

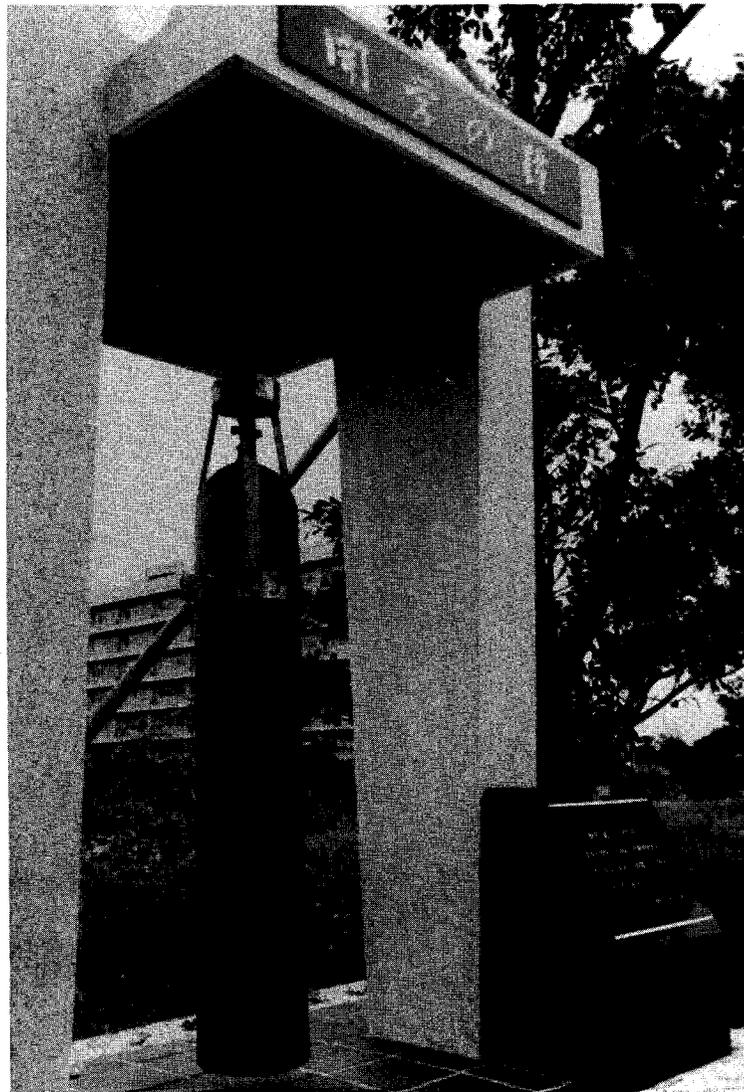
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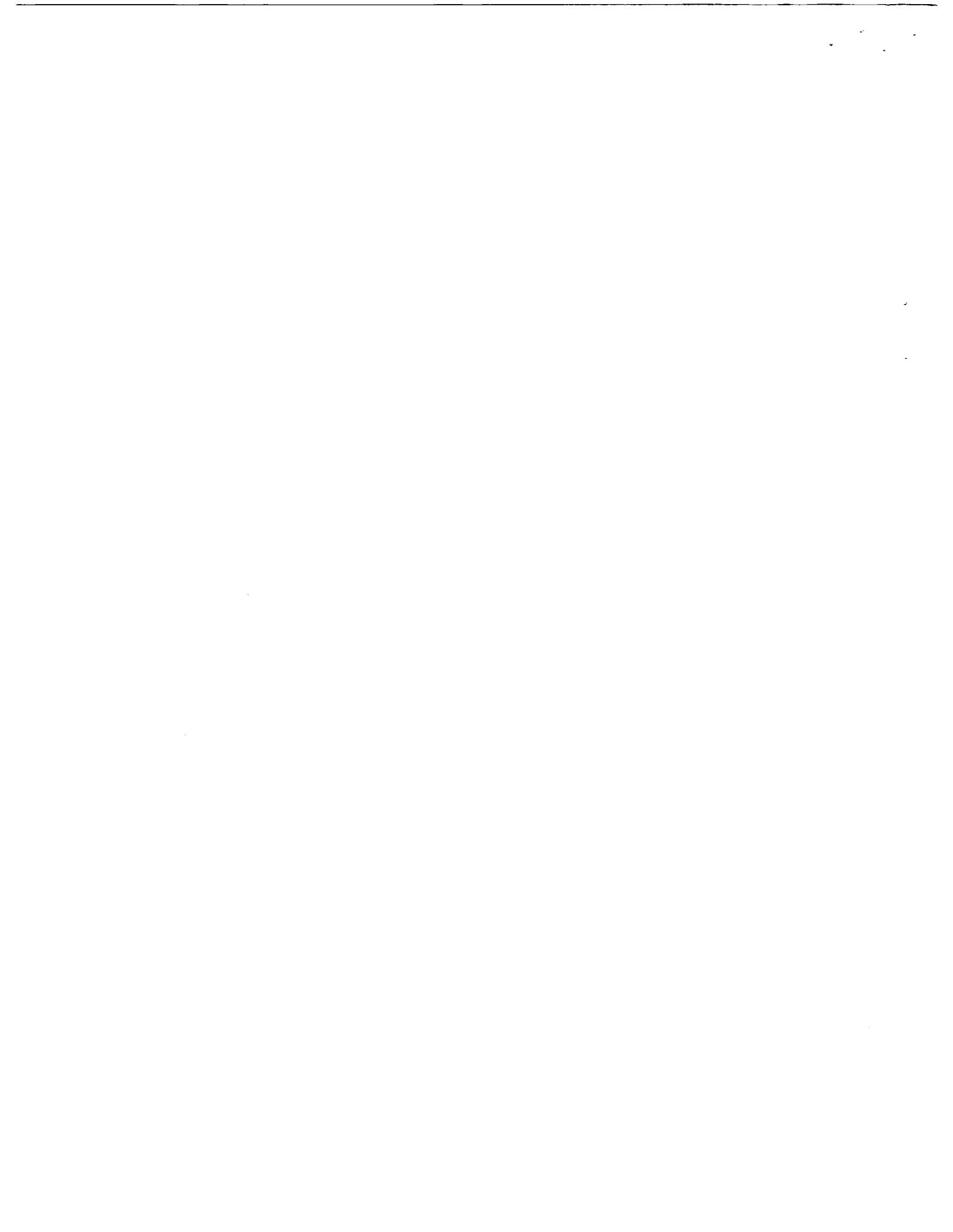


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STATISTICAL QUALITY CONTROL TECHNOLOGY IN JAPAN

K.O. Bowman, T.H. Hopp, R.N. Kacker, and R.J. Lundegard

From 17 May to 1 June 1989, a survey team organized by the National Institute of Standards and Technology visited Japan to assess research and application of statistical quality control technology. The team explored the philosophy and conduct of total quality control (TQC) in Japanese industries, government laboratories, and national agencies. The philosophy and practice of TQC in Japan is quite different from that of the U.S. industries. Our findings are similar to the findings from "R&M 2000 Variability Reduction Process Trip to Japan" (Ref 1).

INTRODUCTION

The purpose of this visit was to assess the latest research and application of statistical quality control technology for product and process design and for manufacture in Japan. We soon found that isolated statistical applications are a very small part of the overall scheme of their industrial operations. The governing concept is total quality control (TQC). Quality control in Japan means *Total Quality Control* with everyone committed from top management to the lowest level workers in all departments, including design, sales, promotion, and service departments.

TQC activities in Japan have intensified over the years, in particular, after oil crisis in 1975 and the rise of the yen in 1987. Each time, Japanese industries braced themselves for worse economic conditions to come and practiced more intense TQC. In both instances, their economy did not decline but grew to higher levels of quality and productivity. To improve and to keep the well oiled machinery of their economy continuously

running is becoming a national obsession; even the self-employed farmer talks about continuously improving processes for his products and harvest. The original idea of involving managers in quality control, based on measurement and analysis, was initiated in the United States during the 1942-1945 war effort. These ideas, originally expressed in a training manual written by the U.S. Army, were introduced to Japan by Dr. Deming in 1950. It was accepted by Japanese industrialists, and the concept has been expanded ever since. In the United States, management did not follow through on the success of the war effort. Although the use of quality technologies and supporting statistical methods in U.S. industries is now increasing, the concept of total quality control and the involvement of top management and the total work force in an integrated quality control team effort has not yet taken hold. Many U.S. leaders are convinced that the division of the total work force along specialist lines is the greatest barrier to progress.

QC ACTIVITIES IN JAPAN

National Research Laboratory of Metrology (NRLM) and Electrotechnical Laboratory (ETL) of the Japanese Agency of Industrial Science and Technology

Dr. Craig T. Van Degrift of the National Institute of Standards and Technology (NIST), Center for Basic Standards, Electricity Division, is currently a guest researcher at ETL. He joined us during the visit and explained the similarities between the work being carried out in NIST and ETL. NIST and NRLM/ETL work programs are very similar.

Dr. Hiroshi Yano, Director of the Mechanical Metrology Department, is one of the authorities on measurement control engineering in Japan. He is the foremost supporter and promoter in Japan of Dr. Genichi Taguchi's ideas. Taguchi's philosophy and approach to quality gained recognition in the United States after segments of AT&T, Ford Motor Company, and Xerox Corporation adopted some of his ideas. One purpose of our visit was to learn more of the Taguchi approach in Japan. We were told that the use of Taguchi's methods is concentrated in a few industries, particularly in firms located in Nagoya. Yano's laboratory is one of the places in Japan where these ideas are used.

Dr. Masayoshi Koike, Chief, Instrumentation Mathematics Section, of NRLM and his team demonstrated the use of the Taguchi approach to the design of computer and robot controlled plastic injection molding processes. A software system called CAMPS (computer aided measurement and process design and control system) supports planning and data analysis of statistically

planned experiments in process design patterned after Taguchi's ideas. This is an excellent example of a systems approach in quality technology research. A realistic systems problem is used to stimulate and focus efforts on those quality technologies that are particularly significant. To accomplish this a system test bed and a team approach involving engineers, statisticians, and computer specialists are required. The purpose of such research is to produce a methodology and software for configuring sensors and measurements for process control and optimization.

Several people we visited at NRLM stated that their goal was to become the premier standards laboratory in the world. They currently view NIST in that regard (a view that might be taken with a grain of salt, considering who we represented). The injection molding project was an example of government/industry cooperation. The equipment was donated by the equipment manufacturer, who also supplied a researcher to cooperate with the NRLM staff for a portion of the project. This arrangement, which appears to be an excellent way to transfer technology from laboratories to industry, appears not to be as widely practiced at NRLM as it is at NIST and other research laboratories in the United States.

At ETL we discussed with Dr. Yoshitane Akiyama, Director of the Technical Information Office, the range of research activities carried out at ETL. We also saw a variety of projects in robotics, machine vision, and electronic device research. The visit to the robotics and machine vision laboratory was somewhat disappointing, as the research we saw was several years old and had been reported in English-language journals as early as 1983. One of the more active areas at ETL used to

be their artificial intelligence and robotics software research efforts. The activity has apparently been much reduced since the fifth generation computer project was transferred to the Institute for New Generation Computer Technology (ICOT). In the areas of materials research and new electronic devices, however, it would appear that ETL is conducting world-class research. We saw an effort to develop a new voltage standard based on Josephson junctions that would provide a self-calibrating standard reference at relatively high voltages. The intent was to make voltage calibrations much easier and accessible to industry. As another example of their work, there was an announcement while we were in Japan that the group at the Tsukuba Laboratory complex working on laser research had developed the "Ashira system," which attained the highest laser beam intensities with one-sixth to one-seventh of the energy previously required.

Kanto Auto Works, Ltd.

Kanto Auto Works, Ltd., is a wholly owned subsidiary of Toyota Motor Company. It is located in Yokosuka not far from the U.S. Naval base. This factory assembles four different types of automobiles. Kanto Auto Works claims that this factory has the highest production record in the world for its size in space and in number of employees. (There are over 1,600 workers, about 150 managers, and about 70 engineers.) The working floor space is limited and very effectively utilized. To accomplish this, management maintains very tight control of materials delivery and handling. Just-in-time scheduling of all activities appears to be the norm rather than the exception.

The factory is highly automated. Four different car models are assembled concurrently on a single production line. Industrial

robots used on the line differentiate among types of automobiles based on a schedule broadcast from a central control system. People are used to load some of the machines, but most of the machines are integrated in the flow line and loaded automatically. The most highly staffed areas are in the assembly of the automobile interior seating and in the final inspection area.

A fully assembled car comes out of the plant every 1.5 minutes. The factory operates with a goal of zero defects: every car that comes off the assembly line is, in principle, defect free. Any production line worker has the authority to stop the line if quality problems are observed.

While production is at a very high level, there is a constant search for opportunities to improve operations. Kanto Auto Works is in the process of building a new factory for robotic assembly of car interiors (currently the most labor-intensive part of production). Unfortunately, we were not able to see the inside of the new factory, which is nearing completion. The manager of the plant told us that much of the design of the new plant is based on suggestions from plant workers participating in QC circles.

The robots used at Kanto Auto Works are very simple as compared to what we think of as a robot in the United States. The robots very seldom use sensors, and the programming is primarily of the pick-and-place variety. There is a strong emphasis on straightforward, low-technology approaches to keeping processes in control. Many processes have been equipped with simple, often mechanical, devices for error detection and, less frequently, error compensation. There are highly visible status indicator lights at every work cell that are used to attract the immediate attention of maintenance personnel when required. The Manager of

Production said that most of the robotic engineering is not done locally but rather by a corporate-wide engineering group. He predicted that unless they expand their local engineering staff, they will have problems in the near future in dealing with the increased number and sophistication of the robots they are planning to install.

One significant difference between Japanese and U.S. industries is the way in which the quality of incoming parts is controlled. Often, suppliers are members of the same conglomerate. Japanese industrialists do not like suppliers over whom they have no control. They prefer trusted subcontractors and often pay a premium cost to maintain a supplier relationship.

At the workplace, as we observed at Kanto Auto Works, workers take only two 10-minute work breaks, one in the morning and one in the afternoon; the lunch break is only 20 minutes.

One interesting aspect of TQC as practiced at Kanto Auto Works concerns the introduction of new products. The standing procedure when, for instance, a new carburetor system starts production is to train everyone who will be in any way involved with the production of that system, be it worker, engineer, or manager, to entirely assemble and explain the operation of that system. According to the Manager of Production, this policy has had a dramatic effect on the attitude of the production staff; they consider themselves all members of a team producing a carburetor, rather than individual workers concerned solely with their personal efforts.

There is no evidence of socializing on the job; every step has a purpose in the production process.

Union of Japanese Scientists and Engineers (JUSE)

We met with Mr. Junji Noguchi, Executive Director of JUSE. He has been with JUSE for many years, and his knowledge about and contributions to the advancement of quality control in Japan are unparalleled.

JUSE was established in 1946, right after World War II. Japan was eager to rebuild industries and to use statistical quality control methods in many of the leading manufacturing companies. In 1962, JUSE was consolidated under an umbrella of formal recognition by the Science and Technology Agency of the Japanese Government to better cope with the rapid technical advancement of Japanese society. JUSE is not a government agency. It is a nonprofit organization supported by membership and the sale of services and technical literature; it is financially independent. It is governed by its corporate members, including manufacturing, construction, and service industries. Most of the major corporations in Japan are members of JUSE. This is an organization unique to Japan; it is devoted almost entirely to the promotion of quality control in Japan. JUSE's function is to educate all levels of the population in concepts of statistics and total quality control.

JUSE sponsors both domestic and international technical meetings. For example, each June and December JUSE sponsors a general quality control meeting [a counterpart in the United States is the annual meeting of the American Society for Quality Control (ASQC)]. The June 1989 meeting was scheduled for 13-14 June (eight parallel

sessions in 2 days) in Hiroshima; its Proceedings were published as a special issue of the monthly magazine *Hinshitsu Kanri* (in earlier years this was translated as "Statistical Quality Control," but now it is translated as "Total Quality Control"), June 1989, Vol 40. This issue contains 90 articles in 441 pages. Topics presented include product improvement, quality assurance and the development of new products, process improvement, software, statistical quality control (SQC) methods, reliability, process control, etc. There is no section on new theoretical development in SQC. Emphasis is on clever usage of statistical methodology for quality control. Presentation of the papers is uniform in style for every topic, reflecting a national approach to education and training in QC methods. Each application follows a cycle: (1) understand the problem, (2) experiment, (3) collect data, (4) perform statistical analysis (regression, factor analysis, multivariate analysis, etc. are used), (5) improve and then return to step (1) for an additional iteration. The procedure is called PDCA (plan, do, check, action), or the Deming Circle (a result of earlier teaching by Dr. Deming). Illustrations (graphs and diagrams of the seven tools of QC) are frequent. Figure 1 illustrates the PDCA approach.

JUSE administers the prestigious Deming Prize, initiated in 1951, the year after Deming taught his first course in Japan. JUSE also administers the Japan Quality Control Medal and the Ishikawa Prize. All the activities are governed by advisors and working committees consisting of university professors and representatives from member corporations.

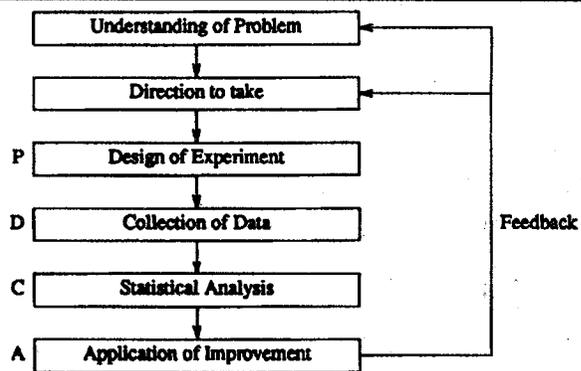


Figure 1. The PDCA approach.

JUSE has played a significant role in industrial advancement at Japan and is the driving force for research, development, education, and dissemination of information on mathematical and statistical methods for quality improvement.

Since 1951, JUSE has published a quarterly journal, *Reports of Statistical Application Research*, in English. Since 1987, JUSE has published a newsletter, also in English. Also JUSE publishes several monthly magazines in Japanese: *Hinshitsu Kanri* (Total Quality Control), *Engineers*, *FQC* (Quality Control for the Foreman), and *QC Circles* (for production workers, office workers, etc.). The June 1989 issue of *QC Circles* is devoted to QC circles of office workers to control inefficient office practices; 18 different cases with solutions are discussed. Some articles in *QC Circles* are written by high school graduates and could be published in ASQC journals in the United States. They all follow the standard PDCA practice.

As of May 1989, 283,693 QC circles representing 2,282,749 members are registered at JUSE. The July 1989 issue of *QC*

Circles is devoted to papers for "nurturing a willingness," telling how to cultivate an environment in which workers enjoy quality improvement activities. The magazines always contains a section of success experiences and a continuing education section. In this issue, instructions on constructing Pareto charts are presented in a step-by-step fashion. This continual repetition of simple QC concepts is typical of the Japanese approach of inculcating QC practices into the entire work force.

The May 1989 issue of the Japanese magazine *Engineers* contains three main papers: "Treating a Customer-Centered Culture for Service Quality--It helps to think of the service as a product," by Robin L. Lawton; "Quality Plan Development: A Key Step Toward Customer Enthusiasm," by J. Stephen Sarazen (both translations into Japanese of articles originally published in *Quality Progress*); and "A Report of the Seven Management Tools for QC Seminar in the United Kingdom," by Ryoji Futami. Both translated papers are directed toward considerations of customer satisfaction and give clear directions for actions to take. The papers appeal to Japanese readers since a stated goal of all Japanese industries is customer satisfaction. The magazine concludes with a section of announcements of symposia, seminars, new publications, and software.

There are many other JUSE publications. For example, there are books in reliability engineering for industry, translations of English books, and theoretical statistics texts, to name a few. The book titled *Check Points for Taking QC Education and Examination* by Isamu Itsukage (published in 1989) lists 47 items to be checked in implementing a TQC program. JUSE also produces a pocket calendar, which has an appendix containing concise information on:

"Business Operation and TQC," "What is QC," "What are QC Circles," "Statistical Tables," and other sections of interest to persons involved in TQC. Committees of JUSE publish books; for example, the failure analysis committee published a *Guide Book For Failure Analysis* in 1986.

Since 1985, JUSE has initiated new education and training courses for international groups. In October 1989 two courses were offered: "JUSE International Seminar on TQC for Senior Management" and "Seeing is Believing," the Second JUSE International Seminar on TQC.

Japanese Standards Association (JSA)

JSA was founded as a nonprofit institution in 1945 under the Japanese Ministry for International Trade and Industry (MITI) to propagate industrial standardization and quality control to all Japanese industries. JSA is similar to JUSE but under the sponsorship of a different ministry of the Japanese government. JSA operates with income from the sales of publications and other sources, such as lecture fees and corporate membership fees (as of March 1988, there were 8,615 member corporations). The publications of JSA are very noteworthy. A large number of these publications are Japanese Industrial Standards (JIS). JIS Z8101 defines total quality control as "a system for producing a quality product or service which satisfies customers in the most economical way." This system includes: market research, engineering research and development, design of the new product, planning, marketing, production, testing, sales, after-service support, worker relations, and education. All the terms related to TQC are standardized in Japan and published by JSA.

JSA publishes many booklets on quality control on different subject matters that are suitable for top management down to blue collar workers. Noteworthy JSA publications (all in Japanese) are:

- *Statistical Tables and Formulas with Computer Applications*, JSA-1972 (720 pages). These tables are not copies of previously published tables; they were recomputed and checked for accuracy.
- *Hand Book of Quality Control*, 1977 (938 pages). This volume covers quality control in Japan, including statistical theories with examples of applications and a history of the development of QC.
- *Lecture Series in Quality Engineering*, Vol 1-7, General Editor, Genichi Taguchi, 1988-1989. These volumes cover: (1) development and planning, (2) production, (3) signal to noise (SN) ratio for quality evaluation, (4) experimental design, (5) examples (Japanese), (6) examples (European and American), and (7) examples in measurements. JSA is organizing a seminar series based on these books. To date, volumes 1-5 have been published.

JSA has organized a quality engineering research group (QRG) that meets once a month on the first Thursday from 0930 to 1630. At these meetings a lecture is given by Professor Taguchi in the morning and the members share their experiences in the afternoon.

JSA also publishes a series of small booklets (all in Japanese) on quality control, including theoretical statistics and introductory texts for production workers. Examples include:

- Kurogane, K. (1986), *Introduction to Quality Control: Total Quality Control and Practice*, 4th edition (122 pages).
- Ozeki, K. (1988), *Introduction to Quality Control: Improvement and Practice*, 8th edition (110 pages).
- Asaka, T. (1988), *Foundation of TQC*, 9th edition (153 pages).
- Sugimoto, T. (1988), *Quality Control*, 4th edition (62 pages).
- Kurogane, T. (1986), *Operation and TQC* (38 pages).
- Makabe, H. (1988), *Quality Assurance and Reliability* (20 pages).

These booklets are relatively short and are designed for easy reading such as on a commuter train. It should be noted that some of these booklets are now in a 9th edition. They are extremely popular.

Matsushita Electric Industrial Company, Ltd.

The VCR factory is an impressive facility. The production floor is configured as a flow line and is fully automated except for monitoring and setup personnel. On the main floor, there are three lines that assemble over 4,000 components per VCR. The chassis are prepared in a part of the building we did not visit. Each production line can handle only one product model at a time. However, a line can be changed to produce any other model amazingly quickly in an average of 3 minutes. The operations are all designed to use the same production robots,

and the unit processes are controlled through downloaded programs to the individual robots.

There has clearly been a great deal of attention given to the design of the facility and to the products it is to produce. As mentioned above, all models of VCRs are assembled using the same production equipment, usually with no change to equipment setup. Every step of the process is designed to take a standard length of time, so the problem of balancing work-in-process inventory against machine utilization effectively does not exist. The assembly processes varied widely and include operations such as screwing, loading of springs, gluing, soldering, and insertion. Nevertheless, there is a uniformity to the processes that clearly speaks of a concern for standardization. All robotic operations are done from above; there is not a single case of having to fight gravity. With only one or two exceptions, every operation uses the same model robot; only the end-effectors change. Every operation is clearly visible to an observer. Finally, again with only a few exceptions, quality is ensured through in-process sensing rather than post-process inspection.

Unlike Kanto Auto Works, the robotic technology in use at Matsushita is highly sophisticated. Nearly all steps in the process involve some sort of sensory-interactive control and/or sensor-based process verification. During the time we spent observing the line (about 2 hours), there were perhaps three instances where we observed sensors detecting a production problem. When such a problem arises, a person arrives within a few seconds to deal with the problem. This gave us a chance to observe the man-machine interactions, which have also been well engineered. Each flow line is arranged in a "U," with someone to monitor the line stationed in the center of the U. Each station,

which performs a single operation, has a poster hanging over it that clearly illustrates what pieces of the VCR are involved in that step. The person need waste no time figuring out what was supposed to happen. Every problem we observed was a case of something (a spring, feed wire, etc.) having gotten stuck and needing to be freed, and it was fixed in under 10 seconds. The VCR in question was simply moved back in the flow line to undergo the operation again.

The VCR factory has one area where significant improvement seems possible. The factory has an imposing automated storage and retrieval system to manage a large inventory of components and completed products. The need for this system was not satisfactorily explained to us. The system is tied into the material handling facilities for all three flow lines and for the rest of the factory building. While the system and the computer interface to it are quite sophisticated and efficient, one gets the feeling that further efficiencies could be gained by working out a way of eliminating the system itself.

We had a very informative discussion with senior managers of the Corporate Quality Assurance Division (CQAD) of the Matsushita Electric Group. This division employs about 120 people and has an annual budget of about ¥2 billion (about \$14M). The primary responsibility of the CQAD is to work with the other divisions of the company to help ensure product quality. In most U.S. companies, the function of a quality assurance division is cast in terms of ensuring that a product as produced conforms to its original design. The definition used at CQAD is much more general--a product must conform to customer expectations and desires. The most marked effect of this definition is that the Quality Assurance Division has responsibility for gathering market information on existing products, a

function usually found in marketing divisions in U.S. companies. The CQAD has, in addition, the following functions: product evaluation, life-cycle research, planning of quality management, quality administration (domestic and overseas), quality counsel, calibration and other equipment-related measuring tasks, technical promotion, and packaging evaluation.

In touring the CQAD, we saw many facilities for product testing. The usual approach to product testing is to bring in test subjects who represent typical users and have them use not only Matsushita products but a wide variety of competitor products as well. (We must sadly report that U.S. appliances were deemed to be so uncompetitive that they did not need to be tested. U.S. computers, on the other hand, were being extensively evaluated.) The managers proudly emphasize that testing of Matsushita products is done in the name of the company president.

The CQAD has developed a system for managing quality data that appears to be extremely valuable to the company. Every quality-related decision made during the product life cycle is recorded on a standard form. These forms are indexed, electronically imaged, and stored on computer. This quality data base is periodically analyzed statistically to identify problem areas. It is also available online for historical research at the start of any new design. Our hosts appeared reluctant to share any technical details concerning this data base. Its value in enabling TQC clearly makes this data base an invaluable corporate asset.

The Matsushita Museum of Technology is a facility the company uses to display its latest technological developments as well as the company's technical history. The latest Matsushita products, many of them at an experimental or prototype stage,

are demonstrated to a steady stream of Japanese and international visitors. This museum is not only an excellent form of advertising and public relations but is quite likely a source of feedback to market research staff regarding the interest shown in and comments regarding the various experimental products.

DISCUSSION

The history of advancement of quality control in Japan shows clearly that success was not achieved overnight. The Japanese make step-by-step improvements every year with clearly targeted goals each year. All workers know what their goals are and work to achieve them. Statistical methods are utilized on the way, and everyone involved has some level of statistical education and understands basic statistical ideas and methods of quality control. In Japan "everyone" means literally everyone from the company president to the janitors. Success of Japanese industries appears to be founded on the following factors.

Human Relations (Cooperation)

- The trust between workers and management is mutual. All managers and workers consider that without each other there would be no jobs and no profits. It is essential to cooperate with each other.
- Management behavior clearly establishes trust between management and workers. (However, there are indicators that group consciousness sometimes does conflict with individual needs.) To help build this trust there are no executive dining rooms; the CEO dines in the same dining room where every worker eats. Every worker (including the CEO) receives twice a year

bonuses depending on the success of the company. In Japan, the CEO would not get a bonus while workers are asked to take a pay cut.

- Management considers the workers to be knowledgeable about the product and its manufacturing process. Suggestions from workers for improvement are encouraged and considered seriously. Frequently over 80 percent of the suggestions from the workers are implemented.
- When a production failure occurs, management puts all of its energy in finding the cause of the failure and correcting it. Fixing blame is avoided on the grounds that doing so would interfere with accomplishing quality goals.

Education

- Japanese high school graduates have an education comparable to 2-year community college graduates in the United States. They go to school 5-1/2 days a week, for about 7 hours each day, and slightly over 10-1/2 months a year. Science education is mandatory. The literacy rate is 98 percent. There is, however, a concern with the level of stress among school children.
- Japanese businesses consider educating workers as an important investment. The idea of lifetime employment goes hand in hand with this investment.
- Most workers are assigned to every job on the floor so that they know the whole procedure of manufacturing a particular product. In fact, a worker at the Kanto Auto Works is expected to be able to assemble a car by himself.

- Almost all workers have continuing training courses in quality control.

Concept of TQC

- TQC means that everyone is involved in quality control practice. The TQC operation is headed by the CEO. The concept of statistical methods is understood by everyone and applied to every operation company-wide.
- The goal of the company is known to everyone. Usually it is posted for everyone to see, and everyone works to achieve this goal. The nearest thing to this in the United States is the United Way Campaign (UWC): for a period of 1 month or so in the fall, U.S. companies post their goals for contributions and almost everyone participates to achieve this goal. There is a victory celebration and everyone has an opportunity to feel satisfaction in a corporate job well done. The Japanese approach to TQC has much in common with our UWC.
- TQC means quality control by everyone. It means QC for management, QC for engineers, QC for design engineers, QC for workers, and QC for sales operations. It needs the total cooperation of everyone involved.

Goals

- The primary goal is customer satisfaction and production of quality goods. This philosophy is basic and rooted in the Japanese culture. The Japanese have always treasured quality goods. Their export of poor quality products before the war and immediately after the war is not a true representation of the Japanese

emphasis on quality. Today the national viewpoint is that if customers are satisfied, profits will follow.

- Competition is very high in Japan because many companies make the same kind of products.
- Japanese organizations seldom set half-way goals. Whether it be in manufacturing, finance, standards, research, or education, the goal is to be the best in the world.

Application of Statistical Methods

- The basic concept in Japan is to observe and to analyze data with simple statistical tools. The widely used approach is "the seven tools of quality control." Many booklets on this subject have been written and are widely read by both top management and workers. These "seven tools" are described briefly in Appendix A.
- Japanese industries strive for zero defects in production. To do this they test 100 percent on carefully selected measures of production quality. This is a specific example of the general Japanese emphasis on doing things right the first time.
- Quality control applies not only to production but to many other business operations as well. The newest group to enter the practice of quality control is the group of service organizations, for example, banks, restaurants, department stores, and even McDonalds in Japan.
- Taguchi's philosophy of engineering design and his approach to the analysis of data (his initial publication was in 1966) gained

fame as the Taguchi Method in the United States. The timing of his arrival in the United States was concurrent with the recognition of the need of good quality control practice in the United States; it was a time when any application of systematic statistical analysis would have made a significant contribution. Taguchi has a long history in the practice of QC in Japan; for example, he was the first to use orthogonal array designs in Japan, and his book *Design of Experiments* is widely used in Japan. However, his approach to data analysis (SN ratio method) is not well appreciated in Japan. There is some controversy with regard to the theoretical validity of his approach among theoretical statisticians in the United States. Such criticism also exists in Japan. The May issue of *Standardization and Quality Control* has an article titled "Taguchi Method from the Viewpoint of a Statistician," which is a discussion between Professor Taguchi and Professor K. Takeuchi (Tokyo University). A summary of this discussion is in Appendix B.

FUTURE STATISTICAL RESEARCH

Quality control experts in Japan are now questioning the directions they should take in the future. A recent paper by Professor Tadakazu Okuno, Provost, Tokyo Science University, states that "in spite of great advancements in technology, advanced statistical methods have not been utilized to their full potential" (Ref 2). Basic concepts, he states, should be improved. He points out that the time-honored seven tools of quality control should be improved, for example, by replacing histograms with stem-and-leaf displays, which give more information. He also thinks Tukey's data analysis

methods (Ref 3) should be used along with multivariate analysis. Okuno defines the "seven new tools of quality control" as follows:

- (1) Stem-and-leaf display
- (2) Letter value display
- (3) Box-whisker plots
- (4) X-Y plotting
- (5) Resistant line
- (6) Median polish
- (7) Smoothing

These seven new tools should not be confused with the "seven management tools for quality control" developed by a committee of JUSE headed by Professor Yoshinobu Nayatani. Okuno points out that statistical methodology is a most important factor of the practice of quality control and that one must not forget how to apply the iterative PDCA statistical cycle methods.

Okuno asserts that production technology has advanced much faster than quality control technology and that the "zero defects" goal can be satisfied by using online data collection methods and online feedback based on new techniques rather than 100 percent inspection.

In particular, the Toyota SQC Research Group has been studying the method of multivariate analysis in relation to their problems since 1977. They published a book, *Multivariate Analysis for Industries*, in 1986, selecting some examples from their experiences. For example, multivariate analysis was used for the analysis of process factors for auto body painting, for the analysis of materials requirements in the planning stage, for noise analysis at the testing stage, the stamping of body pieces at the production stage, etc. They stress the importance of the acquisition of accurate relevant

information. Also they stress careful analysis of data from all points of view, such as data reduction methods, Tukey's exploratory data analysis, and use of the basic seven tools of quality control.

SAS software is used extensively in Japan. Initially there were many in-house statistical software packages, but the consensus of Japanese is that SAS is excellent and it satisfies their needs.

SUMMARY AND CONCLUDING REMARKS

The United States has as much advanced manufacturing technology as Japan, but the United States does not practice statistical quality control in the broad and coherent national fashion of Japan. The United States can learn from Japan that Total Quality Control technology can be used effectively in achieving quality goals. It is our perception that U.S. research emphasizes general results that can be applied to many situations. In Japan, research on particular conditions related to particular products is emphasized. However, Japan is changing as we observed at the National Laboratory in Tsukuba, where much general purpose research is underway. The United States is also changing, as many U.S. national laboratories are emphasizing technology transfer to industries.

U.S. government agencies that fund research should encourage this change by accelerating their funding of systems research in quality technology generic to particular industries. Such systems research would make use of a laboratory process test bed and a team approach involving engineers, computer specialists, and statisticians and would be oriented to producing a technology for process design and optimization.

We were exposed to such research approaches at NRLM; we suspect that Kanto Auto Works' new production line is founded in such research experience.

We cannot and do not need to transfer everything from Japan. Nothing is perfect, and even with Japan's industrial success, there is a dark side. The Japanese total commitment to the job puts great stress on the family, on the role of women, and on Japan's relations with other nations.

However, we should carefully examine Japan's use of QC techniques to identify methods that can be used to advance quality control in the United States while recognizing that there is still room for improvement in these methods. Our survey of Japan's use of QC techniques leads to the following perspective on U.S. needs:

- Most important for the United States is the education of every involved engineer and manager in TQC philosophy and techniques. Everybody should know how to collect data, how to analyze it, and how to look for significance.
 - A timely editorial appeared in *Science*, June 2, 1989, titled "Teaching Statistics to Engineers." It emphasizes the importance of statistical education for U.S. engineers. This editorial should be given wide distribution to promote the development of statistical thinking in engineering education.
 - U.S. management must create a cooperative environment and take the lead in the practice of quality control. Achieving the high standards set by Japan is not possible without the total commitment that can only flow from top management initiative.
- It is also important to encourage investment by large industries in the United States to help promote technical education, including data analysis and experimentation, at local precollege schools. In this way, competent future workers can be assured.
 - It is important that government agencies, professional societies, and industry give national leadership in bringing quality technology to engineers in industry on a continuing and comprehensive basis. JUSE provides a model for institutionalizing such leadership, as does JSA. The new Congressionally commissioned Baldrige Award is another relevant model. The land-grant universities also have relevant experience. In particular, the Department of Defense should be among the leaders in establishing a coordinated national effort to disseminate quality technology information in a timely, continuing, and comprehensive national fashion.
 - Government research funding agencies should accelerate their support of a systems and cross disciplinary research approach to the further development of quality technology.

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Appendix A

THE SEVEN INDISPENSABLE TOOLS FOR QUALITY

In order to achieve quality goals, it is essential to determine the state of the process from data. The quality of a process can be improved by accurate measurement and corrective action. Problems must be identified as soon as they occur. The so-called seven basic tools of QC are used in Japan to fill this need. It was reported that the use of these seven tools solves a majority of the problems that arise in Japanese industry.

These methods are graphical and are:

- | | | |
|-----|--------------------|---|
| (1) | Easy to apply | Anyone can make a diagram with a little practice. |
| (2) | Easy to understand | Results are transparent on the graph in most cases. |
| (3) | Used by everyone | To promote coordination among all participants. |

The seven tools are:

Histogram	Pareto Diagram
Check sheet	Scatter Diagram
Stratification	Cause and Effect Diagram
Control Chart	

The standard approach to solving quality control problems is:

(1) Investigation of the ongoing process

Find problem areas -- Pareto diagrams

Find existing condition -- histogram, scatter diagram, control charts

Find cause and effect relations -- cause and effect diagrams

(2) Analysis of data

Stratification of data -- histogram, control charts, scatter diagram

Correlations -- scatter diagram, control charts

Changes in time -- control charts, check sheet

(3) Take action

Corrective action may be obvious; if not,
use experimental design to find the corrective action.

(4) Confirmation of the corrective action

Are there favorable results? -- control charts, check sheet, Pareto diagram

(5) Standardization and QC

Is operation normal? -- control charts, check sheet

The above steps are repeated until the operation reaches the desired level. The level should be upgraded each time to improve the operation continuously.

**A SUMMARY OF THE ARTICLE TITLED "TAGUCHI METHOD
FROM THE VIEWPOINT OF A STATISTICIAN"**

Professor Takeuchi compares Fisher's concept of experimental design to Professor Taguchi's concept. Fisher's ideas were motivated by experiments in agriculture where the purpose was to increase the value of the mean (increase production). Taguchi's idea is to reduce variability (increase product robustness), allowing the mean to be corrected in the final engineering process. So, the Taguchi method is experimental design with a different motivation. In any experiment or production process, there are always random errors, which may or may not be significant. It is important that statisticians (including users of Taguchi's approach) study the properties of these random errors by statistical theory. Regrettably, most statisticians in Japan paid little attention to Taguchi's ideas (the initial idea was presented in 1966). Takeuchi agrees with some of the criticisms raised by Professor Box and others, but he also thinks some criticisms are based on a misunderstanding of words. Taguchi agrees with Takeuchi's

assessments. Further, Taguchi states that we should study the error between the observed SN ratio and the ideal engineering process. The problem is how to estimate this error and how to collect proper data. Taguchi calls any departure from the ideal products or ideal process "noise." Taguchi considers noise as a measurable factor that does not contain random error. On the other hand, Takeuchi considers that it may contain random error because there may be some factors in the noise that are unknown. Taguchi stresses robustness in the parameter design and this point is the biggest difference between classical experimental design and Taguchi's design. Taguchi considers that some problems can be addressed only as engineering problems or calibration problems and that statistical approaches are not helpful in these situations; here his ideas diverge from the ideas of statisticians. The editors agreed to have more discussions, further studies, and further publications in future issues.

