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MILITARY HANDBOOK

STATISTICAL PROCESS CONTROL (SPC) IMPLEMENTATION AND EVALUATION AID

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F O R E W O R D

1. This military handbook is approved for use by all Departments and Agencies of the Department of Defense.

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3. Historical perspective.

a. The history of technological advancement has been a mix between breakthroughs in both the private sector and the military. For the body of technical knowledge involving statistical process control (SPC), we can look back to the pioneering work done by Doctor Shewhart in the days before World War II (WWII). During that war, the War Board taught SPC techniques as part of its overall Statistical Quality Control (SQC) program. Following WWII, certain large manufacturers in the United States (U.S.) installed SPC; but for a number of reasons it was later discarded as not being appropriate for commercial application.

b. The military had adopted MIL-STD-105 for attribute sampling, which served very well during WWII, but utilized the basic approach of detection rather than prevention. This resulted in batch rejection of material whenever it was found by inspection to be non-conforming to specification, after the fact. The usual scrap, rework and late deliveries were the natural result.

c. With inexpensive energy, great demand for peace in the world and an unlimited market for American products with little competition, quality was not at the top of the list of priorities. Price and delivery often ranked higher.

d. However, in the arena of higher volume production where quality was paramount, the opportunities for the greatest gains offered by SPC first became evident, namely for:

- Zero defects quality
- Lower Cost
- Timely delivery
- Better products

e. In the commercial arena during the mid-1970's, the American public really started seeing better products, often with a lower price tag; and interestingly enough from a source generally identified historically as producing inferior products, namely, the Japanese. By the mid-1980's, America's casual awareness of the Japanese invasion with their superior quality products and designs had changed to an acute awareness that they were surpassing the U.S. by their industrial superiority.

f. During the 1980's, this invasion was not limited to Japan. Once other countries became aware that Japan's secret weapon worked and that it was available to them as well, the flood gates opened. Yes, we now have the entire international spectrum of Japan, Hong Kong, Singapore, Taiwan and Korea battling for the world market with the U.S. at the top of their marketing list.

g. The U.S. industrial superiority that set the world pace following WWII has taken a severe beating. America's slide backwards does not have to continue. It does, however, require accurate assessment and recognition of how we lost that ground and the need for development of a sound program to reinstate ourselves.

h. American industry, as the major supplier of U.S. military equipment, is being challenged to update its technical resources, knowledge and commitment. The cornerstone for these would-be suppliers to the military, as defined in this document, is to recognize that one of the major requirements for eligibility to participate in the challenge is the actual implementation of an SPC program.

4. Purpose.

a. The purpose of this handbook is to serve as a guide for SPC implementation and program audit. It is designed for use by Government personnel for reviewing and assessing a contractor's SPC system, set-up, and performance. It may also be used by suppliers in establishing their SPC systems.

b. This handbook also acts as a bridge between SPC theory and application and as a reference document to evaluate SPC programs and tools. Quality and productivity improvements start with basic technical knowledge, but will not be fully realized without a structured program for applying the knowledge and sustaining the improvements through continuous monitoring, feedback, and commitment to correct problems when identified. Formulas and examples of SPC are available in a wide variety of excellent textbooks. The problem remains, however, that knowledge of statistical methods alone is not sufficient to bring about improvements in quality and productivity.

5. Implementation. Proper application of statistical theory is fundamental to any SPC program, but it is not enough by itself to get you to the required goal. The essential guide for an SPC program comes from management in the form of an implementation plan. Countless organizations, perhaps even your own, have learned that classes in statistics are not enough. Effective control charts won't magically appear just because the company has sponsored a one day seminar. To make SPC work, a step-by-step process, whose emphasis is implementation, is required with support, participation, and visibility at all levels of management and a follow-up system must be established to ensure timely completion of all critical steps and continued use of SPC techniques. For implementation purposes, contractors should consider the following:

a. SPC working manual. The contractors should provide a practical SPC system's manual to define and support their efforts. This manual should specify the following:

(1) Their philosophy, including their quality commitment.

(2) Their policy statements designed to implement their company philosophy.

(3) Their standard operating procedure (SOP) designed to support the stated policies. The SOP in particular should define the implementation elements of SPC.

b. In-plant applications. In-plant applications for SPC should be utilized by contractors, as follows:

(1) At receiving inspection if your supplier is not using SPC control as required by this guide. Since this is detection, after-the-fact and contrary to the intent of this guide, this will be considered a temporary condition and will be governed by the terms of your individual purchase orders. Any approvals for contracts would be conditional and temporary. The lifting of such conditional approvals would be directly related to the supplier's having up-graded their in-process systems to fully utilize SPC.

(2) During manufacturing where the application of appropriate charts is mandatory. This is subject to survey and audit prior to purchase order release and on-going audit surveillance, thereafter, on both the prime and subcontractors.

(3) At final inspection and audit.

6. Methodology. The prime contractor's SOP for subcontractor surveillance and control should define methodology for auditing, evaluating and controlling each supplier (subcontractor) in terms of both required SPC and other SOP and policy statement areas in which the supplier is required to provide adequate coverage.

7. Electronic data processing (EDP). Utilization of EDP capabilities by the contractor along with the necessary SPC software is optional. The parameters of implementation and control are defined in detail later in this SPC handbook.

8. Format. The format of this handbook was designed in sections, with each section covering a specific topical area. For ease of use and reference, all tables and figures applicable to a section were placed at the end of the section. Also, the tables and figures were consecutively numbered, but a numerical suffix was added to indicate the applicable section in which they appear.

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CHAPTER 1
SCOPE

1.1 Scope. This handbook establishes the guidelines for developing and implementing a practical SPC system by the contractor and provides the criteria for reviewing contractor SPC systems and evaluating their performance.

1.2 Coverage. Formulas, tables and examples of SPC are available in a wide variety of excellent textbooks. The problem remains, however, that knowledge of statistical methods alone is not sufficient to bring about improvements in Quality and Productivity.

Proper application of statistical theory is fundamental to any SPC program, but, something like the rear wheel of a bicycle, it is not enough by itself to get you where you want to go. The front wheel of a bicycle provides the ability to steer, thereby helping you avoid potholes, tree stumps, and other obstacles in the road. The "steering" for an SPC program comes from management in the form of an implementation plan. Countless organizations, perhaps even your own, have learned that classes in statistics are not enough. Effective control charts won't magically appear just because the company has sponsored a one day seminar. To make SPC work, a step-by-step process, whose emphasis is implementation, is required with support, participation, and visibility at all levels of management. Also, a follow-up system must be established to ensure timely completion of all critical steps and continued use of SPC techniques.

This handbook briefly describes the key elements of SPC implementation. Definitions of pertinent concepts are provided along with suggestions of where and how to get help as you proceed.

1.3 Topical content. The following is a synopsis of the major chapters that comprise this handbook:

a. Chapter 2: This chapter contains a glossary of terms and symbols commonly used in statistical work.

b. Chapter 3: Advantages and goals of SPC are described in this chapter. An effective program cannot be initiated until objectives and purpose are clearly understood.

c. Chapter 4: This chapter contains specific SPC implementation requirements. Note - refer to figure 8-4 for an example of an SPC implementation plan.

d. Chapter 5: This chapter proposes a format for evaluating SPC programs in a supplier's facility. Each supplier's approach will differ slightly according to manufacturing technology and management philosophy. It is important to be able to assess these differences, and to ensure that the supplier's objectives match the Army's requirements.

e. Chapters 6 and 7: Chapter 6 describes some of the SPC software programs available and Chapter 7 provides some guidelines for evaluating this software, without making any specific recommendations. Software selection and installation can become a project in itself depending on the degree of sophistication of the system and integration with real-time control.

f. Chapter 8: This chapter offers requirements and standards as an aid in selecting a consulting firm to help with SPC implementation. The objective here is to provide the means for making an informed selection by asking the right questions and comparing answers.

g. Chapter 9: This chapter contains miscellaneous notes.

1.4 Summary. In conclusion, this material should be considered a bridge between SPC theory and application and a reference document to evaluate SPC programs and tools. Quality and productivity improvement starts with basic technical knowledge, but will not be fully realized without a structured program for applying the knowledge and sustaining the improvements through continuous monitoring feedback and commitment to correct problems when identified.

CHAPTER 2
DEFINITIONS

2.1 Glossary. This chapter contains a glossary of statistical terms and symbols commonly used in statistical work.

2.2 Definition of terms.

2.2.1 Advanced statistical methods. More sophisticated and less widely applicable techniques of statistical process analysis and control than is included in basic statistical methods. This can include more advanced control chart techniques, regression analysis, design of experiments, advanced problem-solving techniques, etc.

2.2.2 Attributes data. Qualitative data (characteristics) than can be counted for recording and analysis. Examples include characteristics, such as, the presence of a required label, the installation of all required fasteners, the absence of errors on an expense report. Other examples are characteristics that are inherently measurable (i.e., could be treated as variables data), but where the results are recorded in a simple yes/no fashion, such as, the acceptability of a shaft diameter when checked on a go/no-go gage or the presence of any engineering changes on a drawing. Attributes data are usually gathered in the form of nonconforming units or of nonconformities; they are analyzed by p, np, c and u control charts (see also variables data).

2.2.3 Average. The sum of values divided by the number (sample size) of values; designated by a bar over the symbol for the values being averaged: e.g., $\bar{X}$ (X bar) is the average of the X values within a subgroup; $\bar{\bar{X}}$ (X double bar) is the average of subgroup averages; $\bar{p}$ (p bar) is the average of p's from all the subgroups (see also mean).

2.2.4 Awareness. Personal understanding of the interrelationship between quality and productivity, directing attention to the requirement for management commitment and statistical thinking to achieve never-ending improvement.

2.2.5 Basic statistical methods. Applies the theory of variation through the use of basic problem-solving techniques and statistical process control, and includes control chart construction and interpretation (for both variables and attributes data) and capability analysis.

2.2.6 Basic statistics. Applies the theory of variation through the use of applied statistics in collecting and summarizing data, analyzes grouped as well as unwrapped data, includes histogram construction and interpretation.

2.2.7 Capability. Capability can be determined only after the process is in statistical control. A process is said to be capable when the process average plus and minus the 3-sigma spread of the distribution of individuals ($\bar{X} \pm 3\sigma$) is contained within the specification tolerance (variables data), or when at least 99.73 percent (%) of individuals are within specification (attributes data). Efforts to improve capability must continue, however, consistent with the operational philosophy of never-ending improvement in quality and productivity.

2.2.8 Cause-and-effect diagram. A simple tool for individual or group problem-solving that uses a graphic description of the various process elements to analyze potential sources of process variation. Also called "fishbone diagram" (after its appearance) or "Ishikawa diagram" (after its developer).

2.2.9 Central line. The line on a control chart that represents the average or median value of the items being plotted.

2.2.10 Characteristic. A distinguishing feature of a process or its output on which variables or attributes data can be collected.

2.2.11 Common cause. A source of variation that affects all the individual values of the process output being studied. In control chart analysis it appears as part of the random process variation.

2.2.12 Consecutive. Units of output produced in succession; a basis for selecting subgroup samples.

2.2.13 Control chart. A graphic representation of a characteristic of a process characteristic showing plotted values of some statistic gathered from that characteristic, a central line, and one or two control limits. Its primary function is to discern assignable from random causes of variation. It has two basic uses: as a judgement to determine if a process has been operating in statistical control, and as an operation to aid in maintaining statistical control.

2.2.14 Control limit. A line (or lines) on a control chart used as a basis for judging the significance of the variation from subgroup to subgroup. Variation beyond a control limit is evidence that special causes are affecting the process. Control limits are calculated from process data and are not to be confused with engineering specifications.

2.2.15 Detection. A past-oriented strategy that attempts to identify unacceptable output after it has been produced and then separate it from the good output (see also prevention).

2.2.16 Distribution. A way of describing the output of a common-cause system of variation, in which individual values are not predictable, but the outcomes as a group form a pattern that can be described in terms of its location, spread, and shape. Location is commonly expressed by the mean or average, or by the median. Spread is expressed in terms of the standard deviation or the range of a sample. Shape involves many characteristics, such as, symmetry and peakedness, but these are often summarized by using the name of a common distribution, such as, the normal, binominal, or Poisson.

2.2.17 Failure mode and effects analysis (FMEA). Is an analytical technique which uses the potential failure modes of a process and the resulting effects to prioritize corrective actions, and for identifying the characteristics of a process that are vital to product quality.

2.2.18 Gage accuracy. The difference between the observed average of measurements and the true average of the same parts using precision instruments.

2.2.19 Gage linearity. The difference in the accuracy values through the expected operating range of the gage.

2.2.20 Gage repeatability (precision). The variation in measurements obtained with one gage when used several times by one operator while measuring the identical characteristic on the same part.

2.2.21 Gage reproducibility. The variation in the average of the measurements made by different operators using the same gage while measuring the identical characteristic on the same part.

2.2.22 Gage stability. The difference in the average of no less than two sets of measurements obtained with a gage on the same parts as a result of time.

2.2.23 Gage system error. The combination of gage accuracy, repeatability, reproducibility, stability and linearity.

2.2.24 Histogram. A pictorial way to display data in frequency form. This provides a visual way to evaluate the form of the data.

2.2.25 Individual. A single unit or a single measurement of a characteristic.

2.2.26 Inspection and test capability studies. This step has been called the "Missing Link" in SPC. It is a technique for evaluating and quantifying the errors present in inspection systems for either variables or attributes data. It also defines the criteria of when to accept and when to reject any given inspection and test process. Inspection and test capability studies also set the stage for the next step of the SPC process.

2.2.27 Location. A general concept for the typical values or central tendency of a distribution.

2.2.28 Mean. The average of values in a group of measurements.

2.2.29 Median. The middle value in a group of measurements, when arranged from lowest to highest. If the number of values is even, by convention the average of the middle two values is used as the median. Subgroup medians form the basis for a simple control chart for process location. Medians are designated by a tilde (~) over the symbol for the individual value, e.g., $\tilde{X}$ is the median of a subgroup.

2.2.30 Never-ending improvement in quality and productivity. The operational philosophy that makes best use of the talents within the company to produce products of increasing quality for our customers in an increasingly efficient way that protects the return on investment to the stockholders. This is a dynamic strategy designed to enhance the strength of the company in the face of present and future market conditions. It contrasts with any static strategy that accepts (explicitly or implicitly) some particular level of outgoing defects as inevitable.

2.2.31 Nonconforming units. Units which do not conform to a specification or other inspection standard; sometimes called discrepant or defective units. To analyze systems producing nonconforming units, p and np control charts are used.

2.2.32 Nonconformities. Specific occurrences of a condition which does not conform to specifications or other inspection standards; sometimes called discrepancies or defects. An individual nonconforming unit can have the potential for more than one nonconformity (e.g., a door could have several dents and dings; a functional check of a carburetor could reveal any of a number of potential discrepancies). To analyze systems producing nonconformities, c and u control charts are used.

2.2.33 Normal distribution. A continuous, symmetrical, bell-shaped frequency distribution for variables data that underlies the control charts for variables. When measurements have a normal distribution, about 68.26% of all individuals lie within plus or minus one standard deviation unit of the mean, about 95.44% lie within plus and minus two standard deviation units of the mean, and about 99.73% lie within plus and minus three standard deviation units of the mean. These percentages are the basis for control limits and control chart analysis (since subgroup averages tend to be normally distributed even if the output as a whole is not), and for many capability decisions (since the output of many industrial processes follows the normal distribution).

2.2.34 Operational definition. Operational definition is a means of clearly communicating quality expectations and performance. It consists of (1) a criterion to be applied to an object or to a group, (2) a test of the object or group, and (3) a decision (yes or no) that the object or group did/did not meet the criterion.

2.2.35 Pareto chart. A simple tool for problem-solving that involves ranking all potential problem areas or sources of variation according to their contribution to cost or to total variation. Typically, a few causes account for most of the cost (or variation), so problem-solving efforts are best prioritized to concentrate on the "vital few" causes, temporarily ignoring the "trivial many".

2.2.36 Performance improvement process. The operational philosophy within the company to produce products of increasing quality for its customers in an increasingly efficient way that protects the return on investment to the stockholders. This is a dynamic strategy designed to enhance the strength of the company in the face of present and future market conditions.

2.2.37 Prevention. A future-oriented strategy that improves quality and productivity by directing analysis and action toward correcting the process itself. Prevention is consistent with the philosophy of never-ending improvement (see also detection).

2.2.38 Problem-solving. The process of moving from symptoms to causes (special or common) to actions that improve performance. Among the techniques that can be used are Pareto charts, cause-and-effect diagrams and statistical process control.

2.2.39 Process. The combination of people, equipment, materials, methods and environment that produce output, i.e., a given product or service. A process can involve any aspect of our business. A key tool for managing processes is statistical process control.

2.2.40 Process average. The location of the distribution of measured values of a particular process characteristic, usually designated as an overall average, $\bar{X}$.

2.2.41 Process capability studies. The process capability study is a systematic procedure for determining the natural or inherent variation in a process. To measure and evaluate the true capability of a process, statistical control chart methods are applied. As with inspection and test capability studies, this step provides the user with criteria for acceptance or rejection and guidelines for corrective action. The power of the process capability study is that it will demonstrate whether or not the process is actually capable of meeting specifications. The process capability study will result in the location of the centering of the process, the spread of the process and stability of the process.

2.2.42 Process spread. The extent to which the distribution of individual values of the process characteristic vary; often shown as the process average plus or minus some number of standard deviations (e.g., $\bar{X} \pm 3\sigma$).

2.2.43 Randomness. A condition in which individual values are not predictable, although they may come from a definable distribution.

2.2.44 Range. The difference between the highest and lowest values in a subgroup. The expected range increases both with sample size and with the standard deviation.

2.2.45 Run. A consecutive number of points consistently increasing or decreasing, or above or below the central line. Can be evidence of the existence of special causes of variation.

2.2.46 Run chart. A simple graphic representation of a characteristic of a process, showing plotted values of some statistic gathered from the process (often individual values) and a central line (often the median of the values) which can be analyzed for runs (see also control chart).

2.2.47 Sample. In process control applications, sample is a synonym with subgroup. This use is totally different from the purpose of providing an estimate of a larger group of people, items, etc.

2.2.48 Shape. A general concept for the overall pattern formed by a distribution of values.

2.2.49 Sigma (σ). The Greek letter used to designate a standard deviation.

2.2.50 Special cause. A source of variation that is intermittent, unpredictable, unstable; sometimes called an assignable cause. It is signaled by a point beyond the control limits or a run or other non-random pattern of points within the control limits.

2.2.51 Specification. The engineering requirement for judging acceptability of a particular characteristic. A specification is never to be confused with a control limit.

2.2.52 Spread. A general concept for the extent by which values in a distribution differ from one another; dispersion (see also process spread).

2.2.53 Stability. The absence of special causes of variation; the property of being in statistical control.

2.2.54 Stable process. A process that is in statistical control.

2.2.55 Standard deviation. A measure of the spread of the process output or the spread of a sampling statistic from the process (e.g., of subgroup averages); denoted by the Greek letter sigma (σ).

2.2.56 Statistic. A value calculated from or based upon sample data (e.g., a subgroup average or range) used to make inferences about the process that produced the output from which the sample came.

2.2.57 Statistical control. The condition describing a process from which all special causes of variation have been eliminated and only common causes remain; evidenced on a control chart by the absence of points beyond the control limits and by the absence of non-random patterns or trends within the control limits.

2.2.58 Statistical process control (SPC). The use of statistical techniques such as control charts to analyze a process or its outputs so as to take appropriate actions to achieve and maintain a state of statistical control and to improve the process capability.

2.2.59 Subgroup. One or more events or measurements used to analyze the performance of a process. Rational subgroups are usually chosen so that the variation represented within each subgroup is as small as feasible for the process (representing the variation from common causes), and so that any changes in the process performance (i.e., special causes) will appear as differences between subgroups. Rational subgroups are typically made up of consecutive pieces, although random samples are sometimes used.

2.2.60 Technical data package (TDP). Composite of specifications, plans, drawings, standards, and such other data necessary to properly describe material for acquisition purposes.

2.2.61 Type I error (overcontrol). Taking action appropriate for a special cause when in fact the process has not changed.

2.2.62 Type II error (undercontrol). Not taking appropriate action when in fact the process is affected by special causes.

2.2.63 Variables data. Quantitative data where measurements are used for analysis. Examples include: the diameter of a bearing journal in millimeters, the closing effort of a door in kilograms, the concentration of electrolyte in percent, or the torque of a fastener in newton-meters. $\bar{X}$ and R, $\bar{X}$ and s, median and individuals control charts are used for variable data. (See also attributes data).

2.2.64 Variation. The inevitable differences among individual outputs of a process. The sources of variation can be grouped into two major classes: common causes and special causes.

2.3 Symbols and their definitions:

Symbol	Definition
A_2	- A multiplier of $\bar{R}$ used to calculate the control limits for averages.
A_3	- A multiplier of $\bar{s}$ used to calculate the control limits for averages.
B_2, B_3	- Multipliers of $\bar{s}$ used to calculate the lower and upper control limits, respectively, for sample standard deviations
c	- The number of nonconformities in a sample.
$\bar{c}$	- The average number of nonconformities in samples of constant size n.
c_4	- A divisor of s used to estimate the process standard deviation.
C_p	- A capability index that indicates potential process capability, defined as: total tolerance/6σ.
Cpk	- The Capability Index, defined as: $Z_{min}/3$.
d_2	- A divisor of $\bar{R}$ used to estimate the process standard deviation.
D_3, D_4	- Multipliers of $\bar{R}$ used to calculate the lower and upper control limits, respectively, for range.
GRR	- Gage repeatability and reproducibility (gage error).
k	- The number of subgroups being used to calculate control limits.
LCL	- The lower control limits; $LCL_{\bar{x}}$, LCL_R, LCL_p, etc., are, respectively, the lower control limits for averages, ranges, proportion nonconforming, etc.
$LCL_{\bar{x}}$	- Lower control limit for averages.
LCL_R	- Lower control limit for ranges.
LCL_p	- Lower control limit for proportion nonconforming.
LSL	- The lower engineering specification limit.

Symbol	Definition
n	- The number of individuals in a subgroup, the subgroup sample size.
$\bar{n}$	- The average subgroup sample size.
np	- The number of nonconforming items in a sample of size n.
$n\bar{p}$	- The average number of nonconforming items in samples of constant size n.
p	- The proportion of units nonconforming in a sample.
$\bar{p}$	- The average proportion of units nonconforming in a series of samples (weighted by sample size).
PCR	- The Process Capability Ratio, defined as 6σ/total tolerance, where total tolerance = (upper spec. limit) - (lower spec. limit).
R	- The subgroup range (highest minus lowest value).
$\bar{R}$	- The average range of a series of subgroups of constant size.
s	- The sample standard deviation, sigma (σ).
$\bar{s}$	- The average sample standard deviation of a series of subgroups, weighted if necessary, by sample size.
SL	- A unilateral engineering specification limit.
u	- The number of nonconformities per unit in a sample which may contain more than one unit.
$\bar{u}$	- The average number of nonconformities per unit in samples not necessarily of the same size.
UCL	- The upper control limit: $UCL_{\bar{x}}$, UCL_R, UCL_p, etc., are, respectively, the upper control limits for averages, ranges, proportion nonconforming, etc.
$UCL_{\bar{x}}$	- Upper control limit for averages.
UCL_R	- Upper control limit for ranges.
UCL_p	- Upper control limit for proportion nonconforming.

Symbol	Definition
USL	- The upper engineering specification limit.
X	- An individual value, upon which other subgroup statistics are based.
$\overline{X}$	- The average of values in a subgroup.
$\overline{\overline{X}}$	- The average of subgroup averages (weighted if necessary by sample size); the measured process average.
Z	- The number of standard deviation units from the process average to a value of interest such as an engineering specification. When used in capability assessment, Z_{USL} is the distance to the upper specification limit, Z_{LSL} is the distance to the lower specification limit, and Z_{min} is the distance to the nearest specification limit.
Z_{LSL}	- $\frac{\overline{\overline{X}} - LSL}{\sigma}$
Z_{USL}	- $\frac{USL - \overline{\overline{X}}}{\sigma}$
Z_{min}	- The minimum value of the (Z_{LSL}, Z_{USL}).
σ (sigma)	- The standard deviation of the distribution of individual values of a process characteristic, defined as follows:

$$\sqrt{\frac{\Sigma (X - \overline{X})^2}{N}} \quad \text{OR} \quad \sqrt{\frac{\Sigma (X - \overline{X})^2}{n-1}}$$

Depending on the value of N

$\hat{\sigma}$	- An estimate of the standard deviation of the distribution of individual values of a process characteristic, defined as: $\bar{R}/d_2$.

NOTE - The symbol σ is often mistakenly used interchangeably with s. Consideration should be given when σ is used. One should realize that there exists a σ respective of individual values, and a σ respective of sampling data averages, The difference in the two may be expressed as:

$$\sigma_A = \sigma_I / \sqrt{n}$$

where:

σ_A = the standard deviation of averages.
σ_I = the standard deviation of the respective individuals.
n = the subgroup sample size.

CHAPTER 3
ADVANTAGES AND GOALS OF SPC

3.1 Advantages of SPC. The advantages of SPC are:

a. Ability to understand process variation. SPC is the application of statistical techniques to management of an operation or process. It involves the identification of events that are beyond the natural variation of the process and the systematic elimination of the causes of such events. When appropriate statistical techniques are built into the process or operation, management gains the ability to understand the nature of the process variation and to bring the variation within the desired limits.

There is a natural variation inherent in any process. The diameter of a drilled hole, for example, will vary due to wear of the drill bit, material hardness, operator skill and accuracy, and ambient temperature. For another example, time to receive your food in a restaurant will vary according to the efficiency of the serving person, the reliability of the cook, the availability of ingredients, and the workload on the restaurant personnel.

b. Ability to control process variation. Variation will exist within the process. Parts will be acceptable only when they conform to the specification. However, to control a process, reduce variation, and ensure that the output continues to meet the expressed requirements, the causes of variation must be identified in the data or in dispersion (spread) of the data. Collection of these data are characterized as mathematical models called "distributions" that are used to predict the overall performance. Certain factors which may cause a variation that cannot be adequately explained by the process distribution are called "assignable causes". Unless these assignable causes are identified and removed, they will continue to affect the process in an unpredictable manner. A process is said to be in statistical control when the only source variation is the natural process variation and "assignable causes" have been eliminated.

Variation that is outside of the desired process distribution can usually be corrected by someone directly connected with the process. For example, a machine set improperly may produce defective parts. The responsibility for corrective/preventive action in this case belongs to the operator, who can readjust the machine to prevent recurring defects.

c. Ability to effectively manage process variation. Causes of natural variation may only be correctable by management action such as capital investment in new equipment or a redesign of the material processing. It may, in fact, be determined that enough variation cannot be economically eliminated to produce items consistently within specification.

A successful SPC requires management action. This action takes place in the form of a monitoring system and a feedback loop consisting of a corrective and preventive action plan. For example, a control chart may be in place to record the average fraction defective at a work station, but it is only of a marginal value unless the people responsible for the process know what action to take when the process moves out-of-control.

SPC is the most effective method of process management. It eliminates subjectivity and provides a means of comparing performance to clearly defined objectives. The same control chart used to identify variability and existence of assignable causes will be used to track process improvement.

d. Kliminates firefighting. Through the application of statistical techniques the need for what is called "firefighting" is eliminated. Problems are identified, quantified and solved at the source in an optimum time. "Out-of-control" conditions become evident quickly as does the magnitude of the problem. With this information, action can be taken before the condition becomes a crisis.

e. Immediate feedback. Immediate feedback is the key to success of any SPC system. SPC is not solely a quality department function. The responsibility for control should be in the hands of the user. This provides the dual advantage of giving the operator a better understanding of what is expected, as well as, providing a means of detecting undesirable conditions before it is too late.

f. Identifies responsibility. SPC logically identifies responsibilities and accountabilities, and eliminates "finger pointing" and confusion. There is less tendency to hide or ignore problems when an efficient system is in place to correct problems.

3.2 Goals of SPC. The goals of an SPC program are consistent with typical corporate goals to improve quality, increase profits, and to enhance their competitive advantage.

3.2.1 Specific goals. Specific goals of an SPC program are as follows:

a. Improve quality and reliability of products and services without increasing cost. This objective is a necessity for any organization that aims to remain competitive. Steps taken to improve a process will result in fewer escaped defects and, therefore, a better quality product to the customer. The reduction of variability in a process increases the quality of the product.

b. Increase productivity and reduce costs. The application of SPC can produce immediate improvements in yield, reduction of defects, and increases in efficiency that are directly related to cost reduction. An SPC program is the best means of reducing scrap, reducing rework and increasing production capacity. Most organizations just starting out to implement SPC are not aware that their process is out-of-control, causing needless defects.

c. Provide a practical working tool for directing and controlling an operation or process. The tools of SPC are available for management and non-management personnel alike. Implementation of SPC creates a high degree of visibility of process performance. The same statistical techniques used to control the process can be used to determine its capability to the desired specification.

d. Establish an on-going measurement and verification system. It is difficult to control a process without a meaningful measurement of process parameters. Measurements will provide a comparison of performance to target objectives and will assess the effectiveness of problem solutions.

e. Prioritize problem solving activities and help management with decisions on allocation of resources for the best return on investment. SPC reduces the "squeaky wheel" phenomenon and directs efforts in a systematic and disciplined approach.

f. Improve customer satisfaction through better quality and reliability, and better performance to schedule. Aside from the traditional definition, a customer may be within an organization and simply the next operation or department in a factory.

g. Reduce Army cost of ownership for procured material. The Army's mission mandates that they operate and maintain their own equipment. With reduced variability, increased reliability and improved quality, the material operation and support costs are minimized to what was originally designed.

3.2.2 Control charts. The control chart is the basic tool to achieve SPC goals. A control chart is a graphic representation of the process variation plotted against time. It compares ongoing performance to control limits calculated from the natural process dispersion. Because of the low probability of data occuring outside the control limits by random chance, such points are considered to arise from assignable cause that can be identified and corrected. The control chart allows the use of small samples taken at specified time intervals to evaluate the process within its process limits on a real time basis.

3.2.2.1 Classification. Control charts are primarily classified into two types, variable data and attribute data. Variable data is that derived from any measurement, such as, length, weight, or temperature. Attribute data comes from non-measurable characteristics where the sample can be judged only as being acceptable or not acceptable. An example of attribute data would be inspection for missing or damaged parts. The method of maintaining control is essentially the same for either type of data.

3.2.2.2 Application. Control charts can be maintained by the personnel directly involved in the operation. For some applications, they can be automatically generated by the measuring equipment or from dedicated computer software. Whether manual or automatic, control charts must be used in conjunction with a feedback system that traces causes and instructs the operator on how to bring the process back into a state of statistical control. Examples of control charts are as follows:

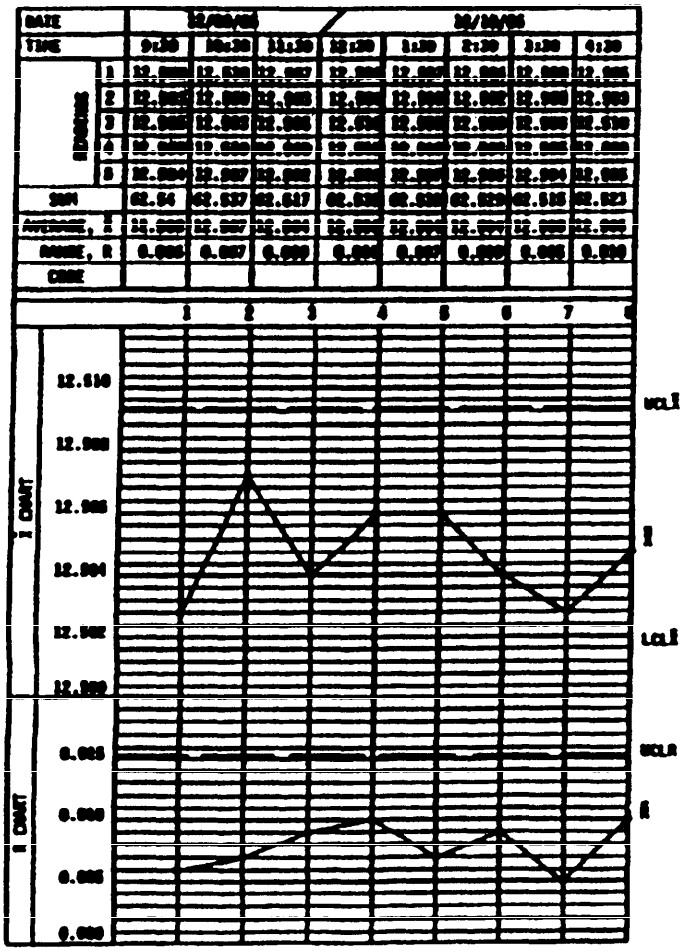
a. Figure 1-3: The control chart in this figure is an example of an average ($\bar{X}$) and a range (R) chart for a variable measured on a push rod at a stud weld operation. After 25 subgroups of 5 parts each, process centerline and control limits have been calculated and are recorded on the chart. Measurements were taken each hour over three shifts. The process average and range is in control.

b. Figure 2-3: The control chart in this figure is an example of an average ($\bar{X}$) and range (R) chart for spring compression force. Subgroups of five springs each have been measured every 2 hours (hr) and data is recorded on the chart for 25 subgroups. Process centerlines and control limits are recorded on the chart.

c. Figure 3-3: The control chart in this figure is an example of a "p-chart" for fraction defective found at the final inspection of an ammunition shell. Inspection is performed once each hour on subgroups of 25 parts each. The centerline of the process was calculated at 0.008 and the upper control unit at 0.0615. The spikes on the chart occur because of the relatively small subgroup size. Only two types of defects are recorded at this station.

PROCESS CONTROL CHART

OPERATION STUD WELD	PART NAME PUSH ROD	OPERATOR	DATE	INSPECTOR	DATE
FIXTURE/MACHINE NO. 3	PART NO. HX-2345/Revis B	12	12/09 & 12/10/86	06	12/09&10
SUBGROUP SIZE 5	SPECIFICATION 12.430"-12.530"	19	12/10/86	03	12/10
SUBGROUP FREQUENCY 1 Per Hour	REMARKS MILITARY VEHICLE	16	12/10/86	04	12/10



CODE	ACTIONS TAKEN	
	CORRECTIVE	PREVENTIVE
1		
2		
3		
4		
5		

CENTERLINE AND CONTROL LIMITS

R CHART

$\bar{R}$ = AVERAGE R = _____

$UCL_R = D_4\bar{R}$ _____

$LCL_R = D_3\bar{R}$ _____

X̄ CHART

$\bar{\bar{X}}$ = AVERAGE X̄ = _____

$UCL_{\bar{X}} = \bar{\bar{X}} + A_2\bar{R}$ _____

$LCL_{\bar{X}} = \bar{\bar{X}} - A_2\bar{R}$ _____

FIGURE 1-3. Example of an average($\bar{X}$)and(R)chart for a push rod.

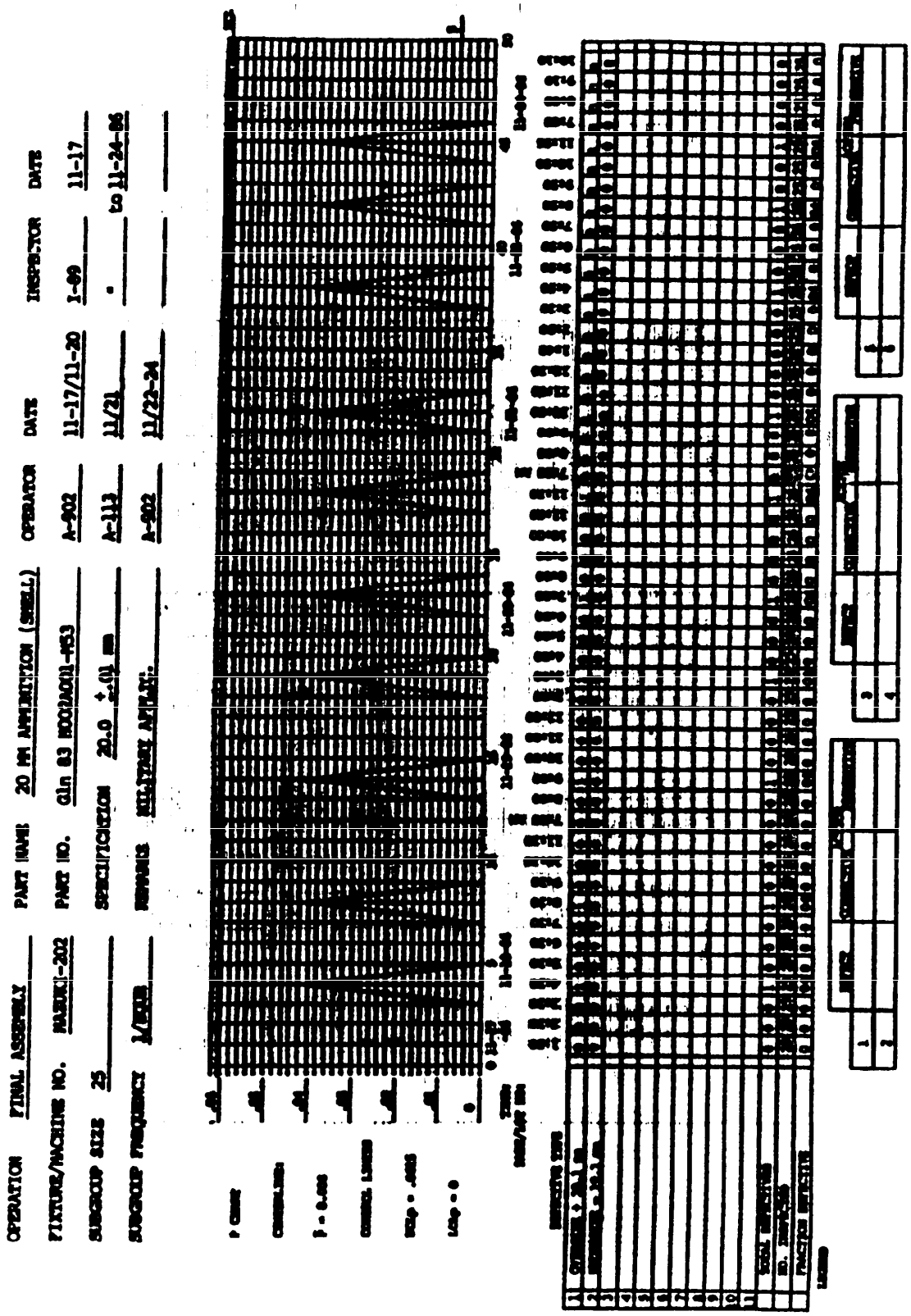


FIGURE 2-3. Example of an average($\bar{X}$) and (R) chart for a compression spring.

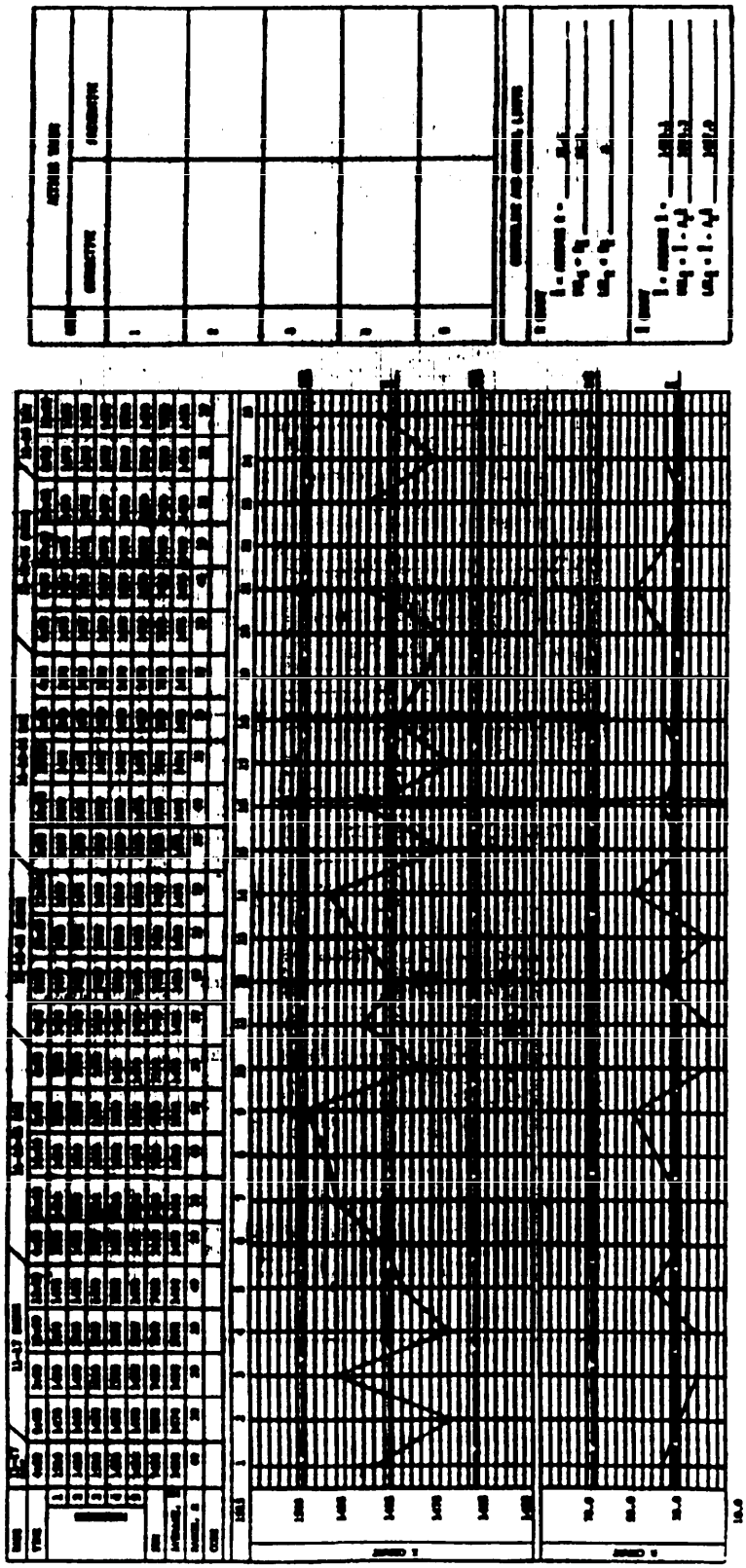


FIGURE 3-3. Example of a P-chart for 20 mm ammunition (shell).

CHAPTER 4
IMPLEMENTATION REQUIREMENTS FOR AN SPC PROGRAM

4.1 SPC implementation requirements. This chapter contains the requirements for the implementation of an SPC program.

4.2 Upper management involvement. The involvement of upper management in SPC requires that they must understand the program in order to support, participate in, and commit themselves to this program. Once they understand what SPC is, its benefit, what to expect, how to implement it, and how to sustain it, then they can make the commitment. This commitment is not a one time thing, it's a continuous act. The commitment is to transform their vision to reality. They understand that commitment is to provide continuous support and participation during the implementation phase and the sustaining phase.

This process can take place in a seminar for executives. Then each executive can participate in a similar seminar with his staff, and cascade this understanding, commitment, support and participation throughout his staff and the organization.

4.3 Education in SPC and statistical techniques. Once the organization is prepared for the challenge of implementation, education must be provided in basic statistics, histogram, pareto analysis, process control charts (including analysis of control charts), inspection/test capability studies and process capability studies (see chapter 2 for definitions of these terms, especially the power of the process capability study).

4.4 Education in problem-solving techniques. SPC without problem-solving techniques yields a syndrome called "Wall Papering". This syndrome is evidenced by the posting of control charts with many points out-of-control and minimal action taken to bring the process back in-control. Although there are several problem solving techniques available, each key element of the problem statement must be present before any one of these techniques can be applied. For this purpose, a problem is a deviation from a standard or desired level of performance for which the cause is unknown and a resolution is required. There are six problem solving techniques which are:

a. Events Log

b. Diagnostic Process Audits

c. Cause and Effect Diagram

d. Cause Analysis

e. Design of Experiments

f. Failure Mode and Effects Analysis (FMEA).

These techniques have specific applications with advantages and disadvantages. Each technique has various skill levels and amount of training required and ease of implementation. In addition, the group size and the usefulness of the results may vary.

The techniques are not new but they are highly recommended for their practicality and effectiveness. They are the "How To's" for analyzing problems. Since each out-of-control situation is unique in character and complexity, so too are the techniques utilized to identify the cause. A brief description of the aforementioned techniques follows.

4.5 Problem solving techniques.

4.5.1 Events log. [a/] The Events Log is similar to a diary and contains records of key daily events within the process (see figure 4-4). It is usually located at or near a critical work station where control charts are posted. The purpose of the Events Log is to maintain a chronological history of anything that is new, different, or changed, in or around the process.

4.5.2 Diagnostic process audit. [a/] Diagnostic Process Audit is used to evaluate what is contributing to the undesirable condition which produces defects. First, it addresses if the operator/inspector was complying to the documented process. It then addresses the process documentation, tools, materials, and environment. A favorable audit would result in a certified process and operator. An unfavorable result would lead to corrective and preventive action on the process, i.e., documentation, tools, materials, or operator.

4.5.3 Cause and effect diagram. [a/] The Cause and Effect Diagram relates an observed effect with its possible causes. The diagram when completed resembles a fishbone and is often referred to as a "fishbone diagram". Possible causes are generated using brainstorming techniques in a meeting which includes all people who might have power, control or influence over the effect or problem (see figure 5-4). The effect is usually a performance characteristic which results from a specific cause and it is manifested in a symptom. Causes are variables or factors which contribute to the variation or level of the resultant effect. They can usually be grouped into the categories of people, machine, methods, materials, measurements, or movement.

4.5.4 Cause analysis. [b/] The Cause Analysis technique uses a structured method of questioning (the process) which taps the relevant information about problems (see figure 6-4). Unlike the Cause and Effect Diagram, brainstorming is not used in Cause Analysis. The goal of the technique is to draw out precise information. "Precise" in this sense means definite, exact, accurate and specifically stated information.

[a/] See reference, 9.4.a.
[b/] See reference, 9.4.b.

Another aspect of Cause Analysis is that it compares and creates comparative test bases. The advantage of this technique is the high quality of the results generated. Only known facts and relevant information are used to draw out likely causes.

When using Cause Analysis it is useful to think of the problem as an iceberg - what you see initially hints at the entirety of the problem. Through the analysis, a manager can then determine the actual size and scope of the problem. By being aware of this "iceberg" phenomenon, most managers try to better understand the problem at hand by collecting more data. Then they may be able to see the whole iceberg (specific problem). However, they still may be unable to deal with the problem unless they classify the data into a useful format, separating the relevant from the irrelevant. They don't need to collect data on the entire polar cap (whole problem) in order to put a particular iceberg (problem) into proper focus.

Cause Analysis will provide the format to help classify data and acts as a guide to collect only the relevant data in terms of what, where, when and magnitude.

Since this is a very structured technique, it also requires further training for application.

4.5.5 Design of experiments. The objective of a designed experiment is usually to determine which of the many variables or causes are the most influential on some response or output variable. The designed experiment is the only way of properly evaluating and quantifying the interaction between the variables. To perform a "Designed Experiment", the following steps are presented to assure the experiment is properly designed, conducted, analyzed and presented.

a. Plan the experiment.

b. Develop the design.

c. Conduct the experiment.

d. Perform the analysis.

e. Report the results.

4.5.6 Failure mode and effects analysis (FMEA). FMEA is a method of problem prevention that can be carried out by design and reliability engineering in the early stages of product introduction. It assigns probability of detection to each failure mode.

This technique is a structured method of design review that causes engineers to consider potential failure modes and to rank failure modes according to their impact on reliability. FMEA will identify the problems that need immediate attention and will define preventive action that must be taken prior to release of a new design.

FMEA is an excellent tool for design and reliability review and should be required in conjunction with reliability testing.

4.5.6.1 Procedure. The procedure for conducting FMEA is as follows:

a. Determine potential failure modes. This is clearly the most difficult step in the process and relies on engineering experience and historical data taken from other products or previous designs. It is necessary to consider what could go wrong with the part or assembly and what symptoms or effects on the product would be observed. For example, in analyzing a radio, one potential failure mode would be that the speaker connection breaks. The effect of this failure would be---no sound.

b. Determine the most likely cause for each of the failure modes to be addressed. Any of the problem solving techniques discussed in problem analysis and solution may be applied at this point. There may be more than one cause for a given failure mode.

c. Estimate a probability of occurrence for each failure mode. To simplify this estimate, use a scale of 1 to 10 to indicate probability with 1 being a very low probability and 10 being the highest probability of occurrence.

d. Estimate the relative weight or criticality of each failure mode. It is important to consider safety, conformance to specification, product function and customer satisfaction when assigning a relative weight. The same scale of 1 to 10 is used with 1 being an incidental failure that is unlikely to affect product performance or the customer's perception of quality, and 10 being a critical failure that will cause personal injury or certain product failure.

e. Estimate the probability of escaped defects, again using the 1 to 10 scale. A perfect inspection station would catch all the defects and would be rated 1 (low probability of escaped defects). This estimate may be derived from an Inspection Capability Study for a similar part.

f. Calculate a risk priority number multiplying the factors determined in Steps b, c, and d. The higher the risk priority number, the more important it will be to find a cause and preventive action.

g. Identify appropriate preventive action that will eliminate the cause of the potential failure mode. Needless to say, the problem with the highest risk priority number should be worked on first.

4.5.6.2 Example of how to conduct a FMEA. The following is an example of how to conduct a FMEA using the above procedure. For this purpose, the FMEA worksheet (figure 7-4) is used to describe the project and to record the results of the review.

a. The project in this example is to design an automatic umbrella. In the upper section of the worksheet, the part number and description of the item, the name of the engineer and date of the project will be noted.

b. For the sake of brevity, two potential failure modes were selected: (1) fracture of the umbrella shaft, and (2) separation of the stitching of the umbrella fabric.

c. Based on these two potential failure modes, the effects of these failures are recorded. The effect of the first failure would be catostrophic in that the umbrella would be rendered useless. The second failure effect may range from a cosmetic problem to leaks.

d. The next step is to determine the cause of failure. In the example, the fracture of the umbrella shaft could have been caused in two ways. The shaft material may be thinner than specified or the environmental conditions (severe high winds) may have exceeded design expectations. Regarding the umbrella cover where the stitching separates, the cause of failure is attributed to poor workmanship.

e. In the risk analysis phase of FMEA, the probability of the failure of occurance is considered and rated. The failure is then weighted for severity and capability to escape detection. These are subjective factors based on the engineer's experience and previous history on similar items. Also, each failure mode is independently evaluated.

(1) With regard to the first failure mode---shaft fractures, the cause of failure due to thin material was considered not especially likely to occur and was given a low rating of three; whereas, the failure due to severe high winds was even less likely to occur and was given a very low rating of one. Regarding the second failure mode---stitching separates, the sole cause of failure due to poor workmanship was considered to almost always occur and was given a very high rating of nine.

(2) Next, the severity/criticality of the failure was analysed. Since failure of the shaft made the umbrella unusable, it was given a very high severity rating of nine. On the other hand, stitch separation did not render the umbrella unusable although it may adversely impact on user acceptability. It was given a moderate severity rating of five.

(3) Since the escape detection factor is essentially a function of inspection, the probability of detecting a weak umbrella shaft was considered to be slightly better than average and was given a rating of six. Detecting poor workmanship in the stitching was considered excellent; hence was given a very high rating of nine.

f. The next step in FMEA is to assign a risk priority number to each cause of failure. This is accomplished by multiplying together each of the risk factors rated in the aforementioned risk analysis phase and recording them on the worksheet. Top priority for corrective action should be given to the cause of failure with the highest risk priority number and all causes of faulures reviewed in descending order from highest to lowest risk priority number.

g. The final step in the FMEA is to identify the corrective actions required to eliminate the cause of each failure and to select the most appropriate ones for implementation.

This example is intended to demonstrate the concept that failure modes and causes may be ranked by the risk priority number and addressed in order of significance.

4.6 Organizational structure. The implementation of SPC requires a cultural change. The first action required in order to achieve the necessary culture change is to establish the organizational structure which will provide the foundation, direction and support for SPC process implementation. Change begins at the top and it will naturally cascade down to every level of the corporate structure. The organizational structure described is not intended to replace the existing structure of the company. It shall function as an integral complimentary framework having the purpose and objective of implementing SPC through a systematic process. the main elements of the structure should include the following:

a. President's Quality Council

b. Steering Committee

c. Project Teams

d. Team Leaders

e. Team

f. Facilitators

4.6.1 President's quality council. The Executive Board is the highest authority within the structure. Its members are primarily vice presidents whose operations have a direct influence on the costs of quality relating to prevention, appraisal and internal and external failure. Typically these members come from the functions of product development, design engineering, manufacturing, finance, quality control and customer service.

The President's Quality Council is chaired by an individual whose position holds the responsibility and influential control over a majority of the board's resources. This individual will also have the most to gain from success of the program. Typical positions that carry such responsibility and influence include the President, Executive Vice President and Vice President of Operations.

4.6.2 Steering committees. Steering Committees report to the Executive Board and are composed of individuals who have the responsibility to direct and support the activities of the individual teams implementing SPC. Members of Steering Committees primarily consist of middle managers who are directly responsible for, or support the processes being addressed. Typical Manufacturing Steering Committee members are Quality Engineering Manager, Manufacturing Engineering Manager, Design Engineering Manager and a Finance Manager. The chairman and leader of this committee, when addressing production processes, is most frequently the Plant Manager, Manufacturing Manager, or General Manager. This individual usually has the most to gain from the results of SPC and is the one who typically manages most of the resources required to implement such a program.

The Steering Committee is the administrator and overseer of the policies set forth by the Executive Board and acts to enforce them.

4.6.3 Project teams. An effective Project Team will collectively have all the knowledge necessary about the specific product or process in order to implement SPC. The Project Teams normally have members who will benefit from the project's success. Team members should include representatives from the following:

a. Design Engineering

b. Quality Engineering

c. Manufacturing Engineering

d. Quality Control

e. Production

f. Test Engineering

The Project Teams are guided by a Team Leader who is selected by the Steering Committee. The responsibility of the Project Team is to execute the implementation of the SPC process as assigned by the Team Leader.

4.6.3.1 Roles and responsibilities of project teams. The specific roles and responsibilities of the Project Teams are as follows:

a. Perform each step of the systematic SPC process

b. Identify obstacles to progress

c. Develop recovery plans to overcome obstacles

d. Communicate constraints to the Steering Committee

(1) The actual constraint

(2) Actions taken

(3) Recommendations

e. Identify and present potential projects to the Steering Committee

f. Maintain files on each approved step

g. Attend weekly meetings to review progress and coordinate future actions

The Project Team is the ultimate unit in the organization structure having authority, power and influence over the project.

4.6.4 Team leader. The Team Leader is the manager of the Project Team, reports to the Steering Committee, and is the single most important individual in the process. The success of the program is directly proportional to the strength of the Team Leader. Leaders are selected by the Steering Committee usually from first level management and are individuals with past proven track records or high growth potential.

A good Team Leader like a good manager must possess a balance of leadership, technical and managerial skills. They may be selected from any department within the organization provided they meet the following criteria:

a. Be results oriented

b. Be skilled at managing administrative details

c. Be skilled at managing time

d. Have the ability to create and sustain a climate of teamwork

e. Be a skilled delegator, communicator and motivator

f. Be skilled at leading group problem solving

g. Be skilled at coaching other team members

In addition to the above, the Team Leader must be an individual who is "biased for action". In other words, a risk taker whose main approach is moving the team forward through planning and contingency planning.

4.6.4.1 Team leader's role and responsibilities. The Team Leader's role and responsibilities are as follows:

a. Assists in the selection of Team Members

b. Schedules Team meetings

c. Prepares meeting agenda

d. Makes task assignments to Team Members

e. Develops preliminary Milestone Plan

f. Issues weekly Team Progress Reports

g. Identifies constraints and elevates issues to Steering Committee

h. Develops recovery plans when applicable

i. Assures timely closure of each step of the Systematic Productivity and Quality Improvement Process

j. Evaluates members' performance and provides input to the appraisal process

k. Conducts presentations to Steering Committee

The job of the Team Leader is the most demanding in the program. As can be noted from the above responsibilities and characteristics, this individual must often be many things to many people. If the prospective Team Leaders do not possess all the above mentioned characteristics, an acceptable alternative is to select individuals based on their future potential and develop that person in the deficient areas. This is one of the many side benefits that the program offers; it is also a vehicle for developing future leaders and managers.

4.6.5 Team. The team concept has been a common method used by businesses faced with the task of introducing a critical program or project. The implementation of SPC is not complex and one individual could perform every step, but individual contribution does not lead to rapid culture change. It is for this reason, along with the underlying message that productivity and quality improvement is everybody's business, that the Team approach has been selected and has proven to be most successful.

A Team can be defined as two or more individuals who coordinate their activities in pursuit of a common goal. This definition will help determine when the use of a Team is most appropriate if the situation is not clear or straightforward.

Specific situations where a Team is most appropriate include the following:

a. When programs call for wide exposure in order to promote awareness throughout the organization.

b. When a problem spans departmental boundaries.

c. When sequencing or coordination of effort is necessary to accomplish the proposed solution or goal.

d. When knowledge is needed form different specialists, or joint decisions are required.

e. When no single person has total control, influence, and authority over the problem, resources or services.

f. When no single department has full ownership of the program.

g. When departmental barriers exist due to the company's culture operating in a traditional mode.

The Team concept is a powerful approach for its ability to produce results as well as for its educational contributions.

improvement (see also detection)

4.6.5.1 Synergism. Synergism is the simultaneous action of various elements, together having a greater total effect than the sum of their individual contributions. The use of a Team is especially effective because of the synergism created by the mixture of the member's different skills. Synergism is achieved in a team because an environment is created where:

a. The effectiveness of decision making is enhanced.

b. More innovative ideas are generated through group interaction.

c. The diverse talents and experiences of the members are best utilized.

d. The evaluations of the group will likely be more accurate assessments of situations.

e. Decisions made are generally supported be all parties included or affected.

f. Efforts of different specialists are effectively coordinated.

g. Team members and other managers often look at problems more deeply or objectively, and re-examine their own biases and perspectives.

4.6.6 Facilitators (desirable-not mandatory). The role of a facilitator is to nurture the development, leadership and effectiveness of the Team Leader and to expedite the project so that results will be maximized. The facilitator will assist the Team Leader to plan the project and the meetings. He will help the Team Leader to ensure that the meetings are organized, the outcome is clearly identified, everyone participates, and the integrity of the Systematic Process is maintained. The facilitator must be committed to the success of the project. Specifically, the facilitator will:

a. Be a guide around the many pitfalls and special applications not found in textbooks.

b. Have experience introducing SPC in manufacturing operations.

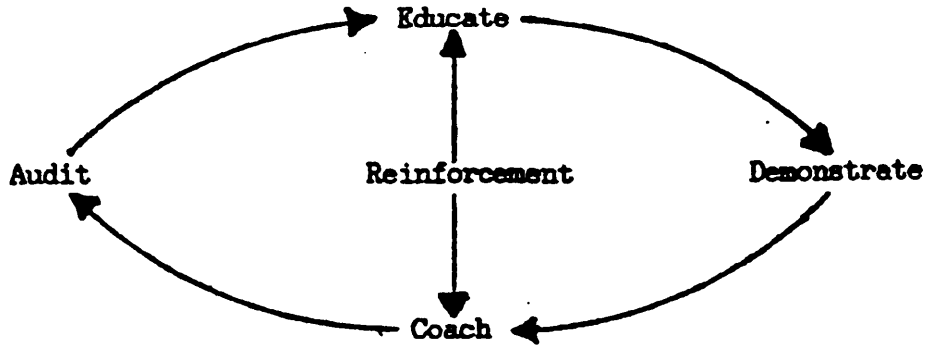
c. Act as a catalyst, provide follow-up to all management levels and maintain continuity.

d. Be results oriented, and whose performance and tenure is directly related to success.

e. Be recognized as an expert in SPC so that education, coaching and advice are received positively by the Team Leader, Team Members, and others involved in the process.

f. Objectively evaluate and audit progress of the process, and identify the obstacles to progress.

The role of the facilitator is to educate, demonstrate, coach and audit the results of SPC implementation. The approach can be viewed like the facilitation closed loop illustrated below.



4.6.6.1 Skills of the facilitator. The facilitator must be skilled in the areas of motivating people, knowledge of the systematic process, coaching and technical knowledge. He must have the ability to make things happen and in-depth experience in the manufacturing, service or administrative areas.

When using a facilitator, a person from within or outside the organization, it is important to clarify the working arrangement by establishing mutually agreed upon guidelines. These guidelines should be consistent with the roles and responsibilities of the Team Leader and the facilitator.

An effective facilitator will guide the Team through the program and assure timeliness of action, optimum results, objectivity and a standard approach throughout the company. A facilitator is to the implementation of SPC, as SPC is to the control of a process. Results will be realized in a quicker time because the facilitator guides the Team around obstacles and ensures that it is done right the first time.

4.7 SPC implementation plan. The implementation plan should contain the sections listed below. For an example of an SPC implementation plan, see figure 8-4.

a. Contractor's policy statement

b. Contractor's goals

c. Master milestone plan

d. Project milestone plan

e. Project detailed plan

f. Management structure

g. Training plan

h. Supplier SPC philosophy and policy

i. Systematic process

4.7.1 Contractor's policy statement. The policy statement states the detailed requirements of SPC and who is responsible for implementing the requirements.

4.7.2 Contractor's goals. The goals clearly define the scope of the products and processes to be addressed by SPC and the expectations for quality levels at each operation. The quality targets for each product should be established by the contractor and subject to Government approval.

4.7.3 Master milestone plan. The Master Milestone Plan identifies the products and processes where SPC is to be implemented in accordance to a time phased schedule. The schedule would reflect the month to start the SPC implementation and the month that the process will be in control and achieve the quality target for the process. The Master Milestone Plan is to be initially approved by the Government prior to implementation by the contractor. Also all revisions require Government approval. The status of the Master Milestone Plan should be issued monthly by the contractor, or on some other cyclic basis as required by the Government.

4.7.4 Project milestone plan. A Project Milestone Plan identifies the key activities of each project where SPC will be implemented in accordance to a time phase schedule. The activities would be the process which is advocated. The schedule would reflect the week "to start" each activity and the week "to complete" each activity.

The Project Milestone Plan would be submitted for Government approval and should contain all projects planned to be started in the first three (3) months of the Master Milestone Plan. Each month, one additional month is added to it. The following activities should be planned in the Project Milestone Plan and approved by the Govenrment:

a. Determine the classification of characteristics

b. Conduct inspection capability study

c. Conduct process capability study

d. Prepare the repair and corrective actions

e. Prepare the process control procedure

f. Implement process control charts

g. Audit

4.7.5 Project detailed plan. The Project Detailed Plan should specify the following:

a. Identification, name and description of the process

b. Characteristics to be measured (variable or attribute)

c. Production

d. Number of redundant tools, machines, or stations

e. Production rate per hour

f. Number of shifts

g. Number of operators

h. Inspections, include the following:

(1) Number of inspection gages

(2) Variable of attribute characteristics

(3) Number of inspectors

(4) Number of shifts

(5) Inspection time and unit

(6) Time difference between production and inspection of the part

i. Charts, include the following:

(1) Type of the chart selected

(2) Number of charts to be used

(3) Location of charts to be posted

4.7.6 Management structure. The management structure should include an organization chart which reflects the responsibilities to implement and sustain SPC.

Each level should be supported by a section for roles and responsibilities. Names of the President's Quality Council; steering committees, and team leaders should be identified. A company Process Control Procedure should be available which reflects responsibilities for all the actions relative to implementing and sustaining SPC. This procedure should be customized for each process, however, many will be identical. The contents of the organization chart should specify the following:

a. Who performs the inspections

b. Who posts control charts

c. Who establishes and updates control limits

d. Who responds on out-of-control conditions

e. Who provides corrective and preventive action

f. Who audits the process

4.7.7 Training plan. The training plan should include the following:

a. The content of training by level of participants

b. The number of seminar hours

c. The sample of handout material

d. The mode of training

e. Qualifications of instructor

f. The location of training

g. The number of hours on-job-training (OJT)

h. OJT by whom and qualifications

i. The testing to assure competence

4.7.8 Supplier SPC philosophy and policy. Supplier controls require the supplier, vendor, or the subcontractor to have SPC on all critical and major characteristics.

The suppliers are required to submit a copy of the process control chart for each process with SPC along with a certification of "lot integrity" indicating the parts were produced under the process control chart that was submitted.

What are the auditing techniques to assure the quality is the same level as indicated by the control charts.

4.7.9 Systematic process. Since many steps 2/ in applying SPC are common, the following systematic approach is recommended.

2/ See reference, 9.4.a, for details to each step.

4.7.9.1 Procedure. The procedure for conducting MIRA is as follows:

Step 1. Identification - The purpose of this step is to immediately define the process and characteristics to have SPC implemented. A systematic process is necessary for the following reasons.

a. It provides a comprehensive and fast process to effectively implement SPC.

b. It provides a consistent method of implementing and sustaining SPC.

c. It provides the foundation for a culture change. It provides a plan, the how to's and means, to monitor success and to measure its effectiveness.

The process is defined, including a flow chart and the selection of characteristics to be controlled by SPC is made.

A formal definition of critical, major, minor and incidental classification of characteristics should be issued to each contractor. A meeting between the Government and the contractor should be used to reach agreement on what characteristics are to be classified as critical, major, and minor.

Characteristics identified as critical and major must have SPC implemented. Exceptions are not to be permitted.

Step 2. Planning and reporting - The purpose of this step is to create the foundation for effectively managing the resources allocated to the team, and to assure the timely completion of the overall project.

This is an administrative step to assist the team leader in managing the project. It is designed as a means to keep the project on plan, both in terms of timing and performance of the project goals.

The team must draft a Milestone Plan indicating the start and completion of each of the 12 steps along with any subordinate tasks identified at this time. The team will also generate a Progress Report immediately following each meeting showing team objectives, status of the project, accomplishments since the last meeting, exceptions to the plan and responsibilities, risks and exposures requiring management action, the outlook for task completion, and detailed assignments to team members.

Step 3. Performance measurements - This step establishes a method to measure performance in quality, productivity and schedule.

Performance measurements should be developed in order to monitor the success level achieved by the team relative to time that reflects the criteria sighted in the project objectives. A simple graph is adequate as long as it is published regularly and the responsibility for maintaining the measurement is clearly understood.

Step 4. Problem analysis and solution - This is the first step directed at actual improvement of the process. It is accomplished by applying problem solving techniques as specified in 4.5. The process dispersion must represent the normal curve prior to determining if the process is capable or incapable.

Step 5. Inspection capability study - An inspection capability is a measure of how good the inspection measurement is.

The study should be conducted on all gages and instruments authorized per the inspection instructions and on all appraisers. The study would be applicable to both variables and attributes data. The inspection system is certified only when the gages, instruments, and appraisers results are determined to be acceptable.

Standards for rating the study acceptable, marginal, or unacceptable will be issued by the Government.

Step 6. Process capability study - A process capability study will be conducted on all machines, fixtures, stations and operators involved in the process to determine the capability of the process and natural and unnatural variations. It must be conducted on critical and major characteristics. This study is applicable to both variables and attributes data.

When the results of the study are acceptable, the operators are certified to perform the process. Acceptable ranges for capability ratios will be determined by the Government. Unless otherwise specified, a process capability of 1.33 is required.

Step 7. Corrective and preventive action matrix - A corrective and preventive action matrix provides specific actions which should be taken to bring the process back in control.

It is a document posted with each control chart that lists all known defects or out-of-control conditions which can exist in the process. With each defect or condition, action is specified to correct the process. In essence, it is a prioritized trouble shooting guide.

Along with the document, a procedure should be defined for review and update of the matrix as new defects and solutions are identified.

Step 8. Process control procedure - The process control procedure documents the method for introducing and sustaining SPC. It establishes responsibilities to all the various activities. It is a procedure that must be provided for each of the following processes:

a. A process which identifies rationale for the following:

(1) Type of control chart selected

(2) SPC principles applicable

(3) Subgroup selection

(4) Subgroup size

(5) Subgroup frequency

(6) Multiple machine for the process

b. A process which identifies strategy for the following:

(1) Calculation of control limits

(2) Adjustment of control limits

(3) Recording actions on control charts

c. A process which identifies criteria for the following:

(1) Out-of-control process

(2) Action on out-of-control process

(3) Action on non-conforming product

d. A process which identifies responsibilities for the following:

(1) Out-of-control conditions

(2) Installation and maintenance of charts

Step 9. Process control implementation - This step communicates and coordinates the implementation of SPC with everyone involved. A meeting is held to review a checklist of requirements confirming that all documentation has been completed, to make clarifications, and to assure commitment of responsibilities.

Step 10. Problem prevention - Problem prevention provides for the teams to anticipate future problems. This step assures all gains are maintained and provides information valuable for future improvement or breakthroughs to new levels of performance.

It develops and implements a plan for generating corrective and preventive action. The plan should include a means for identifying potential problems as well as existing conditions. Triggering mechanisms or flags should be identified that initiate positive action to maintain process control.

Step 11. Defect accountability - Defect accountability is a system for identifying and reporting the different defect types and their sources, for example, operators, inspections, design, process, or component sources. This provides opportunities for further improvement with a closed loop system.

It creates a reporting system to further segregate problem areas. The primary objectives are to report defects based on their source (process, components, design, or workmanship).

Step 12. Measurement of effectiveness - The measurement of effectiveness is utilized to assure that the desired results were achieved and a plan is in place to sustain the results. This is accomplished by conducting one or more of the following audits:

a. Process audit

b. Product audit

c. Systems audit

d. Financial audit

4.8 Quality Target (attribute data only). The customer requirements for the outgoing quality of the final product are achieved through a technique known as "Quality Targets". The technique establishes individual workstation targets for quality levels and uses the final quality target as a basis.

Each process must have a quality target expressed either in percent defective reported, number of defects per 1000 units, or parts per million (PPM).

Actual results should be compared against quality targets. When actual results exceed targets in unfavorable direction, then action should be taken to bring process levels equal to or favorable to the quality target.

Once SPC has been implemented, the process should be improved to a level that meets customer requirements. Customer quality requirements are usually expressed as the maximum fraction or percent defective allowed; that is , the number of defects per opportunities divided by the number produced. For example, a customer may require that the product contain no more than one percent (1%) defective when shipped. The most cost effective way to meet this requirement is to establish quality targets for each step in the process with the final target being the customer's requirement. Then the final product will meet the customer's need without extensive internal inspection or sorting.

Whenever the process average exceeds the quality target, then corrective action must take place.

Quality targets, like SPC, are 90% management actions and 10% statistics. Quality targets without management action is actually detrimental to the efforts of productivity and quality improvements. Therefore, quality targets should never be used alone. To be effective, they should be accompanied by a plan and subsequent management action.

Regardless whether quality targets are met or not, each work station must maintain a constant quality improvement program (QPI). The ultimate quality target for attributes is zero defects. To achieve this goal, it will become necessary to periodically review and revise the established quality targets. It is the Government position that continuous quality improvement through SPC is the minimum requirement in attribute type processes.

4.9 Pitfalls to implementing an SPC Process. Implementing SPC is a challenge and there are numerous pitfalls involved with the implementation, as well as, the mechanics of applying it. Table I-4 contains a list of some of the common pitfalls that have been encountered in implementing SPC and their recommended solutions.

4.10 Pitfalls to implementing SPC techniques. Numerous pitfalls are involved in implementing SPC techniques. Table II-4 contains a list of the common pitfalls that have been encountered in implementing SPC at client companies and in industry and the possible consequences of those pitfalls.

balances, motors, hydraulic cables, and any movable components shall be

TABLE I-4. Pitfalls and solutions to implementing an SPC process.

Pitfall	Solution
Upper management does not understand what SPC is, its benefits and how to manage the implementation. Consequently they do not get involved and the process essentially dies due to starvation.	Educate and motivate upper management so once they understand, they will commit and support the process by providing effective management and achieving the desired results. The use of seminars, plant visits and reports of SPC successes are recommended.
Frequently, people are well grounded in the traditional way of thinking that productivity is emphasized over quality. To change this attitude seems monumental since quality is spelled "QUANTITY".	Change management attitudes and priorities. Workers will respond to or perceive what management wants. Management must not send the wrong signals.
Statistics first mentioned appears as a disease to some people. This can be a turn-off and hence people are not receptive to learning.	The persons providing the education must be seasoned in both manufacturing and statistics, and in selling people in the benefits of SPC, and the ease and fun of implementing it.
Fear, uncertainty and doubt are normally present when people start to do something new. Using SPC is not different. Fear that one may make a mistake, look foolish, or even succeed plagues some people. Fear that they have been operating a poor and inefficient operation and will be found out through SPC is a common pitfall. Uncertainty when not having confidence in what to do or how to do it may also be present. This person may know the concepts but lacks the confidence. People being doubtful is also common because of the lack of experience; they truly do not believe they can achieve the results.	Once the proper education is provided through seminars, facilitators from outside consultants should be utilized to demonstrate how to do it, reinforce techniques taught in the seminars, and create positive experiences.

TABLE I-4. Pitfalls and solutions to implementing an SPC process - Continued.

Pitfall	Solution
The persons conducting the advanced seminars (for example, design of experiments) do not have any formal education in statistics. These people may have degrees or advanced degrees in other fields, but without formal education in statistics, they cannot assume they are qualified to teach statistics.	Require the seminar leader to have a formal foundation in statistics. Someone in the organization must have a masters or doctorate in statistics.
People can become most dangerous players once they attain ample education, have successful experiences, and are ready to be on their own. The problem comes when more people get educated in SPC, they go off in different directions. All may be acceptable, but few may be effective, some may be semi-effective and others are ineffective. Consequently, no one way gets implemented. Hence, the process does not become internalized by the personnel and it may become habit forming to a point it is the company's culture.	The 12-step systematic process specified in 4.7.9.
Education in statistics is only given to the personnel. Consequently, the SPC charts are wallpaper and only a few are in control. A culture change has not transformed.	Educate personnel on problem solving techniques, high performance attitudes and systematic approach.
People have fear of being part of the problem rather than part of the solution.	Upper management announces they take responsibility for the past. The teams have responsibility for improving the processes in the future.
Management does not give any clear expectations of what needs to be accomplished.	Clear, concise statements must be documented on the teams progress reports regarding expectations.

TABLE I.4. Pitfalls and solutions to implementing an SPC process - Continued.

Pitfall	Solution
Management does not assign responsibility for the expectations or results.	A process control procedure, a step in the systematic approach addresses this issue.
Management does not feedback evaluations, positive or negative, on a regular basis.	Hold monthly meetings with steering committees and quarterly progress reviews. These are detailed in the systematic process (see 4.7.9).
Lack of recognition by management. A once highly energized process starts to die.	Have a structured recognition program for results.
Team leaders are weak. All personnel do not want to be team leaders.	a. Further educate. b. Coach. c. Clarify expectations. d. Remove.

TABLE II-4. Pitfalls to implementing SPC techniques.

Pitfall	Possible Consequences
Not verifying calibration of measuring equipment.	Judging acceptable parts as defective when they are good or good when they are defective.
Failing to verify testing procedures by Inspection Capability Studies.	a. Judging acceptable parts as defective or defective parts as acceptable. b. Conflicts over what constitutes good and defective parts. c. Conflicting decisions as to whether process is in control.
Not selecting the proper Control Chart for the characteristic being measured.	Misleading results; looking for assignable causes when there are none and failing to look for assignable cause when one is present.
Using subgroups sizes of 2 or 3 ($\bar{X}$ and R Charts) for an inexpensive inspection.	Increased chance of not detecting a process shift when one has occurred.
Using subgroup sizes of 10 or more ($\bar{X}$ and R Charts).	Increased inspection costs because $\bar{X}$ and R Charts are not as efficient for large group size (n).
Using small subgroup sizes for a p chart with low percent defective.	Control limits are such that the chart cannot detect an out of control condition.
Confusing subgroup sample size with the number of subgroups when selecting A_2, D_3, D_4, d_2 factors for control limits.	Incorrect control limits resulting in failure to detect assignable causes or looking for assignable causes when none present.
Not selecting successive units for subgroups ($\bar{X}$ and R Charts).	Assignable causes become part of within subgroup variation causing unnecessarily wide control limits. This results in failure to detect assignable causes when they are present.

TABLE II-4. Pitfalls to implementing SPC techniques - Continued.

Pitfall	Possible Consequences
Not selecting subgroups on a real-time basis.	Assignable causes become part of within subgroup variation causing unnecessarily wide control limits. This results in failure to detect assignable causes when they are present.
Subgroups are too close together during Process Capability Study.	Inability to evaluate the stability of the process.
Subgroups are too far apart, too much time between subgroups.	Shifts may occur and not be detected and large number of defective parts produced.
Operators are aware of which samples will be used for the subgroup.	Will not know true process averages and variation. The process may appear in-control when it is actually not.
Using subgroups when individuals are appropriate for a process with a low production rate.	a. Assignable causes become part of within subgroup variation causing unnecessarily wide control limits. This results in failure to detect assignable causes when they are present. b. Shifts may occur and not be detected and large number of defective parts produced.
The average of the daily percent defective is used for the process average ($\bar{p}$) rather than the formula: $\bar{p} = \frac{\text{Total Rejects}}{\text{Total Inspected}}$	More weight will be given to days with lower production rates. Those might be days with highest percent defective.
No control limits or center line plotted on charts.	No indication when to take action. Action taken may be based upon personal choice.
Plotting specification limits on a control chart with normal control limits.	Confusion as to whether action should be taken. Process may appear within specification when it is not.

TABLE II-4. Pitfalls to implementing SPC techniques - Continued.

Pitfall	Possible Consequences
Using specification limits as control limits on an $\bar{X}$ chart.	Fail to detect and react to assignable causes when they occur.
Not using "modified" control limits when applicable. "Modified" control limits are applied when a process stays well within specification limits, but the average shifts outside the normal control limits.	Natural control limits may cause process adjustments even though all parts are well within specification.
Not calculating the values of subgroups and plotting them.	No control whatsoever.
Not taking appropriate action when a point is out of control.	Process may produce many parts out of tolerance.
Not reacting to a point out of control on the R Chart if $\bar{X}$'s still in control.	Failure to detect a shift in process variability. Individual product may be outside specifications even though average has not shifted
Not examining patterns on control charts for trends or shifts.	Fail to detect and react to assignable causes when they occur.
Not adjusting process average to specification nominal even when $\bar{X}$ Chart is in control.	Unnecessary production of defective parts even though process may be capable of meeting specifications.
Not summarizing data for on-going charts to review if limits are changed.	Failure to adjust parts to reflect long term trends. Outdated information as to what process is currently doing.
Not using separate control charts for various defects when the process is out of control.	Inability to find real cause of defective product.
Believing that a process in Statistical Control meets specification requirement.	A process in Statistical Control merely means consistency over time. This stable process may or may not be meeting outside requirements imposed by others.

SYSTEMS DAILY EVENTS LOG

OPERATOR CHANGES *		INSPECTOR CHANGES *		
H.K. Davis		S. Que		PRODUCT LINE: 12-19
C. Kent		C. Aul		STATION: 110
				DATE: 10/31/84
				SHIFT: DAY
				SUPV. INITIALS: IAM

CHANGES:	EXPLANATION:
PROCESS MATERIAL	
x TOOLING	Introduced tooling plates for PCBA's.
DCO CUT-IN	
x OTHER	Average defects per board decreased by 50%.
MACHINE SET-UP	
x PROCESS CONTROL CHART	A shift (improvement) in the process average was observed. After investigation it was found that the change was caused by the improved tooling plates.

CONFIGURATION MIX:
(NON-STANDARD PRODUCTS)

P/N:	QTY.	TOTAL QTY. PRODUCED: 1095
N/A	1	YIELD: 28%

MATERIAL SHORTAGES:

NEW SHORTAGES:		SHORTAGES FILLED:	
P/N: 10239-001		P/N: NONE	
11271-001			

* NEW OPERATOR/INSPECTOR
x CHANGE IN O/I

FIGURE 4-4. Daily events log sheet.

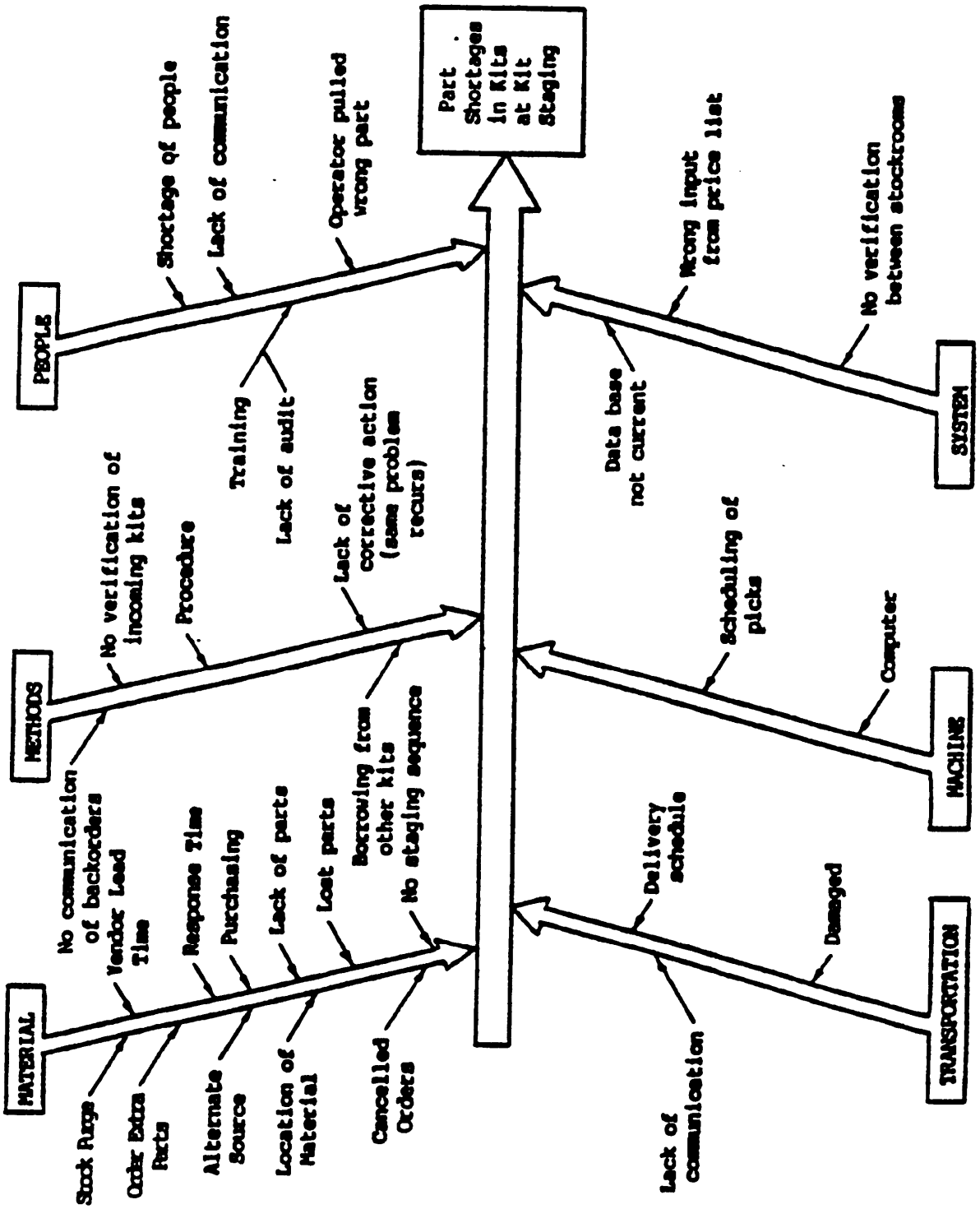


FIGURE 5-4. Cause and effect diagram.

CAUSE AND ANALYSIS WORKSHEET

Step 1. Problem Statement (include object and defect)

Step 2. Describe the Problem	Step 2.1 List Observed Facts	Step 2.2 List Comparative Facts	Step 3. Identify Differences	Step 4. List Relevant Changes	Date Time	Step 5. Generate Likely Causes
What 1. On what object is the defect observed 2. What exactly is wrong (defect)? Where 3. Where is the object with the defect observed (geographically)? 4. Where on the object does the defect appear? When 5. When was the object first observed (clock & calendar time)? 6. When in the life cycle of the object was the defect first observed? 7. Is what pattern is the defect observed? Magnitude 8. How much of the object is defective? 9. How many units/objects are defective? 10. What is the trend?						
Step 6. Test Likely Causes			Step 7. Verify Most Likely Cause			

FIGURE 6-4. Cause analysis worksheet.

FAILURE MODE EFFECT ANALYSIS WORKSHEET

Part No. 99-10001-01 Engineer _____

Description Umbrella Date _____

Test Assembly Top

Part Name/ Number	Failure Mode	Effect of Failure	Cause of Failure	Risk			Risk Priority	Corrective Action
				Occur	Severity	Escape Detection		
Umbrella Shaft	Fracture	Umbrella not usable	1. Thin material below specification	3	9	6	162	1. Specify thicker tubing for shaft 2. Change to solid graphite shaft
			2. Umbrella caught in severe wind shear or microburst during thunderstorm	1	9	6	54	1. Print warning in owners manual
Umbrella Cover	Stitching Separates	Rain leaks through seams- owner gets wet	1. Poor workmanship	9	5	2	90	1. Review operator training and workmanship manual

FIGURE 7-4. Failure mode effect analysis worksheet.

SPC IMPLEMENTATION PLAN FOR MODEL XYZ PRODUCT

A. Policy statement. Our policy is to use real time SPC on all processes for Model XYZ product which has critical and major classification of characteristics. The tasks and responsibilities assigned for this purpose are as follows:

Task	Responsible activity
Implement SPC	- Teams
Maintain SPC	- Production management
Audit SPC	- Quality management and production management

B. Goals.

1. Customer quality requirement: 5 defects/1,000 parts.
2. Inspection station quality target:
   a. Each inspection station shall have a quality target based on the aforementioned customer quality requirement.
   b. Responsibilities for the tasks to be performed are as follows:

Task	Responsible activity
Calculate goals	- Quality engineering
Achieve goals:	
Workmanship defects	- Production
Design defects	- Design engineering
Process defects	- Manufacturing engineering
Components	- Quality engineering
Report status	- Quality engineering

FIGURE 8-4. Example of SPC implementation plan.

C. Master milestone plan. 1/

Part No. (PN)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1P1	S2/	-------	C3/									
1P2			S	----------	C							
1P3					S	----------	C					
1P4							S	----------	C			
1P5										S	---------	C
1P6												
1P7												

1/ This is a small supplier with capabilities of only one team.
2/ S: SPC implementation start.
3/ C: Process is in state of statistical control.

FIGURE 8-4. Example of SPC implementation plan - Continued.

D. Project milestone plan.

WEEK:	Month 1				Month 2				Month 3			
	1	2	3	4	5	6	7	8	9	10	11	12
Project Identification	S	-	-	C								
Planning & Reporting		S										
Performance Measurements		S	-	C								
Problem Analysis		S	-	-	-	-	-	C				
Inspection Capability Study				S	-	-	-	C				
Process Capability Study						S	-	-	-	C		
Corrective and Preventive Action Matrix					S	-	-	C				
Process Control Procedure								S	-	-	C	
Process Control Implementation									S	-	-	C
Problem Prevention										S	-	-
Defect Accountability											S	-
Measurement of Effectiveness												S/C

FIGURE 8-4. Example of SPC implementation plan - Continued.

E. Project detailed plan.

Key activity	Final Inspection	Brazing	Grinding	Bonding
Production:				
Critical characteristics	2	1	1	1
Major characteristics	1	0	0	0
Redundant machines	1	3	2	N/A
No. fixtures	0	N/A	N/A	N/A
Shifts	2	1	2	2
No. operators/shift	4/4	3/0	2/2	6/3
Production rate	30/hr	240/hr	200/hr	30/hr
Inspection:				
No. gages	1	3	1	1
Variable	0	Y	Y	Y
Attribute	Y	N	N	N
No. inspectors/shift	2/2	1/0	1/1	1/1
Inspection time/unit	.6	3 min	.3 min	2 min
Time difference between production and inspection	on-line	on-line	on-line	on-line
Process control charts:				
Type selected	C	$\bar{X}$,R	$\bar{X}$,R	$\bar{X}$,R
No. of charts	2	3	2	14
Locations of charts	@ process	@ process	@ process	@ process

FIGURE 8-4. Example of SPC implementation plan - Continued.

F. Management structure.

Team leader	-	Bill Elm
Quality engineer	-	Stan Hickory
Manufacturing engineer	-	John Black
Production supervisor	-	Nellie Gale
Production operator	-	Jim Blott

Steering committee chairman	-	John Nablo, Plant Manager
Quality engineer manager	-	Harry Katz
Manufacturing engineer manager	-	Willie Wilson
Production manager	-	Jill St. George

President's Quality Council

President	-	James
V.P. operations	-	Sam
V.P. quality	-	Jack
V.P. engineering	-	Bill
V.P. field service	-	Phil
V.P. marketing	-	Bob

G. Training requirements.

1. Type of training. The training will be given in the form of a "seminar-workshop" on implementing SPC. This training is mandatory for all personnel designated to attend. It will be conducted in a classroom environment and will require active participation by the attendees.

2. Purpose. The seminar-workshop presents a grounding in the fundamentals of SPC. The emphasis is on implementation of these techniques. Participants will learn the principles of control charts, the fundamentals of inspection and process capability studies, and the procedures for effective implementation of these techniques.

FIGURE 8-4. Example of SPC implementation plan - Continued.

3. Attendance. People who will be required to attend the seminar-workshops are managers, supervisors, and operating support personnel in inspection, planning, and administration desiring to know how to implement or supervise the implementation of SPC.

4. Benefits. Benefits of the seminar-workshop include the following:

a. Ability to implement control charts.

b. Ability to design and conduct inspection capability studies.

c. Ability to design and conduct process capability studies.

d. Increase knowledge of data collection and analysis methods.

e. Consulting hours equivalent to the number of workshop hours are provided to assist in implementing the techniques presented and to develop case studies.

f. Receive a full set of course material, with examples, for immediate use on the job.

5. Classroom and instructor requirements:

a. Length of the seminar-workshop - 24 hours.

b. Classroom, to be provided by the company, to suit number of attendees.

c. Workshop samples to be provided by the company.

d. Test - Each attendee to be tested.

e. No on-the-job (OJT) training is available.

f. Instructor qualification - knowledge in statistics, preferably one with a masters degree in statistics.

6. Notice of training. Each person designated to attend this training will be notified in writing, including a copy of the agenda (see figure 9-4 for a sample agenda).

FIGURE 8-4. Example of SPC implementation plan - Continued.

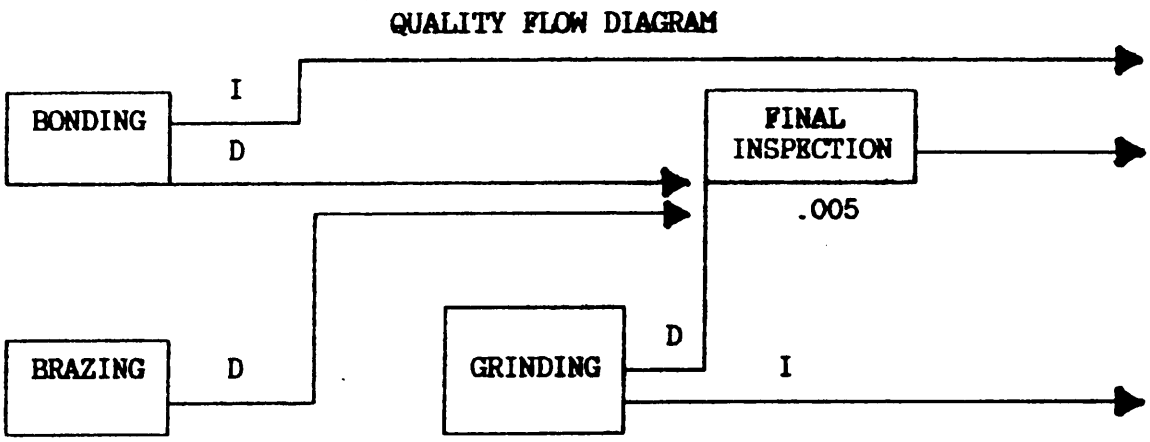
H. Supplier SPC policy. Suppliers shall have on SPC requirement on all critical and major characteristics. Upon successful implementation of SPC charts on the processes with critical and major characteristics, the suppliers will be required to submit a copy of the process control chart for each SPC process along with a certification of "Lot Integrity" indicating the parts were produced under the chart that was submitted. The following requirements are applicable:

1. Audit. The supplier parts will be audited on a 1 in 5 probability for concurrence to the control charts.

2. Milestone plan. The suppliers will furnish a milestone plan the sixth month of the program.

3. Outgoing quality target. Based on the (customer) requirement of 5 defects/1000 units, the suppliers outgoing quality target for all characteristics will be the same, i.e., 5 defects/1000 units. This is illustrated in the following quality flow diagram.

FIGURE 8-4. Example of SPC implementation plan - Continued.



D - Direct characteristic which will be next observed at the customer.

I - Indirect characteristics which will be next observed at another inspection station.

I. SPC audits.

1. Inspection capability studies shall be performed on all inspection processes no less than twice a year. The objective is to have an inspection effectiveness of not less than 90%.

2. The first level managers of the plant, i.e., production, quality engineer, and manufacturing engineer will rotate weekly in auditing the SPC process implementation and document their finding and actions required.

3. Quality engineering shall monitor the actions required and maintain documented progress.

FIGURE 8-4. Example of SPC implementation plan - Continued.

J. Systematic process. The systematic process shall be performed by the teams and shall be documented. The steps shall include the following:

Step 1 - Identification of characteristics

Step 2 - Planning and reporting

Step 3 - Performance measurements

Step 4 - Problem analysis and solution

Step 5 - Inspection capability study

Step 6 - Process capability study

Step 7 - Corrective and preventive action matrix

Step 8 - Process control procedure

Step 9 - Process control implementation

Step 10 - Problem prevention

Step 11 - Defect accountability

Step 12 - Measurement of effectiveness

FIGURE 8-4. Example of SPC implementation plan - Continued.

SEMINAR-WORKSHOP
IMPLEMENTING STATISTICAL PROCESS CONTROL
(24 HOURS)

	TOPICS	HOURS
o	INTRODUCTION/OVERVIEW	0.5
o	BASIC STATISTICAL CONCEPTS	1.5
o	DATA COLLECTION/ANALYSIS	1.0
o	NORMAL PROBABILITY PAPER	1.0
o	CONTROL CHART CONCEPTS	1.0
o	X-BAR/R CHARTS	2.0
o	INDIVIDUAL/MODIFIED LIMIT CHARTS	1.0
o	p, Np CHARTS	2.0
o	C, U CHARTS	2.0
o	IMPLEMENTING CONTROL CHARTS	4.0
	o FLOW CHARTS o EVENTS LOG o CORRECTIVE/PREVENTIVE ACTION MATRIX o SHIFTS/TRENDS	
o	INSPECTION CAPABILITY STUDIES	2.0
o	PROCESS CAPABILITY STUDIES	4.0
o	IMPLEMENTATION PITFALLS	1.5
o	SUMMARY EVALUATION	0.5

NOTES:

a.	Length of course	-	24 Hrs.
b.	Mode of training	-	Class room - workshop
c.	Training location	-	Training room - company
d.	Handout material	-	To be provided
e.	OJT	-	N/A OJT
f.	Instructor qualifications	-	M.S. Statistics
g.	Testing required	-	Each attendee will be tested

FIGURE 9-4. Sample agenda for SPC seminar-workshop.

CHAPTER 5
EVALUATION GUIDE FOR A SUPPLIER'S SPC PROGRAM

5.1 Methods for evaluating a supplier's SPC program. This chapter provides methods for conducting a systematic evaluation of an SPC program at a supplier (the term "supplier" denotes both prime contractors, subcontractors and vendors) and methods for conducting compliance audits on supplier's who have implemented some level of SPC.

SPC compliance audits are best integrated with an overall quality audit because the SPC activities must be integrated with the other quality, engineering and manufacturing control systems in order to be effective. The checklists should also be used independently to conduct follow-up evaluations of specific SPC program elements.

Audit methods are used to minimize the time and money spent conducting the evaluation while still gaining a thorough understanding of how completely the organization has adopted the attitude of controlling process variations during production.

5.2 Other types of SPC audits. Similar evaluation methods may be used by a customer to determine if a current supplier has properly implemented SPC techniques or by company personnel to conduct a self-assessment.

Conducting an audit of a potential supplier differs from auditing a current supplier primarily because the business relationship does not have a historical perspective. The potential supplier evaluation is made more difficult by the lack of experience with change order implementation, a lack of common understanding about drawing and specification interpretations, workmanship standards, and all of the other elements which define a total business relationship. Evaluation of a current supplier will tend to be more critical because each of the contractual elements which have created problems between supplier and customer should be fully examined and preventive measures developed to control any negative impact on the SPC program.

Self assessment audits by a manufacturing organization are valuable to the extent that the auditors are impartial and receive recognition for their services by the company management.

5.3 Preparation for the audit.

5.3.1 Management responsibilities. Establishing the audit objectives and selection of the audit team are management responsibilities. The philosophy for SPC audits should be documented in a policy statement which establishes the members and leadership of the audit team, the reporting responsibilities of the audit team, provides funding for the audit process and establishes the relationship of the SPC audit to the overall procurement activity of the customer.

If the SPC audit must be passed before business can be conducted with the supplier, then management must establish this as a criteria. If conditional acceptance with a commitment to corrective action for discrepancies is adequate to begin procurement, then management must establish the follow-up process and give it credibility with predefined rules for continuing the business relationship during the corrective action process.

5.3.2 Audit team.

5.3.2.1 Audit team membership. An SPC audit should be conducted by a team of individuals representing purchasing, quality and manufacturing. Engineering or other personnel may be added to the team if the technology being evaluated is sophisticated or if previous audits have shown that additional support is needed. The selection of additional personnel should be the responsibility of the team leader.

5.3.2.2 Audit team preparation responsibilities. The audit team should be called together by the team leader in time to prepare documentation, review audit objectives, and make travel or other arrangements. At their initial meeting they should review the following areas:

a. Quality history of similar products

b. Delivery history of similar products

c. Part and assembly drawings and artwork

d. Product specifications

e. Cost objectives

f. Processes

g. Inspection requirements

h. Packaging requirements

i. Manufacturing schedule

j. Procurement administration

The audit team chairman is responsible for completing the review and noting any action items or issues which are discovered during the meeting. Items requiring resolution within the team shall be scheduled for review at a follow-up meeting before the team notifies the supplier of the audit. The team should be ready to conduct an audit after all open issues have been resolved.

5.3.2.3 Supplier notification. Depending on the circumstances, the purchasing department should notify suppliers of the audit and arrange to have the appropriate personnel on hand during the audit. For internal audits, notification can be accomplished on the day of the audit by the team leader but two weeks notification should be provided for an audit of a new supplier. The activity being audited should be prepared to conduct a plant tour for the audit team and arrange to have the supervisors and operators of the area available to answer questions from the audit team. After the tour, the audit team should meet with management representatives from the supplier being audited to conduct a joint review of their findings. Accordingly, supplier personnel capable of answering questions on those subjects should also be made available.

5.3.2.4 Plant tour. On the day of the audit, the audit team should be introduced to the area personnel and their supervision. The area personnel should be instructed to follow their normal operating procedures and answer questions from the audit team.

The audit team should use the System and Process Audit Checklists, figures 10-5 through 15-5, during the tour to record their observations as acceptable, marginal or unacceptable for each of the elements listed.

5.4 Joint supplier review. After completing the plant tour, the audit team should meet with supplier management representatives. An acceptable format for the review is for the audit team to present their findings to the supplier and to have the supplier present their assessment of the same items based on having responded to questions posed before meeting with the audit team. This format has the advantage of getting to the heart of any differences which may exist, but may run the risk of creating more conflicts than a jointly negotiated evaluation for each item. The actual format may be selected during the plant tour by the audit team based on their assessment of the relationship which forms.

During the review, any discrepancies or issues which are identified should be documented for follow-up action if a resolution cannot be reached during the review. The team chairman should establish a schedule for resolution of any action items which result from the review. Items corrected on the spot need to be documented and a commitment obtained from the supplier to review his operations for similar items and correct them.

In addition to reviewing the supplier's general SPC implementation, this joint review should be used to establish specific SPC criteria for the intended procurement.

If the supplier is a potential source of individual parts or assemblies, the audit team should be prepared to point out the drawing or specification elements which are deemed candidates for SPC control chart monitoring. The supplier should be prepared to generally discuss his approach to implementing SPC on those elements.

If the supplier is a potential source for complex systems which would require him to select his own control points for statistical monitoring, he should present his approach to inspection and test planning to the audit team.

The audit team should be prepared to establish a follow-on schedule for finalization of the inspection and test parameters to be monitored during the procurement. This follow-on activity should be integrated with the Government quality assurance activity, as discussed in 5.5.

5.5 Results of the audit evaluation. The evaluation results of the audit are summarized from the checklists completed during the plant tour and the joint review. The team chairman should bring his team together after completing the process audit and document the specific actions required to correct unacceptable items using the Audit Corrective Action Summary Report (see figure 16-5).

The audit team should report the overall results of the plant tour as acceptable if 90% or more of the elements audited are acceptable. If less than 90% are acceptable, the audit team should report that corrective action is required and require that all items in the Audit Corrective Action Summary Report be thoroughly discussed with the supplier. After a schedule for corrective action is established, a follow-up audit should be conducted and the results of this new evaluation should be used to determine acceptability.

If the overall results are not acceptable, the audit team should consider a limited qualification for the supplier. It may be possible to approve individual facilities or individual part numbers or processes even though the overall system requires further work.

5.6 Audit team final report. The audit team's final report should provide both the supplier and management with a summary of the plant tour results and the action items from the joint review. The report should be essentially completed before the team leaves the audit site with only final typing and proofreading required at the audit team's home facility. The report should be signed by all team members and presented to appropriate Government management with recommendations for follow-up. The management review team should formally accept the team's recommendations or modify them as needed and the final results communicated to the supplier through purchasing or if it's a prime contractor audit, through the appropriate Government office.

5.7 Follow-up and corrective action. The action items resulting from the plant tour and joint review with the supplier should be scheduled for follow-up reviews on a frequency consistent with the importance of the account. A supplier who is delivering critical assemblies on a high cost contract could be subject to a corrective action review before each delivery or weekly. Suppliers still in the negotiation stage of a contract may be able to conduct a monthly review of status. It is preferable for the audit team to establish the frequency and intensity of follow-up action with the supplier during the audit, but management may change these parameters based on knowledge not available to the team.

A minimum response should be a monthly written report from the supplier which shows progress on the actions defined. If the corrective actions extend over several months, a quarterly or monthly meeting between both parties should be scheduled to review progress and to repeat the audit on critical elements.

5.8 Monitoring and surveillance of incoming product. The audit report should be used to adjust the contract final inspection requirements for products delivered. If the plant tour proves that SPC has been established for specific parameters and the supplier provides control charts for those parameters with each shipment, there is an opportunity to reduce or eliminate inspection for those parameters. If certain parameters require corrective actions to demonstrate complete implementation, then these parameters can be more closely scrutinized during final inspection or prime contractor incoming inspection. This will allow the available receiving inspection expenses to be channeled into the most productive areas.

As the supplier's corrective action program proceeds, receiving inspection controls may be relaxed based on the evidence available. The ultimate objective is to eliminate receiving inspection entirely and rely on periodic audits of the supplier SPC system to retain confidence in the product.

Usage data from higher level assembly inspections and tests should be integrated into the supplier feedback loop during follow-up meetings scheduled at least quarterly. These meetings should be continued as part of the purchasing program even after all corrective action programs have been completed.

SYSTEMS AUDIT CHECKLIST FOR DATA COLLECTION
AT WORK OR INSPECTION STATION

LOCATION: _____
PRODUCTION/AREA: _____
STATION: _____
DATE: _____
AUDITOR: _____

ELEMENT NUMBER	ELEMENT DESCRIPTION	ACCEPTED	MARGINAL	UNACCEPTED	COMMENTS
1.	Are the control charts posted? Clearly visible? Properly labeled?				
2.	Is the data on the control charts current to today's date?				
3.	Are actions for out-of-control points indicated in the legend?				
4.	Are signatures of supervisors on the control charts?				
5.	Are center lines and control limits on the chart; if X-Bar, R chart-on both charts?				
6.	Is there a corrective/preventive action matrix? Current?				
7.	Are the PQI teams performing to a process control procedure?				

FIGURE 10-5. Systems audit checklist for data collection at work or inspection station.

PROCESS AUDIT CHECKLIST DOCUMENTATION - PART I

LOCATION: _____
PRODUCT/AREA: _____
AUDITOR: _____
DATE: _____
STATION: _____

NUMBER	DOCUMENT DESCRIPTION	AVAILABILITY		COMMENTS
		YES	NO	
1.	Process control procedure			
2.	Work Instructions			
3.	Documentation/Design			
4.	Company Policy			
5.	Station Layout			
6.	Training Records			
7.	Product/Document Specification			
8.	Flow Diagrams			
9.	Process Rework			

FIGURE 11-5. Process audit checklist for documentation (Part I).

PROCESS AUDIT CHECKLIST DOCUMENTATION - PART II

LOCATION: _____
PRODUCT/AREA: _____
STATION: _____
DATE: _____
AUDITOR: _____

ELEMENT NUMBER	ELEMENT DESCRIPTION	ACCEPTED	MARGINAL	UNACCEPTED	COMMENTS
1.	Are documents complete?				
2.	Are documents clear?				
3.	Are documents correct?				
4.	Are operations in proper sequence?				
5.	Are interactions included for errors to be verified?				
6.	Are documents to the latest revision?				
7.	Are reference documents included where applicable?				
8.	Are necessary support documents available? (e.g. design standards, photographs, sketches, minimum acceptable samples)				

FIGURE 12-5. Process audit checklist for documentation (Part II).

PROCESS AUDIT CHECKLIST - HUMAN FACTORS

LOCATION: _____
PRODUCT/AREA: _____
STATION: _____
DATE: _____
AUDITOR: _____

ELEMENT NUMBER	ELEMENT DESCRIPTION	ACCEPTED	MARGINAL	UNACCEPTED	COMMENTS
1.	Has the employee been given skills training, on job training, other? Has the operator been tested on his skills and knowledge? By whom? Method?				
2.	Can the physical elements of the process be accomplished by the employee?				
3.	What's the employee's attitude toward adequacy of the documentation?				
4.	Are working conditions conducive to quality workmanship?				
5.	Is the employee committed to the use of SPC at his/her workstation? To the overall SPC program?				

FIGURE 13-5. Process audit checklist for human factors.

PROCESS AUDIT CHECKLIST - STATION LAYOUT

LOCATION: _____
PRODUCT/AREA: _____
STATION: _____
DATE: _____

ELEMENT NUMBER	ELEMENT DESCRIPTION	ACCEPTED	MARGINAL	UNACCEPTED	COMMENTS
1.	Does the station location conform to the area floor plan?				
2.	Does the station physically conform to station layout plan?				
3.	Is the station identified by number of the function/ operation performed?				
4.	Is general housekeeping maintained?				
5.	Are safety practices adhered to?				

FIGURE 14-5. Process audit checklist for station layout.

PROCESS AUDIT CHECKLIST - OPERATION

LOCATION: _____
PRODUCT/AREA: _____
STATION: _____
DATE: _____
AUDITOR: _____

ELEMENT NUMBER	ELEMENT DESCRIPTION	ACCEPTED	MARGINAL	UNACCEPTED	COMMENTS
1.	Are process documents present?				
2.	Is document revision status correct?				
3.	Do the documents reflect the master copy? (no unauthorized changes)				
4.	Are required materials available at the station?				
5.	Does the employee perform the operation exactly according to the process documents?				
6.	Does the employee follow the sequence prescribed by the method?				

FIGURE 15-5. Process audit checklist for operation.

PROCESS AUDIT CHECKLIST - OPERATION

LOCATION: _____
PRODUCT/AREA: _____
STATION: _____
DATE: _____
AUDITOR: _____

ELEMENT NUMBER	ELEMENT DESCRIPTION	ACCEPTED	MARGINAL	UNACCEPTED	COMMENTS
7.	Does the employee properly utilize his tools and equipment?				
8.	Does the employee have authority to stop the process when an out-of-control condition exists?				

FIGURE 15-5. Process audit checklist for operation - Continued.

AUDIT CORRECTIVE ACTION SUMMARY REPORT

AUDIT DATE _____ AUDITORS _____ LINE AND/OR STATION _____

ITEM NUMBER	DEFICIENCY AND PROBABLE CAUSE (OBSERVATION)	ACTION TO BE TAKEN	RESPONSE	TARGET DATE	ACTION STATUS/COMMENTS
1					
2					
3					
4					
5					
6					
7					

STEERING COMMITTEE APPROVAL _____

FIGURE 16-5. Audit corrective action summary report.

CHAPTER 6
DESCRIPTION OF PROPER SPC SOFTWARE

6.1 Description of proper SPC software. SPC software is a set of programs that provide analysis and support to the development and maintenance of an SPC program.

6.2 SPC software advantages. Major advantages of using SPC software include computational accuracy and output standardization.

During the development phase of an SPC program, manual computation or hand calculator errors rarely will cause serious problems in achieving the program goals. This is due to the review procedures which are required to make the program successful. Reasonableness tests conducted by engineers and management are generally adequate to detect any significant computational errors. During on-going operation, computational errors can initiate corrective actions when inappropriate, but these problems are usually quickly detected. the most significant risk is that a computational error will allow an out of control point to go unnoticed or uncorrected.

Standardizing output from the various processes being monitored through the use of a software program can encourage management participation and help to gain understanding from personnel operating in physically separated operations. Whether the standardization is achieved through software or a forms standardization procedure is a decision best made by the people involved in the particular company culture. If the choice is to achieve these benefits through software, the SPC training process should be certain to explain the use of this software to both the operational personnel and the managers responsible for the program.

During process capability studies or designed experiments, the use of computer aided data reduction is more frequently necessary or desirable due to the large volume of data involved. If this data is entered into a multi-purpose software program, the ability to easily perform a variety of analyses from the single data base can often yield insight into the process being studied.

6.3 SPC software disadvantages. Successful SPC programs depend on real time data availability to control production processes. SPC software can help make the information immediately visible or it can become an excuse for allowing uncontrolled processes to produce defects.

The utility and portability of today's personal computers creates tremendous demands for machine time. If a company elects to routinely use software based SPC program, they must ensure that higher priority tasks do not remove the equipment from the area where it is needed for process control. Dedicated equipment for production SPC purposes is one solution to the problem and may be justified in specific cases. Likewise, management must ensure the data is inputted and printed by the computer immediately upon

collection and inspection of the parts. If this does not occur on a real time basis, the result is the control charts are merely quality reports with control limits and not truly real time process control.

Other commitments required to ensure continuity of SPC data in the automated data collection environment include having back-up equipment available to replace equipment down for maintenance and having multiple copies of the selected software available to counteract the inevitable damaged floppy disk.

Data input errors on a computer or a dedicated SPC analyzer are a potential problem source when using software controlled SPC. These errors are generally self-correcting in a system with good overall design, with the greatest potential for error coming in the form of missed identification of out of control points.

The remainder of this chapter describes a minimum set of characteristics to consider when selecting SPC software. The essential features are the ability to enter and display data on a real time basis and the ability to display data in a control chart format. All other features are desirable to different degrees depending on the particular environment in which the SPC system is operating.

6.4 Essentials.

6.4.1 Real time data. To minimize the number of out of control parts produced by a process, the SPC data must be available immediately after production of the parts. This real time emphasis characterizes all successful SPC programs. Processes allowed to operate in an out of control condition will quickly demoralize the production work force and undermine the credibility of the entire SPC philosophy.

Therefore, a primary criteria for SPC software selection is the ability of the software to be easily started, operated continuously during production, and capable of rapid data entry, computation of the appropriate data points and display of the calculated information. Software which requires complicated start-up procedures, a system operator for access or complicated graphics add-on programs to display data should be used only in specialized situations where these features shall not degrade the prime objective of real time data availability.

Graphic data display is essential if runs, trends and other out of control indicators are to be easily recognized. It is not enough to have the software determine that a particular point is in or out of control based on pre-programmed criteria. The trained statistician or engineer monitoring the processes should be able to spot a new pattern which demands attention when looking at a good graphical display more readily than when looking through tabulated or quasi-printouts.

The last key element which real time software must contain is a provision to trace process control data directly to the products manufactured. This traceability is generally provided by date or lot codes, by serial number, batch number or work order number. If data cannot be traced back to the products, the difficulty in implementing corrective actions for out of control conditions is multiplied. Preventive actions can be taken to prevent recurrence of the condition, but the material produced during the out of control condition must be identified, reworked, sorted, repaired or scrapped to prevent defects from reaching the customer.

6.4.2 Control charts. The most used feature of an SPC software program is the display of control charts. The essential charts fall into two basic categories as follows:

a. Charts used to represent variables data.

b. Charts used to display attributes data.

6.4.2.1 Variables control charts. The types of variables control charts supported must and should include the following:

a. Average or $\bar{X}$ charts.

b. R charts.

c. Sigma (σ) charts.

d. Moving R charts.

6.4.2.2 Attributes control charts. The types of attributes control charts provided should include the following:

a. P charts.

b. np charts.

c. c chart.

d. u charts.

The P and u charts should have provisions for dealing with equal and unequal lot sizes.

6.4.2.3 Control chart format. Whether variables or attributes data is depicted, the control chart format should display centerlines and control limits along with the actual observed data. Changes to the individual observations should be possible through an on-line editing program. The control limits should be user selectable to be defined by the observed data or set manually in the form of modified control limits based on the specification range for the parameter being studied.

6.4.3 Data entry and display features. The primary requirement for the data entry and display features of the software is that data can be entered and corrected easily by an operator with limited statistical knowledge. Menus which lead the operator step by step to the point of entering the process data can facilitate the use of programs. Menu driven programs should have an option to abbreviate the start-up sequence in order to save time once the operator has become familiar with the program.

Once the data has been entered, the time to complete computations and produce a result should be minimal. The steps required for the machine to process the data shall require little or no operator intervention to reach the conclusion.

A further requirement for data entry is that editing incorrectly entered data, after the initial calculations are complete, should be as simple as possible.

Color can enhance graphic displays and add operator interest. The software, therefore, should support color monitors, even though this feature may not be used at all stations.

6.4.4 Data analysis. Basic analysis needs for statistical data include the ability to construct histograms, Pareto diagrams and descriptive statistics such as average, standard deviation and range.

Histograms should be user controllable to allow specification limits to be superimposed on the collected data. This allows engineers and managers to quickly assess the magnitude of defective material likely to be produced if the process is allowed to continue under the conditions present during the study. Two sample histogram formats are shown in figure 17-6.

Pareto diagrams should be available as an analysis tool to help pick out the most significant contributors to a particular process or defect summary. The diagrams should display the cumulative percentage contribution of the elements in a straightforward manner, as well as, the percentage contribution of the individual elements. A sample Pareto diagram is shown in figure 18-6 which illustrates the essential features.

The descriptive statistics are available in almost all spreadsheet and data base management programs. More sophisticated programs may offer a wide range of additional statistics, but these must be weighed carefully if the added power complicates the operation of the software for day-to-day use.

6.4.5 Process capability analysis. The parameters Cp and Cpk are useful ratios for comparing the improvements made in a process over a period of time. They are easily computed in a software package if the specification limits, process average and standard deviation of the process are known.

6.4.5.1 Cp ratio. The Cp is the ratio of the engineering tolerance to the process capability and the software should provide this data along with an interpretation along the following guidelines:

a. If Cp is equal to or less than 1, the process setup should be rejected.

b. If Cp is equal to or greater than 1.33, the process setup should be accepted.

c. If Cp is greater than 1 and less than 1.33, the process is marginal.

6.4.5.2 Cpk ratio. The Cpk ratio is the distance from the process mean to the nearest specification limit divided by three times the standard deviation. The appropriate guidelines which should be provided by the software are:

a. If Cpk is greater than 1, the process is acceptable.

b. If Cpk is less than 1, the process in incapable.

c. If Cpk is equal to 1, the process can be improved by centering the process, reducing the standard deviation or critically reviewing the specification limits.

6.4.6 Inspection and test capability analysis. The ability to enter and analyze data taken during inspection or test capability studies is a highly desirable feature for any SPC software package. It is not critical that this capability be available to production personnel because the studies will normally be conducted by engineers.

The software should have the capability of analyzing variables data for both the repeatability and reproducibility of the inspection or test process and operators being studied. It should also give an overall inspection capability combining error sources using least square summation methods.

Another level of utility is added if the inspection or test capability can be studied using attributes analysis. Output data from an attributes study should include the probability of misses and false alarms, as well as, computing the effectiveness and bias of the operators and process studied.

6.4.7 Report formatting. Proper SPC software will provide the engineers with the capability to format output reports in ways which convey the desired message to a variety of audiences. If all of the features cited in this chapter are available, then data can be easily cross correlated to add cost analysis for high level management reviews or extraneous data can be removed when using the information to communicate with the hourly work force.

A useful feature is the ability to add several levels of titles, labels and dates to graphs which can be called up on the screen. This capability should be available on-line and the result should be visible on screen. Embellishments which can add to the professional appearance of the output include a variety of type sizes and fonts. These should be consistent with the hardware available for hard copy output and drives for a variety of different printers and plotters should be selectable from the printing menus.

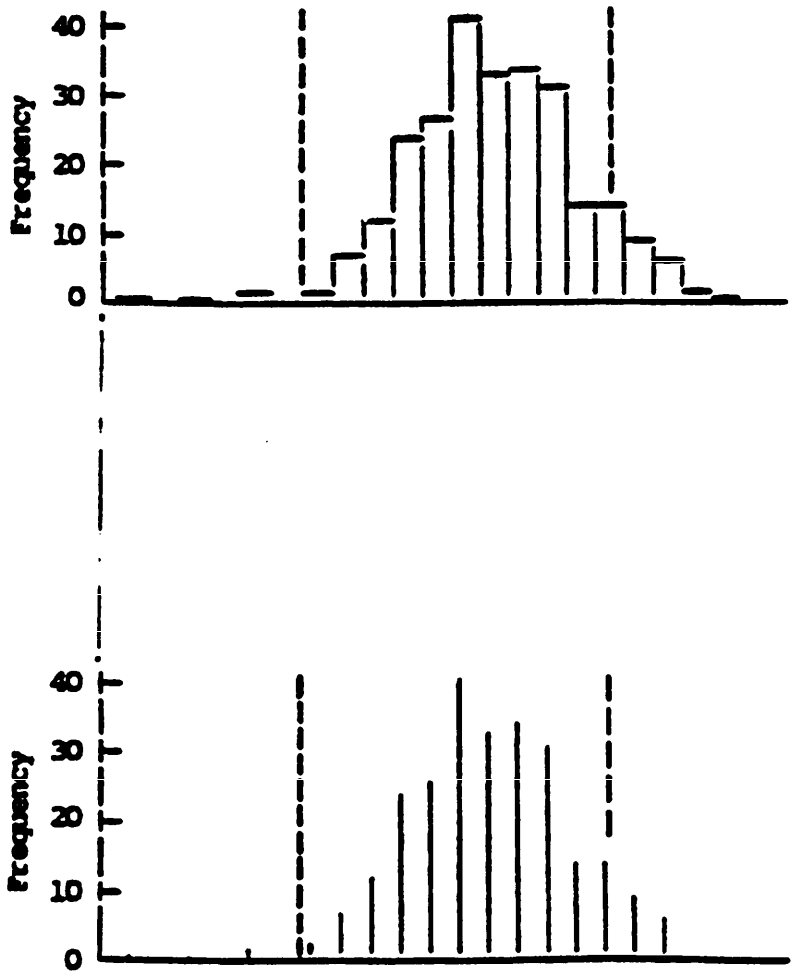


FIGURE 17-6. Sample formats of histograms.

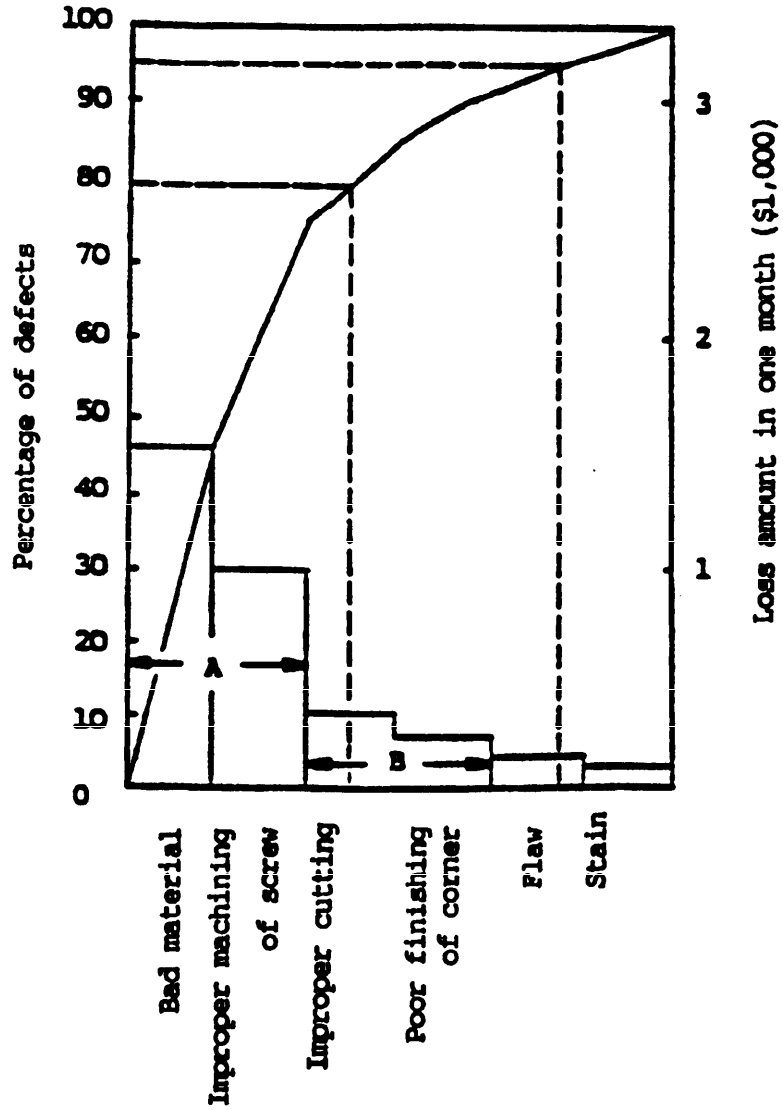


FIGURE 18-6. Pareto diagram.

CHAPTER 7
EVALUATION GUIDE FOR SUPPLIER'S SPC SOFTWARE

7.1 Evaluation guide for supplier's SPC software. This chapter provides checklist formats for use in evaluating SPC software. The first checklist (figure 19-7) evaluates the software using the essential characteristics specified in 6.4 as the basis for acceptability. Once the essential features of the software have been evaluated, a sample comparison matrix (figure 20-7) is provided to assist in evaluating supplier business practices, hardware considerations, price and other factors which influence the final selection.

In figure 19-7, an acceptable rating for an item indicates that the characteristic meets the real time criteria specified in 6.4.1 and that there is no noticeable difficulty in using the feature. A marginal rating is assigned when the feature meets the real time criteria but there is some difficulty in accessing it. Unacceptable indicates that the characteristic is not included or cannot be used or that it does not meet the real time criteria.

Since most SPC software is constructed in a modular fashion, the ratings can only be applied to individual modules being evaluated. It is possible, or even likely, that a particular software package will have acceptable ratings for some characteristics and marginal or unacceptable ratings for others.

7.2 Evaluating the software supplier. The checklist (figure 19-7) will allow evaluation of the software for essential characteristics that will be used every day on the manufacturing floor. For many potential users, the need for support from the software supplier is equally important. An indication of the software supplier's business practices may be gained by looking into the items listed below (see figure 20-7):

a. Suppliers who can provide a users list and telephone contact numbers should be encouraged to do so. One of the easiest ways to build confidence in a particular software program is to find a number of companies who are using it on a day-to-day basis. It is well worth a trip to nearby users to learn first hand their experiences with the software under consideration, but this should be required only after the list has been pared to three or four contenders.

b. Software suppliers who are willing to provide their product on a trial basis or with a money back guarantee generally have had the product tested under operating conditions and their offers should be accepted, especially, if this is your first adventure into the world of SPC software.

c. Program updates provided at minimal or zero cost should be a minor comparison criteria. The current version of the product should be adequately tested before purchase rather than relying on features which are promised for the future.

d. Multi-site licenses are a consideration for those companies which have multi-plant operations or where logistics of production dictate that several systems may be required to control the necessary processes.

7.3 Interface with other software. As the company or department using SPC advances its knowledge and applications of statistics, a substantial data base will accumulate. Analysis of this data base may serve to help in a variety of production problems, but the software in use may not lend itself to long term analysis as easily as it handles day-to-day production work. For this reason, it is highly desirable for the data to be stored in a format that is transportable to standard spread sheet and data base management systems (DBMS). File interfaces are generally facilitated if the data storage is in the American Standard Code for Information Interchange (ASCII) format. Some SPC software incorporates DBMS capabilities, but these are often limited either in the size of the data files which can be handled or the analysis capabilities offered. It is useful if this data can be interfaced to standard programs such as the Lotus 1-2-3, Symphony, data base III (dBASE III), Business Management Data Processing (BMDP) or another standard statistical analysis program.

Such programs may offer capabilities such as file merging, multiple key sorting, file builders and other features which the day-to-day software does not make readily available.

7.4 Hardware Considerations. With the International Business Machines (IBM) personal computer (PC) and its derivatives becoming more available in some companies, a very desirable feature for SPC software is the ability to run under some form of the standard Disk Operating System (DOS) used in these machines. The ability to run under both PC DOS, and Machine Systems (MS) DOS is often assumed but not always possible without some modification. Regardless of the system chosen, the hardware compatibility should be thoroughly checked before a purchase commitment is made.

Figure 20-7 is a sample comparison matrix which can be tailored to the particular needs of a company contemplating the purchase of SPC software.

The checklist (figure 19-7) should have been used with acceptable results for each package of software being considered before making this comparison. Additional features may be added to the left-hand column of this checklist to satisfy particular needs.

ESSENTIAL FEATURE EVALUATION CHECKLIST				
Item	Real Time (?)	Ease of Use		
		Acceptable	Marginal	Unacceptable
Variables Charts:				
X bar				
Range				
Sigma				
Moving Range				
Attributes Charts:				
P Chart:				
Equal lot size				
Unequal lot size				
NP Chart				
C Chart				
U Chart:				
Equal lot size				
Unequal lot size				

FIGURE 19-7. Essential feature evaluation checklist.

COMPARISON CHART FOR SOFTWARE PACKAGES (SP)				
Item	SP No. 1	SP No. 2	SP No. 3	SP No. 4
Supplier business practices:				
Customer list				
Trial policy				
Refund policy				
Update cost				
Multi-site license cost				
Interface with other software:				
Spread sheets				
Data Base Managers				
Operating system requirements:				
Hardware requirements:				
Price:				

FIGURE 20.7. Comparison chart for software packages.

CHAPTER 8
SELECTING AN SPC CONSULTING FIRM

8.1 Selecting an SPC consulting firm. This chapter explains why a consulting firm may be required to implement SPC and identifies factors which may be used for selecting one.

8.2 Need for SPC consulting firm. SPC is being accepted as a means to improve a company's profits and competitive edge. It accomplishes the improvement of quality and productivity to a degree that the company's products become reputable in the market.

It is also being recognized that in order to implement SPC effectively the first time, and to optimize the results in the shortest possible time, outside consultants may be required for education and facilitation. Even the largest firms seldom have the luxury of employing full-time specialists who can devote 100% of their time and effort to implementation of SPC. This type of specialized support is typically only available from consulting firms. The question now arises, how such consultants can be selected?

This decision will significantly influence the success or failure of the SPC effort and possibly the company's future. In selecting a consulting firm it is important not only to focus on cost, but also on return-on-investment (ROI), anticipated results, and quality of the service.

8.3 Criteria for selecting SPC consulting firm. Suggested criteria for selecting a consulting firm to assist in implementing SPC are listed in table III-8.

TABLE III-8. Requirements and standards for selecting a consulting firm.

Requirement	Standard
Length of experience as consultants.	Look for no less than four years. Four years or more indicates a track record of seasoning as consultants and stability.
Length of experience specifically in training and installing SPC.	Look for no less than three years. Anything less may indicate a firm that is still learning and experimenting. It will take no less than three years to develop the required expertise and to establish an effective SPC program.
The consulting firm's proposal should include the following:	
a. A list of clients and references.	a. The client list should include companies in similar or related industries.
b. Expected time to achieve bottom line results.	b. Expected time to achieve initial results should be within 90 days.
c. Estimated ROI.	c. Consultant should be able to demonstrate an ROI of between "4 to 1" and "10 to 1".
d. Total dollar savings for previous clients.	d. Total savings for an active firm should exceed ten million dollars.
There should be a statement of the capabilities and capacity of the consulting firm.	The consulting staff should have a broad manufacturing, service and administrative functions.
Members of the consulting staff should have adequate experience in SPC.	Look beyond tenure in the consulting firm, look for other related experience in SPC. Also look for sound theoretical foundation in the staff. Bachelors, Masters or even Doctorate degrees in other disciplines do not necessarily qualify for teaching and installing SPC.

TABLE III-8. Requirements and standards for selecting a consulting firm - Continued.

Requirement	Standard
Member of the consulting staff should have relevant work experience.	Look for positions in middle and upper management and experience as engineers with similar companies. This type of background should ensure the proper perspective.
The consulting firm should have a comprehensive plan for installing SPC.	The plan should include education with hands-on experience and follow-up systems to sustain the implementation. The firm should be able to provide training and in-house support that is appropriate for your organization.
The consulting firm should have a well defined style or approach.	Look for a consulting firm who will actively support and assist in expeditiously installing the SPC plan. It is not sufficient to provide training or perform an evaluation of your "problems" and walk away. Look for a firm who will act as your partner in training, demonstration, and application.
There should be a clear understanding of the extent of the firm's involvement and the manner in which progress will be monitored.	Consultant visits should be on a predetermined schedule to ensure access to the right people when questions arise. Progress reports should be documented regularly.

CHAPTER 9
NOTES

9.1 Intended use. This standard provides instruction and guidance for the preparation and implementation of SPC programs. It is designed for Government personnel for reviewing and evaluating a contractor's SPC system, set-up and performance. It may also be used by contractor's in implementing their own in-house SPC system and also to evaluate/monitor their subcontractors/suppliers SPC systems.

9.2 Supersession data. This standard was prepared from and supersedes the TACOM Product Assurance and Test Pamphlet, AMSTA-P-702-167, dated September, 1987, Statistical Process Control (SPC) Requirements.

9.3 Subject term (key word) listing.

Audits
Evaluation guide
Facilitator
Inspection capability study
Management structure
Measurement of effectiveness
Performance measurements
Planning and reporting
Problem analysis and solution
Problem prevention
Problem solving techniques
Process capability study
Process control procedures
Project teams
Quality council, President's
Quality target
SPC
Statistical techniques
Systematic process
Team approach

9.4 References:

a. Hradesky, John L., "Productivity/Quality Improvement", Mc Graw Hill (1986).

b. Plunkett, Lorne C. and Hale, Guy A., "Proactive Manager", Wiley and Sons (1982).

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CONCLUDING MATERIAL

Custodian:
Army - AT

Preparing activity:
Army - AT

(Project QCIC-A128)

Subject term (key word) listing

FOLD

U.S. ARMY TANK - AUTOMOTIVE COMMAND
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