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Control charts - General guide and introduction

Control charts -- General guide and introduction

Cartes de contrôle -- Principes généraux et introduction à l'emploi

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Control charts — General guide and introduction

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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 7870 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Sub-Committee SC 4, *Statistical process control*.

Annex A of this International Standard is for information only.

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Control charts — General guide and introduction

1 Scope

This International Standard presents key elements and philosophy of the control chart approach, and identifies a wide variety of control charts, including those related to the Shewhart control chart and those with process acceptance or on-line predictive emphasis.

It presents an overview of the basic principles and concepts and illustrates the relationship among various control chart approaches to aid in the selection of the most appropriate standard for given circumstances.

It does not specify statistical control methods using control charts. These methods will be specified in ISO 7873 and ISO 7966, and in other future International Standards.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3534-1:1993, *Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms.*

ISO 3534-2:1993, *Statistics — Vocabulary and symbols — Part 2: Statistical quality control.*

ISO 7873:1993, *Control charts for arithmetic average with warning limits.*

ISO 7966:1993, *Acceptance control charts.*

ISO 8258:1991, *Shewhart control charts.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 3534-1 and ISO 3534-2 apply.

4 General

Control charts are a fundamental tool of statistical quality control. They are a method for comparing information from samples representing the current state of a process against limits established after consideration of inherent process variability. Their primary use is to provide a means of evaluating whether a manufacturing service or administrative process is or is not in a "state of statistical control". While originally developed for industrial production and development applications, control chart methods are now widely used in a very broad range of service and support operations as well. In essence, control charts are a management tool to assist in determining when a process is stable or has changed and they are useful at management levels as well as for the operator to control at the workplace.

Inherent variability is present in all operations due to numerous, but usually minor, chance causes, so that the observed results from a stable process are not constant, and statistically valid limits are required to minimize erroneous decisions leading to over- or under-control.

A process is considered to be in a "state of statistical control" if there are no systematic shifts entering the process. In essence, when a process is "in control" it is possible to predict reliably the behaviour of that process, whereas when non-chance (or special) causes enter the system, the process is subject to the results of these causes and the outcome cannot be predicted without information about their presence and effect. A process that is found to be not in a "state of statistical control" requires intervention to bring it into such a state. For certain economic or natural phenomena there may be no known way to intervene and the control chart simply serves to identify a lack of control.

Control charts provide a simple graphical method for evaluating whether or not the process has attained, or continues in, a "state of statistical control". The determinations are made through comparison of the values or patterns of some statistical measure(s) for an ordered series of samples, or subgroups, with control limits. There is a variety of specific control charts, each designed for the types of decision to be made, the nature of the data, and the type of statistic used. The word "statistic" emphasizes that measurements are subject to inherent errors from such sources as obtaining the sample, or from the measurement process itself, and therefore represent a sample with inherent sampling variability.

A major virtue of the control chart is its ease of use and construction. It provides an indicator of the "state of statistical control" to the production or service operator, engineer, administrator and manager. However, the control chart serves only as part of the complete analysis procedure. It may suggest when an assignable cause has entered the process, but independent study is required to determine the nature of that cause and the corrective action needed.

5 Control charts for variables and attributes

Control charts may be used for either "variables" data or "attributes" data. Variables data represent observations obtained by measuring and recording the numerical magnitude of a characteristic for each of the units in the group under consideration. This involves reference to a continuous scale of some kind. Attributes data represent observations obtained by noting the presence (or absence) of some characteristic or attribute in each of the units in the group under consideration, and counting how many units do (or do not) possess the attribute, or how many such events occur in the unit, group, area, or volume in the sample.

In the case of variables data, two types of control chart are generally plotted. The first treats a measure of location such as the sample or subgroup average $\overline{X}$ or median. The second treats a measure of dispersion of observations within the sample or subgroup, such as the "range" (R or w), or the sample standard deviation (s). Both types of chart are required to constitute an effective variables control chart approach.

The chart for location is used to evaluate whether there is evidence of an actual shift in process level, while the chart for dispersion is used to evaluate whether there is evidence of a change in the magnitude of the within-sample or subgroup standard deviation. The control limits for the chart for location are a function of the within-sample or subgroup standard deviation. It is important to verify that this inherent variability parameter remains in control.

For most variables control charts, the normal distribution (see ISO 3534-1) is assumed. It is usual to plot averages of n measures from a subgroup because, except in extraordinary situations, averages tend to follow the normal distribution even when the distribution pattern of the individual observations is not normal, and because the contributions of random variations are reduced through the process of averaging. The reduction sharpens the ability to detect a signal that an assignable cause has occurred. While sample sizes of $n = 4$ or $n = 5$ are frequently selected for convenience, economical analysis may suggest more appropriate numbers. Amplification of these points may be found in the specific International Standards for various control charts.

In the case of control charts for attributes data, only one chart is plotted. The "p" chart (proportion of some specified classification), is based on the binomial distribution. The standard deviation (or standard error) for such a proportion is denoted s_p. Since

$$s_p = \sqrt{p(1-p)/n}$$

and therefore depends only on n and p, there is no need to plot a separate chart for s_p. Similarly, the "c" chart (count of events of a given classification) is based on the Poisson distribution. The standard deviation (or standard error) of the count is called s_c. Since $s_c = \sqrt{c}$, there again would be no value in plotting a separate chart for variability.

6 Control limits

Control limits are used as criteria for signalling the need for action, or for judging whether a set of data does or does not indicate a "state of statistical control". Sometimes a second set of limits called "warning limits" is also used, and the control limits are then sometimes called "action limits". Action may be in the form of

a) investigation of the source(s) of an "assignable cause";

b) making a process adjustment; or

c) stopping the process.

Rules for determining what constitutes exceeding the action or warning criteria are defined in the specific International Standards for control charts (see ISO 7873, ISO 7966 and ISO 8258), and take various forms such as points falling beyond the limits, runs, or patterns of observations within the limits.

7 Rational subgroups

A rational subgroup is a subgroup or sample, chosen for technical reasons, within which variations may be considered to be due only to non-assignable chance (or common) causes but between which there may be variations due to assignable (or special) causes whose presence is considered possible and important to detect. Technical reasons include issues of homogeneity, ability to sample, and economic considerations. One of the essential features of the control chart is the use of rational subgroups for the collection of data. The variability measured within reasonably homogeneous subgroups is used to determine the control limits, or to verify short-term stability, while longer-term stability is usually evaluated in terms of changes between subgroups. While a relatively short time span is a common basis for a rational subgroup on the basis of a limited length of potential exposure to assignable causes, other bases such as a relatively homogeneous sub-area or common conditions (e.g. work by a particular operator) may be appropriate. The same definition of a rational subgroup shall be used for data collection and for the determination of the control limits.

In most production applications, the rational subgroup represents data collected over a short period of time under essentially identical condition of material, tool setting, environmental conditions, etc. In service and office applications, the rational subgroups may be defined in terms of specific periods or logical groupings within tasks or assignments of some person or team. The variability encountered in these circumstances should represent that due only to chance (or common) causes. With longer time intervals, it can be expected that assignable (or special) causes may occur, such as a change in the source of material, a different variety of data to record, a readjusted tool setting, a new service environment, or a change of operator.

While it may be that such changes will not shift the process level, these causes represent potential variability above that due to chance causes. Thus the within-subgroup standard deviation (whether estimated from a set of subgroups, or known from past experience) serves as the basic measure of "random variability".

Note that the rational subgroup must be subject to all usual sources of chance (or common) variation if it is to have a meaningful value. For example, a series of repeat readings on a piece of material set in a testing instrument might fail to include the contribution of locating the material in the instrument or of obtaining the sample. If these aspects are inherent in a usual testing environment, the repeat readings would give an unrealistic, low estimate of inherent measurement variability. Thus almost any actual measure from the process would appear "out of control". However, if the subgroup is too large, so that variation due to assignable causes inflates the within-subgroup standard deviation, many assignable causes may occur without detection.

As indicated above, the standard deviation of the observed measures within each subgroup constitutes the basic measure of inherent variability for the control chart. When this is not already known, it is estimated by pooling the information collected from a sizable set of subgroups. It is recommended that the information from at least 20 subgroups be used. It is important to verify that the data collected during this base period are in a "state of statistical control" by plotting subgroup ranges or standard deviations on a control chart (i.e. data are in a state of statistical control with respect to within variation), and if they are not, to take the corrective action required to obtain valid base data.

Control limits are based on a multiple of σ_e, the standard error of the statistic being plotted, which in turn is derived from this within-subgroup standard deviation. The multiple of σ_e, the number of individual observations averaged (sample size), the use of supplementary rules (e.g. runs), and frequency of sampling and similar aspects are considered in the specific International Standards for control charts (see ISO 7873 and ISO 7966). If the sample range is used as a measure of variability, control limits are based on a multiple of $\overline{R}$, bypassing the estimate of the standard error σ_e.

8 Types of control chart

There are three major types of control chart (including cusum charts):

a) the Shewhart control chart, with several closely related variations (see ISO 8258);

b) the acceptance control chart (see ISO 7966);

c) the adaptive control chart.

The Shewhart control chart is used primarily to evaluate the "state of statistical control", although charts in this category are often used as a process acceptance tool, even though they are not specifically designed to relate to use criteria or process tolerance limits.

The acceptance control chart is intended specifically for this process acceptance role.

The adaptive control chart is used to regulate a process by anticipating trends and making adjustments beforehand based on predictions.

Some of the specific charts within these general types are described in clauses 9 to 11.

9 Shewhart and related control charts

9.1 General

Since the purpose of control limits is to offer a consistent procedure for reaching a decision about the "state of statistical control", Dr. W.A. Shewhart, who proposed the use of control charts for the "economic control of quality", selected limits derived on an empirical basis, but making use of knowledge of statistical considerations. Assumptions about the collection