SECTION 4
THE QUALITY CONTROL PROCESS

J. M. Juran
A. Blanton Godfrey

INTRODUCTION

Quality Control Defined. This section describes the quality control process. "Quality control" is a universal managerial process for conducting operations so as to provide stability—to prevent adverse change and to "maintain the status quo."

To maintain stability, the quality control process evaluates actual performance, compares actual performance to goals, and takes action on the difference.

Quality control is one of the three basic managerial processes through which quality can be managed. The others are quality planning and quality improvement, which are discussed in Sections 3 and 5, respectively. The Juran trilogy diagram (Figure 4.1) shows the interrelation of these processes.

Figure 4.1 is used in several other sections in this handbook to describe the relationships between quality planning, quality improvement, and quality control and the fundamental managerial processes in total quality management. What is important for this section is to concentrate on the two "zones of control." In Figure 4.1 we can easily see that although the process is in control in the middle of the chart, we are running the process at an unacceptable level of waste. What is necessary here is not more control but improvement—actions to change the level of performance.

After the improvements have been made, a new level of performance has been achieved. Now it is important to establish new controls at this level to prevent the performance level from deteriorating to the previous level or even worse. This is indicated by the second zone of control.

The term "control of quality" emerged early in the twentieth century (Radford 1917, 1922). The concept was to broaden the approach to achieving quality, from the then-prevailing after-the-fact inspection, to what we now call "defect prevention." For a few decades, the word "control" had a broad meaning which included the concept of quality planning. Then came events which narrowed the meaning of "quality control." The "statistical quality control" movement gave the impression that quality control consisted of using statistical methods. The "reliability" movement claimed that quality control applied only to quality at the time of test but not during service life.

In the United States, the term "quality control" now often has the narrow meaning defined previously. The term "total quality management" (TQM) is now used as the all-embracing term. In

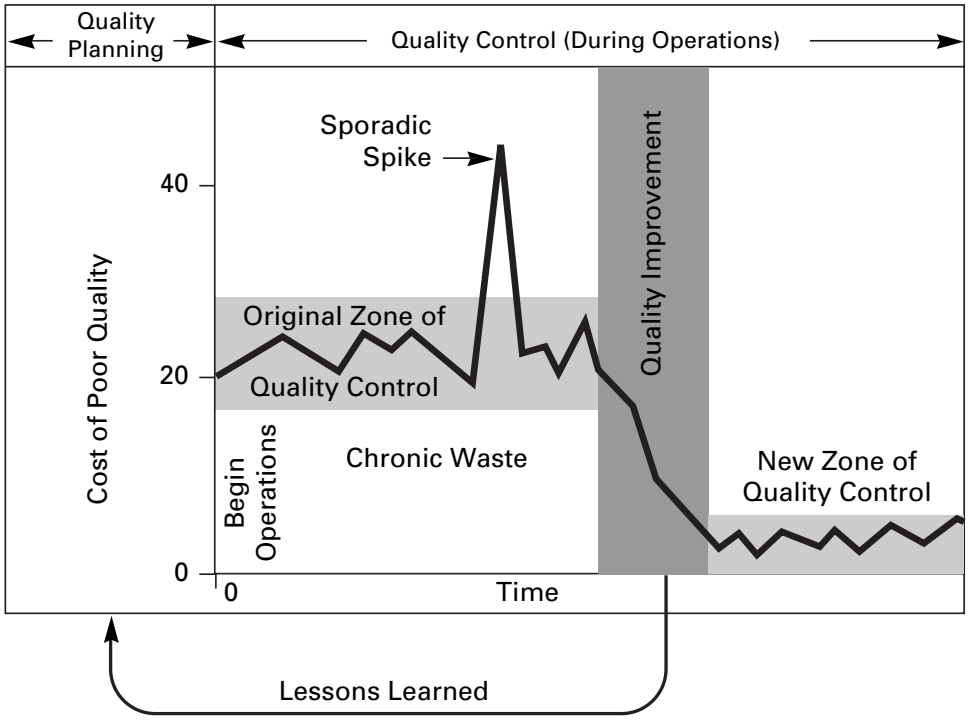


FIGURE 4.1 The Juran trilogy diagram. (*Juran Institute, Inc., Wilton, CT.*)

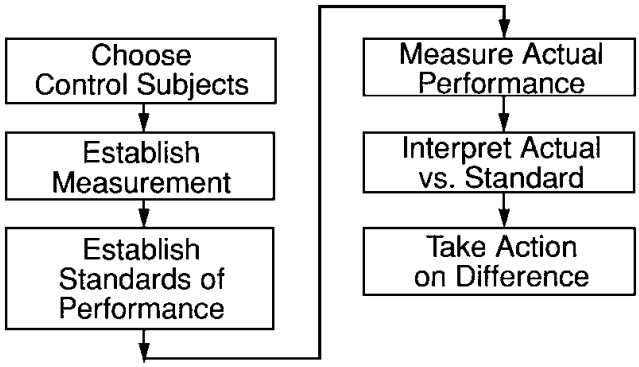


FIGURE 4.2 The input-output diagram for the quality control process.

Europe, the term "quality control" is also acquiring a narrower meaning. Recently, the European umbrella quality organization changed its name from European Organization for Quality Control to European Organization for Quality. In Japan, the term "quality control" retains a broad meaning. Their "total quality control" is roughly equivalent to our term "total quality management." In 1997 the Union of Japanese Scientists and Engineers (JUSE) adopted the term total quality management (TQM) to replace total quality control (TQC) to more closely align themselves with the more common terminology used in the rest of the world.

The quality control process is one of the steps in the overall quality planning sequence described in Section 3, The Quality Planning Process, and briefly again in Section 14, Total Quality Management. Figure 4.2 shows the input-output features of this step.

In Figure 4.2 the input is operating process features developed to produce the product features required to meet customer needs. The output consists of a system of product and process controls which can provide stability to the operating process.

The Relation to Quality Assurance. Quality control and quality assurance have much in common. Each evaluates performance. Each compares performance to goals. Each acts on the difference. However they also differ from each other. Quality control has as its primary purpose to maintain control. Performance is evaluated during operations, and performance is compared to goals during operations. The resulting information is received and used by the operating forces.

Quality assurance's main purpose is to verify that control is being maintained. Performance is evaluated after operations, and the resulting information is provided to both the operating forces and others who have a need to know. Others may include plant, functional, or senior management; corporate staffs; regulatory bodies; customers; and the general public.

The Feedback Loop. Quality control takes place by use of the feedback loop. A generic form of the feedback loop is shown in Figure 4.3.

The progression of steps in Figure 4.3 is as follows:

1. A *sensor* is "plugged in" to evaluate the actual quality of the *control subject*—the product or process feature in question. The performance of a process may be determined directly by evaluation of the process feature, or indirectly by evaluation of the product feature—the product "tells" on the process.
2. The sensor reports the performance to an *umpire.*
3. The umpire also receives information on what is the quality *goal* or standard.
4. The umpire compares actual performance to standard. If the difference is too great, the umpire energizes an *actuator.*
5. The actuator stimulates the *process* (whether human or technological) to change the performance so as to bring quality into line with the quality goal.

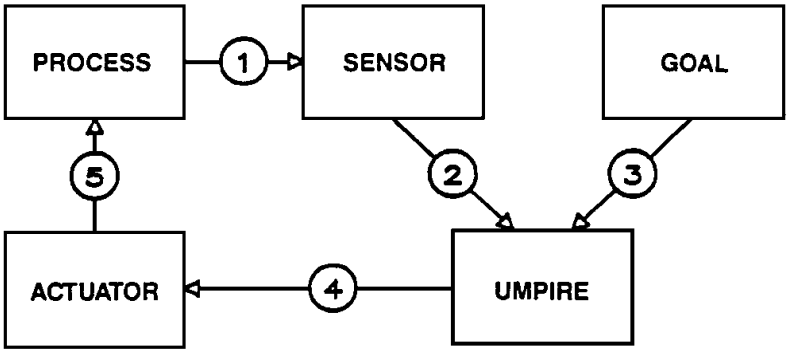


FIGURE 4.3 The generic feedback loop. (*Making Quality Happen, Juran Institute, Inc., senior executive workshop, p. F-3, Wilton, CT.*)

6. The process responds by restoring conformance.

Note that in Figure 4.3 the elements of the feedback loop are functions. These functions are universal for all applications, but responsibility for carrying out these functions can vary widely. Much control is carried out through automated feedback loops. No human beings are involved. Common examples are the thermostat used to control temperature and the cruise control used in automobiles to control speed.

Another frequent form of control is self-control carried out by a human being. An example of such self-control is the village artisan who performs every one of the steps of the feedback loop. The artisan chooses the control subjects, sets the quality goals, senses what is the actual quality performance, judges conformance, and becomes the actuator in the event of nonconformance. For a case example involving numerous artisans producing Steinway pianos, see Lenehan (1982). Self-directing work teams also perform self-control as is meant here. See Section 15 for a further discussion of this concept.

This concept of self-control is illustrated in Figure 4.4. The essential elements here are the need for the worker or work-force team to know what they are expected to do, to know how they are actually doing, and to have the means to adjust their performance. This implies they have a capable process and have the tools, skills, and knowledge necessary to make the adjustments and the authority to do so.

A further common form of feedback loop involves office clerks or factory workers whose work is reviewed by umpires in the form of inspectors. This design of a feedback loop is largely the result of the Taylor system of separating planning from execution. The Taylor system emerged a

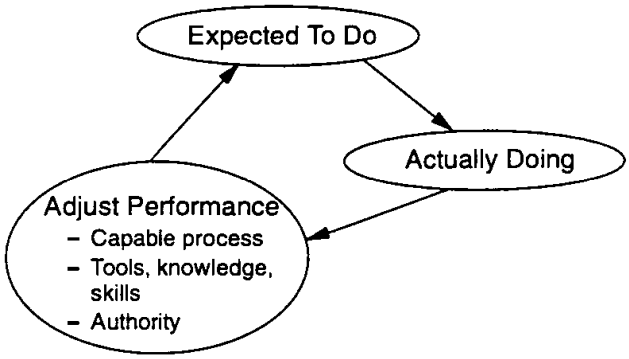


FIGURE 4.4 Self-control. (*"Quality Control," Leadership for the Quality Century, Juran Institute, Inc., senior executive workshop, p. 5, Wilton, CT.*)

century ago and contributed greatly to increasing productivity. However, the effect on quality control was negative.

THE ELEMENTS OF THE FEEDBACK LOOP

The feedback loop is a universal. It is fundamental to any problem in quality control. It applies to all types of operations, whether in service industries or manufacturing industries, whether for profit or not. It applies to all levels in the hierarchy, from the chief executive officer to the work force, inclusive. However, there is wide variation in the nature of the elements of the feedback loop.

In Figure 4.5 a simple flowchart is shown describing the quality control process with the simple universal feedback loop imbedded.

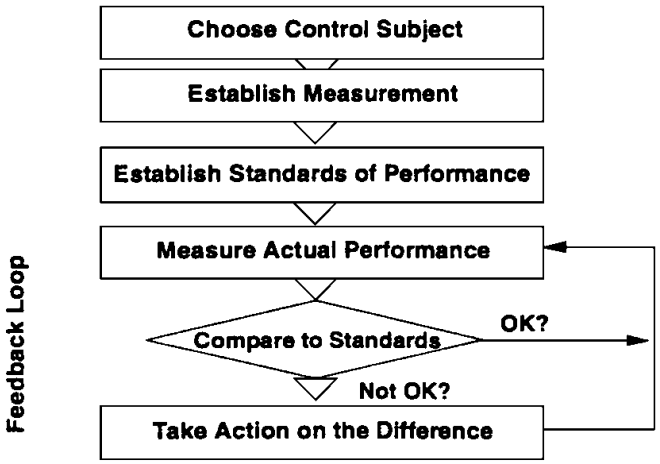


FIGURE 4.5 The quality control process. (*"Quality Control," Leadership for the Quality Century, Juran Institute, Inc., senior executive workshop, p. 2, Wilton, CT.*)

Choose the Control Subject. Each feature of the product (goods and services) or process becomes a *control subject*—a center around which the feedback loop is built. The critical first step is to choose the control subject. Control subjects are derived from multiple sources which include:

Stated customer needs for product features

Technological analysis to translate customer needs into product and process features

Process features which directly impact the product features

Industry and government standards

Needs to protect human safety and the environment

Needs to avoid side effects such as irritations to employees or offense to the neighboring community

At the worker level, control subjects consist mainly of product and process features set out in specifications and procedures manuals. At managerial levels the control subjects are broader and increasingly business-oriented. Emphasis shifts to customer needs and to competition in the marketplace. This shift in emphasis then demands added, broader control subjects which, in turn, have an influence on the remaining steps of the feedback loop.

Establish Measurement. After choosing the control subject, the next step is to establish the means of measuring the actual performance of the process or the quality level of the goods or services. Measurement is one of the most difficult tasks in quality management and is discussed in almost every section of this handbook, especially in the industry sections. In establishing the measurement we need to clearly specify the means of measurement (the sensor), the frequency of measurement, the way the data will be recorded, the format for reporting the data, the analysis to be made on the data to convert the data to usable information, and who will make the measurement. See Section 9, Measurement, Information, and Decision-Making, for a thorough discussion of this subject.

Establish Standards of Performance: Product Goals and Process Goals. For each control subject it is necessary to establish a standard of performance—a quality goal (also called targets, objectives, etc.). A standard of performance is an aimed-at achievement toward which effort is expended. Table 4.1 gives some examples of control subjects and the associated goals.

The prime goal for *products* is to meet customer needs. Industrial customers often specify their needs with some degree of precision. Such specified needs then become quality goals for the producing company. In contrast, consumers tend to state their needs in vague terms. Such statements must then be translated into the language of the producer in order to become product goals.

Other goals for products which are also important are those for reliability and durability. Whether the products meet these goals can have a critical impact on customer satisfaction and loyalty and on overall costs. The failures of products under warranty can seriously impact the profitability of a company through both direct costs and indirect costs (loss of repeat sales, word of mouth, etc.).

The *processes* which produce products have two sets of quality goals:

1. To produce products which do meet customer needs. Ideally, each and every unit of product should meet customer needs.
2. To operate in a stable and predictable manner. In the dialect of the quality specialist, each process should be "under control." We will later elaborate on this, under the heading Process Conformance. These goals may be directly related to the costs of producing the goods or services.

Quality goals may also be established for departments or persons. Performance against such goals then becomes an input to the company's reward system. Ideally such goals should be:

Legitimate: They should have undoubted official status.

Measurable: So that they can be communicated with precision.

Attainable: As evidenced by the fact that they have already been attained by others.

Equitable: Attainability should be reasonably alike for individuals with comparable responsibilities.

TABLE 4.1 Examples of Control Subjects and Associated Quality Goals

Control subject	Goal
Vehicle mileage	Minimum of 25 mi/gal highway driving
Overnight delivery	99.5% delivered prior to 10:30 a.m. next morning
Reliability	Fewer than three failures in 25 years of service
Temperature	Minimum 505°F; maximum 515°F
Purchase-order error rate	No more than 3 errors/1000 purchase orders
Competitive performance	Equal or better than top three competitors on six factors
Customer satisfaction	90% or better rate, service outstanding or excellent
Customer retention	95% retention of key customers from year to year
Customer loyalty	100% of market share of over 80% of customers

Quality goals may be set from a combination of the following bases:

Goals for product features and process features are largely based on *technological* analysis.

Goals for departments and persons should be based on *benchmarking* rather than historical performance. For elaboration, see Section 12, Benchmarking.

Quality goals at the highest levels are in the early stages of development. The emerging practice is to establish goals on matters such as meeting customers' changing needs, meeting competition, maintaining a high rate of quality improvement, improving the effectiveness of business processes, and revising the planning process so as to avoid creating new failure-prone products and processes.

Measure Actual Performance. The critical step in quality control is to measure the actual performance of the product or the process. To make this measurement we need a sensor, a device to make the actual measurement.

The Sensor. A "sensor" is a specialized detecting device. It is designed to recognize the presence and intensity of certain phenomena, and to convert the resulting data into "information." This information then becomes the basis of decision making. At lower levels of organization the information is often on a real-time basis and is used for current control. At higher levels the information is summarized in various ways to provide broader measures, detect trends, and identify the vital few problems.

The wide variety of control subjects requires a wide variety of sensors. A major category is the numerous technological instruments used to measure product features and process features. Familiar examples are thermometers, clocks, yardsticks, and weight scales. Another major category of sensors is the data systems and associated reports which supply summarized information to the managerial hierarchy. Yet another category involves the use of human beings as sensors. Questionnaires and interviews are also forms of sensors.

Sensing for control is done on a huge scale. This has led to the use of computers to aid in the sensing and in conversion of the resulting data into information. For an example in an office environment (monitoring in telephone answering centers), see Bylinsky (1991). For an example in a factory environment (plastic molding), see Umscheid (1991).

Most sensors provide their evaluations in terms of a *unit of measure*—a defined amount of some quality feature—which permits evaluation of that feature in numbers. Familiar examples of units of measure are degrees of temperature, hours, inches, and tons. For a discussion of units of measure, see Section 9, Measurement, Information, and Decision-Making. A considerable amount of sensing is done by human beings. Such sensing is subject to numerous sources of error.

Compare to Standards. The act of comparing to standards is often seen as the role of an umpire. The umpire may be a human being or a technological device. Either way, the umpire may be called on to carry out any or all of the following activities:

1. Compare the actual quality performance to the quality goal.
2. Interpret the observed difference; determine if there is conformance to the goal.
3. Decide on the action to be taken.
4. Stimulate corrective action.

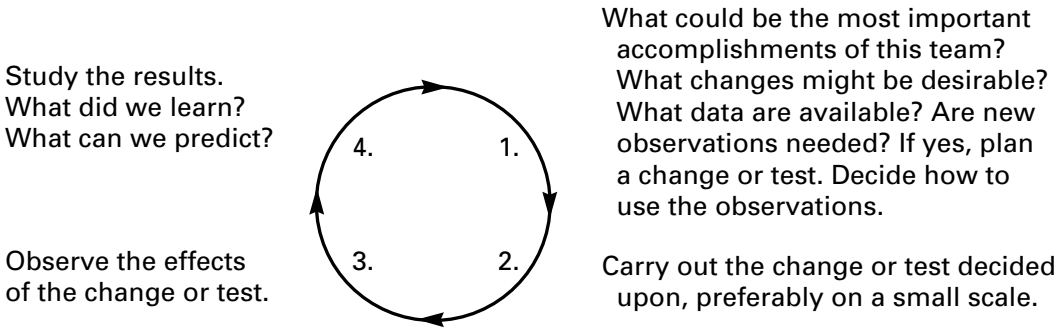
These activities require elaboration and will shortly be examined more closely.

Take Action on the Difference. In any well-functioning quality control system we need a means of taking action on the difference between desired standards of performance and actual performance. We need an actuator. This device (human or technological or both) is the means for stimulating action to restore conformance. At the worker level it may be a keyboard for giving orders to

an office computer or a calibrated knob for adjusting a machine tool. At the management level it may be a memorandum to subordinates.

The Process. In all of the preceding discussion we have assumed a process. This may also be human or technological or both. It is the means for producing the product features, each of which is a control subject. All work is done by a process which consists of an input, labor, technology, procedures, energy, materials, and output. For a more complete discussion of process, see Section 6, Process Management.

The PDCA Cycle. There are many ways of dividing the feedback loop into elements and steps. Some of them employ more than six elements; others employ fewer than six. A popular example of the latter is the so-called PDCA cycle (also the Deming wheel) as shown in Figure 4.6. Deming (1986) referred to this as the Shewhart cycle, which is the name many still use when describing this version of the feedback loop.



Step 5. Repeat Step 1, with knowledge accumulated.
Step 6. Repeat Step 2, and onward.

FIGURE 4.6 The PDCA cycle. (*Deming, 1986.*)

In this example the feedback loop is divided into four steps labeled Plan, Do, Check, and Act. These steps correspond roughly to the six steps discussed previously:

"Plan" includes choosing control subjects and setting goals.

"Do" includes running the process.

"Check" includes sensing and umpiring.

"Act" includes stimulating the actuator to take corrective action.

An early version of the PDCA cycle was included in W. Edwards Deming's first lectures in Japan (Deming 1950). Since then, additional versions have been devised and published. For elaboration, see Koura (1991).

Some of these versions have attempted to label the PDCA cycle in ways which make it serve as a universal series of steps for both quality control and quality improvement. The authors feel that this confuses matters, since two very different processes are involved. (The process for quality improvement is discussed in Section 5.)

THE PYRAMID OF CONTROL

Control subjects run to large numbers, but the number of "things" to be controlled is far larger. These things include the published catalogs and price lists sent out, multiplied by the number of items in

each; the sales made, multiplied by the number of items in each sale; the units of product produced, multiplied by the associated numbers of quality features; and so on for the numbers of items associated with employee relations, supplier relations, cost control, inventory control, product and process development, etc.

A study in one small company employing about 350 people found that there were *over a billion things to be controlled* (Juran 1964, pp. 181–182).

There is no possibility for upper managers to control huge numbers of control subjects. Instead, they divide up the work of control, using a plan of delegation somewhat as depicted in Figure 4.7.

This division of work establishes three areas of responsibility for control: control by nonhuman means, control by the work force, and control by the managerial hierarchy.

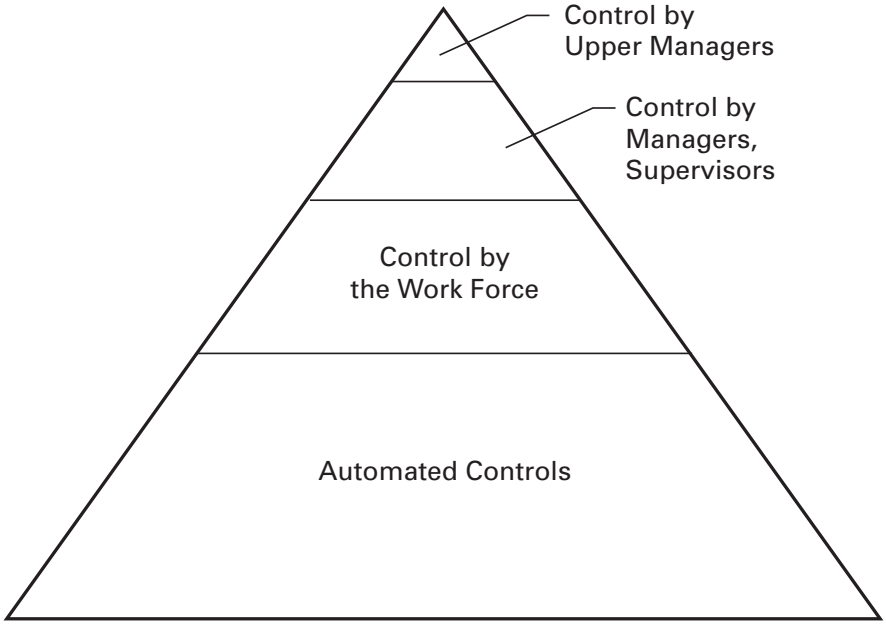


FIGURE 4.7 The pyramid of control. (*Making Quality Happen, Juran Institute, Inc., senior executive workshop, p. F-5, Wilton, CT.*)

Control by Nonhuman Means. At the base of the pyramid are the automated feedback loops and error-proofed processes which operate with no human intervention other than maintenance of facilities (which, however, is critical), These nonhuman methods provide control over the great majority of things. The control subjects are exclusively technological, and control takes place on a real-time basis.

The remaining controls in the pyramid require human intervention. By a wide margin, the most amazing achievement in quality control takes place during a biological process which is millions of years old—the growth of the fertilized egg into an animal organism. In human beings the genetic instructions which program this growth consist of a sequence of about three billion "letters." This sequence—the human genome—is contained in two strands of DNA (the double helix) which "unzip" and replicate about a million billion times during the growth process from fertilized egg to birth of the human being.

Given such huge numbers, the opportunities for error are enormous. (Some errors are harmless, but others are damaging and even lethal.) Yet the actual error rate is of the order of about one in 10 billion. This incredibly low error rate is achieved through a feedback loop involving three processes (Radman and Wagner 1988):

A high-fidelity selection process for attaching the right "letters," using chemical lock-and-key combinations

A proofreading process for reading the most recent letter, and removing it if incorrect

A corrective action process to rectify the errors which are detected

Control by the Work Force. Delegating such decisions to the work force yields important benefits in human relations and in conduct of operations. These benefits include shortening the feedback loop; providing the work force with a greater sense of ownership of the operating processes, often referred to as "empowerment"; and liberating supervisors and managers to devote more of their time to planning and improvement.

It is feasible to delegate most quality control decisions to the work force. Many companies already do. However, to delegate *process control* decisions requires meeting the criteria of "self-control." To delegate *product control* decisions requires meeting the criteria for "self-inspection." (See later in this section under Self-Control and Self-Inspection, respectively.)

Control by the Managerial Hierarchy. The peak of the pyramid of control consists of the "vital few" control subjects. These are delegated to the various levels in the managerial hierarchy, including the upper managers.

Managers should avoid getting deeply into making decisions on quality control. Instead, they should:

Make the vital few decisions.

Provide criteria to distinguish the vital few decisions from the rest. For an example of providing such criteria see Table 4.3 under the heading: The Fitness for Use Decision.

Delegate the rest under a decision making process which provides the essential tools and training.

The distinction between vital few matters and others originates with the control subjects. Table 4.2 shows how control subjects at two levels—work force and upper management—affect the elements of the feedback loop.

PLANNING FOR QUALITY CONTROL

Planning for control is the activity which provides the system—the concepts, methodology, and tools—through which company personnel can keep the operating processes stable and thereby produce the product features required to meet customer needs. The input-output features of this system (also plan, process) were depicted in Figure 4.2.

The Customers and Their Needs. The principal customers of quality control systems are the company personnel engaged in control—those who carry out the steps which form the feedback loop. Such personnel require (1) an understanding of customers' quality needs and (2) a definition

TABLE 4.2 Contrast of Quality Control at Two Levels—Work Force and Upper Management

	At work force levels	At managerial levels
Control goals	Product and process features in specifications and procedures	Business oriented, product salability, competitiveness
Sensors	Technological	Data systems
Decisions to be made	Conformance or not?	Meet customer needs or not?

Source: *Making Quality Happen,* Juran Institute, Inc., senior executive workshop, p. F-4, Wilton, Ct.

of their own role in meeting those needs. However, most of them lack direct contact with customers. Planning for quality control helps to bridge that gap by supplying a translation of what are customers' needs, along with defining responsibility for meeting those needs. In this way, planning for quality control includes providing operating personnel with information on customer needs (whether direct or translated) and definition of the related control responsibilities of the operating personnel. Planning for quality control can run into extensive detail. See, for example, Duyck (1989) and Goble (1987).

Who Plans? Planning for quality control has in the past been assigned variously to

Staff planners who also plan the operating processes

Staff quality specialists

Multifunctional teams of planners and operating personnel

Departmental managers and supervisors

The work force

Planning for quality control of critical processes has traditionally been the responsibility of those who plan the operating process. For noncritical processes the responsibility was usually assigned to quality specialists from the Quality Department. Their draft plans were then submitted to the operating heads for approval.

Recent trends have been to increase the use of the team concept. The team membership includes the operating forces and may also include suppliers and customers of the operating process. The recent trend has also been to increase participation by the work force. For elaboration, see Juran (1992, pp. 290–291). The concept of self-directing work teams has been greatly expanded in recent years and includes many of these ideas. See Section 15 for more details on this topic.

Quality Control Concepts. The methodologies of Quality Control are built around various concepts such as the feedback loop, process capability, self-control, etc. Some of these concepts are of ancient origin; others have evolved in this century. During the discussion of planning for quality control, we will elaborate on some of the more widely used concepts.

The Flow Diagram. The usual first step in planning for quality control is to map out the flow of the operating process. (Design of that process is discussed in Section 3, The Quality Planning Process.) The tool for mapping is the "flow diagram." Figure 4.8 is an example of a flow diagram. (For more examples of this tool, see Appendix V.)

The flow diagram is widely used during planning of quality controls. It helps the planning team to

Understand the overall operating process. Each team member is quite knowledgable about his/her segment of the process, but less so about other segments and about the interrelationships.

Identify the control subjects around which the feedback loops are to be built. [For an example, see Siff (1984).] The nature of these control subjects was discussed previously under the heading, The Control Subject.

Design control stations. (See the following section.)

Control Stations. A "control station" is an area in which quality control takes place. In the lower levels of organization, a control station is usually confined to a limited physical area. Alternatively, the control station can take such forms as a patrol beat or a "control tower." At higher levels, control stations may be widely dispersed geographically, as is the scope of a manager's responsibility.

A review of numerous control stations shows that they are usually designed to provide evaluations and/or early warnings in the following ways:

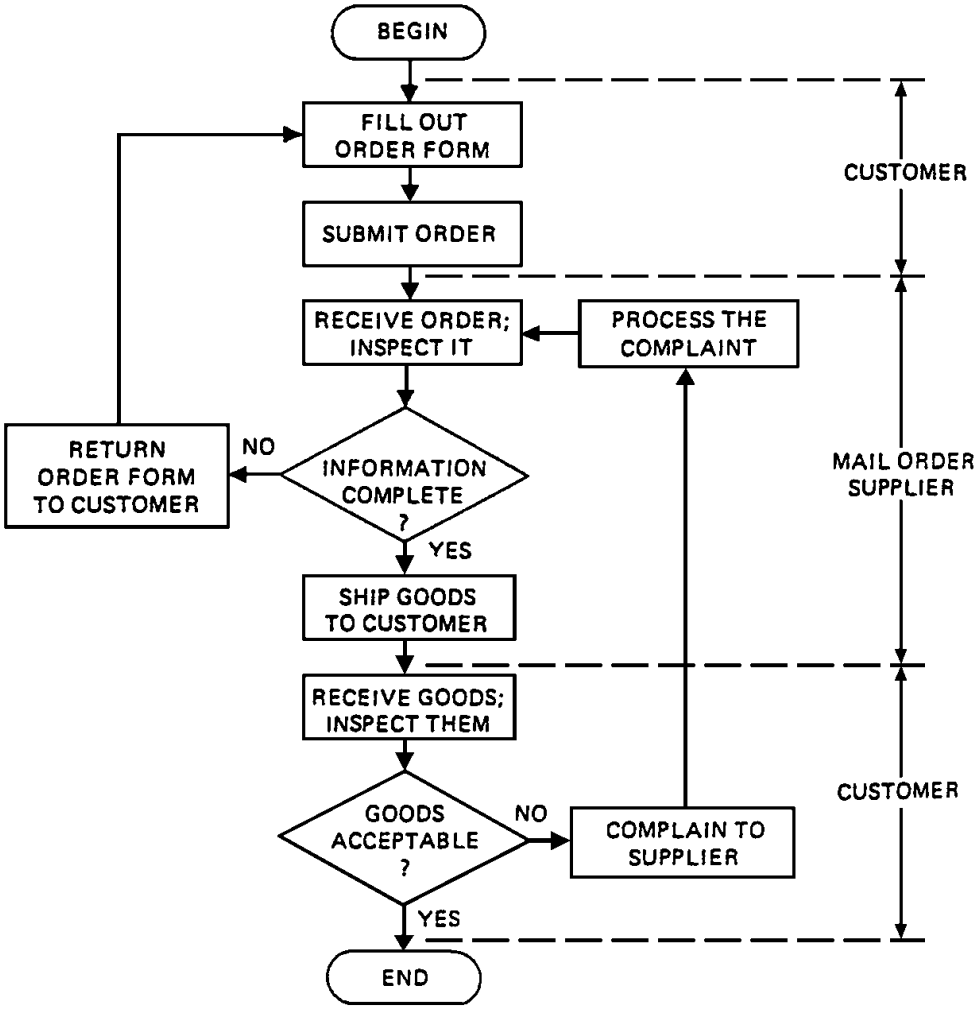


FIGURE 4.8 The flow diagram.

At changes of jurisdiction, where responsibility is transferred from one organization to another

Before embarking on some significant irreversible activity such as signing a contract

After creation of a critical quality feature

At the site of dominant process variables

At areas ("windows") which allow economical evaluation to be made

STAGES OF PROCESS CONTROL

The flow diagram not only discloses the progression of events in the operating process, it also suggests which stages should become the centers of control activity. Several of these stages apply to the majority of operating processes.

Setup (Startup) Control. The end result of this form of control is the decision of whether or not to "push the start button." Typically this control involves

A *countdown* listing the preparatory steps needed to get the process ready to produce. Such countdowns sometime come from suppliers. Airlines provide checklists to help travelers plan

their trips; electric power companies provide checklists to help householders prepare the house for winter weather.

Evaluation of process and/or product features to determine whether, if started, the process will meet the goals.

Criteria to be met by the evaluations.

Verification that the criteria have been met.

Assignment of responsibility. This assignment varies, depending largely on the criticality of the quality goals. The greater the criticality, the greater is the tendency to assign the verification to specialists, supervisors and "independent" verifiers rather than to nonsupervisory workers.

Running Control. This form of control takes place periodically during the operation of the process. The purpose is to make the "run or stop" decision—whether the process should continue to produce product or whether it should stop.

Running control consists of closing the feedback loop, over and over again. The process and/or product performance is evaluated and compared with goals. If the product and/or process conforms to goals, and if the process has not undergone some significant adverse change, the decision is "continue to run." If there is nonconformance or if there has been a significant change, then corrective action is in order.

The term "significant" has meanings beyond those in the dictionary. One of these meanings relates to whether an indicated change is a real change or is a false alarm due to chance variation. The design for process control should provide the tools needed to help the operating forces distinguish between real changes and false alarms. Statistical process control (SPC) methodology is aimed at providing such tools (see Section 45).

Product Control. This form of control takes place after some amount of product has been produced. The purpose of the control is to decide whether or not the product conforms to the product quality goals. Assignment of responsibility for this decision differs from company to company. However, in all cases those who are to make the decision must be provided with the facilities and training which will enable them to understand the product quality goals, evaluate the actual product quality, and decide whether there is conformance.

Since all this involves making a factual decision, it can in theory be delegated to anyone, including members of the work force. In practice, this delegation is not made to those whose assigned priorities might bias their judgment. In such cases the delegation is usually to those whose responsibilities are free from such biases, for example, "independent" inspectors. Statistical quality control (SQC) is a methodology frequently employed to yield freedom from biases.

Facilities Control. Most operating processes employ physical facilities: equipment, instruments, and tools. Increasingly the trend has been to use automated processes, computers, robots, etc. This same trend makes product quality more and more dependent on maintenance of the facilities.

The elements of design for facilities control are well known:

Establish a schedule for conducting facilities maintenance.

Establish a checklist—a list of tasks to be performed during a maintenance action.

Train the maintenance forces to perform the tasks.

Assign clear responsibility for adherence to schedule.

The weakest link in facilities control has been adherence to schedule. To ensure strict adherence to schedule requires an independent audit.

In cases involving introduction of new technology, a further weak link is training the maintenance forces (White 1988).

During the 1980s the auto makers began to introduce computers and other electronics into their vehicles. It soon emerged that many repair shop technicians lacked the technological education base needed to diagnose and remedy the associated field failures. To make matters worse, the auto makers did not give high priority to standardizing the computers. As a result a massive training backlog developed.

For an excellent treatise on facilities maintenance, see Nowlan and Heap (1978).

Concept of Dominance. Control subjects are so numerous that planners are well advised to identify the vital few control subjects so that they will receive appropriate priority. One tool for identifying the vital few is the concept of dominance.

Operating processes are influenced by many variables, but often one variable is more important than all the rest combined. Such a variable is said to be the "dominant variable." Knowledge of which process variable is dominant helps planners during allocation of resources and priorities. The more usual dominant variables include:

1. *Set-up dominant:* Some processes exhibit high stability and reproducibility of results, over many cycles of operation. A common example is the printing process. The design for control should provide the operating forces with the means for precise setup and validation before operations proceed.
2. *Time-dominant:* Here the process is known to change progressively with time, for example, depletion of consumable supplies, heating up, and wear of tools. The design for control should provide means for periodic evaluation of the effect of progressive change and for convenient readjustment.
3. *Component-dominant:* Here the main variable is the quality of the input materials and components. An example is the assembly of electronic or mechanical equipments. The design for control should be directed at supplier relations, including joint planning with suppliers to upgrade the quality of the inputs.
4. *Worker-dominant:* In these processes, quality depends mainly on the skill and knack possessed by the workers. The skilled trades are well-known examples. The design for control should emphasize aptitude testing of workers, training and certification, quality rating of workers, and error-proofing to reduce worker errors.
5. *Information-dominant:* Here the processes are of a "job-shop" nature, so that there is frequent change in what product is to be produced. As a result, the job information changes frequently. The design for control should concentrate on providing an information system which can deliver accurate, up-to-date information on just how this job differs from its predecessors.

Seriousness Classification. Another way of identifying the vital few control subjects is through "seriousness classification." Under this concept each product feature is classified into one of several defined classes such as critical, major, and minor. These classifications then guide the planners in allocation of resources, assignment of priorities, choice of facilities, frequency of inspection and test, etc.

For elaboration, see Section 22, Operations, under Classification of Defects.

Process Capability. One of the most important concepts in the quality planning process is "process capability." The prime application of this concept is during planning of the operating processes. This application is treated in more depth in Section 22, Operations.

This same concept also has application in quality control. To explain this, a brief review is in order. All operating processes have an inherent uniformity for producing product. This uniformity can often be quantified, even during the planning stages. The process planners can use the resulting information for making decisions on adequacy of processes, choice of alternative processes, need for revision of processes, and so forth, with respect to the inherent uniformity and its relationship to process goals.

Applied to planning for quality control, the state of process capability becomes a major factor in decisions on frequency of measuring process performance, scheduling maintenance of facilities, etc.

The greater the stability and uniformity of the process, the less the need for frequent measurement and maintenance.

Those who plan for quality control should have a thorough understanding of the concept of process capability and its application to both areas of planning—planning the operating processes as well as planning the controls.

THE CONTROL SPREADSHEET

The work of the planners is usually summarized on a control spreadsheet. This spreadsheet is a major planning tool. An example can be seen in Figure 4.9.

In this spreadsheet the horizontal rows are the various control subjects. The vertical columns consist of elements of the feedback loop plus other features needed by the operating forces to exercise control so as to meet the quality goals.

Some of the contents of the vertical columns are unique to specific control subjects. However, certain vertical columns apply widely to many control subjects. These include unit of measure, type of sensor, quality goal, frequency of measurement, sample size, criteria for decision-making, and responsibility for decision making.

Who Does What? The feedback loop involves multiple tasks, each of which requires a clear assignment of responsibility. At any control station there may be multiple people available to perform those tasks. For example, at the work-force level, a control station may include setup specialists, operators, maintenance personnel, inspectors, etc. In such cases it is necessary to agree on who should make which decisions and who should take which actions. An aid to reaching such agreement is a special spreadsheet similar to Figure 4.9.

In this spreadsheet the essential decisions and actions are listed in the left-hand column. The remaining columns are headed up by the names of the job categories associated with the control station. Then, through discussion among the cognizant personnel, agreement is reached on who is to do what.

The spreadsheet (Figure 4.9) is a proven way to find answers to the long-standing, but vague, question, "Who is responsible for quality?" This question has never been answered because it is

PROCESS CONTROL FEATURES / CONTROL SUBJECT	UNIT OF MEASURE	TYPE OF SENSOR	GOAL	FREQUENCY OF MEASUREMENT	SAMPLE SIZE	CRITERIA FOR DECISION MAKING	RESPONSIBILITY FOR DECISION MAKING	. . .
Wave solder conditions Solder temperature	Degree F (°F)	Thermo-couple	505 °F	Continuous	N/A	510 °F reduce heat 500 °F increase heat	Operator	. . .
Conveyor speed	Feet per minute (ft/min)	ft/min	4.5 ft/min	1/hour	N/A	5 ft/min reduce speed 4 ft/min increase speed	Operator	. . .
Alloy purity	% Total contaminates	lab chemical analysis	1.5% max	1/month	15 grams	At 1.5%, drain bath, replace solder	Process engineer	. .
	. . .	. . .	. . .	. . .	. . .	. . .	. . .	

FIGURE 4.9 Spreadsheet for "Who does what?" (*Making Quality Happen, Juran Institute, Inc., senior executive workshop, p. F-8, Wilton, CT.*)

inherently unanswerable. However if the question is restated in terms of decisions and actions, the way is open to agree on the answers. This clears up the vagueness.

PROCESS CONFORMANCE

Does the process conform to its quality goals? The umpire answers this question by interpreting the observed difference between process performance and process goals. When current performance does differ from the quality goals, the question arises: What is the cause of this difference?

Special and Common Causes of Variation. Observed differences usually originate in one of two ways: (1) the observed change is caused by the behavior of a major variable in the process (or by the entry of a new major variable) or (2) the observed change is caused by the interplay of multiple minor variables in the process.

Shewhart called (1) and (2) "assignable" and "nonassignable" causes of variation, respectively (Shewhart 1931). Deming later coined the terms "special" and "common" causes of variation (Deming 1986). In what follows we will use Deming's terminology.

"Special" causes are typically sporadic, and often have their origin in single variables. For such cases it is comparatively easy to conduct a diagnosis and provide remedies. "Common" causes are typically chronic and usually have their origin in the interplay among multiple minor variables, As a result, it is difficult to diagnose them and to provide remedies. This contrast makes clear the importance of distinguishing special causes from common causes when interpreting differences. The need for making such distinctions is widespread. Special causes are the subject of quality control; common causes are the subject of quality improvement.

The Shewhart Control Chart. It is most desirable to provide umpires with tools which can help to distinguish between special causes and common causes. An elegant tool for this purpose is the Shewhart control chart (or just control chart) shown in Figure 4.10.

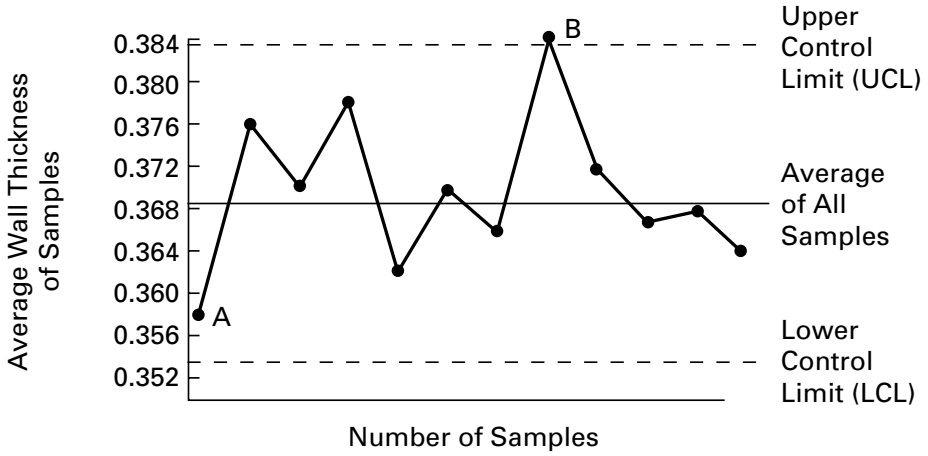


FIGURE 4.10 The Shewhart control chart. (*"Quality Control," Leadership for the Quality Century, Juran Institute, Inc., senior executive workshop, p. 4, Wilton, CT.*)

In Figure 4.10 the horizontal scale is time, and the the vertical scale is quality performance. The plotted points show quality performance as time progresses.

The chart also exhibits three horizontal lines. The middle line is the average of past performance and is therefore the expected level of performance. The other two lines are statistical "limit lines."

They are intended to separate special causes from common causes, based on some chosen level of odds, such as 20 to 1.

Points Within Control Limits. Point A on the chart differs from the historical average. However, since point A is within the limit lines, this difference could be due to common causes (at odds of less than 20 to 1.) Hence we assume that there is no special cause.

In the absence of special causes, the prevailing assumptions include:

Only common causes are present.

The process is in a state of "statistical control."

The process is doing the best it can.

The variations must be endured.

No action need be taken—taking action may make matters worse (a phenomenon known as "hunting" or "tampering."

The preceding assumptions are being challenged by a broad movement to improve process uniformity. Some processes exhibit no points outside of control chart limits, yet the interplay of minor variables produces some defects.

In one example, a process in statistical control was nevertheless improved by an order of magnitude. The improvement was by a multifunctional improvement team which identified and addressed some of the minor variables. This example is a challenge to the traditional assumption that variations due to common causes must be endured (Pyzdek 1990).

In other cases the challenge is more subtle. There are again no points outside the control limits, but in addition, *no defects are being produced.* Nevertheless the customers demand greater and greater uniformity. Examples are found in business processes (precision of estimating), as well as in manufacture (batch-to-batch uniformity of chemicals, uniformity of components going into random assembly). Such customer demands are on the increase, and they force suppliers to undertake projects to improve the uniformity of even the minor variables in the process. There are many types of control charts. See Section 45, Statistical Process Control, for a more detailed discussion of this important tool.

Points Outside of Control Limits. Point B also differs from the historical average, but is outside of the limit lines. Now the odds are heavily against this being due to common causes—over 20 to 1. Hence we assume that point B is the result of special causes. Traditionally such "out-of-control" points became *nominations* for corrective action.

Ideally all such nominations should stimulate prompt corrective action to restore the status quo. In practice many out-of-control changes do not result in corrective action. The usual reason is that the changes involving special causes are too numerous—the available personnel cannot deal with all of them. Hence priorities are established based on economic significance or on other criteria of importance. Corrective action is taken for the high-priority cases; the rest must wait their turn. Some changes at low levels of priority may wait a long time for corrective action.

A further reason for failure to take corrective action is a lingering confusion between statistical control limits and quality tolerances. It is easy to be carried away by the elegance and sensitivity of the control chart. This happened on a large scale during the 1940s and 1950s. Here are two examples from the personal experience of the one of the authors:

A large automotive components factory placed a control chart at every machine.

A viscose yarn factory created a "war room" of over 400 control charts.

In virtually all such cases the charts were maintained by the quality departments but ignored by the operating personnel. Experience with such excesses has led managers and planners to be wary of employing control charts just because they are sensitive detectors of change. Instead, the charts should be justified based on value added. Such justifications include:

Customer needs are directly involved.

There is risk to human safety or the environment.

Substantial economics are at stake.

The added precision is needed for control.

Statistical Control Limits and Quality Tolerances. For most of human history quality goals consisted of product features or process features, usually defined in words. The growth of technology then stimulated the growth of measurement plus a trend to define quality goals in numbers. In addition, there emerged the concept of limits or "tolerances" around the goals. For example:

At least 95 percent of the shipments shall meet the scheduled delivery date.

The length of the bar shall be within 1 mm of the specified number.

Such quality goals had official status. They were set by product or process designers, and published as official specifications. The designers were the official quality legislators—they enacted the laws. Operating personnel were responsible for obeying the quality laws—meeting the specified goals and tolerances.

Statistical control limits in the form of control charts were virtually unknown until the 1940s. At that time, these charts lacked official status. They were prepared and published by quality specialists from the Quality Department. To the operating forces, control charts were a mysterious, alien concept. In addition, the charts threatened to create added work in the form of unnecessary corrective action. The operating personnel reasoned as follows: It has always been our responsibility to take corrective action whenever the product becomes nonconforming. These charts are so sensitive that they detect process changes which do not result in nonconforming product. We are then asked to take corrective action even when the products meet the quality goals and tolerances.

So there emerged a confusion of responsibility. The quality specialists were convinced that the control charts provided useful early-warning signals which should not be ignored. Yet the quality departments failed to recognize that the operating forces were now faced with a confusion of responsibility. The latter felt that so long as the products met the quality goals there was no need for corrective action. The upper managers of those days were of no help—they did not involve themselves in such matters. Since the control charts lacked official status, the operating forces solved their problem by ignoring the charts. This contributed to the collapse, in the 1950s, of the movement known as "statistical quality control."

The 1980s created a new wave of interest in applying the tools of statistics to the control of quality. Many operating personnel underwent training in "statistical process control." This training helped to reduce the confusion, but some confusion remains. To get rid of the confusion, managers should:

Clarify the responsibility for corrective action on points outside the control limits. Is this action mandated or is it discretionary?

Establish guidelines on action to be taken when points are outside the statistical control limits but the product still meets the quality tolerances.

The need for guidelines for decision making is evident from Figure 4.11. The guidelines for quadrants A and C are obvious. If both process and product conform to their respective goals, the process may continue to run. If neither process nor product conform to their respective goals, the process should be stopped, and remedial action should be taken. The guidelines for quadrants B and D are often vague, and this vagueness has been the source of a good deal of confusion. If the choice of action is delegated to the work force, the managers should establish clear guidelines.

Numerous efforts have been made to design control chart limits in ways which help operating personnel to detect whether product quality is threatening to exceed the product quality limits. For a recent example, see Carr (1989). Another approach, based on product quality related to product quality limits, is "PRE-Control." See Juran (1988, pp. 24.31–24.38).

		PRODUCT	
		CONFORMS	DOES NOT CONFORM
PROCESS	DOES NOT CONFORM	B VAGUE	C CLEAR
	CONFORMS	A CLEAR	D VAGUE

FIGURE 4.11 Example of areas of decision making. (*Making Quality Happen, Juran Institute, Inc., senior executive workshop, p.F-21, Wilton, CT.*)

Self-Control; Controllability. Workers are in a state of self-control when they have been provided with all the essentials for doing good work. These essentials include:

Means of knowing what are the quality goals.

Means of knowing what is their actual performance.

Means for changing their performance in the event that performance does not conform to goals. To meet this criterion requires an operating process which (1) is inherently capable of meeting the goals and (2) is provided with features which make it possible for the operating forces to adjust the process as needed to bring it into conformance with the goals.

These criteria for self-control are applicable to processes in all functions and all levels, from general manager to nonsupervisory worker.

It is all too easy for managers to conclude that the above criteria have been met. In practice, there are many details to be worked out before the criteria can be met. The nature of these details is evident from checklists which have been prepared for specific processes in order to ensure meeting the criteria for self-control. Examples of these checklists include those designed for product designers, production workers, and administrative and support personnel. Examples of such checklists can be found by referring to the subject index of this handbook.

If all the criteria for self-control have been met at the worker level, any resulting product nonconformances are said to be *worker-controllable.* If any of the criteria for self-control have not been met, then management's planning has been incomplete—the planning has not fully provided the means for carrying out the activities within the feedback loop. The nonconforming products resulting from such deficient planning are then said to be *management-controllable.* In such cases it is risky for managers to hold the workers responsible for quality.

Responsibility for results should, of course, be keyed to controllability. However, in the past many managers were not aware of the extent of controllability as it prevailed at the worker level. Studies conducted by Juran during the 1930s and 1940s showed that at the worker level the proportion of management-controllable to worker-controllable nonconformances was of the order of 80 to 20. These findings were confirmed by other studies during the 1950s and 1960s. That ratio of 80 to 20 helps to explain the failure of so many efforts to solve the companies' quality problems solely by motivating the work force.

Effect on the Process Conformance Decision. Ideally the decision of whether the process conforms to process quality goals should be made by the work force. There is no shorter feedback loop. For many processes this is the actual arrangement. In other cases the process conformance decision is assigned to nonoperating personnel—independent checkers or inspectors. The reasons include:

The worker is not in a state of self-control.

The process is critical to human safety or to the environment.

Quality does not have top priority.

There is lack of mutual trust between the managers and the work force.

PRODUCT CONFORMANCE; FITNESS FOR USE

There are two levels of product features, and they serve different purposes. One of these levels serves such purposes as:

Meeting customer needs

Protecting human safety

Protecting the environment

Product features are said to possess "fitness for use" if they are able to serve the above purposes. The second level of product features serves purposes such as:

Providing working criteria to those who lack knowledge of fitness for use

Creating an atmosphere of law and order

Protecting innocents from unwarranted blame

Such product features are typically contained in internal specifications, procedures, standards, etc. Product features which are able to serve the second list of purposes are said to possess *conformance to specifications,* etc. We will use the shorter label "conformance."

The presence of two levels of product features results in two levels of decision making: Is the product in conformance? Is the product fit for use? Figure 4.12 shows the interrelation of these decisions to the flow diagram.

The Product Conformance Decision. Under prevailing policies, products which conform to specification are sent on to the next destination or customer. The assumption is that products which conform to specification are also fit for use. This assumption is valid in the great majority of cases.

The combination of large numbers of product features when multiplied by large volumes of product creates huge numbers of product conformance decisions to be made. Ideally these decisions should be delegated to the lowest levels of organization—to the automated devices and the operating work force. Delegation of this decision to the work force creates what is called "self-inspection."

Self-Inspection. We define "self-inspection" as a state in which decisions on the *product* are delegated to the work force. The delegated decisions consist mainly of: Does product quality conform to the quality goals? What disposition is to be made of the product?

Note that self-inspection is very different from self-control, which involves decisions on the *process.*

The merits of self-inspection are considerable:

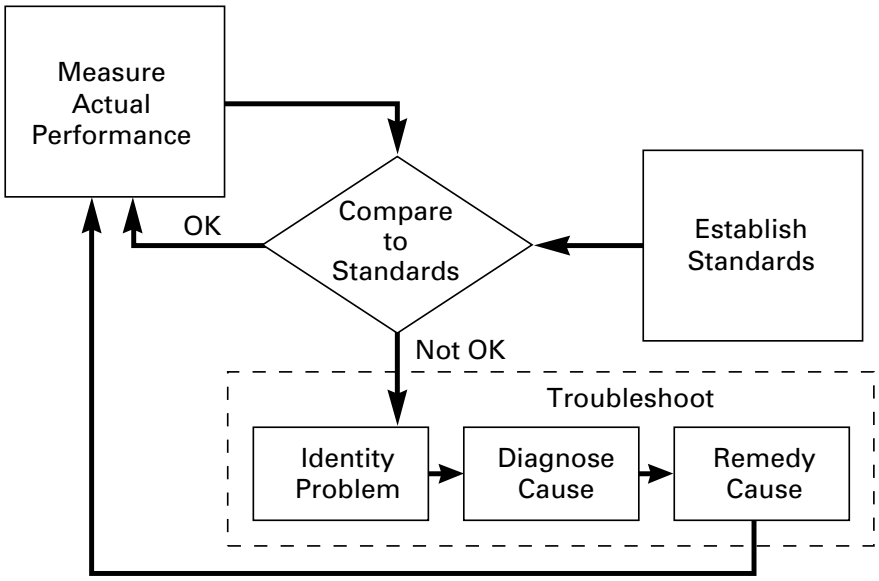


FIGURE 4.12 Flow diagram of decisions on conformance and fitness for use.

The feedback loop is short; the feedback often goes directly to the actuator—the energizer for corrective action.

Self-inspection enlarges the job of the work force—it confers a greater sense of job ownership.

Self-inspection removes the police atmosphere created by use of inspectors, checkers, etc.

However, to make use of self-inspection requires meeting several essential criteria:

Quality is number one: Quality must have undoubted top priority.

Mutual confidence: The managers must have enough trust in the work force to be willing to make the delegation, and the work force must have enough confidence in the managers to be willing to accept the responsibility.

Self-control: The conditions for self-control should be in place so that the work force has all the means necessary to do good work.

Training: The workers should be trained to make the product conformance decisions.

Certification: The recent trend is to include a certification procedure. Workers who are candidates for self-inspection undergo examinations to ensure that they are qualified to make good decisions. The successful candidates are certified and may be subject to audit of decisions thereafter. For examples, see Nowak (1991, Military Airlift Command) and Pearl (1988, Corning Glass Works).

In many companies these criteria are not fully met, especially the criterion of priority. If some parameter other than quality has top priority, there is a real risk that evaluation of product conformance will be biased. This problem happens frequently when personal performance goals are in conflict with overall quality goals. For example, a chemical company found that it was rewarding sales personnel on revenue targets without regard to product availability or even profitability. The sales people were making all their goals, but the company was struggling.

The Fitness for Use Decision. The great majority of products do conform to specifications. For the nonconforming products there arises a new question: Is the nonconforming product nevertheless fit for use?

A complete basis for making this decision requires answers to questions such as:

Who will be the user(s)?

How will this product be used?

Are there risks to structural integrity, human safety, or the environment?

What is the urgency for delivery?

How do the alternatives affect the producer's and the user's economics?

To answer such questions can involve considerable effort. Companies have tried to minimize the effort through procedural guidelines. The methods in use include:

Treat all nonconforming product as unfit for use: This approach is widely used for products which can pose risks to human safety or the environment—products such as pharmaceuticals or nuclear energy.

Create a mechanism for decision making: An example is the Material Review Board so widely used in the defense industry. This device is practical for matters of importance, but is rather elaborate for the more numerous cases in which little is at stake.

Create a system of multiple delegation: Under such a system, the "vital few" decisions are reserved for a formal decision-making body such as a Material Review Board. The rest are delegated to other people.

Table 4.3 is an example of a table of delegation used by a specific company. (Personal communication to one of the authors.)

For additional discussion on the fitness-for-use decision, see Juran (1988, pp. 18.32–18.36).

Disposition of Unfit Product. Unfit product is disposed of in various ways: scrap, sort, rework, return to supplier, sell at a discount, etc. The internal costs can be estimated to arrive at an economic optimum. However, the effects go beyond money: schedules are disrupted, people are blamed, etc. To minimize the resulting human abrasion, some companies have established rules of conduct such as:

TABLE 4.3 Multiple Delegations of Decision Making on Fitness for Use*

	Amount of product or money at stake is	
Effect of nonconformance is on	Small	Large
Internal economics only	Department head directly involved, quality engineer	Plant managers involved, quality manager
Economic relations with supplier	Supplier, purchasing agent, quality engineer	Supplier, manager
Economic relations with client	Client, salesperson, quality engineer	Client: for Marketing, Manufacturing, Technical, Quality
Field performance of the product	Product designer, salesperson, quality engineer	Client: managers for Technical, Manufacturing, Marketing Quality
Risk of damage to society or of nonconformance to government regulations	Product design manager, compliance officer, lawyer, quality managers	General manager and team of upper managers

*For those industries whose quality mission is really one of conformance to specification (for example, atomic energy, space), the real decision maker on fitness for use is the client or the government regulator.

Choose that alternative which minimizes the total loss to all parties involved. Now there is less to argue about, and it becomes easier to agree on how to share the loss.

Avoid looking for blame. Instead, treat the loss as an opportunity for quality improvement.

Use "charge backs" sparingly. Charging the vital few losses to the departments responsible has merit from an accounting viewpoint. However, when applied to the numerous minor losses, this is often uneconomic as well as detrimental to efforts to improve quality.

Failure to use products which meet customer needs is a waste. Sending out products which do not meet customer needs is worse. Personnel who are assigned to make product conformance decisions should be provided with clear definitions of responsibility as well as guidelines for decision making. Managers should, as part of their audit, ensure that the processes for making product conformance decisions are appropriate to company needs.

Corrective Action. The final step in closing the feedback loop is to actuate a change which restores conformance with quality goals. This step is popularly known as "troubleshooting" or "fire-fighting."

Note that the term "corrective action" has been applied loosely to two very different situations, as shown in Figure 4.1. The feedback loop is well designed to eliminate *sporadic* nonconformance like that "spike" in Figure 4.1; the feedback loop is *not* well designed to deal with the area of chronic waste shown in the figure. Instead, the need is to employ the quality improvement process of Section 5.

We will use the term "corrective action" in the sense of troubleshooting—eliminating sporadic nonconformance.

Corrective action requires the journeys of diagnosis and remedy. These journeys are simpler than for quality improvement. Sporadic problems are the result of adverse change, so the diagnostic journey aims to discover what has changed. The remedial journey aims to remove the adverse change and restore conformance.

Diagnosis of Sporadic Change. During the diagnostic journey the focus is on "What has changed." Sometimes the causes are not obvious, so the main obstacle to corrective action is diagnosis. The diagnosis makes use of methods and tools such as:

Autopsies to determine with precision the symptoms exhibited by the product and process.

Comparison of products made before and after the trouble began to see what has changed; also comparison of good and bad products made since the trouble began.

Comparison of process data before and after the problem began to see what process conditions have changed.

Reconstruction of the chronology, which consists of logging on a time scale (of hours, days, etc.): (1) the events which took place in the process before and after the sporadic change, that is, rotation of shifts, new employees on the job, maintenance actions, etc., and (2) the time-related product information, that is, date codes, cycle time for processing, waiting time, move dates, etc.

Analysis of the resulting data usually sheds a good deal of light on the validity of the various theories of causes. Certain theories are denied. Other theories survive to be tested further.

Operating personnel who lack the training needed to conduct such diagnoses may be forced to shut down the process and request assistance from specialists, the maintenance department, etc. They may also run the process "as is" in order to meet schedules and thereby risk failure to meet the quality goals.

Corrective Action—Remedy. Once the cause(s) of the sporadic change is known, the worst is over. Most remedies consist of going back to what was done before. This is a return to the famil-

iar, not a journey into the unknown (as is the case with chronic problems). The local personnel are usually able to take the necessary action to restore the status quo.

Process designs should provide means to adjust the process as required to attain conformance with quality goals. Such adjustments are needed at start-up and during running of the process. This aspect of design for process control ideally should meet the following criteria:

There should be a known relationship between the process variables and the product results.

Means should be provided for ready adjustment of the process settings for the key process variables.

A predictable relationship should exist between the amount of change in the process settings and the amount of effect on the product features.

If such criteria are not met, the operating personnel will, in due course, be forced to cut and try in order to carry out remedial action. The resulting frustrations become a disincentive to putting high priority on quality. Burgam (1985) found:

> In one foundry an automated process design for controlling the amount of metal poured failed to provide adequate regulation. As a result, human regulation took over. The workers then played safe by overpouring, since underpoured castings had to be scrapped. The result was much waste until a new technology solved the problem.

Some companies provide systematic procedures for dealing with sporadic changes. See, for example, Sandorf and Bassett (1993).

For added discussion on troubleshooting, see Section 22.

THE ROLE OF STATISTICAL METHODS

An essential activity within the feedback loop is the collection and analysis of data. This activity falls within the scientific discipline known as "statistics." The methods and tools used are often called "statistical methods." These methods have long been used to aid in data collection and analysis in many fields: biology, government, economics, finance, management, etc. Section 44 contains a thorough discussion of the basic statistical methods, while Section 45 contains a good discussion on those methods used in statistical process control.

During this century, much has happened to apply statistical methodology to quality-oriented problems. This has included development of special tools such as the Shewhart control chart. An early wave of such application took place during the 1920s, largely within the Bell System. A second and broader wave was generated during the 1940s and 1950s. It came to be known as statistical quality control. A third wave, broader still, emerged during the 1980s, and came to be widely known as statistical process control. This is covered in Section 45.

Statistical Process Control (SPC). The term has multiple meanings, but in most companies it is considered to include basic data collection; analysis through such tools as frequency distributions, Pareto principle, Ishikawa (fish bone) diagram, Shewhart control chart, etc.; and application of the concept of process capability.

Advanced tools, such as design of experiments and analysis of variance (see Section 47), are a part of statistical methods but are not normally considered to be a part of statistical process control.

The Merits. These statistical methods and tools have contributed in an important way to quality control and also to the other processes of the Juran trilogy—quality improvement and quality planning. For some types of quality problems the statistical tools are more than useful—the problems cannot be solved at all without using the appropriate statistical tools.

The SPC movement has succeeded in training a great many supervisors and workers in basic statistical tools. The resulting increase in statistical literacy has made it possible for them to improve their grasp of the behavior of processes and products. In addition, many have learned that decisions based on data collection and analysis yield superior results.

The Risks. There is danger in taking a tool-oriented approach to quality instead of a problem-oriented or results-oriented approach. During the 1950s this preoccupation became so extensive that the entire statistical quality control movement collapsed; the word "statistical" had to be eliminated from the names of the departments.

The proper sequence in managing is first to establish goals and then to plan how to meet those goals, including choice of the appropriate tools. Similarly, when dealing with problems—threats or opportunities—experienced managers start by first identifying the problems. They then try to solve those problems by various means, including choice of the proper tools.

During the 1980s, numerous companies did, in fact, try a tool-oriented approach by training large numbers of their personnel in the use of statistical tools. However, there was no significant effect on the "bottom line." The reason was that no infrastructure had been created to identify which projects to tackle, to assign clear responsibility for tackling those projects, to provide needed resources, to review progress, etc.

Managers should ensure that training in statistical tools does not become an end in itself. One form of such assurance is through measures of progress. These measures should be designed to evaluate the effect on operations, such as improvement in customer satisfaction or product performance, reduction in cost of poor quality, etc. Measures such as numbers of courses held, or numbers of people trained, do *not* evaluate the effect on operations and hence should be regarded as subsidiary in nature.

Information for Decision Making. Quality control requires extensive decision-making. These decisions cover a wide variety of subject matter and take place at all levels of the hierarchy. The planning for quality control should provide an information network which can serve all decision makers. At some levels of the hierarchy, a major need is for real-time information to permit prompt detection and correction of nonconformance to goals. At other levels, the emphasis is on summaries which enable managers to exercise control over the vital few control subjects (see Sections 9 and 34). In addition the network should provide information as needed to detect major trends, identify threats and opportunities, and evaluate performance of organization units and personnel.

In some companies the quality information system is designed to go beyond control of product features and process features; the system is also used to control the quality performance of organizations and individuals, for example, departments and department heads. For example, many companies prepare and regularly publish scoreboards showing summarized quality performance data for various market areas, product lines, operating functions, etc. These performance data are often used as indicators of the quality performance of the personnel in charge.

To provide information which can serve all those purposes requires planning which is directed specifically to the information system. Such planning is best done by a multifunctional team whose mission is focused on the quality information system. That team properly includes the customers as well as the suppliers of information. The management audit of the quality control system should include assurance that the quality information system meets the needs of the various customers. (For additional discussion relating to the quality information system, see Section 9, Measurement, Information, and Decision Making.)

THE QUALITY CONTROL MANUAL

A great deal of quality planning is done through "procedures" which are really repetitive-use plans. Such procedures are thought out, written out, and approved formally. Once published, they become

the authorized ways of conducting the company's affairs. It is quite common for the procedures relating to managing for quality to be published collectively in a "quality manual" (or similar title). A significant part of the manual relates to quality control.

Quality manuals add to the usefulness of procedures in several ways:

Legitimacy: The manuals are approved at the highest levels of organization.

Readily findable: The procedures are assembled into a well-known reference source rather than being scattered among many memoranda, oral agreements, reports, minutes, etc.

Stable: The procedures survive despite lapses in memory and employee turnover.

Study of company quality manuals shows that most of them contain a core content which is quite similar from company to company. Relative to quality control, this core content includes procedures for:

Application of the feedback loop to process and product control

Ensuring that operating processes are capable of meeting the quality goals

Maintenance of facilities and calibration of measuring instruments

Relations with suppliers on quality matters

Collection and analysis of the data required for the quality information system

Training the personnel to carry out the provisions of the manual

Audit to ensure adherence to procedures

The need for repetitive-use quality control systems has led to evolution of standards at industry, national, and international levels. For elaboration, see Section 11, The ISO 9000 Family of International Standards. For an example of developing standard operating procedures, including the use of videocassettes, see Murphy and McNealey (1990). Work-force participation during preparation of procedures helps to ensure that the procedures will be followed. See, in this connection, Gass (1993).

Format of Quality Manuals. Here again, there is much commonality. The general sections of the manual include:

1. An official statement by the general manager. It includes the signatures which confer legitimacy.

2. The purpose of the manual and how to use it.

3 The pertinent company (or divisional, etc.) quality policies.

4 The organizational charts and tables of responsibility relative to the quality function.

5. Provision for audit of performance against the mandates of the manual.

Additional sections of the manual deal with applications to functional departments, technological products and processes, business processes, etc. For elaboration, see Juran (1988, pp. 6.40–6.47).

Managers are able to influence the adequacy of the Quality Control manual in several ways:

Participate in defining the criteria to be met by the manual.

Approve the final draft of the manual to make it official.

Periodically audit the up-to-dateness of the manual as well as conformance to the manual.

CONTROL THROUGH THE REWARD SYSTEM

An important influence on Quality Control is the extent to which the reward system (merit rating, etc.) emphasizes quality in relation to other parameters. This aspect of quality control is discussed throughout Section 15. See also Section 40, under Motivation, Recognition, and Reward.

PROVISION FOR AUDIT

Experience has shown that control systems are subject to "slippage" of all sorts. Personnel turnover may result in loss of essential knowledge. Entry of unanticipated changes may result in obsolescence. Shortcuts and misuse may gradually undermine the system until it is no longer effective.

The major tool for guarding against deterioration of a control system has been the audit. Under the audit concept a periodic, independent review is established to provide answers to the following questions: Is the control system still adequate for the job? Is the system is being followed?

The answers are obviously useful to the operating managers. However, that is not the only purpose of the audit. A further purpose is to provide those answers to people who, though not directly involved in operations, nevertheless have a need to know. If quality is to have top priority, those who have a need to know include the upper managers.

It follows that one of the responsibilities of managers is to mandate establishment of a periodic audit of the quality control system.

QUALITY CONTROL: WHAT IS NEW?

Recent decades have witnessed a growing trend to improve the effectiveness of quality control by formal adoption of modern concepts, methodologies, and tools. These have included:

Systematic planning for quality control, with extensive participation by the operating personnel

Formal application of the feedback loop, and establishment of clear responsibility for the associated decisions and actions

Delegation of decisions to the work force through self-control and self-inspection

Wide application of statistical process control and the associated training of the operating personnel

A structured information network to provide a factual basis for decision making

A systematic process for corrective action in the event of sporadic adverse change

Formal company manuals for quality control, with periodic audits to ensure up-to-dateness and conformance

SUMMARY

The quality control process is a universal managerial process for conducting operations so as to provide stability—to prevent adverse change and to "maintain the status quo." Quality control takes place by use of the feedback loop. Each feature of the product or process becomes a *control subject*—a center around which the feedback loop is built. As much as possible, human control should be done by the work force—the office clerical force, factory workers, salespersons, etc. The flow diagram is widely used during the planning of quality controls. The weakest link in facilities control has been adherence to schedule. To ensure strict adherence to schedule requires an independent audit. Knowing which process variable is dominant helps planners during allocation of resources and priorities. The work of the planners is usually summarized on a control spreadsheet. This spreadsheet is a major planning tool.

The question "Who is responsible for quality?" is inherently unanswerable. However, if the question is restated in terms of decisions and actions, the way is open to agree on the answers. The design for process control should provide the tools needed to help the operating forces distinguish between real changes and false alarms. It is most desirable to provide umpires with tools which can help to distinguish between special causes and common causes. An elegant tool for this purpose is the

Shewhart control chart (or just control chart). The criteria for self-control are applicable to processes in all functions, and all levels, from general manager to nonsupervisory worker. Responsibility for results should be keyed to controllability. Ideally the decision of whether the process conforms to process quality goals should be made by the work force. There is no shorter feedback loop.

To make use of self-inspection requires meeting several essential criteria: quality is number one; mutual confidence, self-control, training, and certification are the others. Personnel who are assigned to make product conformance decisions should be provided with clear definitions of responsibility as well as guidelines for decision making. The proper sequence in managing is first to establish goals and then to plan how to meet those goals, including the choice of the appropriate tools. The planning for quality control should provide an information network which can serve all decision makers.

TASKS FOR MANAGERS

Managers should avoid getting deeply into making decisions on quality control. They should make the vital few decisions, provide criteria to distinguish the vital few from the rest, and delegate the rest under a decision-making process.

To eliminate the confusion relative to control limits and product quality tolerance, managers should clarify the responsibility for corrective action on points outside the control limits and establish guidelines on action to be taken when points are outside the statistical control limits but the product still meets the quality tolerances.

Managers should, as part of their audit, ensure that the processes for making product conformance decisions are appropriate to company needs. They should also ensure that training in statistical tools does not become an end in itself. The management audit of the quality control system should include assurance that the quality information system meets the needs of the various customers.

Managers are able to influence the adequacy of the quality control manual in several ways: participate in defining the criteria to be met, approve the final draft to make it official, and periodically audit the up-to-dateness of the manual as well as the state of conformance.

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