

Guide to

Number-defective charts for quality control

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- Institute of Quality Assurance*
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- Ministry of Defence*
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- Chemical Industries Association
- Department of Industry (National Engineering Laboratory)
- Economist Intelligence Unit Limited
- Electronic Components Industry Federation
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- National Coal Board
- Post Office
- Royal Statistical Society
- University of Birmingham
- University of Essex

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Foreword

This revised standard includes within the one document all the guidance needed to prepare and use number-defective quality control charts. It incorporates material previously found only in BS 2564, and the necessary rewriting has enabled minor discrepancies between the two earlier standards, BS 1313 (now withdrawn) and BS 2564, to be removed. Although the charts suggested by the new standard will look familiar to past users of BS 1313, there are changes in the setting of control limits, and new and simpler warning limits are introduced. In addition a new measure of effectiveness for a control chart is introduced, namely, average run length before an indication of poor quality appears. These changes, however, do not affect the use of this standard as a guide to the preparation and use of traditional control charts for number-defective whilst they do allow comparison with other types of control chart such as cusum charts.

Other documents in the series are as follows:

BS 5700, *Guide to quality control chart methods*¹⁾.

BS 5702, *Guide to quality control charts for variables*¹⁾.

BS 5703, *Guide to data analysis and quality control using cusum techniques*¹⁾.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 24, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ In course of preparation.

0 Introduction

0.1 The term “quality control chart” denotes the use of charted results, obtained from samples taken routinely during the manufacture of a product, to aid the control of the process and hence to maintain a desired quality in the product. This replaces, wholly or in part, inspection after manufacture, which detects defective product only after it has been produced, possibly in large quantities. The modern method is to hold the required quality at each stage of the process so that the properties required to make a product acceptable are built into it during manufacture. Quality control charts may be broadly classified as “control charts for variables” or “control charts for number-defective”. The former are described in BS 5702²⁾ and the latter in this document.

0.2 Number-defective quality control charts are used for two groups of process inspection. The first is the obvious use, when the quality of a product is not measurable using ordinary methods employing measurement capable of a continuous range of variations.

Typical examples of use are in assembly, where an article or component is either right or wrong, present or not present; the production of articles such as storage tanks, which either leak or do not; and of articles such as ammunition, which either fires or does not. This group covers processes where articles of awkward or complicated shape are accepted or rejected after examination with an optical projector. It also covers visual examination of textiles, the production of internal screw threads, castings and the plating or finishing of surfaces, where examination can be by visual assessment as serviceable or not, or else by counting blowholes or surface defects per article or per unit area. There can be no argument as to the method of examination in such cases, for the number-defective method is the only one available.

0.3 The second group of examinations is where the number-defective method is used deliberately for processes, when the quality of the product can be assessed by measurement and when it would be possible to use other forms of control chart, such as charts for average and range.

Number-defective quality control charts are sometimes used in this way for the sake of simplicity, cheapness, or speed, but it should be noted that these advantages are gained at some expense of sensitivity.

Number-defective quality control charts are used in cases where examination could be by measurement, as for example in the following cases.

a) When the process is purely manual and contains little or no provision for adjustment. For example, consider the stamping out of blanks, discs, washers, etc., and the manufacture of cardboard tubes, to limits of, say, ± 0.25 mm, by rolling pasted sheets of paper round a former. Adjustment is possible by changing a tool, by using a greater length of paper to allow for a decrease in thickness of the paper and so on, but the adjustment is so radical that it amounts to a change in the process.

b) When multi-dimensional checking is necessary, especially on a process with high output. If an article to be inspected is complicated, involving a number of what are in themselves straightforward dimensions, measuring each dimension may absorb a prohibitive amount of time and labour while the charts would reach an excessive size.

c) When examination is by gauging, which is always far quicker than measuring. A given output can be covered, using number-defective methods, by fewer examiners than would be needed for other methods.

0.4 The quality control chart is an invaluable tool for those concerned with production, and those who have not yet used number-defective quality control charts are urged to make and use one as soon as possible; clause 4 describes how to do this.

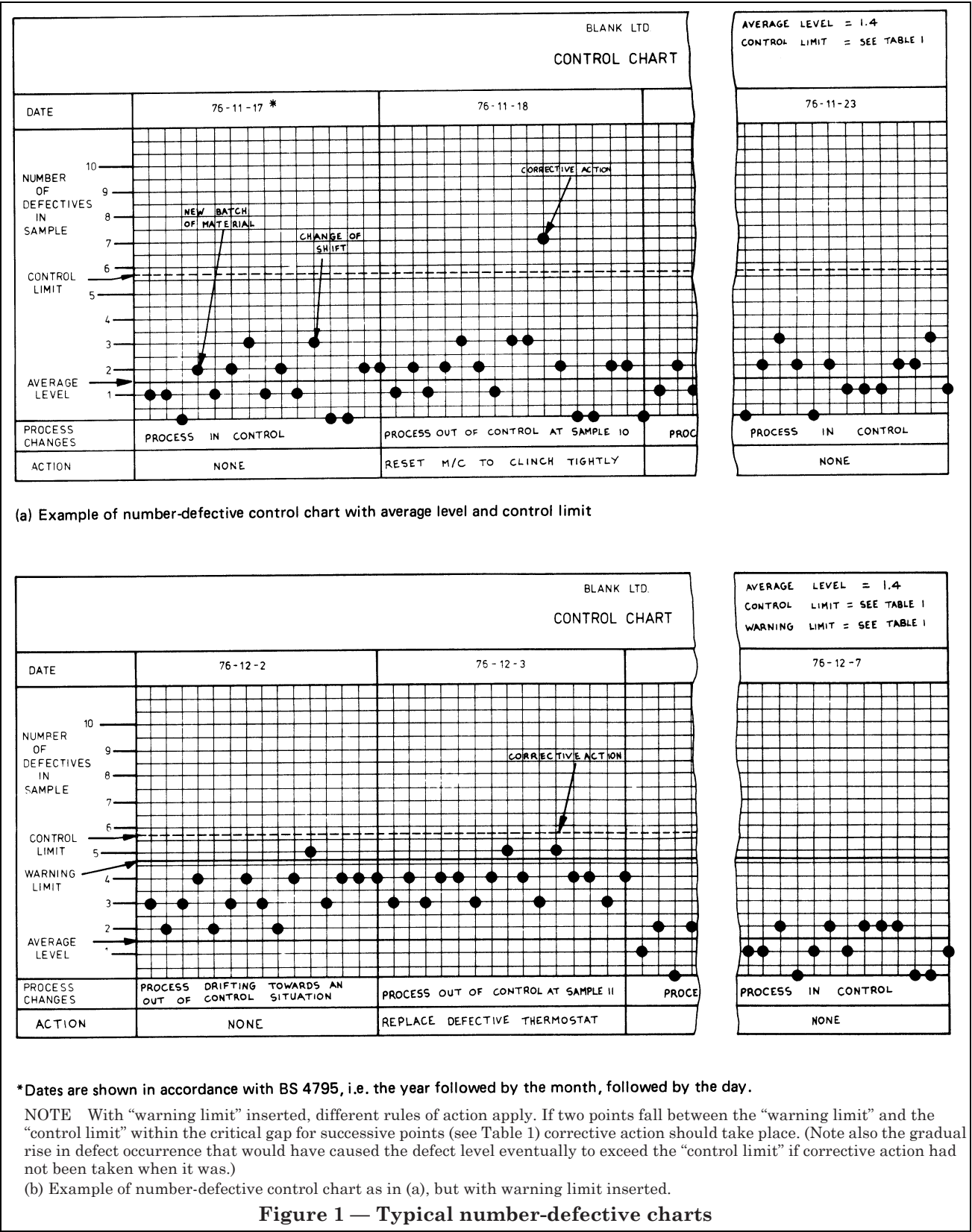
The guidance in clause 5 should be followed after this preliminary trial; it gives the information needed to extend the use of the charts to cover any process that is likely to be encountered.

Clause 6, whose purpose is to guide those who are reasonably adept in handling the usual form of number-defective quality control chart, mentions certain refinements to the general method given in clauses 4 and 5. It also describes efficient methods, developed from the forms of chart described in clauses 4 and 5, which may be used to reduce the sample sizes and the amount of inspection needed, and to hold a process at such a quality that defectives are virtually eliminated.

Clause 7 gives the necessary tables and also includes instruction sheets which contain fully worked examples.

The psychological effect of a control chart similar to Figure 1 provides a stimulus to improved quality which has to be experienced to be believed.

²⁾ In course of preparation.



It should be emphasized, however, that the quality control chart only “sounds an alarm” that attention to the process is required to avoid the continued production of defective product, or to prevent an unacceptable increase in the proportion of defective product in output. In order to secure the benefits of quality control, arrangements should be made to apply immediate corrective action to the process, whenever the control chart shows that quality has deteriorated.

1 Scope and field of application

This British Standard describes the simplest method of statistical quality control, i.e. by examination for the number of defectives in samples taken from a process that produces individual or discrete units of product rather than a bulk commodity or continuous material.

This standard sets out accepted methods of charting which are easy to use, and which may safely and profitably replace 100 % inspection or routine examination.

No attempt is made to deal at length with the statistical principles underlying these methods, the object being to show how to use them.

It should be stressed that these methods may be employed far more widely than merely for the examination of dimensions. They are applicable whenever the quality of work done can be assessed by classifying it as right or wrong. The methods have been used, with complete success, for unusual processes, such as making up packages at large mail-order stores and stores depots, in addition to the more usual manufacturing processes.

2 References

The titles of the publications referred to in this standard are listed on the inside back cover.

3 Definitions

For the purposes of this British Standard, the definitions given in BS 4778 and BS 5532 apply.

4 The first control chart

4.1 For the first trial of a number-defective quality control chart, select a process that can be expected to give reasonably continuous production and that produces output containing an expected proportion of defectives in the range 1 % to 10 %.

4.2 Select samples each of 25 items (or of 50 items if the general level of defectives in the product is 5 % or less and the rate of production permits) from the most suitable point in the process (see 5.2). The interval between samples should be such that approximately 5 % of the product is selected for examination.

4.3 Examine each item, note the number of defective specimens in each sample and record this number in the order in which the samples were taken, on a control chart as shown in Figure 1.

4.4 Example

a) When the results from 25 samples (each of 25 or 50 items) have been plotted in this way, find the control limit, as shown below, and mark it boldly as a broken line on the control chart.

b) To find the control limit:

1) calculate the average number of defective items (“defectives”) per sample in these twenty-five samples,

2) refer to Table 1, in clause 7; the control limit will be shown against the average number of defectives per sample.

c) For example, consider the following results of the first 25 samples, each of 50 items, taken from a production unit:

1) Number of defectives found per sample = 1, 0, 3, 0, 3, 2, 0, 2, 0, 2, 0, 1, 1, 0, 2, 5, 3, 1, 1, 2, 0, 2, 1, 1, 3.

then:

Average number of defectives = $\frac{36}{25} = 1.44$ per sample

2) On referring to Table 1 the control limit given for 1.53 (i.e. the number in the table next greater than the calculated number) defectives per sample is 5.7 and a broken line is placed on the chart at 5.7 defectives in a sample.

4.5 When the control limit has been placed on the chart, continue to select and examine samples, as before, recording on the chart the number of defectives found in each sample. While these recorded results remain below the control limit, variations in results should be ignored as being due to chance, and confidence may be felt that the quality of the product is not deteriorating. There is the separate question of whether this quality is satisfactory, and the states of “in statistical control” and “producing satisfactory quality” should not be confused.

It is recommended that some mark should be made at the appropriate place on the chart to indicate occurrences of technical importance such as machine adjustment, tool replacement, change of operator, fresh supply of raw material, etc., as these notes will help the correct appraisal of trouble if results fall outside limit values.

If a result falls beyond the control limit it is a signal that the quality of the product has deteriorated and that immediate corrective action is required. If, moreover, results that usually fall below the control limit approach it and cluster near it, this is an indication of a deterioration in quality which, if unchecked, is likely to become serious. To make this indication simpler to detect, a warning limit may be set one unit below the control limit. The presence of several points between these limits in a short period of time can be used to signal the need for investigation. Examples of the charts are given in Figure 6 for various states of the process. Technical attention in such a case can remedy the fault before the quality of output becomes unacceptable.

Experience with a chart constructed and used as described above, will show that it can be relied upon to signal a deterioration in quality and that the absence of such a warning can be taken as an indication that quality is being maintained. The product covered by the control chart examination can, if desired, also be 100 % examined for a while, until confidence in the chart is established. An example of the use of an experimental chart of this type to control the assembly and galvanizing of steel dustbins is shown in instruction sheet no. 1.

5 Extending the use of control charts

Once experience in the use of control charts has been gained, it will be desired to extend their use, and to facilitate this it will be worthwhile to consider in greater detail the steps already taken with the first chart.

5.1 The basis of a number-defective quality control chart

It would be very convenient if a sample, found to contain 10 % of defectives, could be assumed to come from a bulk or batch of articles that was also 10 % defective. *In fact, small samples taken from a moderately defective batch, are better than the batch more frequently than they are poorer, so that small samples usually give a flattering result.*

To illustrate this, consider a case where samples of 10 are taken from 10 % defective batches so that one defective is expected per sample; in such a case, it would be found that about 35 % of the samples would contain no defectives. The smaller the sample, the greater the percentage of samples that will contain no defectives.

Figure 2 shows the number of defectives in samples of 10 items, taken at random from a 10 % defective bulk and plotted in order of occurrence. It will be seen that, although the expected number of defectives in a sample is 1.0, individual results vary widely. Many samples contain two defectives and several contain three or four. With small samples of this kind it is easy to be misled into looking for non-existent trouble, but far easier to fail to detect a real deterioration in quality. For a given process average this variation in sample results is due to the chance causes inherent in sampling, but the average over a sufficient period would represent the process average. The range of the variation depends on the process average and cannot be altered without a significant change in the process itself.

In process inspection it is necessary to be able to form an opinion on changes in quality from one sample result, in order to obtain immediate action when quality deteriorates. Therefore, methods have been devised that limit this variation attributed to random causes in any control by sampling and, when such a control limit is put on to a number-defective chart, this becomes a number-defective control chart. A control chart is a record of the number of defective articles in consecutive samples provided with a limit to the variation in results likely to be produced by chance causes.

Sampling results should be recorded on the chart in order of occurrence in order to facilitate decisions upon appropriate action when action is required. The number of defectives found can be shown by either a cross or a dot.

5.2 Taking samples

5.2.1 Where to take samples. Sampling is a matter for practical judgement. If the likelihood of producing defective product is high, or the consequences of defective work are serious, it is better to sample after each stage in production, in order to detect the occurrence of trouble and to correct it as soon as possible. If defective work seldom appears, or if the consequences of it are not very serious, it is possible to economize in inspection by checking several operations at one sampling. Often several operations are completed, either at one time or in an unbroken cycle, before the sample is taken.