INTERNATIONAL STANDARD

ISO 7870-2

First edition
2013-04-01

Control charts —

Part 2:
Shewhart control charts

Cartes de contrôle —

Partie 2: Cartes de contrôle de Shewhart

Reference number
ISO 7870-2:2013(E)

Contents

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 7870-2 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 4, *Applications of statistical methods in process management*.

This first edition cancels and replaces ISO 8258:1991, which has been technically revised.

ISO 7870 consists of the following parts, under the general title Control charts:

— *Part 1: General guidelines*

— *Part 2: Shewhart control charts*

— *Part 3: Acceptance control charts*

— *Part 4: Cumulative sum charts*

— *Part 5: Specialized control charts*

EWMA control charts will from the subject of a future Part 6.

Introduction

A traditional approach to manufacturing has been to depend on production to make the product and on quality control to inspect the final product and screen out items not meeting specifications. This strategy of detection is often wasteful and uneconomical because it involves after-the-event inspection when the wasteful production has already occurred. Instead, it is much more effective to institute a strategy of prevention to avoid waste by not producing unusable output in the first place. This can be accomplished by gathering process information and analysing it so that timely action can be taken on the process itself.

Dr. Walter Shewhart in 1924 proposed the control chart as a graphical means of applying the statistical principles of significance to the control of a process. Control chart theory recognizes two kinds of variability. The first kind is random variability due to “chance causes” (also known as “common/*natural/random/inherent/uncontrollable* causes”). This is due to the wide variety of causes that are consistently present and not readily identifiable, each of which constitutes a very small component of the total variability but none of which contributes any significant amount. Nevertheless, the sum of the contributions of all of these unidentifiable random causes is measurable and is assumed to be inherent to the process. The elimination or correction of common causes may well require a decision to allocate resources to fundamentally change the process and system.

The second kind of variability represents a real change in the process. Such a change can be attributed to some identifiable causes that are not an inherent part of the process and which can, at least theoretically, be eliminated. These identifiable causes are referred to as “assignable causes” *(also known as special/unnatural/systematic/controllable causes*) of variation. They may be attributable to such matters as the lack of uniformity in material, a broken tool, workmanship or procedures, the irregular performance of equipment, or environmental changes.

A process is said to be in statistical control, or simply “in control”, when the process variability results only from random causes. Once this level of variation is determined, any deviation from this level is assumed to be the result of assignable causes that should be identified and eliminated.

Statistical process control is a methodology for establishing and maintaining a process at an acceptable and stable level so as to ensure conformity of products and services to specified requirements. The major statistical tool used to do this is the control chart, which is a graphical method of presenting and comparing information based on a sequence of observations representing the current state of a process against limits established after consideration of inherent process variability called process capability. The control chart method helps first to evaluate whether or not a process has attained, or continues in, a state of statistical control. When in such a state the process is deemed to be stable and predictable and further analysis as to the ability of the process to satisfy the requirements of the customer can then be conducted. The control chart also can be used to provide a continuous record of a quality characteristic of the process output while process activity is ongoing. Control charts aid in the detection of unnatural patterns of variation in data resulting from repetitive processes and provide criteria for detecting a lack of statistical control. The use of a control chart and its careful analysis leads to a better understanding of the process and will often result in the identification of ways to make valuable improvements.

Control charts —

Part 2:
Shewhart control charts

1 Scope

This International Standard establishes a guide to the use and understanding of the Shewhart control chart approach to the methods for statistical control of a process.

This International Standard is limited to the treatment of statistical process control methods using only the Shewhart system of charts. Some supplementary material that is consistent with the Shewhart approach, such as the use of warning limits, analysis of trend patterns and process capability is briefly introduced. There are, however, several other types of control chart procedures, a general description of which can be found in ISO 7870-1.

2 Normative references

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

ISO 3534-2, *Statistics — Vocabulary and symbols — Part 2: Applied statistics*

ISO 16269-4, *Statistical interpretation of data — Part 4: Detection and treatment of outliers*

ISO 5479, *Statistical interpretation of data — Tests for departure from the normal distribution*

ISO 22514 (all parts), *Statistical methods in process management — Capability and performance*

3 Terms, definitions and symbols

3.1 General

For the purposes of this document, the terms and definitions given in ISO 3534-2:2006 apply.

3.2 Symbols

NOTE The ISO/IEC Directives makes it necessary to depart from common SPC usage in respect to the differentiation between abbreviated terms and symbols. In ISO standards an abbreviated term and its symbol can differ in appearance in two ways: by font and by layout. To distinguish between abbreviated terms and symbols, abbreviated terms are given in Cambria upright and symbols in Cambria or Greek italics, as applicable. Whereas abbreviated terms can contain multiple letters, symbols consist only of a single letter. For example, the conventional abbreviation of upper control limit, UCL, is valid but its symbol in equations becomes U_{CL}. The reason for this is to avoid misinterpretation of compound letters as an indication of multiplication.

In cases of long established practice where a symbol and/or abbreviated term means different things in different applications, it is necessary to use a field limiter, thus ⟨ ⟩, to distinguish between them. This avoids the alienation of practitioners by the creation of unfamiliar abbreviated terms and symbols in their particular field that are unlike all related texts, operational manuals and dedicated software programs. An example is the abbreviated term 'R' and symbol '*R*' which means different things in metrology from that in acceptance sampling and statistical process control. The abbreviated term 'R' is differentiated thus:

R ⟨metrology⟩ reproducibility limit

R ⟨SPC and acceptance sampling⟩ range

For the purposes of this document, the following symbols apply.

n Subgroup size; the number of sample observations per subgroup

k Number of subgroups

L Lower specification limit

L_{CL} Lower control limit

U Upper specification limit

U_{CL} Upper control limit

X Measured quality characteristic (individual values are expressed as (X_1, X_2, X_3,...). Sometimes the symbol Y is used instead of X

$\bar{X}$ (X bar) Subgroup average

$\bar{\bar{X}}$ (X double bar) Average of the subgroup averages

μ True process mean value

σ True process standard deviation value

σ_0 A given value of σ

$\tilde{X}$ Median of a subgroup

$\bar{\tilde{X}}$ Average of the subgroup medians

R Subgroup range: difference between the largest observation and smallest observation of a subgroup

$\bar{R}$ Average of the R values for all subgroups

R_m Moving range: the absolute value of the difference between two successive values $|X_1 - X_2|$,$|X_2 - X_3|$, etc.

$\bar{R}_m$ Average of the $(n - 1)$ R_m values in a set of n observed values

s Sample standard deviation obtained from values within a subgroup:

$$s = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n-1}}$$

$\bar{s}$ Average of the subgroup sample standard deviations

$\hat{\sigma}$ Estimated process standard deviation value

p Proportion or fraction of units in a subgroup with a given classification

$\bar{p}$ Average value of the proportion or fraction

np Number of units with a given classification in a subgroup

p_0 A given value of p

np_0 A given value of np (for a given p_0)

c Number of incidences in a subgroup

c_0 A given value of c

$\bar{c}$ Average value of the c values for all subgroups

u Number of incidences per unit in a subgroup

$\bar{u}$ Average value of the u values

u_0 A given value of u

4 Nature of Shewhart control charts

A Shewhart control chart is a graph that is used to display a statistical measure obtained from either variables or attribute data. The control chart requires data from rational subgroups to be taken at approximately regular intervals from the process. The intervals may be defined in terms of time (for example hourly) or quantity (every lot). Usually, the data are obtained from the process in the form of samples or subgroups consisting of the same process characteristic, product or service with the same measurable units and the same subgroup size. From each subgroup, one or more subgroup characteristics are derived, such as the subgroup average, $\bar{X}$, and the subgroup range, R, the standard deviation, s, or a countable characteristic such as the proportion of units with a given classification.

A Shewhart control chart is a plot of the values of a given subgroup characteristic versus the subgroup number. It consists of a centre line (CL) located at a reference value of the plotted characteristic. In establishing whether or not a state of statistical control exists, the reference value is usually the average of the statistical measure being considered. For process control, the reference value may be the long-term value of the characteristic as stated in the product specifications; a value of the characteristic being plotted based on past experience with the process when in a state of statistical control, or based upon implied product or service target values.

The control chart has two statistically determined limit lines, one on either side of the centre line, which are called the upper control limit (U_{CL}) and the lower control limit (L_{CL}) (see Figure 1).

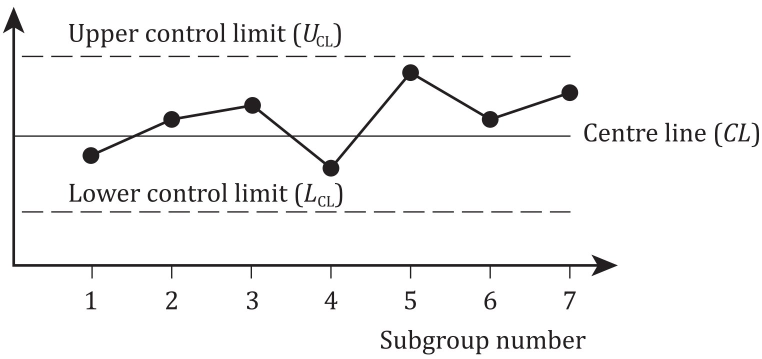

Figure 1 — Outline of a control chart

The control limits on the Shewhart charts are placed at a distance of 3 sigma on each side of the centre line, where sigma is the known or estimated standard deviation of the population. Shewhart chose to use 3 sigma limits on the basis that it made economic sense with respect to balancing the cost of looking for process problems when such problems do not exist and failing to look for problems when the process is not performing as it should. Placing the limits too close to the centre line will result in many searches for non-existing problems and yet placing the limits too far apart will increase the risk of not detecting process problems when they do exist. Under an assumption that the plotting statistic is approximately normally distributed 3 sigma limits indicate that approximately 99,7 % of the values of the statistic will be included within the control limits, provided the process is in statistical control. Interpreted another way, there is approximately a 0,3 % risk, or an average of three times in a thousand, of a plotted point being outside of either the upper or lower control limit when the process is in control. The word “approximately” is used because deviations from underlying assumptions such as the distributional form of the data will affect the probability values. In fact, the choice of *k* sigma limits instead of 3 sigma limits depends on costs of investigation and taking appropriate action *vis-à-vis* consequences of not taking action.

It should be noted that some practitioners prefer to use the factor 3,09 instead of 3 to provide a nominal probability value of 0,2 % or an average of one spurious observation per thousand, but Shewhart selected 3 so as not to lead to attempts to consider exact probabilities. Similarly, some practitioners use actual probability values for the charts based on non-normal distributions such as for ranges and fraction nonconforming. Again, the Shewhart control chart used ±3 sigma limits in view of the emphasis on empirical interpretation.

The possibility that a violation of the limits is really a chance event rather than a real signal is considered so small that when a point appears outside of the limits, action should be taken. Since action is required at this point, the 3 sigma control limits are sometimes called the “action limits”.

Many times it is advantageous to mark 2 sigma limits on the chart also. Then, any sample value falling beyond the 2 sigma limits can serve as a warning of an impending out-of-control situation. As such, the 2 sigma limit lines are sometimes called “warning limits”. While no action is required as a result of such a warning been given on the control chart, some users may wish to immediately select another subgroup of the same size to determine if corrective action is indicated.

When assessing the status of a process using control charts, two types of errors are possible. The first occurs when the process involved is actually in a state of control but a plotted point falls outside the control limits due to chance. As a result, the chart has given a signal resulting in an incorrect conclusion that the process is out of control. A cost is then incurred in an attempt to find the cause of a non-existent problem.

The second error occurs when the process involved is not in control but the plotted point falls within the control limits due to chance. In this case, the chart provides no signal and it is incorrectly concluded that the process is in statistical control. There may also be a substantial cost associated with failing to detect that a change in the process location or variability has occurred, the result of which might be the production of nonconforming output. The risk of this type of error occurring is a function of three things: the width of the control limits, the sample size, and the degree to which the process is out of control. In general, because the magnitude of the change in the process cannot be known, little can be determined about the actual size of the risk of this error.

Because it is generally impractical to make a meaningful estimate of the risk and of the cost of the second type of error in any given situation, the Shewhart control chart system is designed to control the first of these errors. When normality is assumed and 3 sigma control limits are used, the size of this first error is 0,3 %. In other words, this error will happen only about 3 times in 1 000 samples when the process is in control.

In fact the choice of *k* sigma limits instead of 3 sigma limits depends on costs of investigation and taking appropriate action *vis-à-vis* consequences of not taking action.

When a process is in statistical control, the control chart provides a method, which in some senses is analogous to continually testing a statistical null hypothesis that the process has not changed and remains in statistical control. Because, in Phase 1, there is often uncertainty about such matters as the probability distribution of the characteristic of interest, randomness, and the specific departures of the process characteristic from the target value that may be of concern are not usually defined in advance, the Shewhart control chart should not be considered to be a test of hypothesis in the purest sense. Walter Shewhart emphasized the empirical usefulness of the control chart for recognizing departures from an “in-control” process and de-emphasized making probabilistic interpretations.

When a plotted value falls outside of either control limit, or a series of values display an unusual pattern such as discussed in Clause 8, the state of statistical control can no longer be accepted. When this occurs, an investigation is initiated to locate the assignable cause, and the process may be stopped or adjusted. Once the assignable cause is determined and eliminated, the process is ready to continue. As discussed above, on rare occasions no assignable cause can be found and it must be concluded that the point outside the limits represents the occurrence of a very rare event, a random cause, which has resulted in a value outside of the control limits even though the process is in control.

When a process is to be studied for the first time with the objective of bringing the process into a state of statistical control, it is often found necessary to use historical data that has previously been obtained from the process or to undertake to obtain new data from a series of samples before attempting to establish the control chart. This retrospective stage during which the control chart parameters are being established is often referred to as Phase 1. Sufficient data will need to be found in order to obtain reliable estimates of the centre line and control limits for the control charts. The control limits established in Phase 1 are trial control limits as they are based upon data collected when the process may not be in control. The identification of the precise causes for signals given by the control chart at this stage may prove to be difficult because of the lack of information about the historical operating characteristics of the process. However, when special causes of variation can be identified and corrective action taken, the retrospective data from the process when under the influence of the special cause should be removed from consideration and the control chart parameters re-determined. This iterative procedure is continued until the trial control chart shows no signals and the process may then be considered to be in control and hence is stable and predictable. Because some data may have to be removed from consideration during Phase 1, the user may have to obtain additional data from the process to maintain the reliability of the parameter estimates.

Once statistical control has been established, the final trial control chart centre line and control limits identified in Phase 1 are taken as the control chart parameters for the ongoing monitoring of the process. The objective now, in what is referred to as Phase 2, is the maintenance of the process in a state of control as well as the rapid identification of special causes that may affect the process from time to time. It should be recognized that moving from Phase 1 to Phase 2 might prove to be both time consuming and difficult. It is crucial, however, since the failure to remove special causes of variation will result in the process variation being overestimated. In this case the control chart will have control limits that are set too wide apart resulting in a control chart that is not sufficiently sensitive for detecting the presence of special causes.

Details for the procedure to establish control charts for a process will be discussed below.

5 Types of control charts

Shewhart control charts are basically of two types: variables control charts and attributes control charts. For each of the control charts, there are two distinct situations:

a) when no pre-specified process parameter values are given;

b) when pre-specified process parameters values are given.

The pre-specified process values may be specified requirements or target values, or estimated values of the parameters that have been determined over the long term from data when the process is in control.

5.1 Control charts where no pre-specified values are given

The purpose here is to discover whether observed values of the plotted characteristics, such as $\overline{X}$, R or any other statistic, vary among themselves by an amount greater than that which can be attributed to chance alone. Control charts will be constructed using only the data collected from samples from the process. The control charts are used for detecting those variations caused other than by chance with the purpose being to bring the process into a state of statistical control.

5.2 Control charts with respect to given pre-specified values

The purpose here is to identify whether the observed values of $\overline{X}$, s, etc., for several subgroups of n observations each, differ from the respective given values of μ_0, σ_0, etc. by amounts greater than that expected to be due to chance causes only. The difference between charts with given parameter values and those where no pre-specified values are given is the additional requirement concerning the determination of the location of the centre and variation of the process. The specified values may be based on experience obtained by using control charts with no prior information or specified values. They may also be based on economic values established upon consideration of the need for service and cost of production or be nominal values designated by the product specifications.

Preferably, the specified values should be determined through an investigation of preliminary data that is supposed to be typical of all future data. The specified values should be compatible with the inherent process variability for effective functioning of the control charts. Control charts based on such pre-specified values are used particularly during process operation to control processes and to maintain product or service uniformity at the desired level.

5.3 Types of variables and attributes control charts

The following control charts are considered:

a) Variables control charts, used when the measurements are on a continuous scale:

   1) average ($\overline{X}$) chart and range (R) or standard deviation (s) chart;

   2) individuals (X) and moving range (R_m);

   3) median ($\tilde{X}$) chart and range (R) chart.

b) Attributes control charts, used when the measurements are countable or categorized data:

   1) p chart for number of units of a given classification per total number of units in the sample expressed as a proportion or percentage;

   2) np chart for number of units of a given classification where the sample size is constant;

   3) c chart for number of incidences where the opportunity for occurrence is fixed;

   4) u chart for the number of incidences per unit where the opportunity is variable.

Figure 2 shows a process of selecting an appropriate control chart for a given situation.

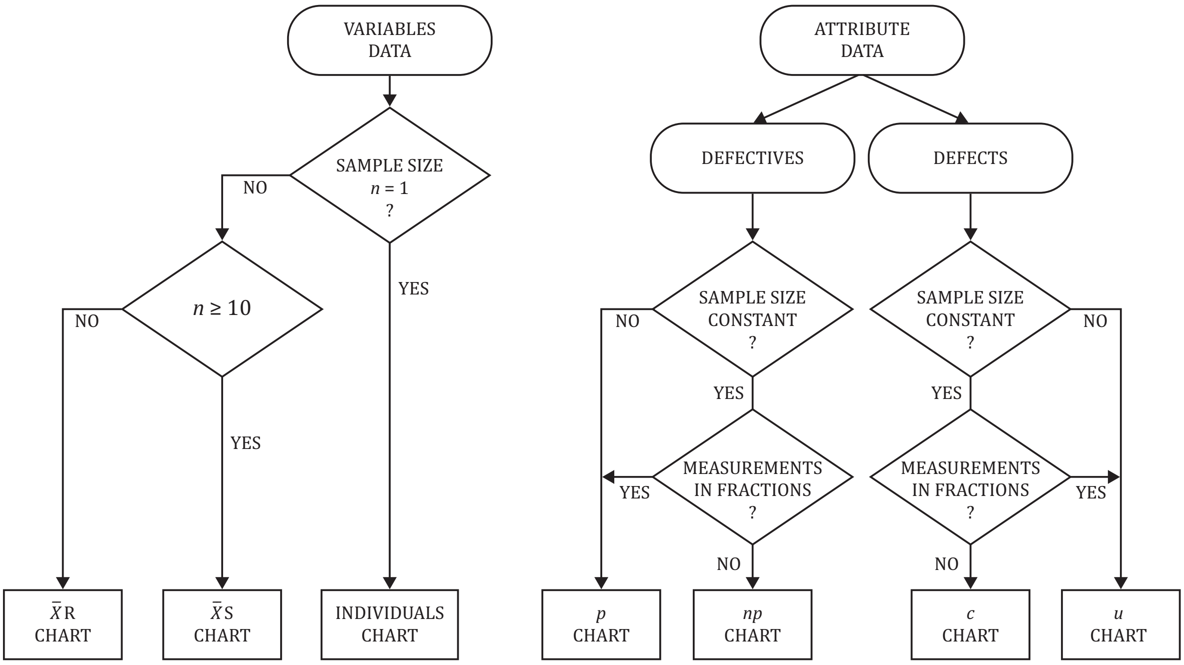

Figure 2 — Types of control charts

6 Variables control charts

Variables control charts, or charts for variables data, and especially their most customary forms, the $\bar{X}$ and R charts represent the classic application of control charting to process control.

Control charts for variables are particularly useful for several reasons:

a) Most processes, and their output, have characteristics that are measurable, hence generate variables data, so the potential applicability is broad.

b) Variables charts are more informative than attributes charts since specific information about the process mean and variance are obtained directly. Variables charts will often signal a process problem before the process has produced nonconforming items.

c) Although obtaining one item of measured data is generally more costly than obtaining one item of go/no go data, the subgroup sizes needed for variables are almost always much smaller than those for attributes, for an equivalent monitoring efficiency. This helps to reduce the total inspection cost in some cases and to shorten the time gap between the occurrence of a process problem and corrective action.

d) These charts will provide visual means to directly assess process performance regardless of the specifications. A close look at variables charts, along with review of histograms at appropriate intervals, will often lead to ideas or suggestions as to how to improve the process.

For all variables control chart applications considered in this International Standard, it is assumed that the distribution of the quality characteristic is normal (Gaussian) and departures from this assumption will affect the performance of the charts. The factors used for computing control limits were derived using the assumption of normality. Since most control limits are used as empirical guides in making decisions, reasonably small departures from normality should not cause concern. In any case, because of the central limit theorem, averages tend to be normally distributed even when individual observations are not; this makes it reasonable for evaluating control to assume normality for $\bar{X}$ charts, even for sample sizes as small as 4 or 5. When dealing with individual observations for capability study purposes, the true form of the distribution is important. Periodic checks on the continuing validity of such assumptions are advisable, particularly for ensuring that only data from a single population are being used. It should be noted that the distributions of the ranges and standard deviations are not normal. Although normality is necessarily assumed in the determination of the constants for the calculation of control limits for the range or standard deviation chart, moderate deviations from normality of the process data should not be of major concern in the use of these charts as an empirical decision procedure.

Variables charts can describe process data in terms of both spread (process variability) and location (process average). Because of this, control charts for variables are almost always prepared and analysed in pairs – one chart for location and another for spread. The chart for spread is usually analysed first, since it provides the rationale and justification for the estimation of the process standard deviation. The resulting estimate of the process standard deviation may then be used in establishing control limits for the chart for location.

Each chart can be plotted using either estimated control limits, in which case limits are based on the information contained in the sample data plotted on the chart, or pre-specified control limits based on adopted specified values applicable to the statistical measures plotted on the chart. The subscript "0" is used in Tables 1 and 3 to designate the specified values, such as μ_0 for the specified process mean or σ_0 for the specified process standard deviation.

Following are the most commonly used variables control charts.

6.1 Mean ($\bar{X}$) chart and range (R) chart or mean ($\bar{X}$) chart and standard deviation (s) chart

$\bar{X}$ and R charts can be used when subgroup sample size is small or moderately small, usually less than 10. $\bar{X}$ and s charts are preferable particularly in the case of large subgroup sample sizes ($n \geq 10$), since the range becomes increasingly less efficient at estimating the process standard deviation as the sample size gets larger. Where electronic devices are available to calculate process limits, standard deviation is preferable.

Tables 1 and 2 give the control limit formulae and the factors for each of these variables control charts.

Table 1 — Control limit formulae for Shewhart variables control charts

Statistic	Estimated control limits		Pre-specified control limits	
	Centre line	U_{CL} and L_{CL}	Centre line	U_{CL} and L_{CL}
$\bar{X}$	X	$\bar{\bar{X}} \pm A_2\bar{R}$ or $\bar{\bar{X}} \pm A_3\bar{s}$	μ_0	$\mu_0 \pm A\sigma_0$
R	$\bar{R}$	$D_4\bar{R}, D_3\bar{R}$	$d_2\sigma_0$	$D_2\sigma_0, D_1\sigma_0$
s	$\bar{s}$	$B_4\bar{s}, B_3\bar{s}$	$c_4\sigma_0$	$B_6\sigma_0, B_5\sigma_0$
NOTE μ_0 and σ_0 are pre-specified values.				

Table 2 — Factors for computing control chart lines

Observations in subgroups of size *n*	Factors for control limits											Factors for centre line	
	$\bar{X}$ Chart			*s* Chart				*R* Chart *				Using *s* *	Using *R* *
	A	A_2	A_3	B_3	B_4	B_5	B_6	D_1	D_2	D_3	D_4	c_4	d_2
2	2,121	1,880	2,659	–	3,267	–	2,606	–	3,686	–	3,267	0,7979	1,128
3	1,732	1,023	1,954	–	2,568	–	2,276	–	4,358	–	2,575	0,8862	1,693
4	1,500	0,729	1,628	–	2,266	–	2,088	–	4,698	–	2,282	0,9213	2,059
5	1,342	0,577	1,427	–	2,089	–	1,964	–	4,918	–	2,114	0,9400	2,326
6	1,225	0,483	1,287	0,030	1,970	0,029	1,874	–	5,079	–	2,004	0,9515	2,534
7	1,134	0,419	1,182	0,118	1,882	0,113	1,806	0,205	5,204	0,076	1,924	0,9594	2,704
8	1,061	0,373	1,099	0,185	1,815	0,179	1,751	0,388	5,307	0,136	1,864	0,9650	2,847
9	1,000	0,337	1,032	0,239	1,761	0,232	1,707	0,547	5,394	0,184	1,816	0,9693	2,970
10	0,949	0,308	0,975	0,284	1,716	0,276	1,669	0,686	5,469	0,223	1,777	0,9727	3,078
11	0,905	0,285	0,927	0,321	1,679	0,313	1,637	0,811	5,535	0,256	1,744	0,9754	3,173
12	0,866	0,266	0,886	0,354	1,646	0,346	1,610	0,923	5,594	0,283	1,717	0,9776	3,258
13	0,832	0,249	0,850	0,382	1,618	0,374	1,585	1,025	5,647	0,307	1,693	0,9794	3,336
14	0,802	0,235	0,817	0,406	1,594	0,399	1,563	1,118	5,696	0,328	1,672	0,9810	3,407
15	0,775	0,223	0,789	0,428	1,572	0,421	1,544	1,203	5,740	0,347	1,653	0,9823	3,472
16	0,750	0,212	0,763	0,448	1,552	0,440	1,526	1,282	5,782	0,363	1,637	0,9835	3,532
17	0,728	0,203	0,739	0,466	1,534	0,458	1,511	1,356	5,820	0,378	1,622	0,9845	3,588
18	0,707	0,194	0,718	0,482	1,518	0,475	1,496	1,424	5,856	0,391	1,609	0,9854	3,640
19	0,688	0,187	0,698	0,497	1,503	0,490	1,483	1,489	5,889	0,404	1,596	0,9862	3,689
20	0,671	0,180	0,680	0,510	1,490	0,504	1,470	1,549	5,921	0,415	1,585	0,9869	3,735
21	0,655	0,173	0,663	0,523	1,477	0,516	1,459	1,606	5,951	0,425	1,575	0,9876	3,778
22	0,640	0,167	0,647	0,534	1,466	0,528	1,448	1,660	5,979	0,435	1,567	0,9882	3,819
23	0,626	0,162	0,633	0,545	1,455	0,539	1,438	1,711	6,006	0,443	1,557	0,9887	3,858
24	0,612	0,157	0,619	0,555	1,445	0,549	1,429	1,759	6,032	0,452	1,548	0,9892	3,895
25	0,600	0,153	0,606	0,565	1,435	0,559	1,420	1,805	6,056	0,459	1,541	0,9896	3,931

* Not recommended for sample size $n > 10$.

6.2 Control chart for individuals (X) and control chart for moving ranges (R_m)

In some process control situations, it is either impossible, impractical, or it does not make sense to select rational subgroups. It is then necessary to assess process control based on individual readings using X and R_m charts.

In the case of control charts for individuals, since there are no rational subgroups to provide an estimate of variability, control limits are based on a measure of variation obtained from moving ranges of two consecutive observations. A moving range is the absolute value of the difference between successive