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A Chronology of Quality

Matthew Barsalou
Fort Hays State University

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Matthew A. Barsalou

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Introduction

This research paper will explore the chronology of quality. To explore the chronology of quality, some terms such as quality, quality assurance and quality management need to be explained. Experts cannot agree on an exact definition of quality (Gryna, 2001, p. 6). However, there is some similarity between the various experts' definitions of quality. Gryna (2001) defines quality as “external and internal customer satisfaction” (p. 6). He also gives the International Standards Organization definition of quality, which is the “totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs” (Gryna, 2001, p. 7). *The Quality Technician's Handbook* also uses the International Standards Organization definition of quality (Griffith, 2003, p. 1). Feigenbaum (1983) defines quality as “The total composite product and service characteristics of marketing, engineering, manufacturing, and maintenance through which the product and service in use will meet the expectations of the customer” (p. 7). Ishikawa (1985) defines quality as "satisfying the requirements of customers" (p. 44). Juran (1988) defines quality as “fitness for use” (p. 1.1). Crosby (1980) defines quality as “conformance to requirements” (p. 15).

Within the field of quality, there are terms such as quality control, quality assurance and total quality management. *The Quality Technician's Handbook* explains that quality assurance is “primarily a planning and analysis function” (Griffith, 2003, p. 13) and these functions provide feedback for product and process design based on failure reports, test data and experiments. Quality assurance begins in the planning phase of a new product and lasts the life cycle of the product. Quality control is measuring the process and the resulting quality performance data are compared against a standard. In quality control the difference between the performance and the standard is determined and acted on (Griffith, 2003). Inspection is a part of quality (Gryna, 2001) and Griffith (2003) defines inspection as “an appraisal activity that compares products with applicable standards" (p. 13). Ishikawa (1985) states that "to practice quality control is to develop, design, produce and service a quality product which is most economical, most useful, and always satisfactory to the customer" (p. 46).

Griffith (2003) explains that total quality management "is the process of continuously improving performance at every level and in every area of the company" (p. 12). Feigenbaum (1983) defines total quality control as "an effective system for integrating the quality-development, quality-maintenance, and quality-improvement efforts of the various groups in an organization so as to enable marketing, engineering, production, and service at the most economical levels" (p. 6). Ishikawa (1985) uses Feigenbaum's definition to define total quality control.

To explore the chronology of quality, this paper explains the early history of quality and then will move forward to the events relevant to quality that happened around the beginning of the 20th century. This paper will then progress to the origins of statistical process control. The paper will also describe quality and lean manufacturing and quality during the 1980s and 1990s. Quality and six sigma as well as quality awards and certifications will be addressed. Finally, there will be a section explaining the need for quality today.

The Early History of Quality

The *Certified Quality Engineer Handbook* reports that Joseph Juran traced the history of quality management back to the time when the pyramids were built in Egypt. However, until the time of the industrial revolution quality management was little more than craftsmen checking their own work (Borror, 2009). The need for quality in the production of parts increased with the quest for parts produced exactly alike as a part of the American system of manufactures (Hounshell, 1984).[1]

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[1] Hounshell (1984) refers to the manufacturing system as the "American system of

Quality During the Industrial Revolution

The industrial revolution and the beginning of mass production would be an appropriate time to start a study of the history quality because quality was controlled by the individual craftsman before the start of mass production. Craftsmen were the people responsible for their product and they had control of every step of the production process. Parts move from person to person in mass production; therefore, in mass production many people have an influence on the quality of the product.

According to Stearns (1998), society was drastically changed by the industrial revolution. The industrial revolution in early 1800s England was fueled by cheap labor that was worked very hard. Machine-made goods lowered the income of rural laborers and mechanization in the textile industry lowered the income of workers who spun cloth by hand. Some skilled workers did well during this time, but many employers used orphans and low-paid women as sources of cheap labor. Industrialization had some benefits at this time, such as lowering the selling price of many goods; however, it was still a difficult time because work was unpredictable and many people could find themselves out of a job because of constantly changing economic conditions. Some workers rioted because of job loss caused by mechanization. They claimed to be following a mythical figure named Ned Ludd. The Luddites attempted to have machinery banned, but they failed.

Life in the early factories was both hard and dangerous. Many factories worked the workers up to sixteen hours a day, six days a week and there was little protection from moving machinery that could injure workers. This was also at a time when an injured employee could not expect financial assistance from his or her employer or the government; therefore, an injury could lead directly to unemployment and poverty. In the western world, this situation has changed drastically (Stearns,

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manufactures” (p. 17).

1998). Factory life during the industrial revolutions was so unpleasant that Marx (1975) described work in a British match factory as being so bad that Dante would have found his levels of Hell surpassed because of the long hours, short breaks and the constant smell of sulfur in the air.

According to Wren (2005), many factory managers during the early industrial revolution complained that workers were not accustomed to the regular hours and monotony of factory work. However, many were enticed into giving up agricultural work because of the pay available in industry. Industrial work provided a chance to accumulate a small savings and was less variable than agricultural work that left people dependent upon the weather. Skilled labor in the early factories could get a premium wage and some employers kept their workers working in slack times just to ensure that they would still be there when production demands went up.

Training was also a problem in early factories. Employees could seldom read and were therefore incapable of understanding written directions. Training was typically oral if there was any. Most of the time, employees learned on the job by observing people who had been in the job for a longer time. Workers were also often opposed to changes and this was a problem when attempts were made to implement the standardization of parts that is common to mass production. Some employers attempted to school workers so they would have the basic skills required to do their jobs (Wren, 2005).

Motivating workers was an issue in early factories. Many employers believed that high pay reduced output because they thought that workers would stop working as soon as they had enough money. Adam Smith opposed this belief and argued that people would work more if they could get more for their work. Many industries such as textiles used a piece-rate system that tied pay to output. This method worked well in early textile mills where there was a clear connection between work and output. It did not work as well in industries such as mining where team efforts were required (Wren, 2005, p. 49).

Management as a profession also originated in the early days of the industrial revolution. In 1832, James Montgomery wrote a book that is considered the first management textbook. It dealt primarily with issues such as product quality and quantity of work, maintaining machines and keeping costs down. Around this time, most supervisors were paid little more than the workers and those that made more, made it because of their social class and not because of ability. A shortage of talented managers also drove up manager's pay. John Stuart Mill recommended tying the manager’s interest to the company's interest by giving the manager a percentage of the company's profits (Wren, 2005).

Mass production developed around the same time as the industrial revolution. According to Hounshell (1984) Mass production's origins can be traced to the French General Jean-Baptiste de Gribeauval who attempted to standardize parts in the French arms industry in 1765. The U.S. War Department was heavily influenced by the French around this time and the War Department started experimenting with interchangeable parts at American federal armories. This work was further encouraged by Thomas Jefferson who was a strong supporter of interchangeable parts in weapons manufacturing. In addition to interchangeable parts, the American government encouraged mechanization at federal arsenals. This system was known as the American system of manufactures (Hounshell, 1984).

American System of Manufacturing

The arms maker Samuel Colt invented a pistol and opened a company to produce and sell it, but was hindered by quality problems. Colt blamed lack of uniformity of parts for the quality problems and he addressed this problem when he opened his new Colt armory in 1855. Colt invested in machinery and attempted the complete mechanization of the revolver manufacturing process in order to achieve product quality and uniformity. Even the use of machine tools was not sufficient to ensure interchangeable parts in the mid-nineteenth century, so jigs and fixtures were often used to test the parts. Interchangeable parts were expensive and their use may not have been profitable for most companies; however, interchangeable parts were considered necessary by the U.S. War Department, therefore they were often funded by tax money. Like the arms industry, the American clock industry of this era attempted to ensure quality and uniformity of parts by the extensive use of a jig and fixture system (Hounshell, 1984).

Quality Chronology at the Turn of the 20th Century

The next major changes in factory work were the coming of Henry Ford and Fredrick Winslow Taylor around the turn of the last century. Henry Ford created the Ford Motor Company in 1903 and his company produced medium-priced automobiles. Fredrick Winslow Taylor attempted to separate the planning function from the actual work performed (Aitken, 1985). People such as Karl Pearson, Roland A. Fisher and William Sealy Gosset made advances in statistical methods that would be later incorporated in to the field of quality (Salsburg, 2001).

Ford's New Assembly Line

In 1907 Ford gained full control of Ford Motor Company and he instructed his engineers to design a light-weight and low-cost car for the American public. The first ford Model T was sold in 1908 and the annual production rate grew every year until the First World War. Ford had a core of young and talented engineers and mechanics that were given room to experiment with production methods, work layouts, quality control and material handling (Hounshell, 1984). Hounshell (1984) believes that there would never have been a mass-produced automobile if the early Ford Motor Company engineers had simply copied older manufacturing methods.

Henry Ford began his involvement with the concept of interchangeability while planning the production of his Model N automobile. He considered interchangeability to be essential to increasing the production output. To accomplish this, the hand fitting of parts had to be eliminated. Ford went as far as to boast that every one of the parts that went into his car was all produced exactly alike (Hounshell, 1984).

One of Ford's mechanics made machines that the mechanic claimed were simple enough for farmers to use to produce high quality mechanical work. And all parts were checked for conformance with requirements by using jigs and fixtures. At this time in the history of manufacturing, manufacturing was still dependent on inspection and the heavy use of tools such as jigs and check fixtures for the checking of parts (Hounshell, 1984).

Ford Motor Company also started setting up machine tools according to the order of operations for a smoother work flow. Gravity slides were installed to move parts from one machine to another by letting them slide down a slide that resembled a rain gutter. Engineers placed brass tags on machine tools identifying the machine tool's location. The information contained on the tags was later used for planning the locations of the machine tools at the new Highland Park factory where production reached 200,000 automobiles per year in 1913. This was also the time of Ford's first experimental assembly line. Typical output for machines was determined and this information was used for scheduling purposes. Additional progress was made by simplifying operations for unskilled machine operators (Hounshell, 1984).

Ford engineers simplified tasks by designing parts that could be assembled without the use of skilled fitters. To eliminate the labor-intensive threading of radiator fins into radiators, the engineers built a device that could automatically complete the assembly with one movement. Teams of employees would move from one work station to another, but this resulted in problems when the individuals worked at different speeds. This problem was eliminated by leaving the employees stationary and moving the work pieces to and from them. With the assembly line, the line controlled the speed and not the employees (Hounshell, 1984).

On April Fools Day in 1913, Ford employees started assembling flywheel magnetos on an assembly line. Some operators performed tasks as simple as tightening a few nuts. The production rate increased from between 35 and 40 magnetos per day to 1,188 per day. There were problems with some operators working too fast and others intentionally working slowly. The engineers wanted to use a piece-rate system so that the slower operators would quit; but the engineers did not think Henry Ford would approve of the piece-rate so they solved the problem by setting the assembly line speed and letting it control the operator's speed. The assembly line cut production time in many departments and the overall assembly time for a Model T engine dropped by more than fifty percent (Hounshell, 1984).

Henry Ford started paying production workers five dollars per day to reduce employee turnover that had reached 380 %. Hounshell (1984) considers Henry Ford's five-dollar day to be the final step in the move towards mass production. The new assembly line was so distasteful to production workers that Ford Motor Company needed to hire more than nine hundred just to get one hundred because so many would quit in a short time. Henry Ford was also concerned with the growing differences between management pay and worker pay and this as well as labor unrest may have influenced his five dollar day (Hounshell, 1984).

Around the time that Henry Ford and the Ford Motor Company were implementing the production line, Fredrick Winslow Taylor was bringing scientific management to industry. According to Peter Drucker (1993), Taylor is very misunderstood and few people appreciate the impact he has had on the world. Taylor felt that workers should receive a larger share of profits and using scientific management to make them more productive was a way to earn better pay; however, Taylor was often opposed by labor unions who objected to his simplification of work because that meant people with fewer skills than their members could perform the work (Drucker, 1993). Shingo (1987) was one of the people who created lean manufacturing and he was heavily influenced by Taylor's scientific management.

Quality During the Era of Taylorism

Taylor (2008) begins his book *The Principles of Scientific Management* with the claim: “the principle object of management should be to secure the maximum prosperity for the employer, coupled with the maximum prosperity for each employee” (p. 5). Aitken (1985) reports that Taylor, the father of scientific management, was once a foreman and chief engineer at a time when foremen were primarily responsible for ensuring that standards were met by hiring competent people and firing incompetent people. Foremen also needed to ensure that the production output was sufficiently high. Taylor suspected his employees were intentionally working slower than they could work and he attempted to speed them up with the threat of termination, verbal persuasion and a piece-rate system. He also trained unskilled people in the basics of the jobs, but they started working at the same rate as everybody else once they were experienced. Taylor believed that through careful measurement he could determine the rate at which people could work. Unfortunately, the studies performed by Taylor were often more subjective and less scientific than he realized. For example, for experimenting Taylor (2008) recommends using people who are used to conducting experiments, but he does not describe how to conduct an experiment or what qualifications the experimenters need other than experience (p. 36).

Taylor used job analysis and time study to determine the proper work rate for different jobs. Job analysis broke the work down into individual tasks and Taylor attempted to determine which steps were productive. Aitken used the sharpening of a machine tool to illustrate this part of Taylorism. A machinist may consider sharpening his tool to be part of his job, but Taylor looked at tool sharpening as a separate job that could be performed by somebody with less machine skill than the machinist, but who had skills as a tool sharpener. Taylor did not get worker input in the task of analyzing tool sharpening (Aitken, 1985).

The next step in scientific management is time and motion study, which is used to determine how fast a task should be performed. Time -motion study results were typically adjusted with an arbitrary allowance to account for variation in the times. The final results were seldom arrived at scientifically (Aitken, 1985).

Quality and Advances in Statistics

Around the beginning of the 20^{th} Century many advances in statistics were made (Salsburg, 2001). Statistics and probability are “an essential tool of the modern approach to quality” (Gryna, 2001, p. 241). Statistical process control is “the application of statistical methods to the measurement and analysis of variation in a process” (Gryna, 2001. p. 495).

It was in 1820 that Laplace discovered the bell-shaped curve that often appears in statistical data. Many statistical concepts such as correlation and regression were discovered by Sir Francis Galton in the late 1800s. Galton's associate Karl Pearson made additional advances in statistics such as probability distributions. Pearson suspected that one could get to the true underlying value with enough measurements. Galton and Pearson worked together at Galton's biometrical laboratory in England and they created the journal *Biometrika*. The journal *Biometrika* printed data on things such as the measurements of the cranial capacity of human skulls and the arm lengths of Albanian soldiers. Pearson would estimate the statistical parameters of the various data sets that *Biometrika* published. Salsburg suspects there was no real purpose behind the measurements other than estimating the parameters (Salsburg, 2001).

In 1908 *Biometrika* published an article about t-tests by an author who wrote under the name of Student. T-tests are used in quality when comparing the averages of two populations when the standard deviation is not known (Gryna, 2001, p. 286). Salsburg (2001) explains that the writer who used the name Student was actually named William Sealy Gosset. Gosset worked as a mathematician for

Guinness. Guinness did not permit its employees to publish in journals to prevent the release of company secrets so Gosset published under a different name. He had already published research results in *Biometrika* in 1904 and took a year off from working at Guinness to study statistics under Pearson. Student's t-test was created because previous formulas for estimating the error of samples required a large sample size and Gosset had found that there were often only small samples available (Salsburg, 2001).

Gosset met a student named Roland A. Fisher in 1912. Fisher eventually met Karl Pearson and Pearson gave him a difficult statistical problem to solve. Fisher solved it in a week and submitted it to *Biometrika,* which had become the main journal for statistics. Pearson held the submission for a year while he had people verify it and then published a shortened version of it as an appendix to his own article. Fisher never submitted anything to *Biometrika* again. In 1935 Fisher wrote a book called The *design of experiments*; unfortunately, the mathematics Fisher used in the book were too difficult for most scientists; therefore most scientists could not design their own experiments unless they copied one of the examples used in Fisher's book (Salsburg, 2001). Design of experiments is one of many statistical tools used by quality professionals (Gryna, 2001).

Further advances in experimental design were made by Fisher's son-in-law George Box. Box started to study chemistry but was drafted into the British army during World War II. He was assigned to a chemical defence research station because he had been a chemistry student. He recommended bringing in a statistician to look at some data and an officer asked what he knew about statistics. He explained that he had read a book by Fisher so he was told to do the statistical work himself. Box ordered all five books that had been published on statistics and he found that the available experimental designs were not adequate so he created his own. Box eventually studied statistics and received a Ph.D. based on statistical research that he had previously done. After receiving his PhD. Box made many advances in experimental design (Salsburg, 2001). Box also made many advances in quality engineering, particularly in regards to using statistics to solve practical problems (Vining, 2010).

Quality and the Beginning of Statistical Process Control

Advances in the use of statistics in the field of quality were made at AT&T’s Western Electric Company’s Hawthorne plant and AT&T's Bell Labs (Dodge, 1969a). During the Second World War engineers were trained in quality to help the American war effort (Struebing, 1996). American quality experts went to Japan to teach quality after the war was over and Japan made many advances in the field of quality (Juran (2005g).

The Rise of Statistical Methods in Quality

Product quality after the arrival of mass production and scientific management was dependent upon inspectors. There were breakthroughs in quality control at the AT&T’s Western Electric Company’s Hawthorne plant. The plant itself was made famous in industrial psychology because of the Hawthorne Experiments, which determined that employees work better when they feel that management has taken an interest in them. Less famous is what was happening in the Hawthorne plant's inspection department in the mid 1920s. This was the time when Joseph Juran joined the Hawthorne plant's inspection department (Butman, 1997).

Joseph Juran is well-known within the field of quality and he got his start in quality at the Hawthorne plant’s inspection department around the time when it was attempting to scientifically determine the optimal sampling plans (Juran, 1997. p. 79). There were many weaknesses in the Hawthorne plant’s reliance on inspection. For example, waste from producing defects, production workers did not have a say in controlling their own work, inspection gages sorted good product from bad product without providing feedback on the process, sampling tolerated a specific percentage of defective parts and inspectors were not capable of detecting 100% of the defective parts (Juran, 2004. p

96). Another problem with inspection is that even if defective parts are prevented from reaching the customer, the customer will still pay for the defects because of the higher cost of producing the parts if many are defective. The cost of inspection would also be a factor that could drive up the cost of finished products (Deming, 1986, p. 28). Reliance on inspection is an acceptance of waste that generates higher costs for the consumer. For example, when Juran (1997, p. 74) started at the Hawthorne plant's inspection department 5,200 workers out of 40,000 were in the inspection department. Most inspection department workers inspected and tested the product. Other workers in the inspection department calibrated the various gages and meters that the inspection department used. The products Hawthorne shipped were high quality; however, the costs were high because of all the people involved in inspecting and reworking the products.

Dodge (1969a) explains that in the early 1920s industry was attempting to work scientifically using Taylor's scientific management and tools such as Gant charts. At this time industry was trying to strike a balance between costs and schedules and quality entered the equation as a new factor that needed to be balanced with costs and schedules. These new methods became known as "quality control" (Dodge, 1969a, p.78). Many techniques such as sampling plans and statistical process control resulted in the name "statistical quality control" (Dodge, 1969a, p. 78). In 1924 Bell Labs were using 100% testing and inspection to determine if products were in conformance with requirements and many were being reworked so that they would function correctly (Dodge, 1969a, p.78).

The use of inspection was decreased as the amount of sampling went up and the risk of having material rejected influenced the producers to improve their quality to avoid having material rejected. Inspectors also received better training and measurement accuracy was improved (Dodge, 1969a, p. 88)

Bell Labs was the Western Electric Company’s laboratory. Walter Shewhart was one of their engineers and he invented the control chart on May 16th, 1924 (Juran, 1997, p.79). The control chart was used for statistical process control. It could determine if a process was stable and producing parts that were within specification limits. The control chart used mathematical formulas to determine an upper and lower control limit. If a part was outside of these limits, then there was reason to think that there were parts out of specification and all parts needed individual checking. The control chart was also a signal for the operator to check the machine that produced the parts (Feigenbaum, 1983, p. 455). Shewhart's control charts took many years to be implemented at the Hawthorne plant (Juran, 1997, p. 79). Juran (1997, p. 79) tried to encourage managers to use control charts, but seldom succeeded. He could not understand the manager's reluctance to implement control charts, but Juran later understood that the priorities were to ship products and the workers could get bonuses through a piece-rate system, which gave the workers incentive to ship as much product as possible.

In 1925 Bell Lab's inspection engineering department and Hawthorne's inspection branch formed a Joint Committee on Inspection Statistics and Economy. Two of the committee members were Walter Shewhart and Harold F. Dodge. The Hawthorne plant started a new department called the inspection statistical department and Juran was one of the engineers in the new department. Statistical sampling plans were made based on production lots and each lot was permitted to have a specific percent classified as defective. A single random sample was used to determine if the lot should be accepted or rejected (Juran, 1997, p. 75).

Harold F. Dodge (Harold French Dodge, 1893-1976…, 1977) started as a development engineer at Western Electric Company in 1917. He started in the engineering department that became Bell Laboratories. He became a quality results engineer at Bell Labs and worked together with people such as Walter Shewhart. The team Dodge was on originated the concept of average outgoing quality level and Doge eventually developed sampling plans with H.G. Romig. Dodge also helped to develop the U.S. Army's post-World War Two era sampling plan, Military Standards 105A-105D (p. 96 & 97), which the U.S. Department of Defense discontinued in 1995 (Mouradian, 2002, p. 128). Dodge and Romig (1959) report that their sampling tables were published in January 1941 in *The Bell Telephone System Technical Journal* and then reprinted in 1944 as *Sampling Inspection Tables: Single and Double Sampling*. The sampling tables are known as *The Dodge and Romig Sampling Tables.*

In 1926 Juran (1997) realized that there would be no defective parts in the lots if the production process was perfect and there would also be no defective parts in the lot if the process was very bad because defective parts would be found during random sampling and the entire lot would be 100% inspected. However, if the process was somewhere between the two extremes there would be some defective parts in the lot and Juran called this "the average outgoing quality level" (Juran, 1997, p. 78). Juran thought that he had discovered the concept, but he later learned that Dodge was first. The Hawthorne plant's sampling plans were eventually issued in a U.S. government standard called MIL-STD105A (Juran**,** 1997, p. 79).

Shewhart published *Economic Control of Quality of Manufactured Product* in 1931 (Dodge, 1969a, p. 87) and the book was edited by W. Edwards Deming (Aguayo, 1990, p. 51). Shewhart started lecturing on the use of statistics within the field of quality. In 1935 Egon Pearson also started lecturing in England on the use of statistics for quality and Shewhart's 1938 lectures at the U.S. Department of Agriculture's Graduate School became the basis for Shewhart's 1939 book *Statistics from the viewpoint of quality control* (Dodge, 1969a, p.87).

Quality and the Second World War

Before the start of World War Two Shewhart advised L.N. Simon of the Ordnance Department to use statistical methods (Miranti, 2005, p. 67). The Ordnance Department used statistical methods at the Picatinny Arsenal and Aberdeen Proving Ground and found the methods to be useful. The Ordnance Department decided it must either train all suppliers in statistical process control or it must implement acceptance sampling. The Ordinance Department chose acceptance sampling because of the large amount of material that was needed in a short period of time. The Dodge-Romig sampling tables were ideal for reducing inspection costs in industry; however, the Ordnance Department needed something simple to use so Dodge and others from Bell Labs developed an acceptable quality level table (Dodge, 1969b, p.155 & 156). The acceptable quality level was "defined as the maximum value percent defective that the consumer would consider satisfactory as a process average for purposes of the acceptance sampling to be performed by the consumer”(Dodge,1969, p. 156). The producer's parts would be accepted most of the time if they met the acceptable quality level and more detailed inspections would be performed if the parts failed to meet the acceptable quality level (Dodge, 1969b, p. 156).

W. Edwards Deming recommended that Stanford University's statistics department teach statistical process control and Eugene L. Grant prepared a ten-day class that was later trimmed to eight days. Deming was the lead instructor and Grant handled administrative details and also taught classes. Grant organized a quality society in California in 1943 and this society eventually became a part of the American Society for Quality Control in 1946 (Struebing, 1996).

Grant went to Washington and convinced the War Production Board to organize training in statistical quality control. There was opposition to Grant at the War Production Board and one person even told Grant that he could send people to the training, but people in war industries were too busy for such pointless activities. Eventually, the War Production Board agreed to implement the training and Grant was placed in charge (Struebing, 1996, p.82).

Juran (2004) explains that the War Production Board assigned university statistics professors the task of training government contractors in the use of Shewhart’s control chart. The main affect of these classes was the rise of quality engineers and quality managers within factories as well as the start of quality departments within many manufacturing companies.

There were other breakthroughs in quality during the Second World War; however, most were related to inspection and sampling techniques. At the time, the emphasis was on technical solutions to quality problems and there was little worker involvement. The main objective was often to meet delivery schedules and quality came second to meeting delivery schedules (Stratton, 1996).

There was some progress in the use of statistics during the Second World War. A United States government report on industrial research mentioned how useful statistics were in the purchasing of munitions. The report goes on to say that "there was a day when in engineering circles, mathematicians were contentiously characterized as queer and incompetent. These days are over" (National Research Council, 1940, pp. 287 & 288). The report referred to Shewhart's *Statistical Methods from the Viewpoint of Quality Control* and the report quoted Western Electric company's manufacturing engineer Joseph M. Juran explaining that inspection both removes defective parts and alerts the manufacturer to the existence of a problem (National Research Council,1940, p. 288). A report from the National Academy of Sciences (1947, p. 3) explained that before World War II, statistical methods were not well known in industry outside of Bell Telephone; however, many companies quickly started using statistics for accepting or rejecting deliveries based on statistical sampling.

The report explains that the Office of Production Research and Development of the War Production Board started teaching statistical process control in statistical training classes for production people and engineers in 1943. Around 2000 people from over 800 companies attended the training classes and the report from the National Academy of Sciences was intended to be distributed to organizations that could teach statistics. Walter Shewhart was the chairman of the subcommittee on statistical quality control (National Academy of Sciences, 1947, p. 26).

Juran (1995) explains that many companies stopped using statistical process control after World

War II because the companies did not think it was economical. There was also a shortage of consumer goods at the end of the war and meeting delivery schedules took priority over quality. Some of the new quality engineers participated in quality planning, wrote quality reports, wrote procedure manuals and performed quality audits. Some companies created quality control departments run by quality control managers and the quality managers were in charge of the former inspection departments. Around this time quality departments started to get placed under management in the organizational diagrams. Quality professionals started to focus on the reliability of a product during its lifetime and the position of reliability engineer was created (Juran, 1995).

One of the Office of Production Research and Development of the War Production Board statistic instructors during World War II (Walton, 1986, p. 8) was a U.S. census employee named Dr. W. Edwards Deming. Like Juran and Shewhart (Butman, 1997), he worked at the Hawthorne plant, but only as a student worker during summer months (Walton, 1986, p. 6). Deming met Shewhart in the late 1930s and the two became acquaintances (Aguaya, 1990, p. 7). Gabor (1990) would eventually write a book calling Deming *The Man who Discovered Quality*.

Post-war Developments in Quality

In 1946 Preston Wescot, who had been one of the War Production Board statistical quality control instructors, got together with George D. Edwards of Bell Labs and eight other men and they formed the American Society for Quality Control (ASQC) (Klaus, 1998, p. 57). The Buffalo Society of Quality Engineers donated the journal *Industrial Quality Control* to the ASQC (ASQC History 1946-1966, 1966 p. 566). *Industrial Quality Control* eventually became the journal *Quality Progress* (Spichiger, 1996, p. 42) The society held its first annual convention in June 1947 and Shewhart was inducted as an honorary member and the society created the Shewhart Medal. George Deforest Edwards, who was Bell Labs' director of quality assurance, became the first president of the

ASQC (ASOQ History 1946-1966, 1966, p.566). The ASQC was formed by joining 17 different quality societies together; it eventually became the American Society for Quality. The new society originally had 253 founding members. The young society needed funds so members had the option of paying an additional fee in order to be considered a founding member. There were over 1,000 members by the end of 1946 (Spichiger, 1996).

According to Gabor (1990), U.S. industry had a seller's market after the end of the Second World War and the priority was quantity over quality. Many companies discontinued the use of statistical process control and even AT&T abandoned Shewhart's control chart during the 1950s. Business schools around this time also taught that increased quality was the equivalent of increased costs and this together with a seller's market lowered the quality standard in American industry (Gabor, 1990).

As American quality was declining during the post-war selling frenzy, Japan was struggling to rebuild after the devastation of World War II. Although the Japanese were capable of producing high quality war-machines, Japan was known in the West for low quality goods. Japan had very little natural resources; however, the Japanese realised that they needed to produce quality goods in order to have an export market (Juran, 2005g, p. 271).

In early 1946 (Fisher and Nair, 2009) General MacArthur asked a radio engineer named Homer Sarasohn to go to Japan to help rebuild Japan's war-torn radio industry. MacArthur wanted to broadcast to Japanese households and the Japanese industry was not capable of producing radio receivers because the factories had been bombed and upper managers were killed or jailed. Lower level managers needed to move up into higher management positions and they lacked decision making experience. Charles Protzman arrived to help Sarasohn in 1948 and they prepared a textbook on *The Principles of Industrial Management* that they used to teach the Japanese about manufacturing and mass-production. The textbook contained a section on quality control and some Americans objected to it because they feared that it would make Japan too competitive. MacArthur ordered the training to be conducted and the highest managers in Japan attended the training (Fisher and Nair, 2009).

Deming and Juran go to Japan

In 1950 Sarahson invited Shewhart to teach statistical process control in Japan; however, Shewhart declined the invitation so Sarahson invited Deming in place of Shewhart. Deming introduced the Japanese to Juran's 1951 book *Quality Control Handbook* and the Japanese eventually invited Juran to Japan to teach them about quality (Fisher and Nair, 2009). Deming was invited to lecture on statistical quality control by the Union of Japanese Scientists and Engineers three years after the JUSE started working with quality control (Kolesar, 1994, p.11).

Many people give Juran and Deming credit for improving the quality of products produced in Japan; however, Juran (2005g, p. 271) believes that the Japanese quality revolution was the most important thing to happen after World War II and he thought it would have happened even if Juran and Deming had not gone to Japan.

During his lectures Deming went beyond just teaching statistics and explained the Deming Cycle to the Japanese. Deming always called the Deming Cycle the Shewhart Cycle because it was originally thought up by Walter Shewhart, but it is known today as the Deming Cycle. The Deming Cycle is the concept of plan-do-check-act. These four steps should be started at the design phase of a new product and repeated throughout the life of the product. Plan-do-check-act is used so that the customer’s wants and needs are considered during the design phase. Gabor (1990) explains that General Motors used to design a vehicle and then rely on sales pitches and advertising to sell it. In comparison, a company using plan-do-check-act will study what the customers really want and design a product that meets these needs. Using plan-do-check-act helped the Japanese to build products that were what the customers wanted (Gabor, 1990).

Deming places the responsibility for quality on management's shoulders. Deming explains that some managers believe that quality is the responsibility of the workers and quality inspectors, but management is responsible for quality and the workers "can only try to do their jobs" (Deming. 1994, p. 16). Deming counters the argument that workers need to work harder to protect their jobs by explaining that he knew of an efficient company with a high level of quality and the company went out of business because it was producing a product that customers no longer wanted (Deming,1994).

Deciding what to produce is management's responsibility, not the workers (Deming, 1994). Deming explains that "job security and jobs are dependent on management's foresight to design product and services that will entice customers and build a market" (Deming, 1994, p. 18). Regarding American management, Deming is quoted as saying, "Export anything except American management. At least not to friendly nations" (Aguayo, 1990, p. 28). Although his specialty is statistics, Deming is very opinionated on how to run a company, as well as how not to run a company. According to Deming, "real profits are generated by loyal customers-not just satisfied customers" (Aguayo, 1990, p. 8).

Deming recommends what he calls a "system of profound knowledge" (Aguyo, 1990, p. 93). There are four interrelated components to a system of profound knowledge: "appreciation for a system, knowledge about variation, theory of knowledge" and "psychology" (Aguyo, 1990, p. 93). A system is composed of interdependent units working together towards a common goal. Deming uses an orchestra as an example of a system because all individual parts must function together with the other parts. The individual parts of a system must work towards the common goal and not subvert the goal in favor of self-interest (Aguyo, 1990).

Another part of Deming's system of profound knowledge is an understanding of variation. A manager and people in general should understand the concept of averages. Some people are above average and some are below. Sometimes the people can change places, but there will always be somebody below average because that's how averages work. Deming also expects managers to understand the difference between a stable system and an unstable system. For example, if workers are producing defects in a stable system, then Deming claims that no amount of encouragement, offers of rewards or threats will get them to perform better. If the system is unstable, then there is an opportunity to affect the worker's performance only if the problem is within the worker's control (Aguyo, 1990, p. 100).

Deming frequently lists fourteen points that he believes management must follow. Deming sees management's implementation of his fourteen points as "a signal that management intends to stay in business and aim to protect investors and jobs" (Deming, 1989, p. 23).

The first rule is "create a consistency of purpose for improvement of product and service" (Deming, 1989, p. 24). The management of a company must be both concerned with the present and the future and should not sacrifice the future of the company for a short-term profit (Deming, 1989, p. 25 &2 6). Point number two is "adopt the new philosophy" (Deming, 1989, p. 26). By this Deming means that America no longer has a market that will buy anything produced because there is no other supplier available and management must adapt to the new times in which we live (Deming, 1989, p. 28).

Deming's third point is "cease dependence on mass inspection" (Deming, 1989, p. 28) and point four is "end the practice of awarding business on the basis of price tag alone" (Deming, 1989, p. 31). These two mean that mass inspection is an expensive and unreliable way to achieve product quality and it is better to develop good relationships with suppliers than to purchase based purely on price tag (Deming, 1989, p. 31). Point five is "improve consistently and forever the system of production and service” (Deming, 1989, p. 49).

Point six is “institute training” (Deming, 1989, p. 52) and this is highly relevant for working in a knowledge society. Point number seven is “adopt and institute leadership” (Deming, 1989, p. 54). Deming demands that managers know and understand the jobs under them and he requires managers who are able to inform upper management when there are things inside its control, such as unclear quality requirements (Deming, 1989, p. 54). The eighth point is “drive out fear” (Deming, 1989, p. 59) and he gives the example of a supervisor who knows that he must shut a production line down for maintenance, but keeps it running until it is damaged because of fear of not meeting a quota (Deming, 1989, p. 61). Point number nine is “break down barriers between staff areas” (Deming, 1989, p. 62). For example, the service department of one company frequently needed to rework a machine at the customer’s location because of a design problem, but it did not tell any other department so manufacturing continued to produce the machine in a way that required frequent service calls (Deming, 1989, p. 63).

The tenth point is “eliminate slogans” (Deming, 1989, p. 65) and Deming’s eleventh point is “eliminate numerical quotas” (Deming, 1989, p. 70). Deming’s twelfth point is "remove barriers that rob people of pride of workmanship" (Deming, 1989, p. 77). Point number thirteen is “encourage education and self-improvement for everyone” (Deming, 1989, p. 86). Deming’s fourteenth and final point is “take action to accomplish the transformation” (Deming, 1989, p. 86). This means that management should take action to implement the other thirteen points and Deming recommends using the plan-do-check-act cycle to accomplish this (Deming, 1989, p. 88).

At the tenth anniversary of the Deming Prize, Deming explained that American manufactures could stop worrying about competing with Japan and start producing better quality at lower prices if they switched from spending time and effort on boosting tariffs to concentrating on producing quality goods (Gabor, 1990, p. 149).

Ishikawa and Quality Circles

Deming Prize winner Karou Ishikawa (1985) explains that if quality control places an emphasis only on inspection, then only one department with in a company is involved and

> all they need to do is stand at the exit and guard it in such a way as to prevent defect products from being shipped. If a quality control program emphasizes the manufacturing process, however, involvement is extended to assembly lines, to subcontractors, and to the divisions of purchasing, production engineering, and marketing. (pp. 20-21)

Watson (2004) refers to Ishikawa as "the prime mover of quality in Japan" (p. 54) and "the father of quality circles" (p. 55). Karou Ishikawa was the son of Ichiro Ishikawa (Kondo, 1994) who was the first president of the Japan Federation of Economic Organization. Karou Ishikawa worked as a production engineer at Nissan Liquid Fuel Company until 1947 when he was asked to take a position as a professor at the University of Tokyo. He joined the Quality Control Research Group of the Union of Japanese Scientists and Engineers in 1949 and he spent parts of 1950 researching quality at various companies. Ishikawa believed that plan-do-check-act was the most important part of quality improvement and he believed that processes needed to be controlled to control product quality (Watson, 2004).

Ishikawa (1985) explained that all divisions with within a company should be involved in quality control and this is how one meets the needs of the customer. Ishikawa (1985) also explained that workers and foremen must be good at what they do for quality control to function; but it was not easy to educate workers and foreman in Japan in the late 1950s because there were too many of them and they were too spread out. To address this problem, the Japan Broadcasting Corporation aired programs aimed at introducing quality control to workers and their supervisors. Supervisors asked for their own quality-related journal in 1962 and Ishikawa (1985) worried that many supervisors would not read the journal so he advocated quality circles where those who read the journals can talk to those who didn’t.

Ishikawa (1985) stated that quality circles are intended to contribute to the improvement and development of the company, respect humanity, build a happy workplace and fully utilize human potential. Quality circles are to be organized on a voluntary basis from the bottom up and not top down and they are a form of democratic management. There may be an improvement in working conditions because of quality circles, but the improved working conditions are just a by-product of quality circles and not the actual objective.

Juran (2005c) gives an example of a Japanese quality circle that he encountered in 1966. Three ladies as young as 18 years old presented the results of their quality circle at a conference. The three were production workers and they determined which assembly mistakes occurred the most. They found and implemented solutions to the problems that they identified. For example, an operation was typically forgotten so they had a jig made that depended upon the forgotten parts for it to function correctly so that the assembly operation could not be finished if the parts were missing. Without the help of engineers or management, the three production workers lowered the defect rate from 2.2 percent to 0.6 percent. Juran (2005c) claims that judging quality circles only in terms of reductions in the defect rate is leaving out one of the main benefits of quality circles as practised in Japan: increased morale within the workforce because of increased employee participation (p. 125).

A group of Japanese visited America in 1968 and explained the benefits of quality circles; however, American managers were experienced in Taylorism so they had low expectations of the workers and quality circles got off to a slow start in America. Lockheed Missiles and Space Company studied quality circles in 1973 and it launched a successful quality circle program that influenced other companies such as Harley Davidson and General Motors. Quality circles had spread to England by 1977 and Asia by 1980 (Robinson, 1982).

Robinson (1982) gives the example of bottle inspectors who formed what he considered to be a successful quality circle. The bottle inspectors inspected bottles for foreign contaminants and the bottle inspectors would be moved to other tasks when the machines broke down. The machines often broke down so the quality circle studied the situation and recommended the creation of work stations for manual inspections that could be performed when the machines broke down. The benefits were determined to be over 400,000 British Pounds per year.

In 1967 Juran (2005c) was wondering if quality circles could function outside of Japan. The answer turned out to be “yes.” America had quality circles by the mid 1970s and the companies reported millions of dollars in savings. Many business magazines wrote about how successful quality circles were and other companies became interested in quality circles (Cole, 1999, p. 93). In the late seventies and early eighties American management was often blaming workers for being lazy and causing poor quality. The managers saw quality circles as a chance to let workers fix quality problems. Many American managers went to Japan to witness first-hand the wonder of quality circles, but they failed to notice that quality circles were just part of a bigger picture. Japanese companies with quality circles had engineers and managers working on quality problems and problem prevention at a higher level within the company and the American managers failed to notice this. Quality circles did produce spectacular results, but they were part of an overall system and not the single cause of quality in Japanese products (Juran, 2004).

The American use of quality circles increased dramatically in the early 1980s and then quickly declined sharply, although some were still going into the 1990s after the quality circle craze had ended in failure. The quality circles that did survive did so in a changed form (Juran, 2004).

Deming (1982) states that quality circles should be spontaneous and appreciated by management. He goes on to state that quality circles can't accomplish anything unless they are supported by management and he thinks this seldom happens. Deming also considered the positive results of quality circles to be the result of management showing interest in workers. Deming did not like quality circles and refers to quality circles as a "raging disease" to show his dislike for quality circles (p. 109). Crawford-Mason and Dobyns (1991) think that quality circles are a good thing, but management is often behind them only because quality circles place the burden of quality improvement upon the workers. However, management must support the quality circles for them to function.

Attempting to Achieve Zero Defects

While Japan was organizing quality circles, America started the zero defects movement (Robson, 1982, p.23) based on the writings of the quality guru Phil Crosby. Crosby (1980) explains that mistakes are caused by lack of knowledge and lack of attention. He thinks that lack of knowledge can be corrected through proven methods; however, lack of attention requires the person to correct himself or herself by reappraising morals and values because lack of attention is an attitude problem. Crosby thinks that simply deciding to start paying attention is a major step on the way to achieving a defect rate of zero defects. Crosby (1980) also says that management must inform workers of the need for a zero defects mentality and he claims that 85% of all problems can be solved by the immediate supervisor and of the remaining 15%, 13% can be solved within two levels of supervisors or departments.

Ishikawa (1985) observed the zero defect movement first-hand in 1965 and he predicted that it would fail because it "was a movement without tools" and "it became a movement of mere will" that "emphasized that if everybody did his best there would be no defects" (Ishikawa, 1985, p. 151). Ishikawa goes onto say that the United States is heavily influenced by Taylorisim where "workers are regarded as machines” and “their humanity is ignored” (Ishikawa, 1985, p. 151).

Juran (2005d) argued against zero defects programs as early as 1966 when he did a study that showed that zero defects programs were primarily in defence and aerospace companies. He believed that the zero defects programs were typically implemented at the request of the customer, which was the U.S. government. Juran visited companies that claimed to have been very successful in reducing defects through the use of zero defects programs and his visits failed to find any evidence of positive results (Juran, 2005d, p. 109).

In the early 1960s Shingeo Shingo (1986) provided a method of dropping the defect rate down to close to zero using his successive check method. This method calls for workers to inspect each item they receive when they receive it. By this method they could check the work of the person in the previous operation and mistakes would be caught much faster than through the use of inspections at the end of the manufacturing process or through statistical process control at the end of the manufacturing process. He gives the example of one television manufacturing company with a fifteen percent defect rate. The company reduced the defect rate to six and a half percent through the use of quality circles and statistical process control. The defect rate dropped to 0.016 % using Shingo’s successive check method.

Shingo (1986) explains that people forget things and urging production workers to simply pay more attention is “as good as asking workers to become god” (Shingo, 1986, p. 14). Shingo (1986) recommends poke yoke, which means mistake-proofing, for eliminating mistakes and attaining zero defects. In 1961 Shingo (1986) was observing a manufacturing operation at Yamada Electric and he noticed a worker forgetting to install a spring in a switch. Shingo modified the operation so that the worker would take the required springs out of a box and place them in a holder before they were assembled into the switch. If any springs were still in the holder after the switch was assembled, the worker would have a signal that a spring had been forgotten. A comparable fool-proofing solution was used for a different problem at Arakawa Auto Body and the worker cried because she was so embarrassed by her mistakes and the name fool-proofing. Shingo used the name mistake-proofing to avoid implying that the workers were fools.

Juran (2005a) wrote an article in which he made the claim that most quality-related mistakes are management controllable and the remaining worker errors are often caused by situations such as lack of skill or conflicting standards. Juran (2005a) also reviewed the state of quality in different parts of the world and he found that American companies often had a quality department, but quality-related training was lacking for supervisors and it was often difficult for the quality professionals to work with other departments. Juran (2005f) thinks that Taylorism made sense at a time when workers and line supervisors did not have the skills or education to be making decisions; but now planning and performing should be recombined in America. He found that Western European companies often had line supervisors with more authority than American supervisors and workers that had more skills than American workers. Juran (2005f) reports that Eastern European quality was hampered by central planning that protected the companies from the demands of the market and a lack of competition, which made it difficult to solve quality-related problems. Juran (2005a) stated that Japan's quality revolution had considerable promise of taking Japan to world leadership in quality.

Quality and Lean Manufacturing

One of the inventors of lean, if such a concept could be called an invention, was Taiichi Ohno (1988) of the Toyota Motor Corporation. He says that in the 1930s he heard that it took nine Japanese workers to do the same work as one American worker. He started thinking about the difference and concluded that there must have been a lot of waste in the way manufacturing was done in Japan. This idea was the beginning of the Toyota Production System**,** which is often called lean manufacturing

(Roos, Jones, and Womack, 1990).

The next step in the genesis of lean manufacturing was Toyota Motor Corporation’s Diiji Toyoda's 1959 trip to the Ford Motor Company's Rogue plant in Detroit. He observed that the plant could produce 7,000 vehicles in a day at a time when Toyota Motor Corporation had only produced 2,685 vehicles in thirteen years. Toyoda studied the Ford plant and wrote to Japan to say that “there were some possibilities for improvement” (Roos, Jones, and Womack, 1990).

Roos et al. (1990) report that Taiichi Ohno was the genius who implemented lean manufacturing at the Toyota Motor Corporation. He started with stamping operations, which typically required a day for an expert to change the dies. Companies like Ford used many large and expensive dedicated dies that performed only one operation to reduce the need for die changes. Toyota did not have the economies of scale for so many dedicated dies so Ohno designed new dies that could be quickly changed by production workers. Ohno also realized that producing many small batches of stamped parts was cheaper than producing more parts than were needed. This led to reduced inventories and resulted in mistakes being caught much faster because defective parts can accumulate in inventory when thousands of parts are produced and stored before use.

In 1969 it was taking Toyota four hours to change dies that Volkswagen could change in two hours. Ohno wanted Shingeo Shingo to find a way for Toyota to change dies faster than Volkswagen. Shingeo Shingo (1987) reduced Toyota’s die change time to an hour and a half; however, Shingeo eventually got the die changing time down to three-minutes.

Ohno could not just implement his new manufacturing method and expect it to work. Lean requires an intelligent workforce that is willing to use initiative if a problem is detected. Mass-production workers typically fail to take initiative and forward information and this would not work in a lean system (Roos et al., 1990, p. 53).

Ohno could not force lean on the workers at Toyota and management decided that they must fire a quarter of the work force because of economic conditions. The workers took over the plant and management had to battle a strong union. A compromise was reached: the president of Toyota would take responsibility for the company's troubles and step down from his position and a quarter of the work force would be terminated. The remaining workers received guaranties of lifetime employment and pay was to be determined by seniority and not by type of job. Employees would also receive a bonus based on the company's profitability (Roos et al., 1990).

Ohno realized that workers had become like machinery only in that they had become a fixed cost. This meant that the company must hold onto them in bad economic times, but it also meant that the company could safely train them without worrying that they would leave and take their skills and training with them. Workers in a traditional manufacturing plant perform a few very limited tasks and have no say in what they do. Ohno organized his people into teams that decided how their tasks would be performed and they even performed housekeeping and repairs, tasks which are handled by different departments in traditional manufacturing plants. This resulted in lower labor costs (Roos et al., 1990).

American industry thought that Japan's competitive advantage was in robots and low wages as well as support from the Japanese government (Roos et al., 1990, p. 236). In 1980 Ford Motor Company finally realized something was going on in Japan so members of Ford went to visit a Japanese assembly plant to see what was going on. The Ford people observed that Mazda could assemble a car comparable to theirs with 60 percent of the effort and far less quality problems (Roos et al., 1990, p. 237).

Chrysler spent part of the 1980s being supported by the United States government and it failed to implement lean methods. Ford and General Motors were both in severe financial trouble and they used lean methods to help save themselves. Ford learned about lean during its visit to Japan and

General Motors learned because of its NUMMI plant, which was a joint venture with Toyota (Roos et al., 1990, p. 238).

Japan was successful in launching North American transplants during the 1980s, but Japanese companies preferred to start from scratch because they did not think they could fix traditional mass production plants. The NUMMI plant was the only exception and it had been closed by General Motors two years prior to it becoming a joint venture with the Japanese (Roos et al., 1990, p. 251).

Dertouzos, Lester and Solow (1990) say that in 1990 NUMMI was comparable to Japanese plants in productivity and quality in spite of using American workers. NUMMI and other plants like it showed that American workers were not to blame for America's quality crisis during the 1980s. General Motors attempted to implement NUMMI-like lean methods at a plant in Van Nuys, California and failed because General Motors did not implement the job security that should go with lean manufacturing (Dertouzos et al. 1990, p. 137). NUMMI was producing 50% more vehicles than a comparable General Motors plant and it had the highest quality of any General Motors plants. General Motors management expected to find high technology at NUMMI, but NUMMI was using old machines and had replaced new machines that General Motors had installed with older machines (Aguayo. 1990, p. 49).

Head (2005) is critical of lean manufacturing based on his short visits to Nissan and Honda. He believes that workers are still required to be parts of the machines that they operate and he complains of parts being designed for easy assembly to make production work easier and faster, which results in less work for the workers to do. Head also claims that lean manufacturing is a new version of scientific management and scientific management diminishes quality of life for workers. Head bases his information on two visits to automotive assembly plants and data from a report on productivity. Head failed to present evidence such as a survey explaining that many workers dislike working in a lean environment. Head (2005) accuses lean manufacturers of attempting to reduce the number of skilled workers used, but the inventors of lean manufacturing specifically called for a skilled and educated workforce (Roos, et al., 1990, p. 54 & 55).

Beginning of the Quality Crisis

American automobile quality could not compete with Japanese quality in the 1970s and early 1980s. Automotive components are designed with a tolerance range and even when American manufacturers were producing parts in specification, they could not compete with Japanese parts. For example, Ford Motor Company was producing transmissions and ordering the exact same transmission from Japan. The American transmissions were failing far more often than the Japanese transmissions so Ford engineers disassembled Ford and Japanese made transmissions to determine what the difference was. The Ford made transmissions were all within the specification limits, but the measurements were all at different locations within the tolerance range. The Japanese transmissions were built with the exact same sizes which eliminated variability and resulted in a better transmission (Aguayo, 1990).

Automobiles were not the only industry where America had trouble competing with the Japanese in the 1970s and early 1980s. The quality of American consumer goods was awful in comparison to Japanese producers' products and many American consumers were buying Japanese products, resulting in American manufacturing companies losing market share and workers losing jobs (Juran, 2005g, p. 271).

The American television industry accused Japan of using low wages and government subsidies to help Japanese television manufactures and Zenith Radio Corporation filed a dumping petition against Japan in the 1970s. However, Japan was using lean manufacturing methods to produce televisions and this helped to produce higher quality products at lower prices (Cole, 1990). Although lean manufacturing is not the same as quality assurance, it does contribute to quality. For example, defective parts are detected faster because the parts are used soon after they are produced. In the mid 1970s the failure rate for American televisions was five times higher than the failure rate for Japanese televisions. Most consumers don't purchase televisions on a regular basis, so they may not have realized the quality difference between Japanese and American televisions. However, bulk buyers such as hotel chains did notice the difference (Juran, 2004, p. 70). The American television manufactures blamed labor costs for the competitiveness problems. Around one third of the American workers involved in producing televisions lost their jobs (Cole, 1990, p. 50).

America Discovers Quality and Quality Gurus

Philip Crosby published *Quality is Free* in 1979 and this book made managers aware of a need for quality (Cole, 1999, p. 86). Crosby focused on managers and had very little involvement with employees. His involvement with employees consisted of telling the employees to stop making mistakes; however, he offered little in the way of methods and most of the quality programs that were based on him failed after a few years. In spite of this, Cole (1999) credits Crosby with getting managers to show an initial interest in quality (p. 88).

American industry received a wake-up call on an evening in 1980 when the documentary *If Japan Can, Why Can't We?* aired on NBC. The documentary was made by Lloyd Dobyns and Clare Crawford-Mason and it introduced American executives to Dr. W. Edwards Deming and Japanese quality (Juran, 2004, p. 304). Juran predicted that Japan would lead the world in quality. By 1980 Deming and Juran's predictions had come true and Japan had earned a reputation for quality (Juran, 2005b, p. 250). American manufactures were still producing like they were in a seller's market, but the situation had changed and the documentary let them know that the situation had changed and they would have to change how they did business (Juran, 2005g, p. 272).

The video documentary *If Japan Can, Why Can't We?* was the tipping point that launched

American industry’s interest in quality; however Juran thinks that the documentary *If Japan Can, Why Can’t We?* set the quality movement back by five years and he disagrees with the credit it gives Deming and him for bringing quality to Japan (Butman, 1997, p. 168).

There are men known in the field of quality as gurus. They are not the only ones who advanced the field of quality, but they are the most famous. There are other important people who helped to pave the way for modern quality management, but the gurus are the most famous (Phillips-Donaldson, 2004). The gurus are the Americans W. Edwards Deming, Joseph Juran, Armond Feigenbaum and Phil Crosby (Hoyer and Hoyer, 2001). Also important are the Japanese quality practitioners Karou Ishikawa and Inichi Taguchi (p. 81) and the American Walter Shewhar; however, Shewhart is unknown outside of the field of quality (Crawford-Mason, Dobyns, 1991).

Although Deming has many followers (Gabor, 1990, p. 30), Deming was not the only one responsible for producing high quality parts. Juran (2004) and Feigenbaum (1983) provide guidance on how to implement quality. Ishikawa (1985) and Taguchi (Ryan, 1988) also provided tools and methods for quality professionals. Crawford-Mason and Dobyns (1991) describe the different gurus’ methods by quoting Joseph Oberle, “You can send your top managers to Crosby's college, order Juran's videotapes and materials from his institute or join a waiting list to pay Deming to tell you, in person, what a fool you've been” (p.71). Juran accuses Deming of thinking that statistics alone can solve quality problems and there was no reason to have total quality control because statistical quality control was already “total” (Juran, 2004, p. 303).

Another important person in the field of quality is Genichi Taguchi. He created the Taguchi Loss Function. The Taguchi Loss Function is an attempt to quantify the loss that results when a part is within its tolerance range, but not directly on the planned target. Producing a part that deviates from the planed target measurement results in a loss to the producer and the purchaser of the part even if the part was within tolerance (Ryan, 1988).

Each of the gurus has a different method and they don't necessarily always agree with each other. One example of the disagreement between the gurus was when Juran (2004) claimed that Deming was not as influential in Japan as many people believe and Deming was deluded in thinking that he had so much influence on Japanese quality.

An example of the guru's' attitudes towards each other is Crosby's concept of zero defects, which is basically doing things right the first time. Deming makes fun of it by sarcastically asking, "How about do it right the next time? Makes just as much sense" (Juran, 2004, p. 68). Crosby describes Taguchi as an OK person, but thinks that one must have a doctorate in math or economics to understand Taguchi and he thinks that most American quality professionals can't understand Taguchi, but think that "if its incomprehensible in Japanese, it must be good for you" (Juran, 2004, p. 83). Crosby (1999) also claims that Ishikawa is "the real father of quality in Japan" (p. 16). He describes Deming as being an expert in statistics and Juran as being an expert in quality control. Crosby (1999) reports that he was dealing with quality management and he found the works of the others to be irrelevant to him (p. 207).

Just as Deming (1989) has 14 points, Crosby (1984) has 14 steps for quality improvement. The first step is for the management of the company to write a quality policy and the CEO of the company should make frequent speeches regarding the need for quality. An improvement teams needs to be formed and staffed by a cross-functional team with enough authority to push things through. Measurements such as throughput should be made and Crosby thinks that workers will be able to measure themselves once they know what is needed (pp. 101-109).

Crosby (1984) and Feigenbaum (1983) both say that the costs of quality must be determined. Crosby's (1984) fifth step is quality awareness and he recommends the use of posters such as one that says “Do It Right the First Time” (p. 110 & 111), which is the opposite of Deming's (1989) tenth point, which was “eliminate slogans” (p. 65). Crosby's (1984) sixth step is to implement corrective actions that address the true root cause of non-conformities. Crosby (1984) recommends planning for zero defects and he thinks that somebody should be present to represent the local city to show people how serious the company is. The company should then send the workers to approximately 30 hours of training to teach the workers about the need for quality.

The ninth step on Crosby's (1984) list is to have a zero defects day and he thinks that it will be a day that many workers remember forever. Goal setting is another step and it is followed by removing the causes of errors and then recognizing employees for their contributions. Crosby (1984) believes that “there is gratification in giving out trinkets and certificates that makes everybody want to do it” (pp. 118 & 119). A quality council should be formed to bring quality professionals together and the entire process should be repeated (Crosby, 1984, p.119).

Juran (2005e) has three points which he calls “the concept of the quality trilogy” (p. 254.) However, the Juran Institute asked him to rename his concept “the Juran trilogy” (Juran, 2005e, p.254). The Juran trilogy calls for quality planning, control and improvement. Quality planning requires identifying internal and external customers, determining the needs of the customer, developing products that meet the customer's needs at minimum cost and developing a process that is capable of producing the needed features. Quality control requires determining what needs to be controlled and how to control it, finding units for measuring what must be controlled and comparing the results to the expected results and taking corrective actions when there is a deviation. Quality improvement is determining what needs improving and how to improve it as well as finding causes and correcting them.

The increased interest in quality during the 1980s (Juran, 2004) also has an effect on the

American Society for Quality Control (ASQC). The ASQC only had 32,000 members at the end of the 1970s. Managers viewed the society as an organization for low-level technical people. The majority of members were in the manufacturing sector and few were in positions higher than supervisor or engineer. By the end of the 1990s service sector membership had grown greatly and many of the people in the ASQC were in high level management positions. The papers presented at conferences were all technical in the early 1980s and by the middle of the 1990s around half of the papers presented at conferences were management oriented. The ASQC changed its name to the American Society for Quality (ASQ). The ASQ trains quality professionals and spreads the news of new ideas in quality improvement (Cole, 1999), such as six sigma (Carnel, 2007, p. 67).

Quality and Six Sigma

Gryna (2001) explains that six sigma "is a collection of managerial and statistical concepts and techniques that focus on reducing variation in processes and preventing defects in product" (p. 57). Gryna (2001) then goes on to explain that a process that is capable of operating at a six sigma level only produces an average of 3.4 defects per million units. Six sigma methods are used to identify and control the variables that can have an effect on the output of a process.

Feigenbaum was interviewed by Kubiak (2005) and during the interview Feigenbaum explained that General Electric built a quality system around statistical quality control and this eventually became total quality management. Feigenbaum told Kubiak that Bill Smith created six sigma when he was asked to find a way to use statistical quality control in non-manufacturing related areas such as banking. Smith then moved to Motorola and there Smith turned statistical quality control into six sigma under the leadership of the Motorola CEO Bob Galvin.

A former Motorola employee named Mike Carnell (2007) explains that Motorola developed six sigma in the 1980s as a survival strategy because it was having difficulties competing with Japanese.

There is some criticism that six sigma is only for manufacturing; however, under the leadership of CEO Robert Galvin Motorola implemented six sigma in human resources, purchasing and accounting as well as manufacturing. Six sigma at Motorola was just part of a larger transformation that included cooperation between departments, employee participation and financial improvement as well as cycle time reduction. Doganaksoy and Hahn (2000) report that six sigma has led to Motorola saving almost a billion dollars in three years as wells as a Malcom Baldridge Award. General Electric also saved over a billion dollars in one year using six sigma. Both companies' six sigma programs had the full support of top management. Six sigma was the reason that Motorola won the Malcolm Baldridge Award for quality and Motorola's winning of the award brought six sigma to the attention of other companies in 1988 (Folaron, 2003, p. 42).

The tools used in six sigma such as design of experiments, regression analysis, analysis of variance and statistical process control are themselves not new (Doganaksoy and Hahn, 2000). Ford Motor Company also uses six sigma to address quality issues. Patton (2001) gives the example of a Ford Mustang hood latch that does not close without excessive force. Ford determined that customers were unhappy with the efforts required to close the hood so they assigned a six sigma team to investigate the issue. The team studied vehicles on the production line to see where the problem was occurring and then simulated the conditions on a machine that could measure all the variables. They determined the root cause was excessive variation and experimented until they found a latch angle that would eliminate the problem. They estimate a cost savings of $283,000 a year. Customer satisfaction ratings also went up.

Six sigma is a quality tool that is starting to be used outside of manufacturing (Smith, 2005) The U.S. Navy is not a manufacturing company and it has successfully used six sigma to reduce costs and turnaround time in the repair of aircraft at a repair facility in San Diego. Using six sigma methods, the repair facility reduced aircraft refurbishing time from 192 days to 134 days and saved millions of dollars. The U.S government is even discussing the possibility of using six sigma in the fight against terrorism (Smith, 2005).

The city of Fort Wayne has started using six sigma and this has resulted in over $10 million in savings. The city's first six sigma project was intended to reduce the time it took to repair potholes in the streets. The original objective was to have all potholes repaired within 24 hours of it being reported and nobody thought it was possible except the mayor who had used six sigma in the past. The repair time was reduced to four hours from the time the pothole is reported to the time the repair crew is on the scene. The city also reduced the time it took to issue a permit from 50 days to 11 or 12 days (Smith, 2005).

Greg Brue (2005) was one of the people who were involved in General Electric's start with six sigma and he brought his expertise to the medical industry. He used the *Journal of the American Medical Association* to find data on avoidable hospital deaths. For example, 130 patients were admitted with esophageal cancer and of those nine died and seven of the deaths were preventable. Brue also used six sigma to address anemia. He determined that of 286 anemia patients, 65 were suffering from anemia caused by blood loss. These patients were being treated for the anemia with methods that dealt only with the symptoms, such as administering monthly blood transfusions to the patients. Brue complained that nobody was attempting to find out where the blood was going because the problem was being treated so he investigated and determined that 12 of these patients were losing blood because of hemorrhoids. A one-time surgery costing $7,000 solved the problem for the 12 patients and saved $39,000 per year in annual treatment costs. Brue goes onto state that related costs in poor quality of life are impossible to estimate (Brue, 2005).

American industry and the U.S. government were concerned about low quality in America and America's lack of competitiveness so multiple groups were formed to study the problem. One of the groups sent a report to the White House recommending a national quality award similar to Japan's Deming Prize and a month later a conference was held with President Reagan, Vice President Bush, Treasury Secretary Reagan and Commerce Secretary Malcolm Baldridge as speakers. The conference released a report calling for a national quality prize, which was to be a medal awarded annually by the president. A committee was formed to create the award and its members included people from the American Society for Quality Control, NASA, McDonnell Douglas Corporation, Ford Motor Company and other organizations (DeCarlo and Sterett, 1990).

Legislation for the award was written in 1986 and the bill was passed by the legislature in 1987; however, Malcom Baldridge died in a rodeo accident before it passed and it was renamed in his honor. The Malcom Baldridge Quality Award is managed by the National Institute of Standards and Technology. The Baldridge Award criteria are often used in self-assessments by companies even if the companies don't intend to apply for the award (DeCarlo and Sterett, 1990).

European countries started creating quality awards in 1991 and there were 19 different quality awards by 2001 so the European Foundation for Quality Management created the European Foundation for Quality Management Quality Award**,** which has some similarities to the Malcom Baldridge Quality Award. Toyota Motor Company created the Shingeo Award which is named after Shigeo Shingo and is administered by Utah State University. The Shingeo Award is awarded for the use of just-in-time methods and quality and process improvement (Mouradin, 2002).

Quality awards are not just used in America, Europe and Japan. For example the King Abdullah II Award for Excellence is a Jordanian quality award that the king of Jordan presents to companies for excellence in quality. The award requirements serve as a guide for excellence and the candidate companies all receive performance feedback from the award examiners and the winners may publish their winning of the award (Abu-Hamatteh, Al-Azab and El-Amyan, 2003, p. 649).

The Malcom Baldridge Quality Award was created in the late 1980s (DeCarlo and Sterett, 1990, p. 22), which is around the time that the ISO quality standard was released (Mourdain, 2002, p. 348). The first industrial standards organizations were formed in Great Britain in 1901 and many countries started to use national standards organizations by 1930. The International Standards Organization (ISO) based in Geneva introduced the ISO 9000 quality standard, which was based on the older BS 5750 quality system standard. The ISO 9000 system was implemented in Europe to standardize quality systems across borders and to reduce the number of supplier visits required because the suppliers would have a quality system certified by a third party (Folaron, 2003). Folaron (2003) warns that

> the creation of ISO 9000 helped define many of the elements of sound quality practice, but it did not assure the product's goodness or fitness for use; it only addressed consistency in the process. For example, a company that sells cement life-jackets could be ISO 9000 certified. (p. 42)

General Motors, Ford and Chrysler created QS 9000 as an American automobile industry quality standard. The sub-suppliers requested a single standard because they were subject to different standards for each company to which they supplied parts. The automobile producers based QS9000 on ISO 9001 because of a rumor that they would need ISO certification to sell to Europe. The American automobile manufacturers did not copy ISO 9001 directly because it lacked elements that they wanted in the standard such as manufacturing capabilities and quality planning. The aerospace industry created AS9000 and telecommunications created TL9000 (Reid, 2000, p.115).

In Italy Fiat Auto and IVECO worked together with eighty-five suppliers to create AVSQ as an

Italian automobile industry quality standard and Renault, Peugeot and Citroen worked together with around 300 suppliers to create French automobile industry quality standard EAQF. BMW, Opel, Audi, Daimler Benz, Volkswagen and Ford Werke together with around five-hundred suppliers created VDA 6 as a German automobile industry quality standard (Reid, 2005. p. 33).

The ISO attempted to convince the automobile manufacturers to use the ISO 9001 quality standard due to the number of standards that had been created. ISO 9001 was found to be insufficient for the automobile industry so attempts were made to modify ISO 9001 for the automobile industry. The changes were not relevant to non-automobile industry companies so a new standard was created and released in 1998 under the name ISO TS16949 (Reid, 2000).

The Need for Quality Today

Quality guru Armond Feigenbaum (2009) thinks that quality management could help to lead American industry out of the current financial crisis. He advises companies to make improvements in product development and supplier quality, to recognize quality costs and leadership in management. He also recommends improvements in human resources and he advises against repeating older attempts at human resources improvements such as management lectures and motivational programs. He advises developing and encouraging employees and developing openness and trust within companies.

Feigebaum's (2009) advice is also applicable to other countries and the lessons of the other gurus should be revisited. The quality gurus helped Japan to rebuild its war-torn industries in the 1950s and they helped America to overcome the quality crisis of the 1980s; perhaps it is time for all companies to look to the lessons of the gurus to find a way out of the current financial crisis.

In 1994 an 89 year old Joseph Juran spoke at a convention for quality professionals and he explained that we are “living behind quality dikes” that protect us from our technology and service interruptions (Juran, 2004, p. 273).

Conclusion

Quality was originally concerned with ensuring that parts met specifications and quality was ensured through the use of inspections. Developments at Bell Labs led to the use of statistical quality control; however, during World War II the emphasis was on quality control using sampling tables to randomly sample parts. The era of quality control was followed by the era of quality assurance where preventative actions were taken to ensure that parts were produced according to specifications. The quality crisis of the 1980s and the use of standards such as the ISO 9000 standards for a quality system led to the modern era of quality management. In quality management, upper management is involved in quality and issues such as the wants and needs of the consumer. Processes are designed to ensure that products are produced consistently and correctly.

Quality assurance, quality control and quality management must be integrated and used together to ensure quality. Statistical process control can send a signal when a process is no longer producing parts in specification; but it does not matter if the parts are in specification if the wrong parts are being produced. Quality management provides the system that is used to ensure that such mistakes don't happen. Using quality management without quality assurance or quality control is also a mistake because defective parts could be produced even if the processes are functioning properly. For example, tool wear could result in parts being out of specification. The use of inspection as a part of quality control can still play a role in modern quality; inspection may be needed to control the manual assembly of unique products or in situations where there is a danger to life or limb in the event of a failure. However, use of inspection should not be confused with relying purely upon inspection because as Harold F. Dodge warns “you can not [sic] inspect quality into a product” (quoted in Deming, 1989, p. 29).

The ideal quality system is a system that uses quality management to define the processes that are used and to ensure that the company is producing what the customer wants and needs. Quality assurance is used to ensure that the production system is working properly and quality control ensures that the product is produced in accordance with standards. Quality assurance would be used for ensuring that all measuring devises are properly calibrated and for conducting product and process audits. An example of an integrated quality system would be a mass production company that uses quality management to determine what the customer needs and to ensure that there are clearly defined processes for producing the part. Statistical process control would be used to send a signal to machine operators when the parts are in danger of being out of specification and other quality control methods such as random sampling could be used to further verify the results of the production process. Quality management processes would require corrective actions to be taken based on the results of quality control and quality assurance.

Quality assurance, quality control and quality management are not standalone concepts: they are overlapping and complimentary tools for ensuring quality. Box (1995) states that

> The modern quality movement brings together ideas from, for example, systems analysis, operations research, problem solving, statistics, engineering, group dynamics, management science, human genetics and organizational development. The quality movement will, from time to time, undergo healthy changes and may even be called by different names. I am sure, however, that it is here to stay and can be of great benefit to all of us. (p.7)

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