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Control charts —

Part 8:
Charting techniques for short runs and small mixed batches

Cartes de contrôle —

Partie 8: Techniques de cartes pour petites séries et pour petits lots combinés

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 4, *Applications of statistical methods in product and process management.*

A list of parts in the ISO 7870 series can be found on the ISO website.

Introduction

It is generally recommended 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 variables 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 (for instance, a diameter) or a process parameter (for instance, 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, and so on, 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 control 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, for instance, 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 standard 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; for instance, the high speed stamping operation that may run only for a short period. It is frequently not practicable, in either case, to generate enough subgroups to make the control chart meaningful.

The opportunity arises because much current statistical *process* control is actually statistical *product* control, that is, SPC implementation is often product-focused rather than process-focused. Different products that 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, the 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 (for instance, machine tools) could make good candidates for the application of short run SPC.

Some basic statistical concepts, terminology and symbols are introduced in this document; 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 document readily comprehensible to the extensive range of prospective users and too facilitate widespread communication and understanding of the method.

It is advisable that those who are not familiar with the control chart technique read both ISO 7870-1 and ISO 7870-2 before reading this document.

Control charts —

Part 8:
Charting techniques for short runs and small mixed batches

1 Scope

This document describes ways of applying regular variables control 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-focused 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.

NOTE 1 The terms short run and small batch size are not well defined. Here, short run and small batch size are taken to mean only a few items are manufactured before a different item is then produced.

NOTE 2 For situations where the subgroup size is larger than one, other standards apply.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3534-2 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Symbols

C_L centre line of a control chart

L_{CL} L_{CL_x}, $L_{CL_{\bar{x}}}$ and L_{CL_R} are the lower control limits for individuals, mean and range, respectively

T target (aim) value

n subgroup size

R the difference between the maximum and minimum of the values

R_{exp} the expected value of the range of a particular characteristic

R_{moving} moving range, the difference between the maximum and minimum of the consecutive values

S process standard deviation

s realized value of the process standard deviation

u test statistic for set-up acceptance

U_{CL} U_{CL_x}, $U_{CL_{\bar{x}}}$ and U_{CL_R} are the upper control limits for individuals, mean and range, respectively

$\bar{X}$ general value of a quality characteristic of the process mean

$\bar{x}$ realized value of a quality characteristic of the process mean

4 How to select the correct type of Shewhart control chart for continuous variables 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 three main classes of control charts: Shewhart, cumulative sum (cusum) and exponentially weighted moving average (EWMA).

NOTE Cusum control charts are dealt with in ISO 7870-4 and EWMA in ISO 7870-6.

The Shewhart control chart provides a graphical representation of a process showing plotted values of a representative statistic of a selected characteristic (for instance, the 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 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 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 to be monitored is ongoing with a targeted constant aim and process spread, refer to ISO 7870-2.

b) If the characteristics do not have a constant aim or process spread, and the sample size is limited to one, see 4.3.

c) If the characteristics do not have a constant aim or process spread and the feasible sample size is greater than one, specialist guidance should be sought.

This selection procedure is illustrated in Figure 1.

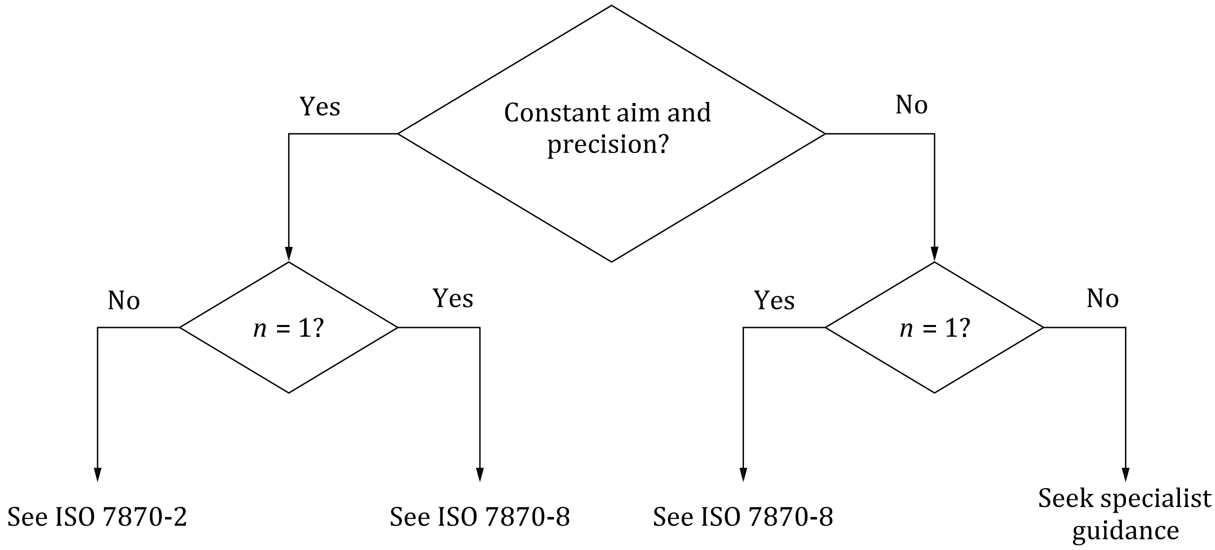

Figure 1 — Shewhart control chart selection flow chart for “measured” data

4.3 How to select the Shewhart control chart when the characteristic does not have a constant aim or process spread

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 or process spread. These include the following:

a) not constant aim, individual and moving range charts;

b) not constant aim, moving mean and moving range charts;

c) universal, moving mean and moving range charts;

d) universal, individual and moving range charts.

The procedure for selecting the appropriate control chart is illustrated in Figure 2.

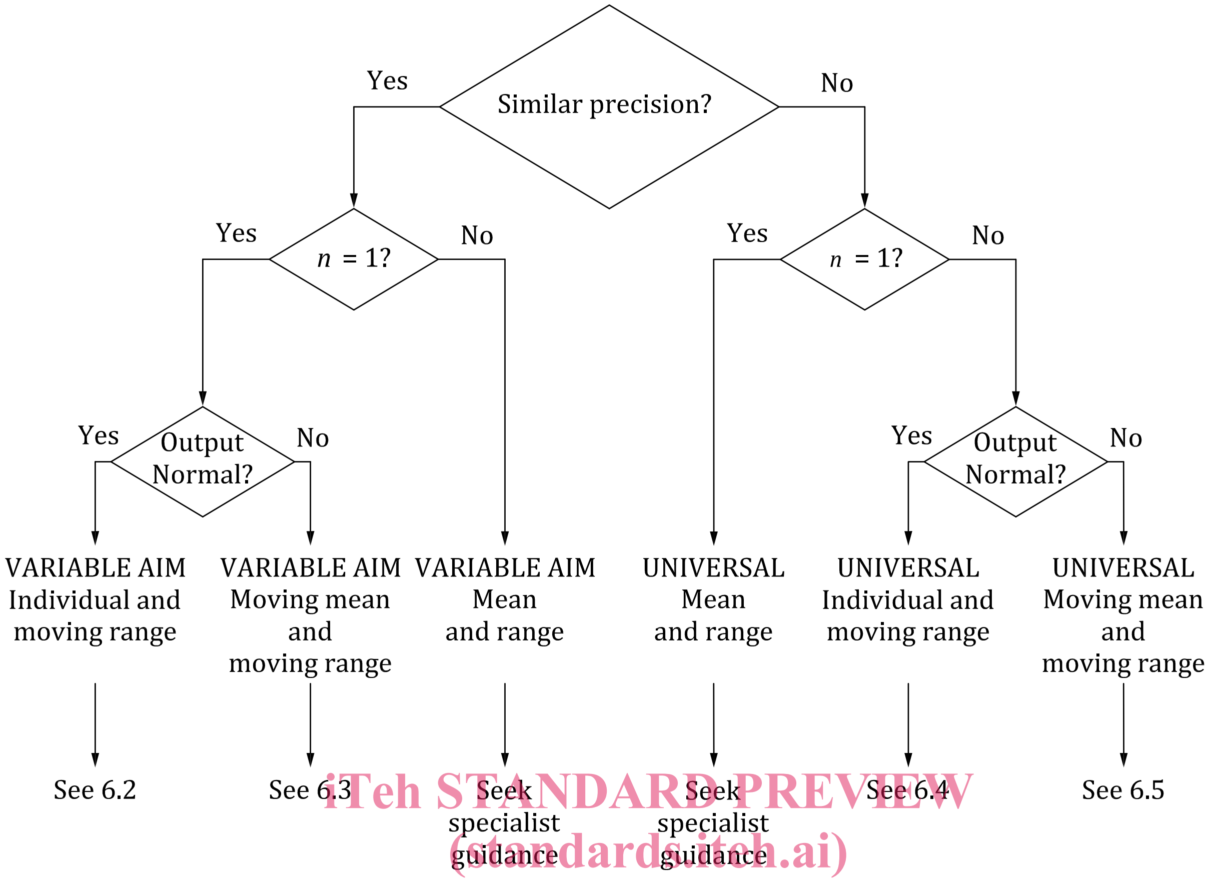

Figure 2 — Control chart selection flow chart for short runs and small batches

Table 1 assists in the interpretation of Figure 2.

Table 1 — Chart selection table for short runs and small batches (subgroup size, *n* = 1)

Parameter or characteristic	Process aim	Process spread	Output	Chart name	Clause reference	*Additional information: Result required*
Single	Dissimilar	Similar	Normal	Variable aim, individual and moving range	6.2	*Quick response to change*
Single	Dissimilar	Similar	Approximately normal	Variable aim, moving mean and moving range	6.3	*Detect trend; smooth data*
Multiple	Dissimilar	Dissimilar	Approximately normal	Universal, individual and moving range	6.4	*Quick response to change*
Multiple	Dissimilar	Dissimilar	Non-normal	Universal, moving mean and moving range	6.5	*Detect trend; smooth data*

5 How to prepare for short run, small mixed batch control charting

5.1 Focus on the process

Shewhart-styled control charts are usually applied to high volume long run products. One of the consequences of this is that SPC often focuses on statistical product control rather than the indicated statistical process control. This is because process results that are after-the-event product characteristics are frequently monitored and concentrated on rather than the process parameters giving rise to them.

Short run and small batch processes typify the flexible strategy essential to meet world class levels of performance. The key to successful short run and small mixed batch statistical process control is to focus on the process rather than the product. While nominal product characteristics necessarily change in both type and size, the process generating the product frequently stays the same, for instance:

a) the same drilling process produces different diameter and depth holes where the nominal values are not the same;

b) the same heading machine produces bolts with various nominal size heads, lengths and diameters;

c) the same press produces stampings with various nominal slot widths;

d) the same mixing process produces different solutions with different chemical elements and target ratios;

e) the same extruder extrudes tubes with different nominal outer and inner diameters and wall thicknesses;

f) the same coiner produces blanks in multiple cavity dies;

g) the same soldering operation produces small batch size printed circuit board assemblies with different nominal solder strengths per board.

NOTE The examples given relate to engineering processes.

SPC techniques are applicable to any short run or small batch process that is in any way repetitive. Process knowledge transfer is feasible from one run or batch to another. SPC techniques provide the means to transform a succession of short run product data into meaningful information in terms of a single long term process. It achieves this by combining multiple product characteristics involving dissimilar nominal sizes and units of measure, unlike characteristics and of different process spread, into a single, process-based, Shewhart control chart.

Short run SPC usually provides a more informative, effective and efficient alternative to traditional methods, for example:

— 100 % final inspection that is an expensive and after-the-event activity;

— first-off inspection based on a single measurement that provides limited set-up information and does not take into account process changes over time;

— last-off inspection, that is a high-risk strategy, taken after the event, that provides too little information and, too late.

If a separate control chart is produced for each feature and nominal dimension, it is not cost effective and is administratively cumbersome to operate. This will lead to an excessive number of charts being produced and often with too few data points to properly interpret them with no benefit.

5.2 Procedure for grouping similar processes

To effectively group characteristics, a procedure is required that prevents that data coming from significantly different processes to be monitored by the same control chart. If the systematic influences are unknown and not compensated for, the unintended consequences are that two or more stable processes create frequent false alarms when monitored in the same chart.

A procedure that combines expert knowledge and data analysis to create groups and adjust them if needed is given in Figure 3.

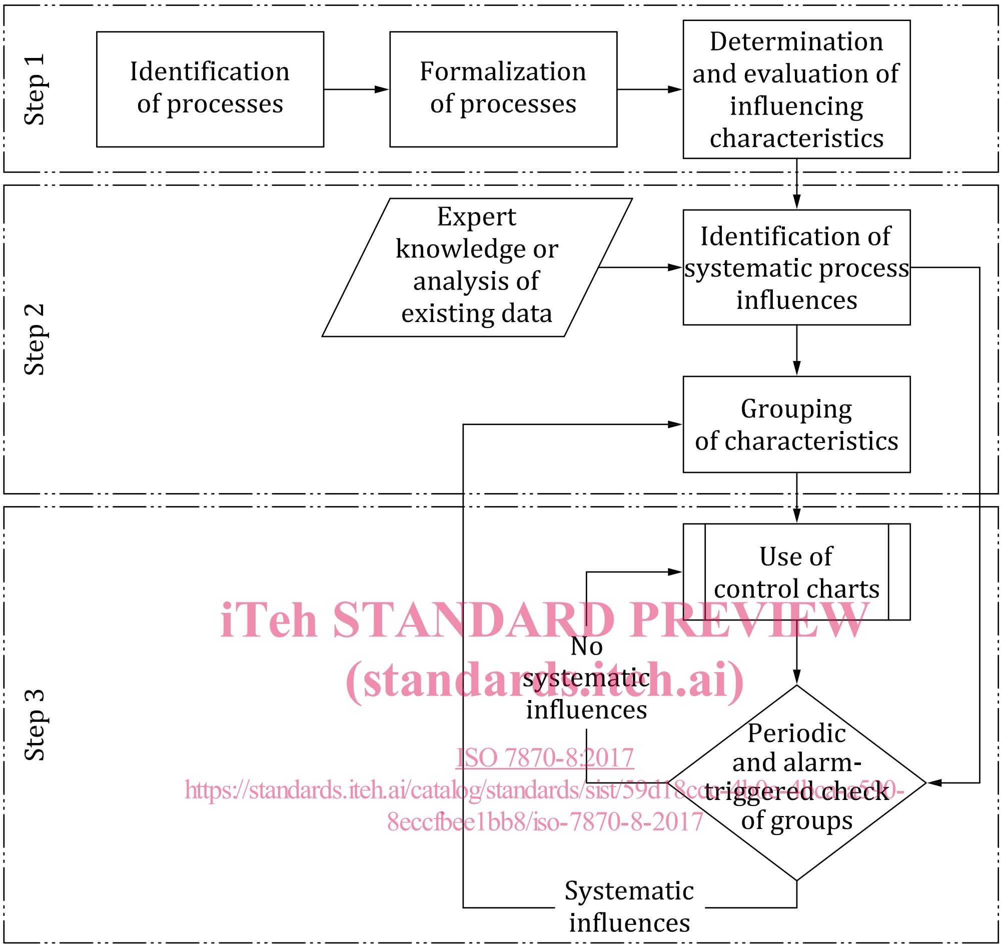

Figure 3 — Procedure for identifying and grouping similar characteristics

a) **Step 1**: First, processes that are potentially "groupable" need to be identified. This can be different processes that follow the same procedure but with varying characteristics, such as nominal/target value, tolerance, material, measurement process, production machine, tool, environmental conditions, etc. Characteristics that vary between processes are plotted in a cause-effect diagram along with their respective parameter space (Figure 4).

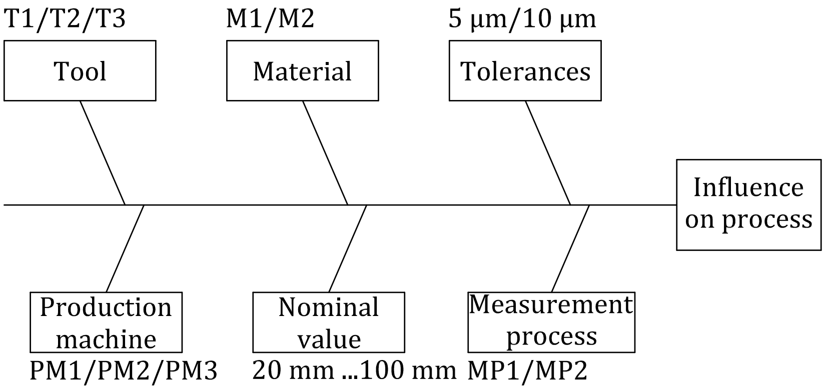

Figure 4 — Cause and effect diagram to establish differences between similar processes