Cooperative Education and Training of
Managers for Development Projects

MDP

CASE HISTORY 1:

Quality Management Program Development in a U.S. Private Industry

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QUALITY MANAGEMENT PROGRAM DEVELOPMENT

IN A U.S. PRIVATE INDUSTRY

by

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1978

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ABSTRACT

This case deals with the development and implementation of a quality management control system in the Telecommunications Division of a Southern-based telephone equipment manufacturing company in the U.S.A. The plant assembled hand-set telephones through mass-production lines but had a relatively ineffective quality control program. The plant management therefore wanted to develop a system that would not only guarantee cost-effective quality but would also pinpoint when and where errors in production occurred. To achieve these objectives, a project team consisting of a private consultant, the manager of the Engineering Department, the manager of the Quality Control Department, and a quality control analyst was formed.

The project team concentrated first on developing quality control procedures that would satisfy all objectives and at the same time be feasible in the mass production environment. Brainstorming sessions and group meetings were held with supervisors, workers, and division managers, both to gain their approval and inputs and to make sure that the program would not interfere with ongoing work procedures. When all personnel were satisfied with the program, a pilot test was initiated, using representative sections of the plant. When these tests proved extremely successful, the project team decided to use the test results to convince the plant manager to trial-test the program for the assembly section. After receiving his approval, the project team tested the program for a two-month period with successful results. The quality control program was then implemented on a permanent basis in the assembly section and was adapted as well to the fabrications section of the plant.

The case illustrates how a private consultant coordinated all elements of the plant management in implementing the program. It further shows how planning and pretesting were aided by an open, participatory style of communication. The case not only provides substantive information about the development and implementation of a quality control system but also demonstrates the values of using a systematic approach to project management.

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ACKNOWLEDGMENT

Grateful acknowledgment is extended to the American Society for Quality Control, Inc., which granted the permission to use information from "Assembly Surveillance Using Defect Controls," copyright © 1965 American Society for Quality Control, Inc.

QUALITY MANAGEMENT PROGRAM DEVELOPMENT IN A U.S. PRIVATE INDUSTRY

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PREFACE TO THE SECOND SERIES

The need for more effective project planning and management has only recently been identified as a critical function for all countries, in both public and private sectors. Vast resources have been channeled into development projects, but lack of viable policies coupled with poor management has resulted in a waste of valuable resources--human, financial, and natural. Attempts to accelerate economic and social growth in developing countries have often floundered because of serious problems with project planning and implementation. Costly mistakes have occurred for the same reasons in projects carried out in highly industrialized Western societies.

Much of the problem lies in traditional project management training programs, which are narrow and segmented in their point of view and fail to provide trainees with a coherent overview of the complex life of a development project. The need to replace these existing educational and training programs with a cohesive framework of studies is more than evident. We need a new program, one which considers the entire project cycle as an integrated process.

The East-West Center has recognized problems in the area of public policy implementation and project management for some years. From 1972 to 1975, the Center has worked cooperatively with a total of over 50 organizations in 15 countries on specific aspects of the overall problem, such as Project Feasibility and Evaluation, and Public Leadership. Since June 1975, the Center, in partnership with scholars and practitioners in seven countries, has developed a prototype curriculum for the education and training of project managers for all sectors of the economy and society. This new program for project managers is aimed at increasing their understanding of the integrated project cycle: the entire spectrum of a given project, ranging from planning through implementation and evaluation.

The prototype curriculum package consists of a detailed syllabus, portfolio of case studies in development projects, teacher's guide on use of the case studies, selected readings, and an annotated bibliography. The curriculum is flexible for adaptation by educational and training institutions in countries with different social and economic settings, as well as different cultural and social values.

Basic to the prototype curriculum is a series of seven case histories covering agricultural, industrial, public works, and social sectors. In recent years, case history research has become a widespread instructional tool in medical and law schools, followed by schools of business, public administration, and engineering. These case histories are innovative, however, in representing the first attempt to construct a series of case analyses within a single conceptual framework--that of the development project as an integrated whole. Participants from a number of countries conducted field research and wrote their cycle. The case studies, which included such diverse topics as a metropolitan water improvement program in Thailand, a Pacific Islands livestock development project, and a rural social development project in the Philippines, were an important feature of the prototype curriculum, providing relevance and practicality both to classroom discussion and the follow-up field practicum. Five of the case studies, together with an introductory chapter explaining the integrated project cycle, will be published as a textbook, Management of Development Projects: An International Case History Approach, in the spring of 1979 by Pergamon Press.

In the next two years, a second series of approximately forty new case histories will be produced under the sponsorship of the Exxon Education Foundation. The writing of the new set of studies will be supervised by an international steering committee composed of senior scholars and practitioners from Indonesia, Malaysia, the Philippines, the United States, New Zealand, and Iran. This second series of case histories differs from the first series in two respects: (1) we have adopted the term case history rather than the previously used case study, to reflect the fact that these reports describe actual field situations rather than hypothetical constructs for the classroom, and (2) the new case histories will be written in the framework of a refined integrated project planning and management cycle (IPPMC), as illustrated in the diagram at the right.

The second series will include case histories of such diverse projects as social condominiums in the Philippines, the Alaska pipeline, industrial engineering in sophisticated factory situations, an integrated water resource and agricultural development project in the Philippines, a timber complex project in Malaysia and many more. The broad scope of this series is meant to reflect our conviction that a development project is not, in the narrow sense, simply a program to upgrade a sector of a developing country but is rather a utilization of resources that provides benefits and services to the people of <u>any</u> country, developing and developed.

Both case history series represent the attempts of the Technology and Development Institute (merged into the Resource Systems Institute as of September, 1977) to achieve the East-West Center's goals of better relations and understanding on economic and social development problems of mutual concern to all countries, East and West, through cooperative research, study, and training activities. Special thanks are due to the authors of the case histories in both the first and second series and to their respective institutions for their fine cooperation. Grateful acknowledgment is also due to the Exxon Education Foundation for providing the grant to continue the research and development of the second series of case histories.

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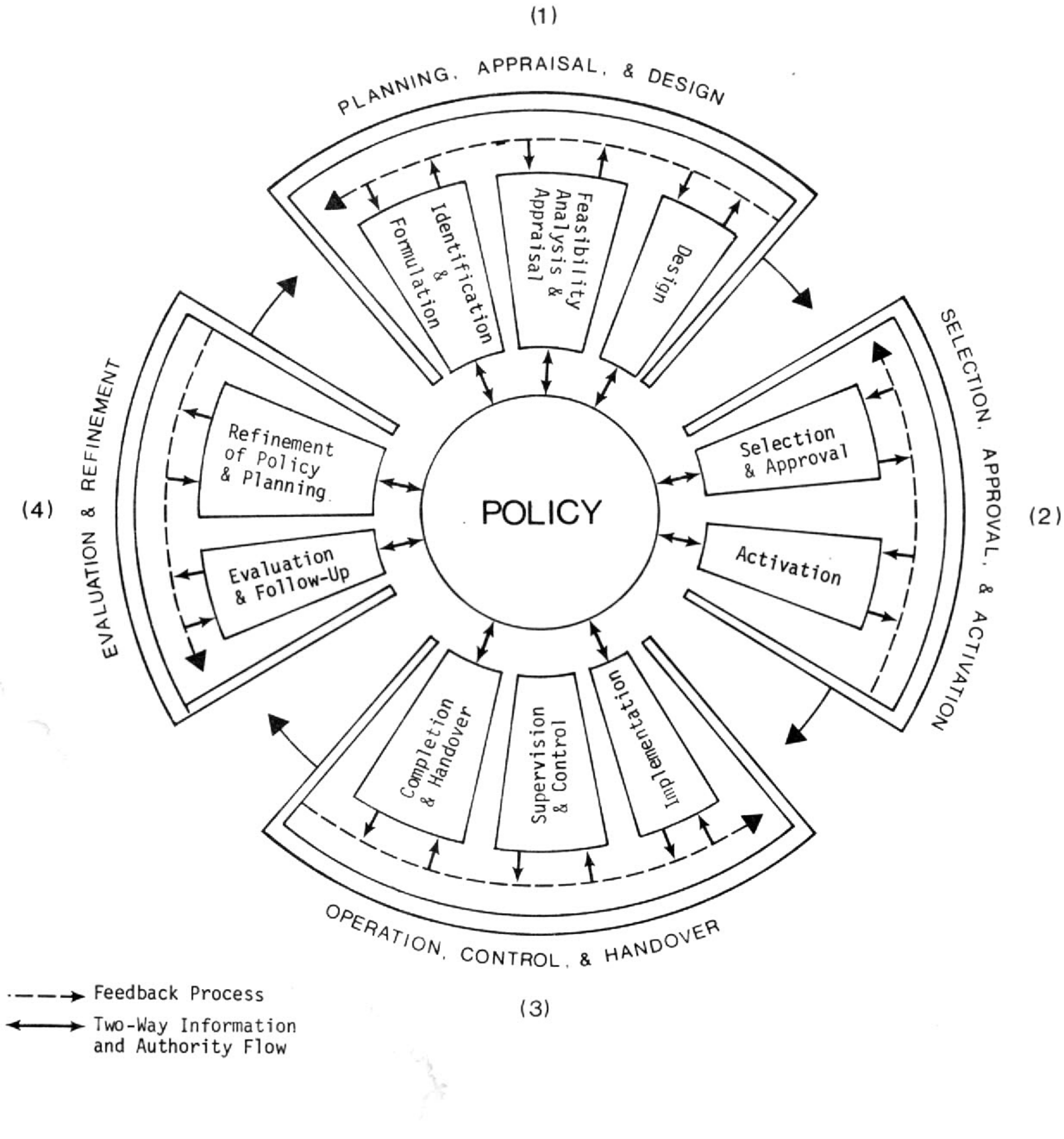
Integrated Project Planning & Management Cycle:

The Four Phases



I. PROJECT BACKGROUND

Quality management is an essential responsibility of management and staff of any production organization. Besides industry, most other business organizations, such as hospitals, merchandisers, and transportation firms, as well as government agencies, must have this capability. Whether the end results of an organization are products or services, quality management is vital as a subsystem that permeates the whole system of activity carried out to provide the goods or services.

In an organization, a quality management system helps to assure that adequate quality is obtained in materials purchased, in work processes, and in final products or services produced. Because quality management must be concerned with achieving superior results in many segments and activities of an organization, a number of different subsystems make up this management system. For example, one subsystem might be used to check and control standards of purchased materials and parts; another to design production processes to achieve necessary results; another to inspect work at different stages of the operations; another to provide proper information about quality to each level of management for their corrective action; and so on. Together, these subsystems comprise the quality management system of an organization.

This case study describes a project involving the development and installation of a quality surveillance system for the assembly operations of an industrial plant producing telephones. In this plant, management at all levels needed to be provided with information that would identify quality problems requiring their corrective action. Management recognized that their whole system of quality management needed to be carefully examined to determine what improvements were feasible. They also were aware that quality surveillance was not adequate, especially in the assembly sections. Consequently, in their program to examine and improve their overall quality management system, one major component project was the development and installation of a new quality surveillance system for assembly sections of the plant.

Since this case study concerns a project in the private sector, it is important to note its applicability also to the public sector. Quality management is generally needed in most types of organizations, both private and public. Such a management system can be applied in all types of industrial firms, as well as in banks, airlines, public utilities, merchandising firms, construction, government agencies, and numerous other types of organized activity.

Although basic technical and management principles and methods are applicable to both private and public organizations, there often are differences in the application of these principles and methods. In the case of quality surveillance systems, the same principles of information collection and feedback for corrective action apply to public and private organizations alike.

Company Setting

This project was carried out in the Telecommunications Division of a Southern-based telephone equipment manufacturing company in the U.S.A. After the plant was well established and had been in operation for several years, the management had reasons to believe that major improvements could be made in their quality management system.

The plant produced hand-set telephones, most of which were assembled on high-quality, mass production lines, although some special-purpose phones were made in low-quality, job-shop assembly areas. Component parts were all made in job-lot production, in which material and in-process parts were processed in job lots through job-shop fabrication areas.

Because the telephones were both electrical and mechanical, with close tolerances and moving parts, quality was important. Furthermore, the company sold its products in the open market, nationally and internationally, competing with other private firms, thus making product quality a critical factor in marketing the phones. Their customers were the private and national phone companies, whose reputation depended on the quality of service they provided, including the quality of the phones used in that service. Quality problems could be detected rather quickly by the phone companies and their customers, as that quality influenced the quality and dependability of the phone service the customers received.

Since product quality was vital to the company, the management needed a quality management system that would assure them that adequate quality was being obtained. To achieve this goal, they needed to be sure that quality problems were detected quickly and that management at all levels would be properly and promptly informed about quality problems. Thus, it was important not only to examine the entire quality management system but also to consider, as one possible project, the development of a sound quality surveillance system. Effective quality surveillance was vital not only to keep management informed about quality conditions throughout the plant, but also to provide management with accurate signals that would inform them when and where their corrective action was needed.

On the other hand, the cost of quality was also important. The cost of obtaining and assuring the high quality of their product could not be excessive; otherwise,the company would have difficulty marketing its product in a competitive market. A new quality surveillance system should not cause quality costs to increase significantly. In fact, it was preferred that a new system result in lower-quality costs, or at least not increase the existing level of those costs.

The plant was using a quality management system inherited from another plant. Although this system was providing quality control in the plant, the management believed that improvements could be made. Consequently, the general manager retained a consultant to assist the company in examining the existing quality management system and in making improvements that were acceptable to them.

The existing quality management system in the plant involved extensive inspection and data collection. Purchased raw materials and piece parts were inspected, using lot-sampling procedures, before they were delivered into inventory or production. Also, on all assembly lines, random sampling inspection was performed at designated inspection stations. When too many defects were found, the line foreman was notified, and he was expected to place a person at that inspection station to inspect every piece until the frequency of defects declined to an acceptable level. The completed product (telephones) were sample-inspected after each of them was tuned and tested in the final test booth. This inspection and quality management system had other components, but these were less related to the project of this case study.

The data collected at the inspection stations provided a permanent record of defects found at each station. Each defect was identified, which made it traceable to its source, at least in many situations. The inspection data were analyzed to calculate the number and frequency of each type of defect on each assembly line. The data were compiled and analyzed weekly, and managers, foremen, and supervisors were provided with the complete information resulting from these analyses.

The existing system had both strengths and weaknesses. Inspection, which was performed by inspectors employed in the Quality Control Department, was reasonably good. Their data were reliable, although improved traceability to the source of each defect was needed. But these data were not providing management with information they really needed for effective quality surveillance. Management was deluged with quality information, but they didn't have time to search through the data to find indications of possible quality problems.

The quality reports provided management with information about the defect levels and the types of defects found on each assembly line. But these reports did not point out quality problems to management; nor did they signal a manager that his attention was needed. Since management had no clear signals when quality problems existed, there was little incentive for production line foremen and supervisors to work at improving quality. Line supervisors are busy people, with demands on them from many directions. Often, there is no way for them to do all that should be done, so they concentrate on what must be done and what will signal the attention of higher management, identifying problems that should have been corrected earlier by lower management.

The primary concern here was the lack of effectiveness of the quality surveillance system. Its efficiency, as indicated by the costs of providing the system, was of interest to management, but this was a secondary feature. There were two reasons for this. First, product quality was vitally important to their customers, as quality defects in the telephones would reduce the quality of service they would provide the customers, and to the customers of their customers. Second, the cost of an effective quality surveillance system often is offset by a reduction in the generation of defects as a result of using the system. Defects are expensive, so if a quality surveillance system causes a lowering of the defect level, this can be a large savings in costs. Thus, the costs of an effective quality surveillance system may be small relative to the savings in costs of defect detection and correction that can accrue from use of the system.

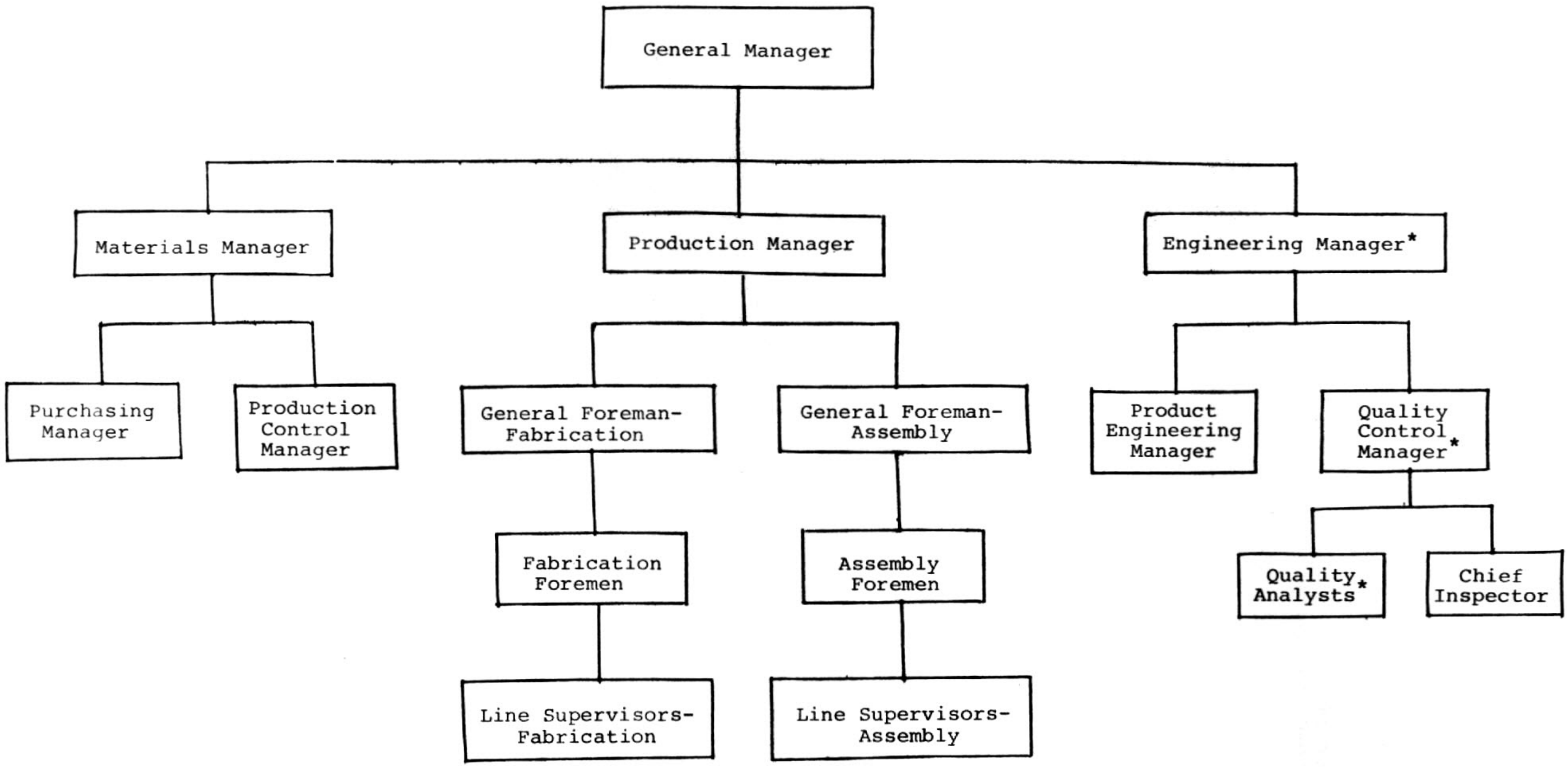
Project Development

The company personnel with whom the consultant worked closely as a team were the manager of the Engineering Department (which encompassed Quality Control), the manager of Quality Control, and a quality control analyst. The three company personnel were familiar with all aspects of the existing quality management system.

The three company members of the project team were organizationally related as shown in Figure 1. The engineering manager reported directly to the general manager, who was in charge of all the plant. The engineering manager had two major departments under his jurisdiction: the Quality Control Department and the Product Engineering Department. Consequently, the quality control manager reported to the engineering manager. The quality control manager had several people reporting directly to him, including a chief inspector and two quality analysts.

Responsibility for quality was allocated to the engineering manager, since quality depended on both the product design and its manufacture. It was the responsibility of Product Engineering to design the product, to specify the materials to be used and the dimensions and characteristics to be achieved in the manufacture of the product, and to specify (in cooperation with the Industrial Engineering Department) what equipment and processes should be established and used in the manufacture. Quality Control had the responsibility of assuring that the design specifications were met in manufacturing the product. Obviously, there was a close working relationship between these two functions, both of which were concerned with product quality and both of which were the responsibility of the engineering manager.

The quality control manager was directly responsible for the function, and he worked closely with the engineering manager in achieving it. The quality control function involved receiving inspection, in-process inspection, analysis of inspection data and preparation of reports to management, and quality engineering to work on solving quality problems. In the assembly sections of the plant, every assembly line had several inspection stations. Each inspector had several stations at which he inspected a sample of several units (the number of units inspected at each station was established based on a standard inspection plan) on a random basis. If the number of defects found in his sample exceeded the acceptable level, he reported this to the line supervisor, who was expected to assign a production worker to that inspection station. That production inspector would inspect every unit flowing through that station, and would continue doing so until the number (frequency) of defects declined sufficiently to indicate that the quality was at or above the acceptance level. Those persons assigned by the line supervisors to screen (100% inspect) at inspection stations were employed as regular



*Company members of the Project Team

FIGURE 1. A Partial Organization Chart of the Plant

production workers. Thus, the cost of these workers was on the budget of the line supervisors and foremen, so they did not want much of this inspection to be required.

The inspectors recorded every defect found, including the type of each defect. This information was accumulated in the Quality Control Department and was organized and analyzed by the quality analysts. These analysts reported directly to the quality control manager, and provided him with information on the number of defects found for the number of units inspected. Also, the defect data were organized to show what kinds of defects were being found in the assembly operations. It was these data that were reported to management to keep them apprised of the quality level of the product as it was being manufactured.

The fourth member of the project team was the consultant, who was retained by the general manager to help them improve the quality management system. He was experienced in designing, improving, and installing management systems, including quality control systems. In addition, the consultant had conducted in-plant seminars for technical staff and line supervisors in the plant. Consequently, he was already acquainted with many of the company personnel with whom he would need to have working contact.

The consultant* was provided access to anyone and any information needed in the program to improve the quality management system. Since the company personnel were normally engaged in their day-to-day operations functions, much of the exploration of improvement prospects and development of procedures for consideration by the team was the responsibility of the consultant. However, the team collaborated closely and frequently. This collaboration benefited the project and also developed the team and other company personnel in any new procedures that were developed and installed.

The team identified several projects which they believed would improve the quality management system. One of these projects, the quality surveillance system, is the subject of this case study.**

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*Author of this study.

**This case study is organized on the sequential unfolding of the project cycle. Consequently, the reader is taken through the project as it was conducted, but with continuing focus on the steps of the project cycle for comparative purposes. Technical details of the new quality surveillance system are summarized in the Appendix so that these details will not interfere with convenient use of the case study by persons not concerned with the technology of quality control.

II. PLANNING, APPRAISAL, AND DESIGN

The general manager and his management personnel wanted an objective examination of the quality management system. They recognized that their existing system was primarily one transferred from another company plant and that improvements in the system probably could be made. It was important to determine if improvements were in fact possible, as the company expected to maintain quality leadership in its field and to do so with a system that would assure moderate quality costs.

To achieve this goal, the consultant provided external objectivity and expertise, while several company personnel provided inside knowledge and carried out the team effort on a continuing basis.

Identification and Formulation of the Project

The consultant met individually with numerous persons, including management and staff personnel directly concerned with the quality management system, line management at all levels, and other managers of staff functions (purchasing, receiving, shipping, and so forth) having indirect concern with quality management. In addition, he examined the manufacturing operations, historical data on quality control, and other information reflecting on the needs, status, and possibilities for the quality management system. Group meetings were held, as needed, to explore information and possible changes in the existing system.

The involvement of other personnel was beneficial in two ways: (1) the various managers and their staffs had detailed knowledge of the operation and problems of the existing quality management system; and (2) participation of these people in examining the need for improving the quality system should increase their interest in having a better system and in making it succeed. Consequently, their participation throughout the project cycle, in genuine and relevant ways, was important in designing a system that could be effective and in helping to assure that the system would be effective.

Two types of meetings were held with other personnel. Some of them were small group discussions in which an informal exploration and interchange took place. Such meetings were with groups of line supervisors and their immediate foreman, or with several foremen and their general foreman. In each such case, an individual, one-to-one meeting would already have been held with the foreman or general foreman supervising those with whom the group meeting was to be held. In this way, the foreman already understood what was being discussed, so he could assist in the discussion of it with his subordinates. This gave his support to the discussion, and he could help clarify points that were discussed. All of these were small groups of three to ten persons, thus providing a good atmosphere for open and easy discussion.

The small group meetings were supplemented by one-to-one discussions with individual members of management and staff. It was in these personalized meetings that many of those interviewed felt most able to express themselves. Some persons were able to converse more easily and were more willing to share their thoughts more readily in a one-to-one discussion than in even a small group meeting.

Both types of meetings were successful in gathering good information about needs and possibilities for improvement of the quality management system. In addition, they laid a sound basis for continued interest in improvements and for their support of these improvements as they occurred. Quality management systems involve people; unless those people understand the new systems and cooperate to make them function effectively, they are unlikely to be successful.

Several analyses were made to identify opportunities for major improvements in the quality management system. These analyses included tracing the principal sources of past quality problems and determining the adequacy of available quality control data to assist in detecting and quickly resolving these problems. Quality costs also were examined, especially to estimate changes in costs that might accrue from potential changes in the quality management system. For example, the team found that inspection costs would be likely to decline if quality surveillance could pinpoint quality problems more effectively and direct appropriate management personnel to their solution. Also, they found that savings would result in reducing the amount of information provided to management, but improving the analysis of those data and giving them that information which would be essential to their knowledge and corrective action.

The analyses, combined with the meetings in which these matters were explored with company personnel, produced evidence to support consideration of several projects for improving the quality management system. These potential projects were considered individually and collectively, as they were separate developments, but all were part of the company's quality management system. Each project had to be justified individually, but its effects on the whole system were vitally important.

One of the potential projects involved the development and installation of a new quality surveillance system for the assembly operations. The examination had shown that the existing system was less satisfactory in the assembly operations than in the fabrication operations (machine operations producing piece parts). Management was not satisfied with the resulting quality in the assembly operations. Nor were they pleased with the delays in detecting and correcting quality problems in assembly (which included testing and packaging).

In the existing system, the reports to management showed the level of defects on each assembly line, but there was no way for each level of management to know when their attention was needed for corrective action. Certainly, it was recognized that higher levels of defects generally implied lower levels of quality. But when was the quality level sufficiently low to warrant taking action? As a result of this uncertainty, quality problems frequently continued and became worse until they demanded immediate attention from high-level management. Management recognized that this situation was not desirable, and they wished for a system that would provide more specific indication of the quality levels and <u>whose</u> attention was needed <u>where</u>. In this way, corrective action could be obtained more promptly and by the proper personnel.

For example, a quality problem might occur in the network assembly and not show up until the final test of the completed network assembly. The network is the electrical control mechanism in the telephone; after assembly, it is filled with epoxy resin. Once the resin has been poured, it is too late to correct any defects in the assembly. The network is scrapped if it is found to be defective after it has been filled with resin. Networks are costly, but they also are critical to the quality of operation of the telephone. A defect that raised the level of defectiveness shown on the quality reports might not be noticed by quality control or management as a significant quality problem until it had become extremely bad. Actually, since every network was checked by the production department at final test, the quality level of the shipped phone assemblies might not be affected. But the scrap rate (of the networks) and scrap cost would rise, and a high level of network scrappage could delay final assembly of the phones. Thus, it was important for quality, cost, and delivery that quality problems be signaled to proper management attention was early as they could be identified. Effective, accurate, and prompt indicators of quality problems were needed.

Preliminary analysis indicated that improvements in these factors could be expected if a new quality surveillance system were properly designed, installed, and operated in the assembly sections. In fact, it appeared that a better system would lower quality costs as well as improve the product quality. Based on these indications, the team began formulating a basic plan for a project to provide a new system.

<u>Project Formulation</u>. The project team met to examine those quality problems that could be reduced by an effective quality surveillance system. They also considered the types of objectives that such a system should meet and the principal criteria to which the system should conform. These objectives and criteria evolved from exploring the results of the numerous meetings held during previous

weeks and from knowledge of the project team. To achieve this, the team discussed these various factors, then listed ("brainstorming") the many objectives and criteria that could be considered. These were then narrowed to a tentative draft of acceptable objectives and criteria. Two weeks later, after further consideration of the draft by these individuals, the team met again to prepare a final listing of objectives and criteria.

Through this process, the team concluded that a new system should meet the following objectives:

1. It should provide management with clear indicators of quality attained and responsibility for low quality.

2. It should signal proper attention to out-of-control conditions.

3. It should be economical.

Plant management and production management needed clear indicators at all levels to signal the existence of significant quality problems and the sources of those problems. If management did not have this information, they might tend to focus their attention on other factors affecting cost and delivery, when quality problems might be the major cause of both high cost and unreliable delivery (completion of the product so that it is available for shipping). Thus, both quality management and line management needed appropriate information on quality. In addition, they needed a system that would enable the principle of "management by exception" to be employed. That is, each level of management should be signaled when they need to take action. For example, line supervisors and their foremen should first be clearly alerted to quality problems in their assembly sections before those problems become bad enough or continue long enough to demand attention from the production manager or the general manager. Most quality problems should be corrected by the lower levels of supervision in their early stages, as that would minimize the effects of the problem on product quality and also would minimize the cost of attaining quality. To do this, however, the quality surveillance system needs to discriminate in its signals. Top management needs to be alerted to action only if the lower levels of management were not solving the problems with sufficient promptness. The quality information should then lead them to the spot where their action was needed and should indicate, if possible, the nature of the problem needing attention and action.

The project team, in its meetings noted earlier, also decided that a new system should conform to certain criteria to attain the three established objectives. The quality surveillance system should:

1. Clearly indicate when the quality of assembly operation is falling or rising significantly.

2. Signal production and quality engineering personnel when out-of-control conditions exist so that they can take corrective measures before the attention of plant management is signaled.

3. Provide meaningful measures of quality attainment for each major assembly line as well as for the overall assembly operation.

4. Provide convenient traceability to the sources of defects.

5. Be easy to understand.

6. Use quality information needed for other purposes, if possible.

Using these objectives and criteria, the consultant examined various statistical methods that might be applicable to designing a quality surveillance system. Then, based on discussions of these statistical methods with the project team, he developed a set of statistical methodology which seemed most appropriate to serve the need. This set would be tested to determine its appropriateness as the statistical basis for a new system.

The approach that the team decided to use was to be based upon the data already being collected through the inspection system on the assembly lines. Also, the term "percent defective" would be used, as the plant personnel were already familiar with this term and its meaning. If, for example, 200 receiver assemblies were inspected during a day, and four defects were found, it was considered that a 2 percent defective level existed. Actually, in more precise terms, this was two defects per hundred units; since more than one defect might be found on a single assembly, it might not be technically accurate to consider that as percent defective. There was much to gain, however, from using the familiar term and nothing to lose in terms of the system, so the term "percent defective" was used interchangeably with "defects per hundred units."

To have a standard of comparison for each assembly line and for each station on each line, a standard ($\bar{u}$) representing the average number of defects per inspection unit in a six-week base period was calculated for each of these points. (An inspection unit was the number of the subassemblies used in a hundred telephones. For example, one hundred networks was an inspection unit, since one network is used in each telephone.)

The standard ($\bar{u}$) would provide a reference level for determining when defects were high or low (in comparison to the reference level). But it would not indicate how high or how low the defect level was, nor when action was needed because the defect level was too high. Consequently, the statistical methods provided for calculating control limits, with which the actual levels of defects could be compared. Control limits are based on probability, and they indicate the probability that a significant change has occurred in the quality level. Comparing defect levels to the control limits, therefore, would indicate the probability that a quality problem actually exists. The basic standards ($\bar{u}$) and the control limits would be updated every few weeks by recalculation based on the most recent six-week period. In this way, the references for comparing the defect levels would reflect long-term changes in quality and would continue their adequacy as bases for comparison.

Using these statistical methods, it was decided that a quality rating plan would be established, so that defect levels would be rated based on their comparison with the control limits. The ratings would be as follows:

E = Excellent:	The average quality level probably had increased.
G = Good:	The average quality level may have increased.
A = Average:	The average quality level remained unchanged.
F = Fair:	The average quality level may have declined.
P = Poor:	The average quality level probably had declined.
U = Unsatisfactory:	The average quality level had declined.

By using these quality ratings, lower levels of management (line supervisors and foremen) would be expected to take action when a rating showed F (fair). General foremen should investigate when P (poor) quality level was shown. And top management would be signaled by U (unsatisfactory) levels of quality. Also, the high levels of quality (G and E) would guide them to situations where commendations were appropriate and to see if the high levels could be continued. This was the basis for "management by exception."

To provide management with the information they needed, the table in Figure 2 would be prepared weekly. The table showed the following information for each assembly line: (1) the reference base ($\bar{u}$) in defects per hundred units; (2) the actual level of defects per hundred units (u) for each of the past several weeks; and (3) the quality rating for each of those past weeks. In addition, each foreman (and the general foreman) would be provided with an additional table for his assembly line, showing all three of these items of information for each inspection station on each line. This would give the foreman and his line supervisors the ability to trace quality problems to the areas where they were detected.

QUALITY CONTROL ENGINEERING
WEEKLY DEPARTMENTAL QUALITY REPORT - ASSEMBLY
(Based on Applicable Defects per Inspection Unit)

Week Ended	Sub A		Sub B		Sub C		Sub D		Sub E		Sub F		Sub G		Sub H		Final Assembly		Total Assembly		Non-Applicable Defects	
	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR
Base	4.2		1.2		3.4		2.1		0.6		2.4		1.4		2.1		1.6		19.0		3.4	
10/6	4.3	A	1.0	G	6.8	U	0.9	E	0.5	A	2.9	F	2.0	P	2.2	A	1.5	A	21.1	F	3.0	G
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CODE: E = Excellent G = Good A = Average F = Fair P = Poor U = Unsatisfactory

FIGURE 2. Layout of Weekly Quality Report
(Data are fictitious, for illustration only)

For example, in the case of the receiver subassemblies (described earlier), the two percent defective level implied two defects per hundred telephone receivers. If the reference base was 1.5 defects per hundred receivers and the quality rating of F (fair) was shown on the table, this would signal the supervisor of the receiver assembly line and his foreman that their attention was needed to check for a possible quality problem. If they failed to heed this warning or were unsuccessful in correcting the problem, it might continue or increase in the defective level. This could cause a quality rating of P (poor) or U (unsatisfactory) to occur, which would be the signal to middle or top management that their attention was needed. Thus, lower levels of management had opportunity to take corrective action; but if it was not taken or was not successful, higher management action would be signaled. When the quality problems were corrected, the quality ratings would reflect this fact by indicating higher ratings (A, G, E) and lower levels of percent defective.

This system could allow each of the objectives and criteria for the quality surveillance system to be met as well as provide the assistance and features requested by the managers and their personnel.

Feasibility Analysis and Appraisal of the Project

It was essential to determine if the new system would be successful, an assessment that needed to be made before the system was further refined and installed in the plant. To have the completed system fail in some significant way, after installation, would be a serious setback to the quality management program and to the plant operations. Consequently, it was important to examine the feasibility of the system, including its ability to meet the established objectives and criteria.

The project involved developing and installing a new quality surveillance system in the assembly operations of the plant. The new system would make use of the existing inspection stations and procedures, except that some revisions in the inspection procedures would be needed. In addition, considerable change was anticipated for the inspection data to be collected, the forms to be used, the data analysis required, and the use made of the resulting quality information.

Feasibility of the new system was divided into three areas: technical, administrative, and economic. Each was explored, as ultimate approval of the project would be based substantially on these three factors.

To determine the technical feasibility of the new system, a pilot study was made by simulating operation of the quality surveillance system using collected quality inspection data and quality actions from the previous six months. In essence, the historical data were used to develop reference standards ($\bar{u}$ and control limits), and the daily and weekly data were analyzed, using the system procedures, as if they were current data.

This pilot study was carried out, using statistical analysis of data collected during the previous six months. It took about a month to make the calculations and to analyze the data and compare it with quality actions taken during the six-month period. To do this, the reference base ($\bar{u}$) and control limits were calculated for each assembly line and for each inspection station on each line. Then, actual defect levels were calculated for each of these points for each week, and these were tabulated, as shown in Figure 2, with quality ratings assigned for each week. Using these tables, quality problems were indicated, based on quality ratings of F, P, and U, and these ratings were compared to recorded information about actions taken to resolve quality problems during this six-month period.

This simulation carried the quality surveillance system through a series of twenty-six weeks, thus iterating twenty-six cycles of calculations and comparative indications of quality levels, actions, and results. In this way, it was shown that the new procedures would meet the technical needs as outlined in the objectives and criteria. The response of the system exhibited in the simulation pilot run exceeded the requirements and the expectations of the project team.

Administrative feasibility was concerned with the manning and management requirements imposed by the system. Would the company personnel understand, accept, and effectively utilize the system? Could they handle the data analysis and information formulation for management needs? Could the system be effectively and efficiently managed?

The answer to the first question seemed to be the most doubtful. Consequently, special attention would be given to planning the design of the quality reports to management and the procedure by which the system would be introduced to management, especially line supervisory personnel. This way, it was believed that company personnel would grasp the system and use it effectively. The quality reports would be designed to involve no statistical symbols, and would provide simple data on actual quality levels (in number of defects per hundred units), quality bases as standards for comparison, and quality ratings (U, P, F, and so on). If a supervisor or other manager needed more details for tracing quality problems to their sources, they had access to the basic inspection data and other information tabulated from them. Quality Control personnel were also available to assist them in finding and correcting quality problems. Thus, the quality reports would be easy to use, and their information would provide definite signals for action and indications of problem locations.

To introduce the system to lower and middle management, it was decided that the characteristics of the proposed quality surveillance system would be compared to the financial budgeting system, with which they already were well acquainted (see the Appendix for this comparison). This would be done at an introductory meeting at which the new system would be proposed, not imposed, for their use. Already, participation of these personnel, through meetings and interviews, had contributed to the system design and planning; consequently, they knew that a new system was being developed and that they contributed to its development.

The other two questions concerning administrative feasibility posed no serious problem. The systems analyst on the team would carry out the statistical analyses and interpretation initially under the guidance of the consultant and the quality control manager. In addition, management personnel would be sufficiently briefed on the system details to assume their ability to manage and use the system. This would include their receiving any counsel or assistance they needed from the Quality Control personnel and the consultant working with them for several months while they learned to use the system effectively.

Economic feasibility was based on the cost increases or the cost savings which would result from changing to the new system. Expected changes in costs were analyzed, and it was found that substantial annual costs savings would occur. In addition, the costs of developing and installing the new system, including training personnel to understand, handle, use, and manage the system, would be paid for in less than a year by the resulting savings in quality costs. After the initial payout period, cost savings would continue to accrue from the system. Accordingly, in economic terms the system would be both directly and indirectly beneficial.

To achieve a general appraisal of the potential system, the project was explored in detail with the general manager and the production manager. The procedures were explained and the feasibility analyses were presented. It was here that the insight of the two managers was merged with that of the project team to determine if any problems were anticipated which could interfere with success of the project and the quality surveillance system. The managers were pleased with the tentative system and with the plans for testing the system and for introducing it to the middle and lower managers. They volunteered their support and assistance to the project.

Design of the Project

Attention was then devoted to completing the design of the system and the step-by-step plan for its introduction and installation. The statistical details are shown in the Appendix.

The new system would use inspection information which was already being collected in the assembly operations and which was familiar to company personnel. However, analysis of the data and its use in reports to management would be new. As described earlier, the inspection data would be used to calculate defect levels in terms of number of defects per hundred units of the final product. From these defect levels, a standard for comparison would be calculated for each assembly line and for each inspection station on each line. In addition, statistical control limits would be calculated for use with each of these reference standards.

Tables would then be prepared in which the actual level of defects would be compared with the reference standards for each assembly line and inspection station, as well as for the assembly department as a whole. From the tables, it would be easy to see how the current and past levels of defects compared with the reference standards. Furthermore, the use of control limits as a basis for rating defect levels would make it possible to detect when a quality problem was likely to exist on any assembly line; these problems could then be traced even further by examining the tables and basic data for the inspection stations on the lines experiencing quality problems.

The quality rating procedure, also vital to providing management by exception, would be based on probability considerations. This rating procedure would assign six quality levels (excellent, good, average, fair, poor, and unsatisfactory) that signaled quality problems as well as areas of quality excellence. This would make it possible to design management reports that were short and clear and would pinpoint where action was needed. Furthermore, these ratings would signal lower levels of management when the probability that a significant problem existed would be relatively low. As the probability of a major problem increased, however, higher levels of management would be signaled that their attention and action were needed. Thus, the system and reports would produce more efficiency in use of management time.

The design of the system was based on statistical logic and accuracy. Ideally, it should be simple to use, and it would tie in with existing understanding of quality concepts by the operating personnel. The system would signal the proper level of management attention and would guide them to the quality problems. It would do this economically, costing less than the existing system.

A detailed description of the new quality management system is shown in the Appendix.

III. SELECTION, APPROVAL, AND ACTIVATION

After the quality surveillance system was designed, plans were made for its presentation to management and its implementation. These plans were as important as the design of the system; a system, regardless of its excellence, is worthless if not approved and successfully implemented.

Selection and Approval

Further pilot runs were made for the project team to be confident in the newly designed system and to select it for recommending to management. Using current inspection data, the system was tested for several weeks for one assembly line. Then it was tested for several more weeks using current inspection data for all lines.

The same procedure was used in these pilot runs as was used in the simulation test described in the previous chapter. In the earlier simulation test, historical data were used, so that a simulated run of six months was achieved in about a month. These later pilot runs, however, used current data, and each set of runs covered a period of six to eight weeks. In each run, standards and control limits were calculated for each assembly line and inspection station, quality ratings for each week were generated, and the quality ratings were compared with quality problems that could be found on the line. This was done weekly for the full pilot-run periods. The pilot runs showed the system to be very satisfactory. It was, in fact, clearly and dependably identifying quality problems as well as areas of quality excellence. Based on these tests, the team was satisfied that this was the system design to select for recommending to management. The pilot runs increased the team's confidence in the design for the system, and it gave them a sounder basis for proposing its approval to top management.

The use of pilot runs is a safe, conservative way to prepare for proposing a new system, design, or procedure; it also builds confidence in all concerned in the proposals as well as in those who prepare and present the proposals. Managers like to have confidence that those developments they approve will be successful; the pilot runs help to raise confidence in the system. If the pilot runs indicate good results, that raises management's assurance that the system will succeed. With these results, the proposed system is more likely to receive management's approval. If the pilot runs yield less than satisfactory results, those developing the new system should pursue its development further before recommending it to management for approval. The pilot runs in this project, however, showed the new system to be sound.

The next step was to obtain approval from plant management for proceeding with implementation of the system. This was pursued in a meeting with the general manager and the production manager. Since top management of the plant had already decided that improvements in the quality management system were to be considered and had retained the consultant to assist them in that endeavor, it was not necessary to sell top management on that need. Neither was it necessary to meet with all the department managers; instead, the team needed only the approval of the two top managers.

If a substantial additional cost or investment had been necessary, additional considerations would have been essential, involving other management personnel. But since the system would improve quality and cost, no other investment decisions were needed. Consequently, approval was feasible by the consent of those two managers.

The team described the proposed system, presented the results of the test runs, and showed predicted cost savings expected from the system. The two managers asked a number of questions. They wanted to know if quality ratings of one assembly line depended on comparing quality with other lines. When they learned that ratings for a line were based entirely on current and past quality results on that line, they were pleased. They also wondered if major temporary deviations from normal quality were included in calculating the reference bases of defect levels. Here, too, they were relieved to find that statistical procedures would be used selectively to exclude extreme, short-term deviations from the standard base when calculating a new standard base.

The managers also wanted to know if managers might be frustrated by ratings that indicated low quality level on some of their lines. Their concern was about the difficulty line managers might have finding the quality problems, which could be frustrating since the quality ratings would be visible to others. Discussion of this question brought to light a likely advantage of the system: when line supervisors and foremen saw a low quality rating on a line or inspection station, if they were unable to locate the quality problem after a brief search, they would now have strong motivation to seek the assistance of the quality control (staff) personnel in finding and resolving the problem. The quality levels would give clear and definite signals; line supervisors and foremen would realize the benefit to themselves of clearing up the quality problems quickly--before attention of top management was signaled. Thus, they would be motivated to use the quality control personnel as staff personnel should be used--to assist them in finding and resolving their problems, and, in follow-up, to find ways to prevent them from recurring. As a result of the meeting, both managers were satisfied with the system and with the evidence of its predicted success and cost savings. They gave tentative approval but requested that care be used in its implementation and that a close surveillance of the system and its use be maintained for about six months.

Activation

It was vitally important for all line managers and supervisors to understand and accept the system and that they cooperate to help make it work. Without their interest and active cooperation, it would be less successful and less valuable to the company. If they resisted the new system, it would fail.

A meeting was held for the project team to present the system to production foremen and supervisors and to discuss all aspects of it that were important to them. They showed intense interest, especially since they realized that they needed better quality information and needed it more quickly.

To help the supervisors and foremen understand the proposed quality surveillance system, it was compared to financial expense budgets, which were already familiar to them. Quality rating was explained as a quality defect budget, which provides production departments with defect allowances just as the expense budget provides them with expense allowances. Figure 3 was used to discuss the features of the plan. This allowed the supervisors to understand each of the details which would assist them in maximizing the potential benefits available from the plan.

Figure 3 also was used to discuss interpretation of the quality ratings and the limitations inherent in the quality rating procedure. Item 6 of Figure 3 was expanded to show that the quality ratings would be based on the probability that a deviation from the quality standard ($\bar{u}$) had occurred, and that these quality ratings would allow the defect level to experience a moderate deviation from "standard" before management's attention would be signaled. Supervisors appreciated the fairness inherent in this evaluation and rating procedure when contrasted to the more arbitrary judgments associated with the expense budget.

The reaction of the foremen and supervisors was excellent. They had ample opportunity to raise questions to assure that they understood the system and how it should be used. The foremen and supervisors requested that the system be installed for a trial period of several weeks, during which time they would give it a genuine trial. They were interested to see if and how it would help them in their responsibilities.

The attitude and response of the production foremen and supervisors at the meeting showed that they were genuinely interested and wanted the new system to

QUALITY CONTROL ENGINEERING
(Comparison of Quality Rating with
Financial Expense Budgeting)

	Financial Expense Budget	Quality Defect Budget
1. Standard or bogey based on recent experience	X	X
2. New standards set as experience warrants	X	X
3. Standards do not differentiate between tight and loose conditions among several lines	X	X
4. Standards reflect approximate capability	X	X
5. Major deviations from standards provide management by exception	X	X
6. Bases available for judging extent of deviations from standard		X
7. Comparisons limited to "within departments"	X	X

FIGURE 3. Exhibit Used to Explain Quality Surveillance System to Middle and Lower Management

succeed. It was obvious that they wanted a better quality surveillance system; but it also was obvious that they felt a part of the development of this new system. Their opinions and suggestions had been used in developing the system; their needs and interests had been a major consideration in designing the system. Now, they were anxious to try it out.

IV. OPERATION, CONTROL, AND HANDOVER

The system had been designed, management had approved its implementation, and plant supervision had agreed to give it a thorough trial. It was now to undergo the "acid test." Would it succeed when in operation? These next stages would determine the answer.

Implementation

The Trial Period. At the meeting with the foremen and supervisors, the project team distributed tabular information showing the current status defect levels and quality ratings on all assembly lines. The team felt that current information would be more interesting to the line foremen than limiting discussion to historical data. Consequently, the foremen had information that specified which lines (and the points on these lines) were currently experiencing quality problems.

Production foremen left the meeting with their copies of the quality rating reports. Using these reports to guide them to quality problems, they investigated assembly lines rated F, P, or U. In doing so, they discovered and corrected quality problems that they had not previously recognized.

The foremen were enthusiastic. The new system provided them with distinct quality ratings that signaled their attention when quality problems existed. By providing these ratings for each inspection station on each assembly line, the system also indicated where those quality problems were being generated, or at least where they could be found. Previously, they had data on quality defect levels, but not in a form or with specific quality ratings that clearly directed them to problems needing their attention.

Top management also was pleased with the quality information they received. On one page, they could see the quality status of the entire assembly section of the plant. Locations that needed their attention were identified. Quality excellence also was indicated, calling their attention to opportunities for commendation.

In the beginning of the trial period, the new quality reports were provided to management on a weekly basis. Later, at their request, the reports were provided daily to line supervisors and foremen. These reports specified the reference base ($\bar{u}$), current defect level (u), and quality rating for each assembly line and for each inspection station on each line. This identified possible quality problems needing the attention of line supervisors and foremen (those lines or stations rated F, P, or U), those needing middle management attention (those rated P or U), and those needing top management attention (those rated U). The defect levels and quality ratings, as well as the reference bases ($\bar{u}$) and control limits, were calculated from the inspection data collected regularly at the assembly line inspection stations.

When a manager was prompted to action by an adverse quality rating, he would search for the quality problem in that portion of the assembly line whose work was inspected at the inspection station reporting the high level of defectiveness. If the quality problem was not quickly apparent, he would obtain from Quality Control an exact listing of the types of quality defects found at that station during the period showing the low quality ratings. This information would further aid in identifying the quality problem. Once it was identified, effort to solve it would begin. If lower levels of management did not clean up the quality problem, top management's attention would be signaled as the quality ratings continued to drop. Top management's attention and support could be very useful in resolving some of the more complex problems, such as those involving origin of defects in another department of the company.

In using the quality reports, the information, interpretation, signaling of attention, follow-up, and corrective action were identical to those involved in the earlier pilot studies and described earlier in this case study. The only difference was that now the full spectrum of management was involved in the process; earlier, in the pilot runs, the Quality Control personnel carried out the entire process.

The trial period was a success. Management gave its approval to complete the system implementation and to exercise surveillance and refinement of the system for the remainder of the six-month installation period.

The Installation Period. During the installation period, company personnel were trained in the details of data analysis, report preparation, and interpretation and use of the quality reports. The consultant and two of the team members (the manager of Quality Control and the quality analyst) worked closely together in data analysis and report preparation. The report to top management included a brief interpretation of the summary report on defect levels and quality ratings; care and precision in preparing this interpretation was essential. Through this close teamwork, the analyst became proficient in handling all the statistical and other details of the analysis. The quality control manager also gained thorough understanding of the analytical procedures, and he wrote the interpretation paragraphs for the report to top management.

In addition, it was important that line supervisors and foremen be thoroughly versed in using their quality reports effectively. Training to achieve this was accomplished in two ways. First, each request from a supervisor or foreman for quality control assistance in finding and solving quality problems was considered a prime opportunity for training. Quality Control personnel, all of whom were familiar with the new system and its use, would work with the line supervisor or foreman to interpret the report data, examine the supporting inspection data for types of defects recorded, and trace down the quality problem and work to solve it. In this way, the supervisors and foremen became proficient in making effective use of the quality reports. To supplement these individual experiences, however, meetings with small groups of line supervisors and their foremen were held every two weeks, then monthly, to answer questions and further clarify the operating details of the new system and its application. Thus, none of them was without opportunity to gain full understanding; and if anyone indicated a need for personal guidance or discussion, this request was honored.

Some training was necessary for the other personnel in the Quality Control Department. The line inspectors needed to be generally familiar with the system and how it was used, for their own information and to provide minor assistance to line supervisors and foremen regarding the reports and quality problems. Other personnel in the Department, however, were primarily the ones who assisted in tracking down and solving quality problems. They, too, needed to understand the system, the reports, and use of the system information. A series of meetings (every two weeks, then monthly) were held during the implementation period to achieve this training.

Supervision and Control

The system continued to achieve the needed results. Numerous quality problems were signaled for investigation and correction. Lower levels of supervision were signaled before top management, and this provided opportunity for problem correction before top management was notified that action was needed by them.

The worksheets on which the ratings were calculated were maintained in the Quality Control Department. They were available to any supervisor to provide information detail he might need for tracking down the sources of defects.

Each adverse quality rating stimulated investigation and follow-up action by the line supervisors and foremen. Those quality problems that were not readily apparent prompted the foremen to seek further information and/or assistance from Quality Control. This resulted in a cooperative exploration by Production and Quality Control to determine the cause. These explorations would involve examination of the inspection worksheets which indicated the types of quality defects found at the inspection station where the defect level was high and the adverse quality rating was reported. With this detailed information, the quality problem would be traced and its solution pursued by the cooperative effort of the production and quality control personnel.

Originally, only weekly quality ratings were prepared and reports issued. However, production foremen started requesting daily reports to investigate quality problems in the earliest stages. In addition, as a result of their interest and satisfaction with the new system, the production supervisors began giving increased attention to request for assembly line screening (100 percent inspection that was required when defects exceeded acceptance numbers in sampling plans). They found that by looking for quality problems when defect levels were excessive at an inspection station, they could often spot serious problems, and correct them, before the defects would show up on the daily reports. In fact, this quick responsiveness often prevented quality problems from showing up on the reports, as they were corrected before enough defective units could be produced to cause the quality reports to reflect an adverse rating. It was obvious that the new system was stimulating interest and attention to the quality needs, as the foremen wanted to catch and correct quality problems before they would signal top management's attention. The system not only signaled proper attention, it also stimulated prompt corrective action.

The system proved to be sensitive to assignable causes for low quality. It also was reliable in signaling real problems for corrective attention and for general quality surveillance over the assembly departments. Both management and quality control used the posted levels of defects per inspection unit and the quality ratings to determine which lines needed special quality attention. The results were very good.

Completion and Handover

The system was a success. It was necessary, however, to maintain close surveillance on the system and its results for the six-month implementation period. During this period, additional refinements were made in the location of inspection stations, the amount and allocation of inspection, forms used for collecting inspection data and for analyzing it, reports for management, and other details of the system. Ideas for improvement and refinements came not only from the project team, but also from foremen and inspectors using the forms and reports.

Also, the training of company personnel in using the system, including data analysis and preparation of reports, was completed. This training was carried out under team supervision during the six months of implementation, surveillance, and final refinements of the system.

As the system refinements and personnel training were moving toward completion, less time involvement was necessary for the project team. The consultant spent more of his time with other projects in the quality management program, but remained on call as his additional counsel was needed. The project was considered complete. The new quality surveillance system was operating smoothly, and management (including line supervision) and quality control were pleased with the results.

V. EVALUATION AND REFINEMENT

It had been decided during the system installation that a review of the system would be made several months following completion of its installation and refinement. New systems and procedures sometimes show success only during the initial periods when special attention is focused on making them succeed; these early successes are often followed by deterioration. Consequently, an examination of the system, its results, and management attitudes about the system was planned.

Evaluation and Follow-Up

Evaluation of the new quality surveillance system was thrust on the project team in an unexpected way, in spite of the plans for an evaluation. During the "settling-in" period, after all refinements and other installation details were complete, supervision in the fabrication sections of the plant began requesting management to have the new system expanded to encompass all production operations. This prompted evaluation of the system and a reexamination to determine its applicability to fabrication operations. Since these requests were made only shortly before the evaluation was to be made anyway, the timing for blending these two considerations into one effort was fortunate.

The fabrication sections included metal and plastics processes, starting with basic raw materials and producing finished component piece parts for the telephone assembly and subassembly operations. Supervision in the fabrication sections had heard of the new system for quality surveillance and the good results it was achieving in the assembly sections. Consequently, they requested that management authorize the project team to explore applicability of the new system to the fabrication operations. If it would apply with results equivalent to those already experienced in assembly, they would like for it to be implemented in fabrication too.

This caused a dual-goal exploration: (1) to evaluate the system and its results and expectation of continuing results in assembly operations: and (2) to explore applicability of the system to fabrication operations. This dual study was made.

It was found that the new system was serving all the intended needs in providing surveillance of quality of the assembly operations. Management, supervision, and quality control were all pleased with the results. No further changes in the system were needed, and it was expected to continue to be successful, useful, and accepted.

Expansion of the system to the entire production operations, including fabrication, would require some minor modifications, but these would not alter its application to the assembly operations. These modifications were planned by the project team, and the application of the system to fabrication was discussed in depth with foremen and supervisors of those sections. They were anxious to give it a trial. Consequently, plant wide application began and was conducted for several months. Again, the system succeeded and company personnel recommended and accepted its approval as a permanent system in the plant. This was approved by top management.

Refinement of Policy and Planning

Although successful completion of the project did not alter the company's policies regarding quality and quality management, it did provide opportunity for reallocation of effort and cost in the quality management activities of the plant. The new system had reduced the amount of inspection data collected as the product quality rose; it had reduced the amount of paper and data analysis by over three quarters; it had substantially increased quality resulting from assembly operations and later from fabrication operations; it had reduced the amount of time necessary for management to allocate to "fighting fires" due to quality problems; and it had given a higher confidence of management in the resulting quality of its product and in the quality control department.

As a result of these improvements, the direction of quality effort would be shifted more into quality engineering--developing production processes and quality assurance of purchased materials--to prevent quality problems from occurring in the first place. This would emphasize defect prevention instead of defect detection and defect correction. This shift would be much more feasible now that a satisfactory system of quality surveillance was operating well.

This was the initial planning, as a reorientation of quality effort, to allocate increasing personnel effort to quality engineering. Less effort in inspection was now needed, and even less would be needed as quality improved further. This began a new project that was a combined effort of quality control, product engineering, and industrial engineering to emphasize "engineering" the quality into the design of the products and the processes producing them.

VI. CONCLUSION

The project was more successful than was originally anticipated. The new system was highly satisfactory in its application to the assembly operations, which was the original intent and major need. In addition, it was equally successful in enabling improved quality surveillance of fabrication operations; here improvement was not critical but was a valuable contribution and enabled the plant wide use of a single quality surveillance system. Finally, quality costs were lowered substantially, and the improved quality and quality costs made it possible to plan a major shift in the quality emphasis from inspection to quality engineering.

The success of the project was contributed to several factors:

1. The excellent teamwork of the company personnel and the consultant serving as the project team.
2. Careful preplanning, especially formulation of project objectives and criteria, based on needs analysis, to guide the whole project.
3. Proper attention to the whole quality management system and how this project, and its resulting system of quality surveillance, related with the system as a whole.
4. Design of a system based on sound principles of statistics, management, and quality control.
5. Testing the system at several stages of its development.
6. Participation of foremen and supervisory personnel who would be directly using the system reports for corrective action, and communicating clearly with them using comparisons and technical jargon already familiar to them.
7. Providing a period of several months after its initial installation to refine the system details and to increase understanding of the tasks involved and confidence of company personnel in their effective use and management of the system.
8. Open-mindedness of plant management and quality control personnel to respond affirmatively to suggestions and requests from foremen and supervisors regarding the system, its refinement, its details of application, and its expansion to encompass the entire plant production operations.

REFERENCE

Cotton, Frank E. Jr. and Higgenbottom, Ezra L., "Assembly Surveillance Using Defect Controls," Industrial Quality Control, May 1965. (Liberal use of this article reporting this project was authorized by the American Society for Quality Control.)

APPENDIX

Statistical Basis

The quality rating system was based on defects per inspection unit. The inspection unit for final assembly is 100 telephones; that for each subassemly, the number of such subassemblies required for 100 telephones. The produce was made from eight subassemblies, as follows:

	Subassemblies							Final Assembly	
Assembly:	A	B	C	D	E	F	G	H	I
No. per telephone:	1	1	1	1	1	3	1	1	1
Inspection unit:	100	100	100	100	100	300	100	100	100

Since an AQL inspection system was already in use throughout the plant, the use of 100 units of the finished product for the basic unit was very convenient. The familiarity of the assembly personnel with percent defective simplified their understanding of defects per 100 units of final product. Furthermore, since the values of defects per inspection unit for the several assembly lines are additive, management had a convenient indicator of the number of defects contributed by each assembly line to 100 units of the final product (see Figure 4).

The original data used for the quality analyses and reports were obtained from the inspectors, who used continuous sampling plans on the production lines. Several inspection stations existed on each line. Consequently, the defects per inspection unit for all inspection stations were summed to give the total defects per inspection unit for the assembly line. This allowed traceability of defect contribution per inspection unit even to sub-subassemblies on production lines. Out-of-control conditions were easily traceable to their sources.

As a result of high quality standards established by company policy, the overwhelming proportion of defects were classified as major. Accordingly, no distinction was made between major and minor defects in the quality rating plan.

Since u-charts were used for the quality evaluation, the calculation of standard deviation (σ) was as follows:

Inspection unit = 100 product units or equivalent

n = average number of inspection units inspected per week

u = defects per inspection unit for a week (total defects divided by number of inspection units, n)

$\bar{u}$ = average number of defects per inspection unit in the base period (six weeks were used)

$$\sigma = \sqrt{\bar{u}/n}$$

For each inspection station and production line, $\bar{u}$, σ, and control limits were calculated for convenient traceability of out-of-control conditions. Both u and σ^2 (variance) are additive, which simplifies the calculation. For a production line, $\bar{u}$ is calculated as follows:

$$\bar{u}_L = \bar{u}_1 + \bar{u}_2 + \ldots + \bar{u}_k$$

where $\bar{u}_L$ is the $\bar{u}$ of the line, and $\bar{u}_1 \ldots \bar{u}_k$ are the $\bar{u}$'s for each inspection station on the line. Similarly, $\bar{u}$ for the total assembly of the product is calculated as follows:

$$\bar{u}_T = \bar{u}_A + \bar{u}_B + \bar{u}_C + \bar{u}_D + \bar{u}_E + \bar{u}_F + \bar{u}_G + \bar{u}_H + \bar{u}_I$$

where $\bar{u}_T$ is the $\bar{u}$ of all assembly for the product, and $\bar{u}_A \ldots \bar{u}_I$ are the $\bar{u}$'s for each line. This is also illustrated in Figure 4.

The relationship between the standard deviation of a line and the standard deviation of total assembly is as follows:

$$\sigma_T^2 = \sigma_A^2 + \sigma_B^2 + \sigma_C^2 + \sigma_D^2 + \sigma_E^2 + \sigma_F^2 + \sigma_G^2 + \sigma_H^2 + \sigma_I^2$$

But since $\sigma = \sqrt{\bar{u}/n}$, this converts to the following:

$$\sigma_T^2 = \bar{u}_A/n_A + \bar{u}_B/n_B + \bar{u}_C/n_C + \bar{u}_D/n_D + \bar{u}_E/n_E + \bar{u}_F/n_F + \bar{u}_G/n_G + \bar{u}_H/n_H + \bar{u}_I/n_I$$

Since each subassembly was included in the final product, the number of units of final product determined the number of units of each subassembly, with the number of inspection units of each subassembly being approximately equal. Accordingly, with $n_A = n_B = \ldots = n_I$

$$\sigma_T^2 = (\bar{u}_A + \bar{u}_B + \bar{u}_C + \bar{u}_D + \bar{u}_E + \bar{u}_F + \bar{u}_G + \bar{u}_H + \bar{u}_I)/n$$

$$= \bar{u}_T/n$$

$$\sigma_T = \sqrt{\bar{u}_T/n}$$

It was assumed, for convenience of calculation and interpretation, that the average number of inspection units inspected from week to week remained unchanged. This was approximately correct; therefore, control limits were revised periodically but were not recalculated each week.

Each set of control limits was reviewed monthly, and these limits were recalculated when: (1) a significant change in production rate occurred; (2) a significant, continuing downward shift in $\bar{u}$ occurred; or (3) a significant upward shift in $\bar{u}$ occurred which must be tolerated permanently.

Calculations of $\bar{u}$ (for determining control limits) were based on the number of defects and the number of inspection units inspected during the six most recent weeks when production was not out of control.

Quality Ratings

Control limits were calculated for each inspection station, for each assembly line and for total assembly. The control limits and corresponding ratings used in the plan were as follows:

E = Excellent	= below $(\bar{u} - 2\sigma)$
G = Good	= $(\bar{u} - 2\sigma)$ to $(\bar{u} - 1\sigma)$
A = Average	= $(\bar{u} - 1\sigma)$ to $(\bar{u} + 1\sigma)$
F = Fair	= $(\bar{u} + 1\sigma)$ to $(\bar{u} + 2\sigma)$

P = Poor = $(\bar{u} + 2\sigma)$ to $(\bar{u} + 3\sigma)$

U = Unsatisfactory = above $(\bar{u} + 3\sigma)$

The quality ratings for a specific week were generally determined by the formula given earlier. To increase the sensitivity of the rating system, however, the quality ratings were modified by the following formulas for continuous runs:

Unsatisfactory quality rating (U):

2 consecutive points above $(\bar{u} + 2\sigma)$
3 consecutive points above $(\bar{u} + 1\sigma)$

Poor quality rating (P):

2 consecutive points above $(\bar{u} + 1\sigma)$
4 consecutive points above $\bar{u}$

Excellent quality rating (E):

2 consecutive points below $(\bar{u} - 1\sigma)$
4 consecutive points below $\bar{u}$

The probability of occurrence for either of the two runs indicating unsatisfactory (U) rating was generally equal to or less than the probability of a single point falling outside the upper 3-sigma control limit of the Poisson distribution. Similarly, the probability of occurrence for either of the runs of two points indicating "P" or "E" was generally equal to or less than the probability of a single point falling outside the respective 2-sigma control limit. However, the probability that either of the two runs of four points would occur was slightly higher than the probability of a single point falling outside the 2-sigma control limit.

In practice, the defect levels (u) for the four most recent weeks were reviewed, and a quality rating was assigned for the most recent week indicating the most extreme deviation from $\bar{u}$ which could be concluded from the rating formulas.

The six quality ratings were used in the following way:

1. Unsatisfactory (U): The average quality level had declined. Attention of plant management was required. Production management and/or Quality Control initiated corrective action and explained causes to plant management.

2. Poor (P): The average quality level probably had declined. Corrective action required by production management and/or Quality Control.

3. Fair (F): The average quality level may have declined. Production supervision performed quick corrective action, followed by closer-than-normal quality surveillance.

4. Average (A): The average quality level remained unchanged.

5. Good (G): The average quality level may have increased. Production supervision noted any unusual factors which may have been favorably influencing quality. Management noted favorable rating.

6. Excellent (E): The average quality level probably had increased. Production supervision and Quality Control sought the principal factors contributing to the high quality rating, and determined if these factors could be retained. Plant management commended production management and Quality Control.

This rating procedure signaled to appropriate operating management the need for corrective action at a lower confidence level, while reserving for top management attention the signal for conditions approaching a probability of certainty. Also, through evaluation of continuous runs, even a moderate decline in quality which might be the start of a trend was brought to the attention of plant management if not corrected within a short period.

The reader will note that the range between $\bar{u}$ and $(\bar{u} + 1\sigma)$ was not considered in evaluating continuous runs for ratings of unsatisfactory (U). This could be accomplished using continuous runs of seven points, or even longer noncontinuous runs; however, it was decided to confine the evaluations of runs to continuous periods not exceeding four weeks for economy of evaluation.

Quality Reporting

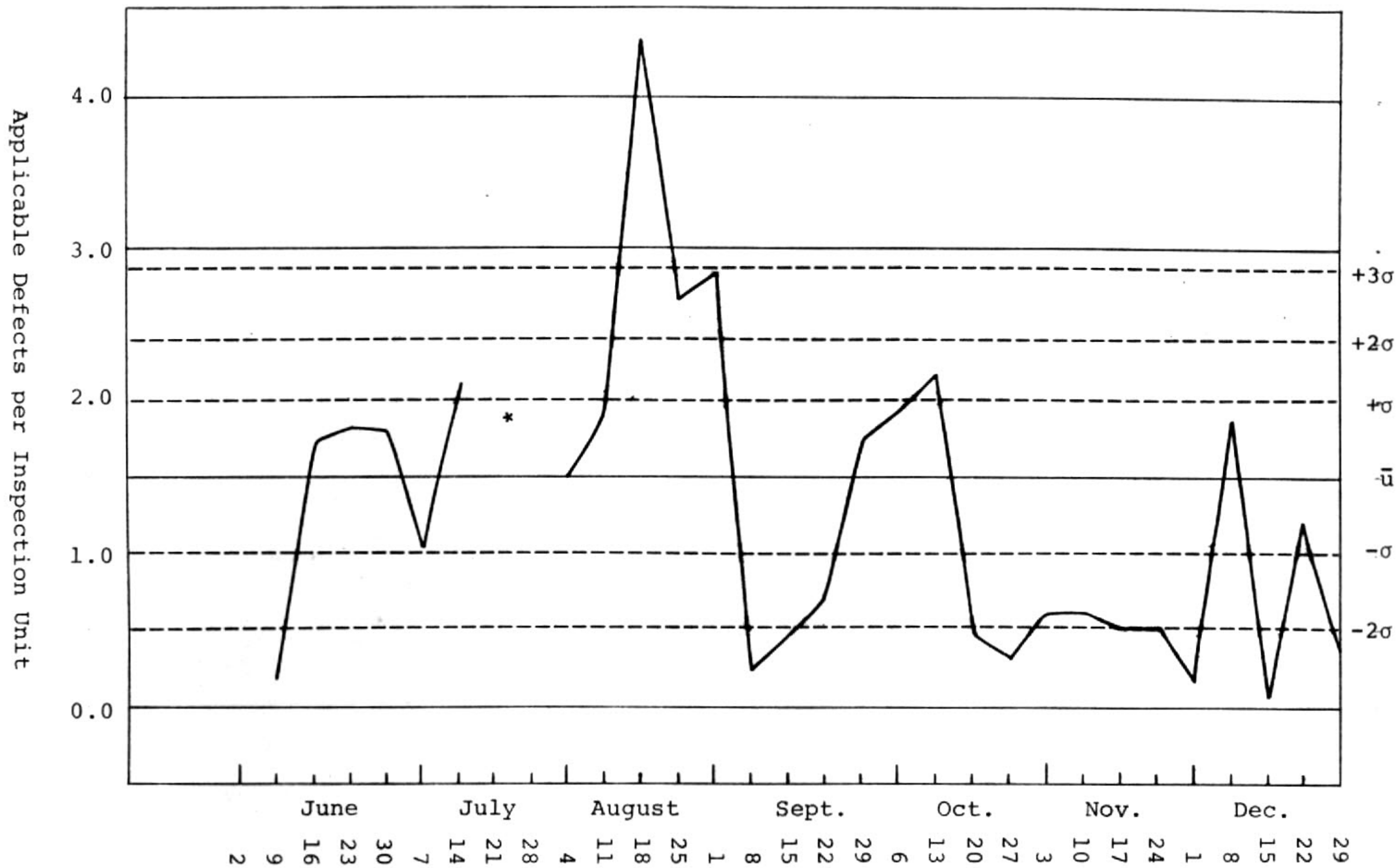
The weekly tabular report (illustrated by Figure 4) was distributed to the plant manager and to production and quality control management. Production and quality control personnel used the report for assembly quality surveillance and as the starting point for many quality engineering investigations. Quality ratings were issued daily to production foremen to assist them in rapid detection of quality problems. (Since the plant worked a five-day week, standard deviation for daily production equaled $\sqrt{5}$ times standard deviation for weekly production.) A set of charts, including one for each assembly line and one for the total product, was maintained by Quality Engineering. A second set was kept current for the plant manager and was retained by him. Figure 5 shows a chart for one of the subassembly lines.

QUALITY CONTROL ENGINEERING
WEEKLY DEPARTMENTAL QUALITY REPORT - ASSEMBLY
(Based on Applicable Defects per Inspection Unit)

Week Ended	Sub A		Sub B		Sub C		Sub D		Sub E		Sub F		Sub G		Sub H		Final Assembly		Total Assembly		Non-Applicable Defects	
	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR	Def. Per 100	QR
Base	4.2		1.2		3.4		2.1		0.6		2.4		1.4		2.1		1.6		19.0		3.4	
10/6	4.3	A	1.0	G	6.8	U	0.9	E	0.5	A	2.9	F	2.0	P	2.2	A	1.5	A	21.1	F	3.0	G
10/13																						
.																						
.																						
.																						
12/22																						

CODE: E = Excellent G = Good A = Average F = Fair P = Poor U = Unsatisfactory

FIGURE 4. Layout of Weekly Quality Report
(Data are fictitious, for illustration only)



* Vacation Period

FIGURE 5. Sample Weekly Quality Rating Chart

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