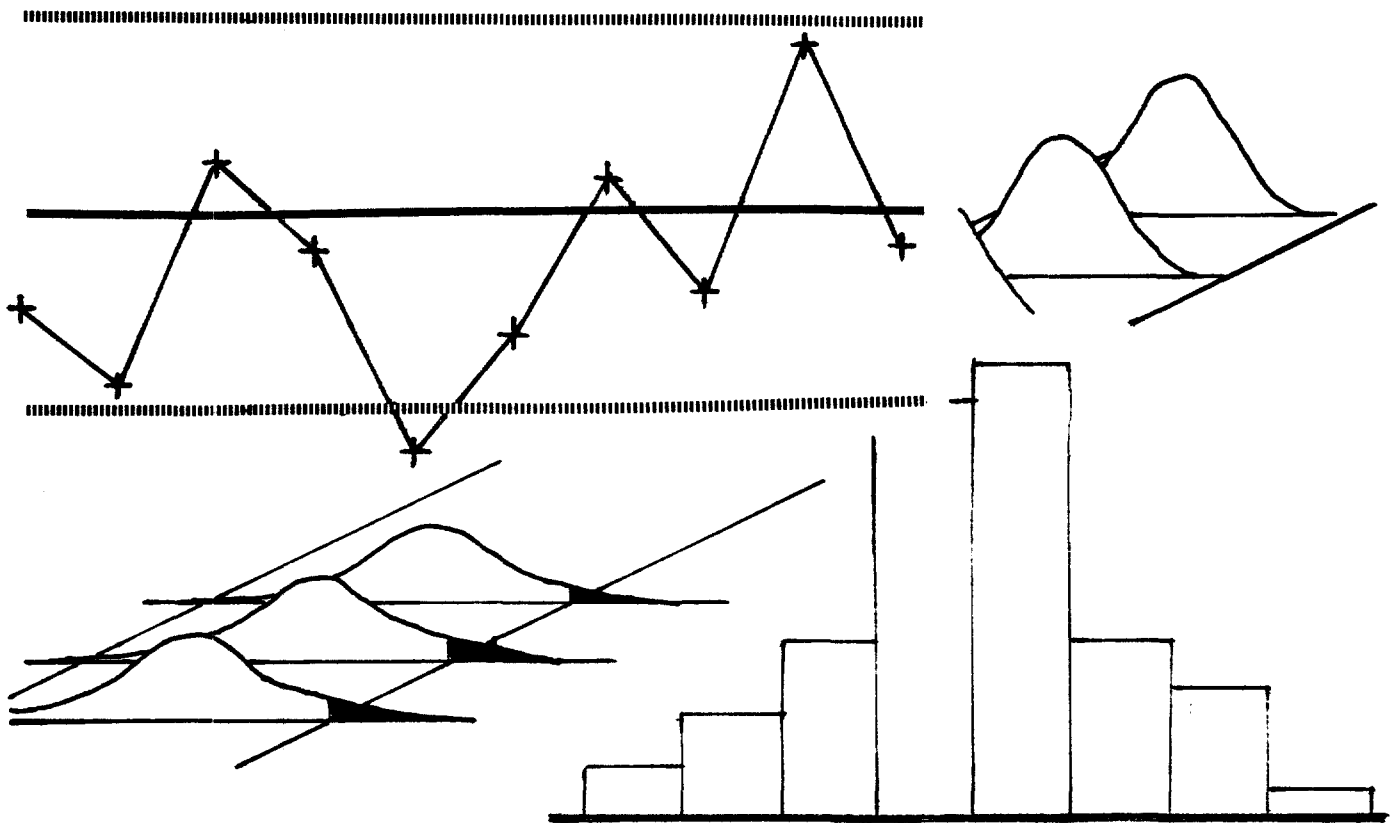


STATISTICAL PROCESS CONTROL



MIKE HUFFMAN
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STATISTICAL PROCESS CONTROL

Michael Huffman

Industries of all types feel the effects of competition, costly resources, poor quality, and countless other negative factors. There is no doubt that if an industry is to prosper in the marketplace, attention needs to be particularly focused on the subject of quality. Trends to combat quality problems include management techniques and statistical observations of production methods. The technique of statistical process control (SPC) is a major tool used in reducing waste and improving productivity. An understanding of this topic is essential for all associated with productive efforts.

A traditional approach to manufacturing is to depend on production to make the product and on quality control to inspect the final product and screen out those items not meeting required specifications. This is a strategy of detection. Unfortunately, it is quite wasteful. Materials and labor are allowed to be invested in products which are not always useable. After-the-fact inspection is uneconomical; it is expensive, unreliable, and wasteful of vital resources.

It is much more effective to avoid waste by not producing these out-of-specification parts in the first place; the strategy of prevention. This is accomplished by controlling the production effort (Fig. 1).

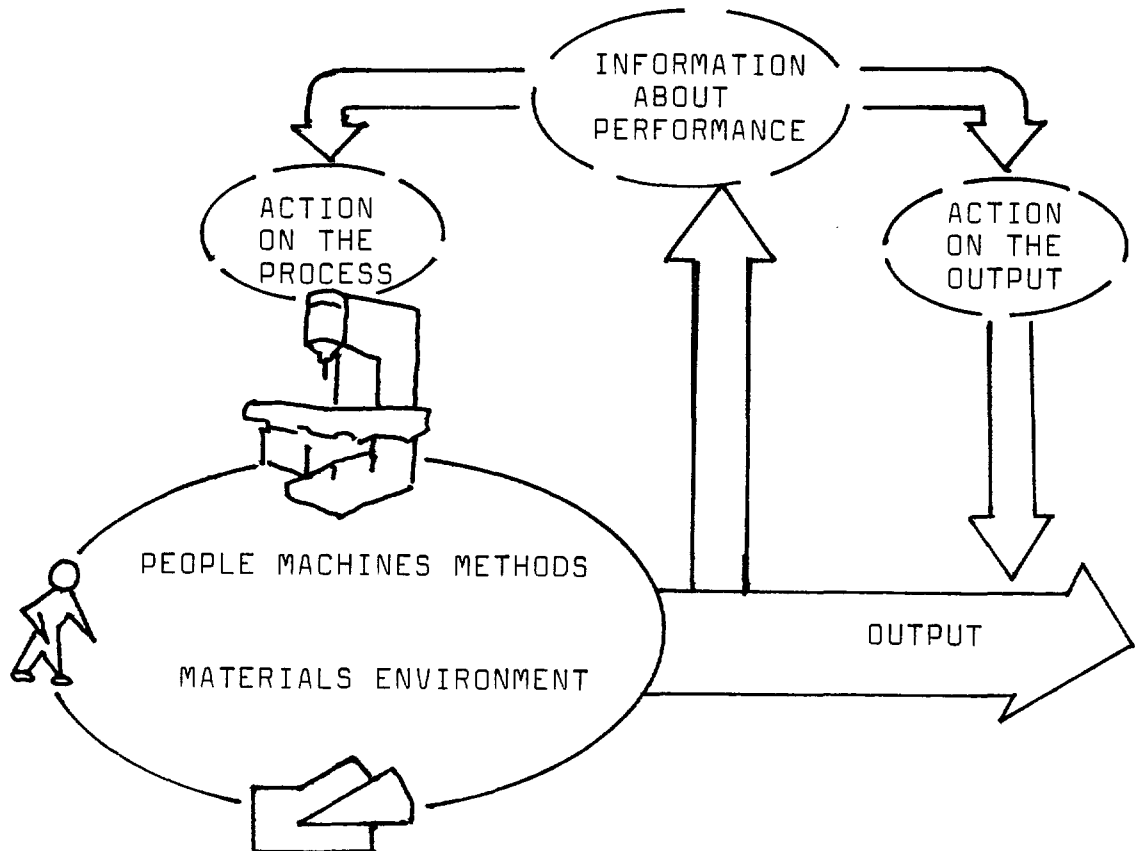


FIG. 1

A PROCESS CONTROL SYSTEM

A process control system can be described as a feedback system. Four elements of that system are key:

1) The process—By process we mean the whole combination of people, machines, materials, methods and the shop environment that work together to produce output.

2) Information about performance—Much information about the actual performance of the process can be learned by studying the process output. The process output includes the products plus factors such as temperatures, cycle times, etc.

3) Action on the processing—Changes on the system is future-oriented. This action might consist of changes in operations (e.g., operator training, changes to incoming material) or the more basic elements of the process itself (e.g., the equipment).

4) Action on the output—Action on the output is past-oriented. Unfortunately, if output does not meet specifications consistently it may be necessary to sort all products and to scrap or rework the items not conforming to requirements.

It is obvious that inspection followed by action only on the output is a poor substitute for effective first-time process performance. Therefore, implementation of a control system is a vital tool to developing a more consistent and marketable output. Knowledge of the SPC system is essential to increase efficiency and profitability in any enterprise.

FUNDAMENTAL CONCEPTS

Statistics is the collection, tabulation, and interpretation of data. One of the primary objectives in using statistics is to render a decision. But no decision can accurately be made without a basic understanding of some fundamental concepts.

In statistical work we are concerned with populations of objects, parts, people, trials, or measurements. Each individual in the population can be characterized by a) a variable such as length, weight or strength, or b) can possess one or more attributes, such as, being defect free or having one or more defects. It is important to keep in mind whether the collection is a variable measurement or attribute data.

Sampling is often done for speed, economy and sometimes because it is the only way to determine a feature (like in destructive tests). Probably the most basic question in all of statistics is the relationship between the sample and the population from which it comes. How does the population

determine what to expect of the samples from it, and what does the sample tell about the population? Of course neither question has any answers unless the the samples are drawn in an approved, un-biased manner, usually and hopefully at random. The objective of sampling is to obtain evidence about the population from which it is drawn. The reason for obtaining this knowledge is to make some decision regarding the population so we want the information from the sample to represent as precisely as possible the true nature of the entire population.

In order to effectively use process control measurement data, it is also important to understand the concept of variation. No two products or characteristics are exactly alike because any production process contains many sources of variability (Fig. 2). The differences among products may be large or unmeasurably small, but they are always present. The diameter of a machined shaft for example, would be susceptible to potential variation from the machine (clearances, bearing wear), tool (strength, rate of wear), material (diameter, hardness), operator (part feed, accuracy), maintenance (lubrication, replacement), and environment (temperature, consistency of power supply), etc. Some sources of variation in the process are short run piece-to-piece differences while other sources tend to cause changes in the product over a longer period of time. Therefore, the time period and conditions over which measurements are made will affect the amount of total variation that will be measured.

From a product specification standpoint, the only concern is with the total variation regardless of source. However, to manage any manufacturing process the total

All items vary to some degree from similar items.

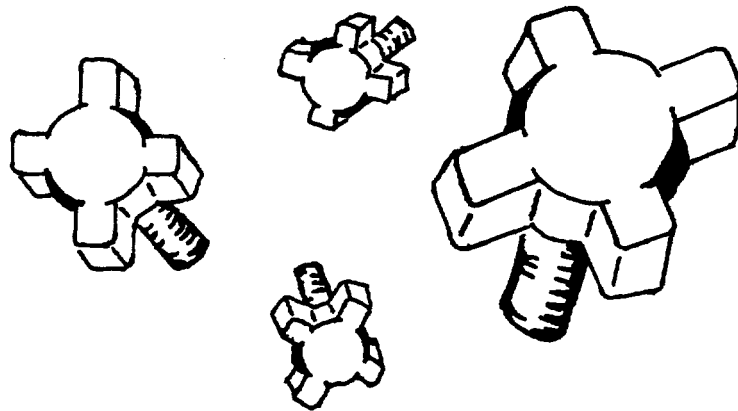


FIG. 2

variation must be traced back to its sources. The first step is to make a distinction between common and special causes. Common causes refer to the many sources of variation within a process that is under control. While the individual values are all different, as a group they can be predicted; this can be described as a distribution (Fig. 3). Special causes refer to any factors causing variation which cannot be adequately described by any single distribution. Unless all special causes of variation are identified and corrected, they will continue to affect the process output in unpredictable ways.

Although control charts are most often thought of in terms of variables, versions have also been developed for attributes. Attribute-type data have only two values (conforming/nonconforming, pass/fail, go/no go, present/absent) but they can be counted for recording and analysis. For example, the glass cover on a pressure guage is either cracked or it is not. Many types of extremes are important considerations in a manufacturing process.

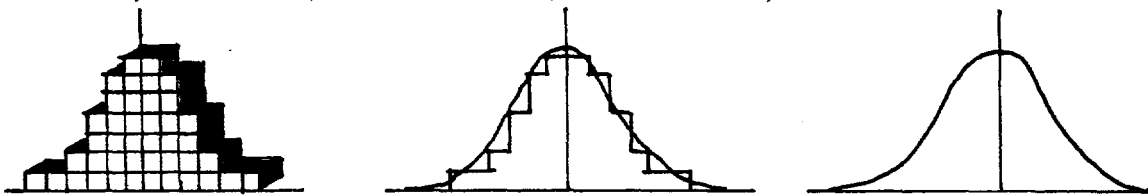
Representation of sample data by means of a frequency distribution is always bulky, frequently time-consuming, and sometimes misleading. Some form of statistical representation is necessary. This always requires at least two numbers, or statistics, one to measure the central tendency of the data and another to measure the spread or dispersion.

DISTRIBUTIONS

Pieces vary from each other:



But they form a pattern that, if stable, is called a distribution:



Distributions can differ in:

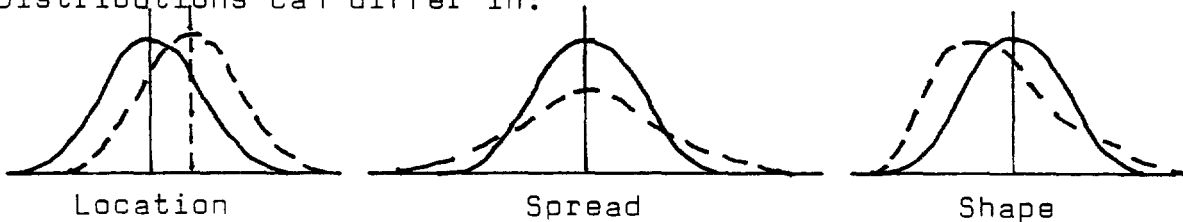


Fig. 3

The most commonly used measure of central tendency is the mean (represented by an " \bar{x} "). In popular language the word "average" usually implies the technical phrase arithmetic mean. Some knowledge about the nature of the population of values comes from a measure of central tendency. But simply knowing a "typical" value is often not enough; that is, we might like to know whether all values were concentrated at the average or spread out all over the place. We would like an indication of how variable the body of data tends to be. Because of the desirability of less sophisticated measures, quality control people use the variability measure known as the "range". The range of any sample is the difference between the highest and the lowest values in the sample.

One last concept the analyst must understand in order to control the process is the control limit. Control limits are statistically established to aid in the interpretation for process control. Control limits are NOT specification limits. They are set by simple statistical calculations from the output itself. The control limits do help signal problems that cause a net loss. The loss can result from two common mistakes made by a typical production workers: .

- 1) Adjust the machine when it would be better to leave it alone.
- 2) Fail to adjust the machine or work when it needs adjustment.

Examples of control limits

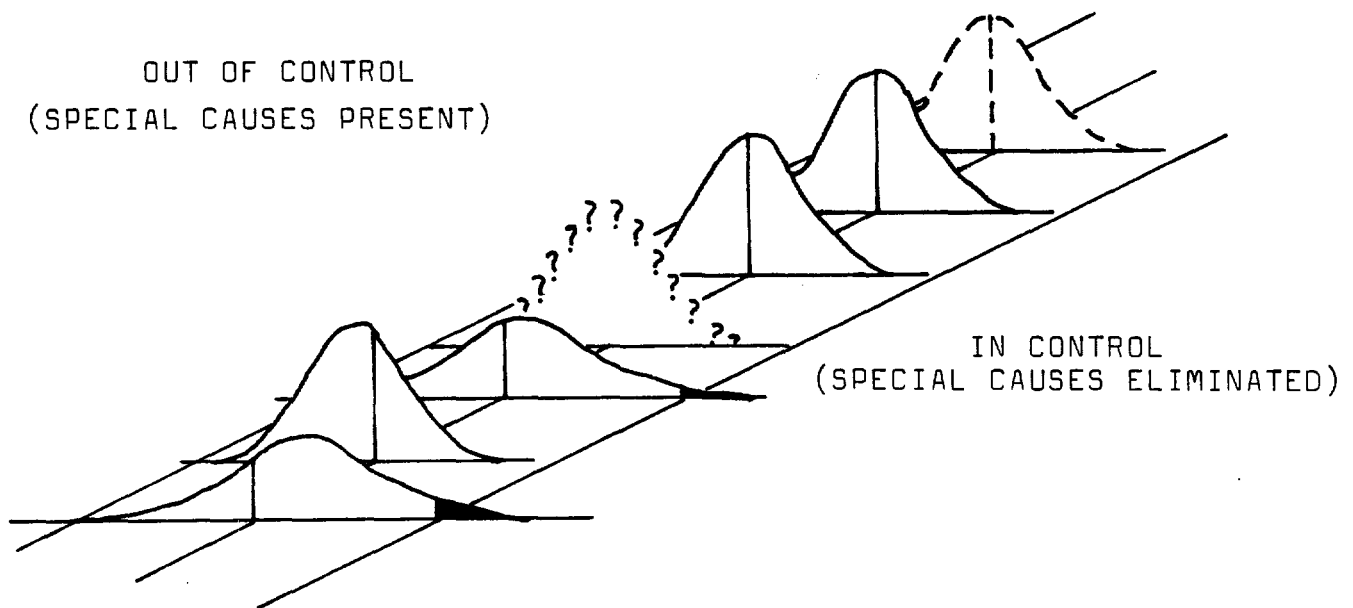


FIG. 4

With the factors of variation, attributes, distribution, means, range, population vs. samples, and control limits in mind, the process engineer can proceed to use this data to their advantage. We may now examine the major tool that brings all of these concepts into useable form, the "Shewart Control Chart". In spite of the apparent simplicity many engineers, production personnel, and inspectors find that the use of it calls for an entirely new point of view.

THE CONTROL CHART

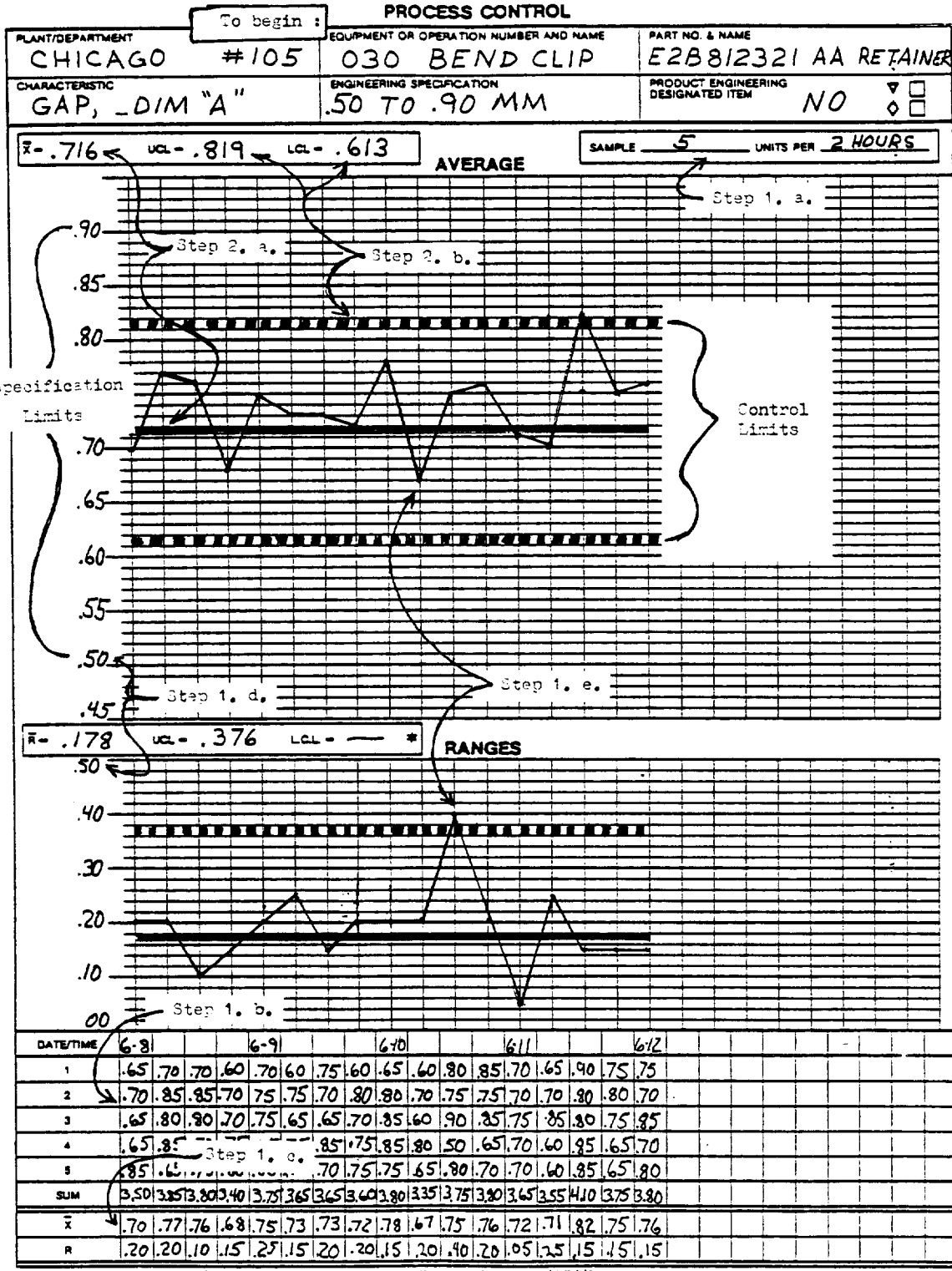
In 1924, Walter A. Shewhart of Bell Telephone Laboratories originated the technique of plotting statistical data on special charts in such a manner as to contribute to the control of quality. The power of the Shewhart technique lies in its ability to separate out the special causes of variation from the system causes. This makes possible the diagnosis and correction of many production troubles and often brings substantial improvements in product quality and reduction of spoilage and/or rework. Furthermore, by identifying some of the quality variations as inevitable chance variations, the control chart tells when to leave the process alone and thus prevents unnecessary adjustments that tend to increase the variability of the process rather than to decrease it.

Typical production workers often plot the statistical charts that help tell them whether and when to take action on their work. This requires only a simple knowledge of arithmetic. However, the production worker cannot devise and implement his own charting system. Management must start the movement and direct the job.

VARIABLE CONTROL CHARTS

Control charts for variables are powerful tools that can be used when measurements from a process are available (Fig. 5). Examples would be the diameter of a bearing, the closing effort of a door or the torque of a fastener. Variable charts-and especially their most common forms, the \bar{x} (x-bar) and R charts-represent the classic application of control charting to process control. Variables charts are typically used for the most important characteristics of a product, and for characteristics under study for quality improvement. Control charts for variables are almost always prepared and analyzed in pairs; one chart for the process central location and another for the process spread. The " \bar{x} " refers to the average of the values in small subgroups (a measure of central location); "R" is the range or "spread" of values within each subgroup (highest minus lowest).

A TYPICAL CONTROL CHART



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* For sample sizes of less than seven, there is no lower control limit for ranges.

FIG. 5

A \bar{x} chart and R chart, as a pair, represent a single product characteristic. These data are reported in small subgroups, usually including from 2 to 5 consecutive pieces, with subgroups taken periodically (e.g., once every fifteen minutes, twice per shift, etc.). The recommended procedure includes the following (refer to Fig. 5):

Step One, the inspection data must be gathered, recorded, and plotted on a chart according to a definite plan.

- a) Select the subgroup period and sample size.
- b) Set up control charts and record raw data.
- c) Calculate the average (\bar{x}) and the range (R) of each subgroup.
- d) Select scales for the control charts
- e) Plot the averages and ranges on the control charts.

Step Two, calculate the control limits. Control limits for the range chart are developed first followed by specifying those for the chart of averages. The calculations of control limits for variables charts use formulas which can be found in any S.P.C. handbook. The factors used vary according to sample size. This step should be calculated and analyzed by management. The substeps are as follows:

- a) Calculate the average range and the process average (\bar{x}) for the study period.
- b) Calculate the control limits: control limits are calculated to show the extent by which the subgroup averages and ranges would vary if only common causes of variation were present. Both the upper control limit (UCL) and lower control limit (LCL) are calculated. Draw lines for the averages and control limits on the charts.

Step Three, interpret for process control. The control limits can be interpreted as follows: If the process piece-to-piece variability and the process average were to remain constant at their present levels (as estimated by R and \bar{x} respectively), the individual subgroup ranges (R) and averages (\bar{x}) would vary by chance alone, but they would seldom go beyond the control limits. The objective of

CONTROL CHARTS FOR ATTRIBUTES

Although control charts are most often thought of in terms of variables, other versions have also been developed for attributes. There are four types of attribute control charts:

A. The p chart for proportion of units not conforming (from samples not necessarily of constant size).

B. The np chart for proportion of units not conforming (from samples of constant size).

C. The c chart for number of non-conformities (from samples of constant size).

D. The u chart for number of non-conformities per unit (from samples not necessarily of constant size).

These charts are quite similar to the development and analysis of the \bar{x} and R charts, although only one graph is constructed (instead of two). Attribute charts are commonly thought of in terms of product control, but can easily be used for process control.

Attribute data is easily collected and plotted.


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FIG. 6

THE DEMING METHOD

Obviously, the Shewart Control Chart is not much good without a practical method for its use. Companies have been able to use this chart and move to a much higher plateau of quality and productivity through the introduction of the Deming Method. Dr. W. Edwards Deming began to develop the ideas that led to his 14 point method during one of his first jobs in the 1920's at Western Electric's Hawthorne Plant in Chicago. The 14 points cover all aspects of quality. Some of his ideas seem obvious while others require a new approach. For example, he urges the elimination of work standards that prescribe numerical quotas. Not only do quotas disregard quality, they put a ceiling on production (point 11). Point 4 says companies should not choose suppliers on the basis of price alone, but instead should consider quality. But the heart of Deming's method for achieving high quality is statistical. Deming gets clients first to bring the manufacturing process under statistical control by eliminating the chaos of special causes, then has them work on the common causes by tinkering with the system and consistently measuring its effects. Using the Shewart chart, Deming shows clients a systematic method for measuring these variations, finding out what causes them, reducing them, and so steadily improving the process and thereby the product. The Deming Method has enormous potential for all industries because it offers the possibility of greatly improving both quality and productivity. The bottom line is that it works! This has been verified by countless success stories from all areas of business. The determining factor behind success or failure is the extent to which top management commits itself to the understanding, implementing and support of the system.

COMPUTERS IN PROCESS CONTROL

Advances in electronics and computers have enabled industries to attain better control of their processes with resulting increases in quality, productivity, profitability and compliance to regulations. The important functions for computers in process control are measurement, control, signal processing, actuation and communication.

Measurement refers to the sensing of variables such as flow rate, temperature, pressure, and chemical composition and transmission of this information to the controller. Control is an important decision-making operation. It involves use of the control chart and determining the action to take or not to take on the operation. Actuation is the means by which variables are manipulated. Typical actuators are valves, heaters, motors, solenoids, and hydraulic or pneumatic cylinders. While electronic devices have improved drastically, sensors and actuators have progressed at a more modest pace. Major improvements in computer-assisted process controls await advances in sensor technology and software.

Communication is the bonus in SPC work done on computers. Communication includes the presentation of information to the operators as well as the transmission of important variables to plant management. Data can be gathered and transmitted at the local level several ways. Operators can read the data and type it into a terminal or sensors can feed in data on a continuous basis. In some cases the computer can make adjustments with no interference if certain instructions are programmed into the system.

Industries recognized early the value of the computer in graphing statistical data. From the operators standpoint, a graphic display of a statistical control chart is a window to the process. With the information presented on the screen variables may be followed more closely. Moreover, operators have the the ability to call up process charts and study the overall process or simply focus on one or more individual operations. The integration of computers is very advantageous in all aspects of production. Using computers to monitor the production efforts, it possible to have the process controlled, regulated, and documented with little or no interference. Also, all of the individual operations can be integrated into a complete system. This results in a significant increase in both quality and productivity.

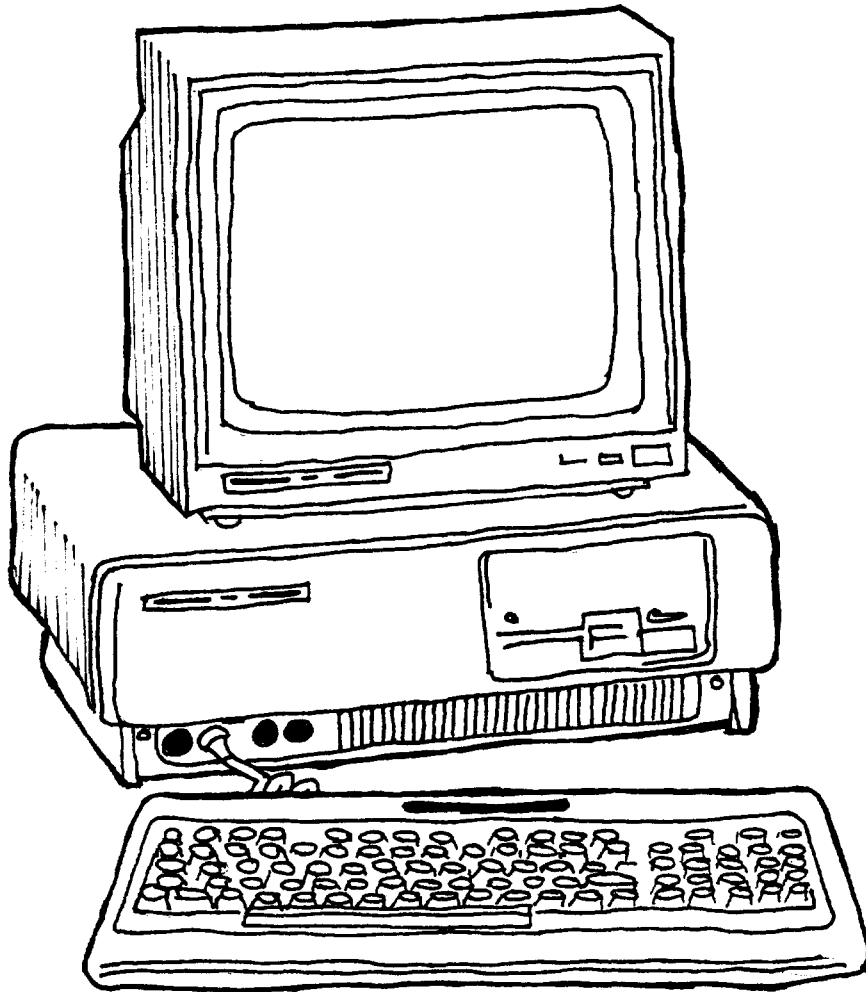


FIG. 7