

BRITISH STANDARD

Guide to statistical process control (SPC) charts for variables –

Part 3: Charting techniques for short runs and small mixed batches

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 33 and a back cover.

Foreword

Publishing information

This part of BS 5702 was published by BSI and came into effect on 30 April 2008. It was prepared by Technical Committee SS/4, *Statistical process control*. A list of organizations represented on this committee can be obtained on request to its secretary.

Relationship with other publications

It is envisaged that, ultimately, BS 5702 will consist of the following parts:

- *Part 0: General introduction to control charts for measurements;*
- *Part 1: Charts for mean, median, range and standard deviation;*
- *Part 2: Charts for individual values;*
- *Part 3: Charting techniques for short runs and small batches;*

BS 5702-3 is self-contained in respect to the specific subject matter. It also provides essential links to, and is consistent in approach, format and style with, BS 5702-1 and BS 5702-2, BS 5701 Parts 1 to 4, BS 600 and BS 5703 Parts 1 to 4.

Use of this document

BSI permits the reproduction of Figures A.1, A.2, A.3, A.4 and A.5, on pages 29 to 33 of BS 5702-3. This reproduction is only permitted where it is necessary for the user to record findings on the figures during each application of the standard.

As a guide, this part of BS 5702 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this part of BS 5702 is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

BS 5702-1 makes the general recommendation that at least 25 subgroups of data be collected, and plotted, before any constructive analysis can take place to form the basis for establishing standard traditional measured data control charts. This represents best practice for the application of standard statistical process control (SPC) charts to long production runs of a single product characteristic (e.g. diameter) or process parameter (e.g. temperature). However, it presents a problem in many potential applications of SPC.

In the business environment there is an increasing need for versatility and flexibility in highly efficient systems. These support just-in-time inventories and create greater product variety, with smaller batches and shorter runs. The consequent ever-increasing resets, changeovers, die changes, etc., bring new challenges to the meaningful application of SPC. These occur at a critical time when the pressure for continual performance improvement has never been greater.

Processes accommodate many part numbers, often of similar shape but different nominal sizes at best, and part configurations having multiple characteristics with different specified nominal values, units of measure and tolerances. For example a bolt maker with short runs of various size bolts (diameter and length), or a tube extruder with tubes of different size outside diameter, inside diameter and wall thickness. The customary approach is to put a different standard SPC chart on each characteristic of each part number. The consequences of this administratively cumbersome, product-focused, procedure would include the generation of large numbers of run charts each containing data too sparse to be useful, either for control or improvement.

In the same way that other functions have responded to the challenge, e.g. the introduction of lean methods and single minute exchange of die (SMED) in production, so the SPC facilitating function responds. This situation presents both a problem and an opportunity.

The problem arises because, in many organizations, production runs are often too small to generate enough data to apply traditional control charts. This can occur in two ways. Firstly, there is the case where the batch, or lot, size itself is very small. Secondly, there is the situation where the run is very short, e.g. the high speed stamping operation that may run only for a short period. It is frequently not practicable, in either case, to generate enough sub-groups to make the control chart meaningful.

The opportunity arises because much current statistical *process* control is actually statistical *product* control, i.e. SPC implementation is often product- rather than process-focused. Different products, which are generated by a single or similar process, are looked upon as dissimilar entities. Consequently, sources of process variation can be overlooked when analysing the product-orientated control chart. Due to the sparseness of product information in short-run, small-batch situations, focus has to be on the common element, the process. Short-run SPC provides the means to transform a succession of short-run product-related jobs into a long-term process. An example is the jobbing shop that does not make many of the same part, but has a number of processes that are continually being employed. They turn many shafts,

drill many holes, etc., continually. The grouping of drilling, turning, grinding processes and the like, or their corresponding facilities, e.g. machine tools, could make good candidates for the application of short-run SPC.

Some basic statistical concepts, terminology and symbols are introduced in this part of BS 5702; however, these are kept to a minimum. The language chosen is that of the workplace rather than that of the statistician. The aim is to make this standard readily comprehensible to the extensive range of prospective users and so facilitate widespread communication and understanding of the method.

It is advisable that those who are not familiar with the control chart technique read both BS 5702-1 and BS 5702-2 before reading BS 5702-3.

1 Scope

This part of BS 5702 describes ways of applying measured data statistical process control (SPC) charts to short runs and small mixed batches where the sample size for monitoring is restricted to one. It provides a set of tools to facilitate the understanding of sources of variation in such processes so that the processes can be better managed.

The charts described are process- rather than product-focused. The user can plot, monitor and control similar characteristics on different items, or different characteristics on an item, on a single control chart.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 600:2000, *A guide to the application of statistical methods to quality and standardization*

BS 5702-1:2001, *Guide to statistical process control (SPC) charts for variables – Part 1: Charts for mean, median, range and standard deviation*

BS 5702-2:2008, *Guide to statistical process control (SPC) charts for variables – Part 2: Charts for individual values*

BS ISO 3534-2:2006, *Statistics – Vocabulary and symbols – Part 2: Applied statistics*

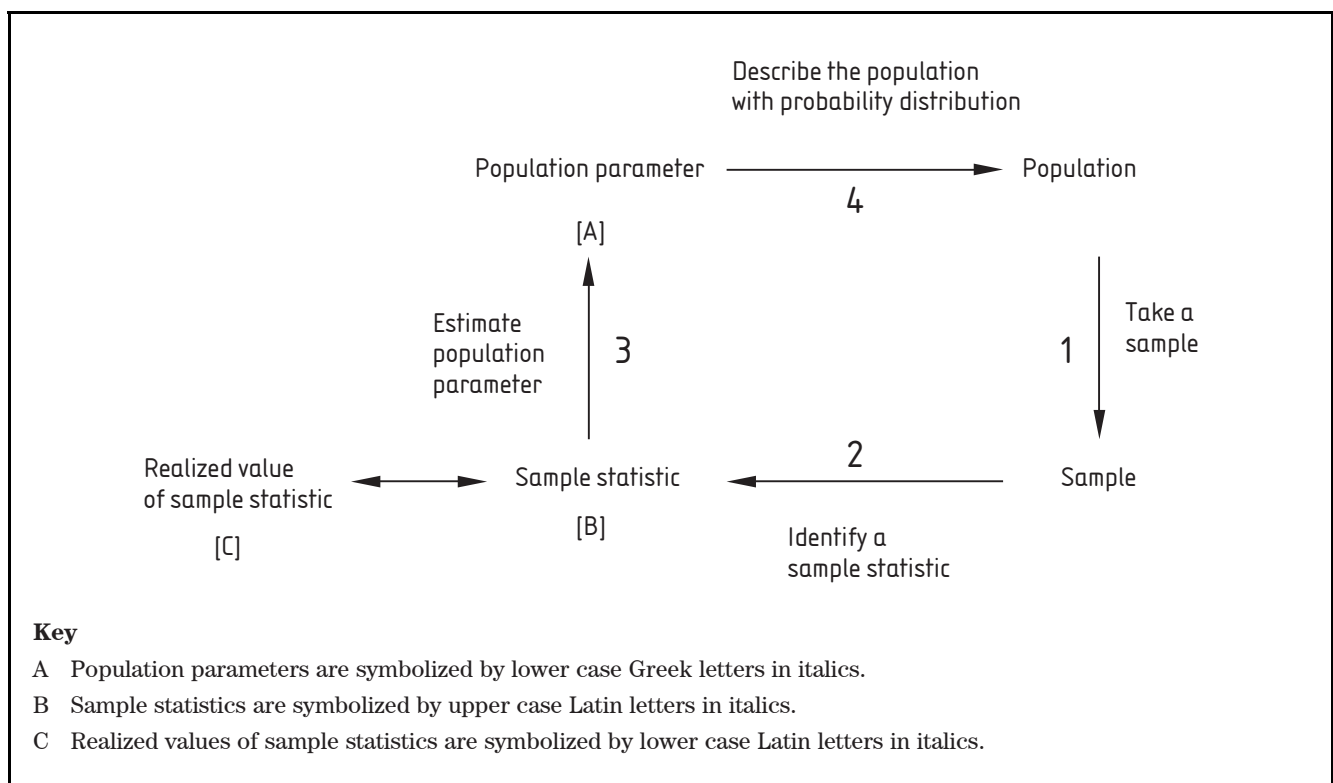
3 Terms, definitions, abbreviations and symbols

3.1 General

For the purposes of this part of BS 5702, the terms, definitions, abbreviations and symbols given in BS ISO 3534-2:2006 and the following apply.

NOTE Whilst the rigour of the statistical treatment in this standard is kept to a minimum it is essential that there is a clear understanding of the distinction between what is a “population parameter” and what is a “sample statistic”, together with the associated notation. This is illustrated in Figure 1.

Figure 1 Diagram distinguishing between a population parameter and a sample statistic



As an illustration of the application of this diagram and the distinguishing between “A”, “B” and “C”:

- a) The lower case Greek letter sigma, σ , a population parameter, represents the standard deviation of a population;
- b) S , a sample statistic, represents the sample estimate of the standard deviation;
- c) s represents the realized, or measured value, of the sample statistic, S .

Similarly:

- 1) the lower case Greek letter mu, μ , a population parameter, represents the arithmetic mean of the population;
- 2) $\bar{X}$, a sample statistic, represents the sample estimate of the arithmetic mean;
- 3) $\bar{x}$ represents the realized, or measured, value of the sample statistic $\bar{X}$.

3.2 Terms and definitions

3.2.1 aim

value from which departure in level is to be detected

NOTE The aim can be the nominal value, the desired or expected value, or the overall mean value experienced or estimated. It is not necessarily the most desirable or preferred value. It is simply a convenient target value for constructing a control chart.

3.2.2 population parameter

summary measure of the values of some characteristic of a population

EXAMPLES Population mean = μ ; population standard deviation = σ .

NOTE Population parameters are usually symbolized by lower case Greek letters in italics.

3.2.3 sample statistic

summary measure of some observed value of a sample

NOTE 1 Sample statistics (random variables) are symbolized by upper case Latin letters in italics (e.g. $\bar{X}$ and S) whereas the actual realization of sample statistics (observed values) are symbolized by lower case Latin letters in italics (e.g. $\bar{x}$ and s). This contrasts with population parameters symbolized by lower case Greek letters in italics (e.g. μ and σ).

NOTE 2 Observed values may be combined to form a test result or measurement result. For instance, the density of a bar may involve the combining of observed values of length, diameter and mass.

3.3 Abbreviations and symbols

CL	centre line of a control chart
LCL	LCL_X , $LCL_{\bar{X}}$ and LCL_R , are the lower control limits for individuals, mean and range, respectively
R_{moving}	moving range, the range of each two consecutive range values
m	number of subgroups
n	number in a sample or subgroup
R	range of two consecutive values
R_{aim}	the aimed value of the range of a particular characteristic
S, s	respectively the general form of the estimator of the process standard deviation and its realized value
t	test statistic for set-up acceptance
UCL	UCL_X , $UCL_{\bar{X}}$ and UCL_R , are the upper control limits for individuals, mean and range, respectively
X, x	respectively a symbol representing a general value of a quality characteristic and a realization of it
$\bar{X}, \bar{x}$	respectively the general form of the estimator of the process mean and its realized value

4 How to select the correct type of Shewhart control chart for measured data

4.1 General

The business aim of statistical process control (SPC) is to control and improve quality, increase productivity and reduce cost. The principal graphical tool of SPC is the control chart. There are two main classes of control chart, Shewhart and cumulative sum (cusum).

NOTE Cusum control charts are dealt with in BS 5703-2.

The Shewhart control chart provides a graphical representation of a process showing plotted values of a representative statistic of a selected characteristic (e.g. individual value, mean, range or standard deviation), a centre line, and one or more control lines. The control line(s) and centre line are used as a basis for judging the stability of the process, namely, whether or not the process is in a state of statistical control. Control lines, representing limits, are derived from the actual performance of the process and are not to be confused with specified limits or specified tolerances.

Shewhart control charts provide a common international language for communicating technical information on the performance of a process. Control charts are effective tools in understanding process behaviour. They distinguish between special- and common-cause variation. When no special cause is present, the process is said to be in a state of statistical control.

When a process is in statistical control, its capability is predictable and can be assessed. Reducing common cause variation and improving process targeting can enhance process capability.

Potentially, the control chart has wide applicability throughout any organization.

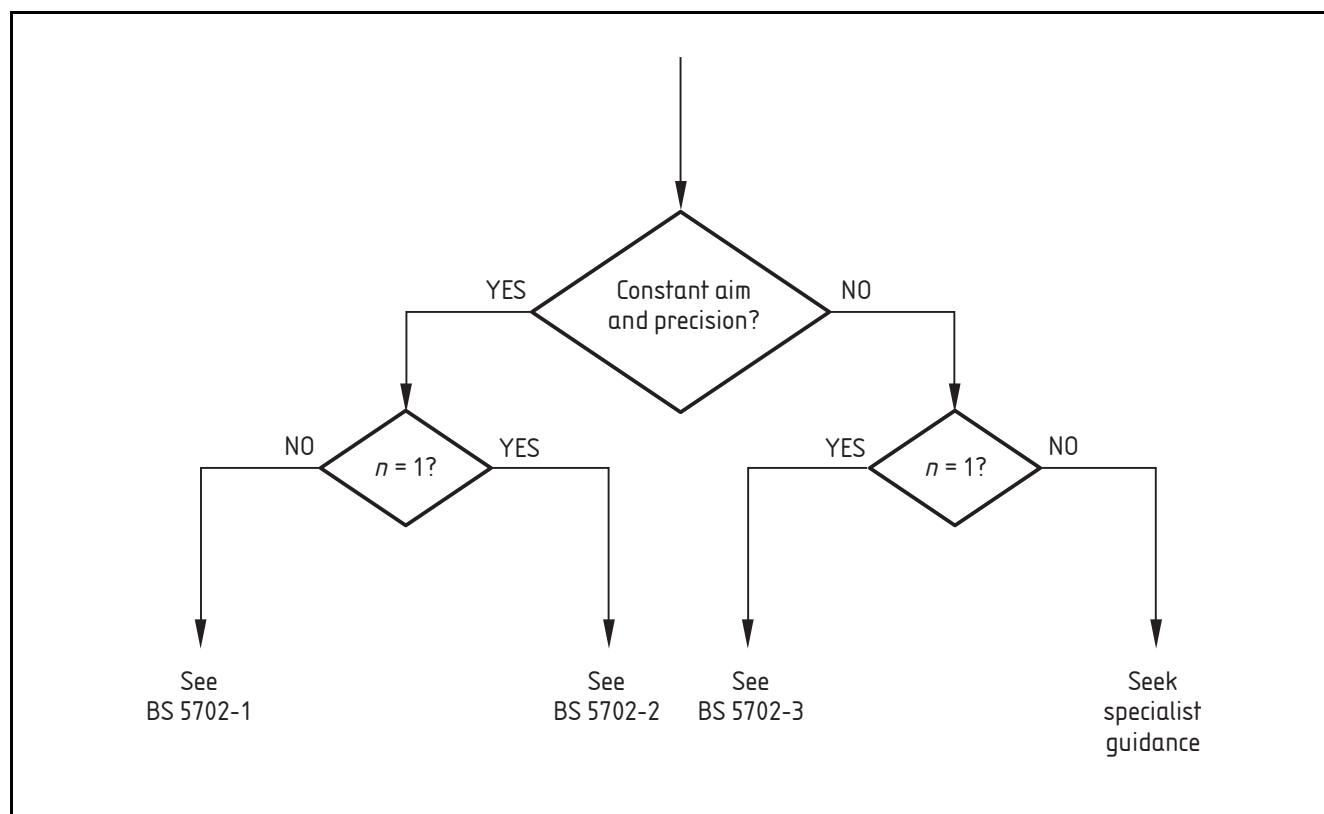
4.2 How to select the correct type of Shewhart control chart for measured data generally

The procedure for selecting a Shewhart-type measured data control chart is as follows:

- a) If the characteristic is ongoing with a targeted constant aim and precision, and the feasible sample size is greater than one, refer to BS 5702-1.
- b) If the characteristic is ongoing with a targeted constant aim and precision, and the sample size is limited to one, refer to BS 5702-2.
- c) If the characteristics or multiple-dimensioned items do not have a constant aim and/or precision, and the sample size is limited to one, see 4.3.
- d) If the characteristics or multiple-dimensioned items do not have a constant aim and/or precision and the feasible sample size is greater than one, specialist guidance should be sought.

This selection procedure is illustrated in the flow chart of Figure 2.

Figure 2 Shewhart control chart selection flow chart for measured data



4.3 How to select the correct type of Shewhart control chart for short runs and small batches

There are a number of Shewhart-type control charts available for handling short-run and small batch situations where there are expected changes in aim and/or precision. These include the following:

- Variable aim, individual and moving range charts.
- Variable aim, moving mean and moving range charts.
- Universal, moving mean and moving range charts.
- Universal, individual and moving range charts.

The procedure for selecting the appropriate control chart is illustrated in the flow chart of Figure 3.