One day the lights were dimmed; however, productivity did not drop. Productivity kept increasing as the light intensity decreased. The study team concluded that it was not the lighting that contributed to increased productivity, but the mere fact that somebody was paying attention to them. This study is called the Hawthorne study and the conclusion is referred to as the Hawthorne effect.

In an authoritarian company, the boss gives orders and the employees carry them out. In these situations, employees often complain about job satisfaction. In recent years, some companies are shedding the boss-worker image by allowing managers to assume the responsibility of coach. Workers are referred to as production associates. The coach's job is to coordinate the work and motivate employees. The employees, whether they are engineers or production associates, become part of the team, not just someone who carries out orders. This approach yields significant rewards for the company and the employee. Company objectives and tasks are carried out in an efficient manner and the employee, by making a contribution, feels good about a job well done.

Human conflict can be minimized but never eliminated. There may be times when engineering decisions are overruled or employee suggestions not adopted. In these cases, the findings should be documented for possible review at a later date, then the engineer or employee can move on to the next assignment. In any conflict, whether it is between management and employees, between management and unions, or between employees, good judgement must be used.

Juran and Deming agree that the majority of problems arise from flaws in the system and not because of employee motivation or employee errors. Deming has stated that 80% of problems are management or system related. When the system is the problem, the output will not meet specifications regardless of employee effort. The outcome is substandard products and employee dissatisfaction. The situation is changing as management approaches are changing. In many companies, management and system problems are being addressed and the outcome is very positive. Management is investing in new equipment, advanced employee training and respect for employee judgement. This results in employee satisfaction, high quality products and increased productivity.

In recent years, computers have changed the way people work. The computer has become an indispensable tool. Former mundane tasks are easier to accomplish and in some cases even fun. In addition to increasing productivity at the workplace, computers and the computer industry have made a significant impact in all areas of human activity.

7.0 A BRIEF HISTORY OF QUALITY

1550 BC - Egyptian royal cubit was standardized. It was about 20.63" ± .02".

1654 - Blaise Pascal with Pierre de Fermat developed the theory of probability. They were prompted by the inquiries of gamblers seeking inside information to help them win at cards and dice.

Early 1800's - Concepts of tolerances and gauging were developed in American armories.

1861-1865, Civil War - Tolerance and gauging concepts were used to mass produce arms with interchangeability of parts.

After the Civil War - Tolerance and gauging concepts were used and improved by companies such as Singer and McCormick.

1916 - Ford Motor Company developed systematic material handling, machine tool design, factory layout and final inspection. Automobile production went from ten thousand cars in 1909 to sixty thousand in 1916. The price decreased from $850 to $350 per car.

1917 - The first published use of the term Control of Quality appeared in *Industrial Management* in an article by G. S. Radford.

1922 - G. S. Radford published the first book on Quality Control: *The Control of Quality of Manufacturing*.

1924 - Dr. Walter A. Shewhart of AT&T developed the concept of control charts. Dr. Shewhart is referred to as the father of statistical quality control.

1925 - Harold F. Dodge of AT&T developed sampling concepts and terminology used in acceptance sampling.

1931 - Dr. Walter A. Shewhart published *Economic Control of Manufactured Product*. This was the first in-depth book on statistical quality control.

1941-1945 - The United States was involved in World War II. The war generated the first extensive use of statistical concepts. U.S. Government suppliers were required to use statistical quality control. The government sponsored many statistics and quality control training classes.

1941 - Harold F. Dodge and Harry G. Romig published a unique book on sampling procedures. *Single and Double Sampling Inspection Tables*. These tables were the forerunners of the military standard sampling tables.

1944 - The *Dodge-Romig Sampling Tables* were published. OC curves, lot sizes and sample sizes are given by AOQL. The tables include single and double sampling plans.

1946 - The ASQC was organized and George Edwards of AT&T became the first president.

1947 - ASQC created the Shewhart medal to recognize outstanding contributors to the quality profession.

1950 - Joseph M. Juran and W. Edwards Deming taught statistical methods and statistical quality control to the Japanese.

1950 - Military Standard for Sampling by Attributes was published as *Mil-Std 105A*.

1951 - Joseph M. Juran published the first edition of *Quality Control Handbook*.

1968 - ASQC administers the first examination for Certified Quality Engineer. There were 147 successful candidates.

1970's - The focus was on continuous improvement and employee involvement.

1980's - The emphasis was on quality of design and design for manufacturability. Computers were used extensively in all aspects of quality.

1987 - The International Organization for Standardization (ISO) establishes ISO 9000 Series Quality System Standards.

1987 - Congress established the Malcolm Baldrige National Quality Award to promote quality awareness, to recognize significant quality achievements of U.S. companies, and to call public attention to successful quality strategies. The award is not for specific products or services.

1988 - The first Baldrige award winners were announced. They were Globe Metallurgical Inc. (small business), Motorola Inc. (manufacturing) and Westinghouse Electric Corporation's Commercial Nuclear Fuel Division (manufacturing).

1989 - Military Standard for Sampling by Attributes is reissued as *Mil-Std 105E*.

1990's - Quality Concepts were extended to service industries. Emphasis is on total quality management (TQM) and customer satisfaction.

1993 - *ANSI/ASQC Z1.4 Sampling Tables and Procedures* replaced *Mil-Std 105E*.

1994 - ISO 9000 Standards were revised (for clarification?). ANSI/ASQC series standards renamed from Q90 series to Q9000 series.

1996 - Eight thousand U.S. companies have achieved ISO registration since its inception. Eight percent of all companies that are ISO registered are located in North America. Forty six percent are located in the United Kingdom.

1996 - Since the ASQC certification program began, more than 55,000 people have become certified in one or more of the certification areas.

1997 - The American Society for Quality Control (ASQC) officially changed its name to the American Society for Quality (ASQ).