

Guide to quality control and performance improvement using qualitative (attribute) data —

Part 2: Fundamentals of standard attribute charting for monitoring, control and improvement

ICS 03.120.30

Confirmed November 2008

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee SS/4, Statistical process control, upon which the following bodies were represented:

- Association for Road Traffic Safety and Management (ARTSM)
- BAE Systems
- British Standards Society (BSS)
- Clay Pipe Development Association (CPDA)
- Federation of Small Businesses (FSB)
- Gauge and Tool Makers Association (GTMA)
- General Domestic Appliances Ltd.
- Institute of Quality Assurance
- National Physical Laboratory
- Royal Statistical Society

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2003

© BSI 31 October 2003

First published as BS 5701 February 1980

The following BSI references relate to the work on this British Standard:
Committee reference SS/4
Draft for comment 02/400887 DC

ISBN 0 580 42735 8

Amendments issued since publication

Amd. No.	Date	Comments

Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
1 Scope	1
2 Normative references	1
3 Terms, definitions and symbols	1
4 The four types of attribute control charts	1
5 The construction and use of standard control charts for attribute data	1
Annex A (normative) Specimen attribute control charts	24
Annex B (normative) Formulae for the control limits	26
Bibliography	27
Figure 1 — Standard charts to monitor different types of qualitative data	2
Figure 2 — Single characteristic “ <i>c</i> ” chart	4
Figure 3 — “ <i>c</i> ” chart set up	6
Figure 4 — Extension of control limits on “ <i>c</i> ” chart	7
Figure 5 — “ <i>c</i> ” chart illustrating a significant change in performance	9
Figure 6 — “ <i>u</i> ” chart	10
Figure 7 — Example of adjustment of control limit for variation in sample size	12
Figure 8 — Computer-generated chart for unequal sample size	13
Figure 9 — Multiple characteristic control chart	14
Figure 10 — Pareto diagram to establish priorities for action	15
Figure 11 — “ <i>np</i> ” control chart	16
Figure 12 — “ <i>p</i> ” chart	19
Figure 13 — Computer-generated “ <i>p</i> ” chart	20
Figure 14 — Sudden shift in process average	21
Table B.1 — Formulae for the control limits	26

Foreword

BS 5701-1 demonstrates the business benefits, and the versatility and usefulness, of a very simple, yet powerful, pictorial control chart method for monitoring and interpreting qualitative data. This is done in a practical and largely non-statistical manner. BS 5701-2:2003 partially supersedes BS 5701:1980 and BS 2564:1955 and all four parts of BS 5701 together supersede BS 5701:1980 and BS 2564:1955, which are withdrawn.

This qualitative data can range from overall business figures such as percentage profit to detailed operational data, such as percentage absenteeism, individual process parameters and product/service features. The data can either be expressed sequentially in yes/no, good/bad, present/absent, success/failure format, or as summary measures (e.g. counts of events and proportions). For measured data control charting refer to BS 5702-1.

BS 5701-2 continues to focus on the application of standard control charts to the monitoring, control and improvement of business processes. However, it deals with the application of standard attribute charting at a technical level more suitable for practitioners. Its aim is still to be readily comprehensible to an extensive range of prospective users and so facilitate widespread communication, and understanding, of the method. As such, it focuses on a practical statistical treatment of the charting of qualitative data presenting examples of construction and application using a mainly simple pictorial approach.

BS 5701-3 provides a more rigorous, statistical approach to process control and improvement using qualitative data. BS 5701-4 deals with measuring and improving the quality of decision making in the classification process itself.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 27 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

1 Scope

BS 5701-2 describes the fundamentals necessary for the successful application, by practitioners, of standard attribute charting for monitoring, control and improvement of business processes.

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 EN ISO 9000:2000, Quality management systems — Fundamentals and vocabulary.

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

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

3 Terms, definitions and symbols

For the purposes of this part of BS 5701, the terms, definitions and symbols given in BS ISO 3534-1, BS ISO 3534-2 and BS EN ISO 9000:2000, Clause 3 apply.

4 The four types of attribute control charts

Qualitative data are divided for convenience, into two categories, *classified data* and *count data*. In conventional statistical process control, classified and countable data are handled using a:

- 1) “*p*” chart for proportion of entities (e.g. units or items), having a particular attribute (e.g. non-conforming), particularly when the sample size is variable;
- 2) “*np*” chart for numbers of entities (e.g. units or items), having a particular attribute (e.g. non-conforming), from samples of constant size;
- 3) “*u*” chart for number of events (e.g. non-conformities) per sample, particularly when the sample size is variable;
- 4) “*c*” charts for number of events (e.g. non-conformities) for samples of constant size.

Figure 1 illustrates the appropriate standard chart to choose to monitor different types of qualitative data.

NOTE 1 Refer to BS 5703 for cumulative sum (CUSUM) methods for handling both discrete and continuous data.

Whilst the four standard discrete data charts of Figure 1 have peculiar names or labels (i.e. “*c*”, “*u*” etc.), these labels are in standard use throughout the world. The charts are extremely easy to set up and apply and provide a pictorial window of the behaviour of the chosen characteristic readily understandable to all.

NOTE 2 See Annex A.

5 The construction and use of standard control charts for attribute data

5.1 The “*c*” chart

5.1.1 General

The “*c*” chart is one of the simplest control charts to construct and use. Samples of a constant size are taken from a process and the number of non-conformities present within each sample counted. These observations (known as “*c*” numbers) can be recorded and plotted onto a control chart and so provide a way of monitoring the process for statistical control. A procedure for setting up such a control chart is given in 5.1.2 to 5.1.11.

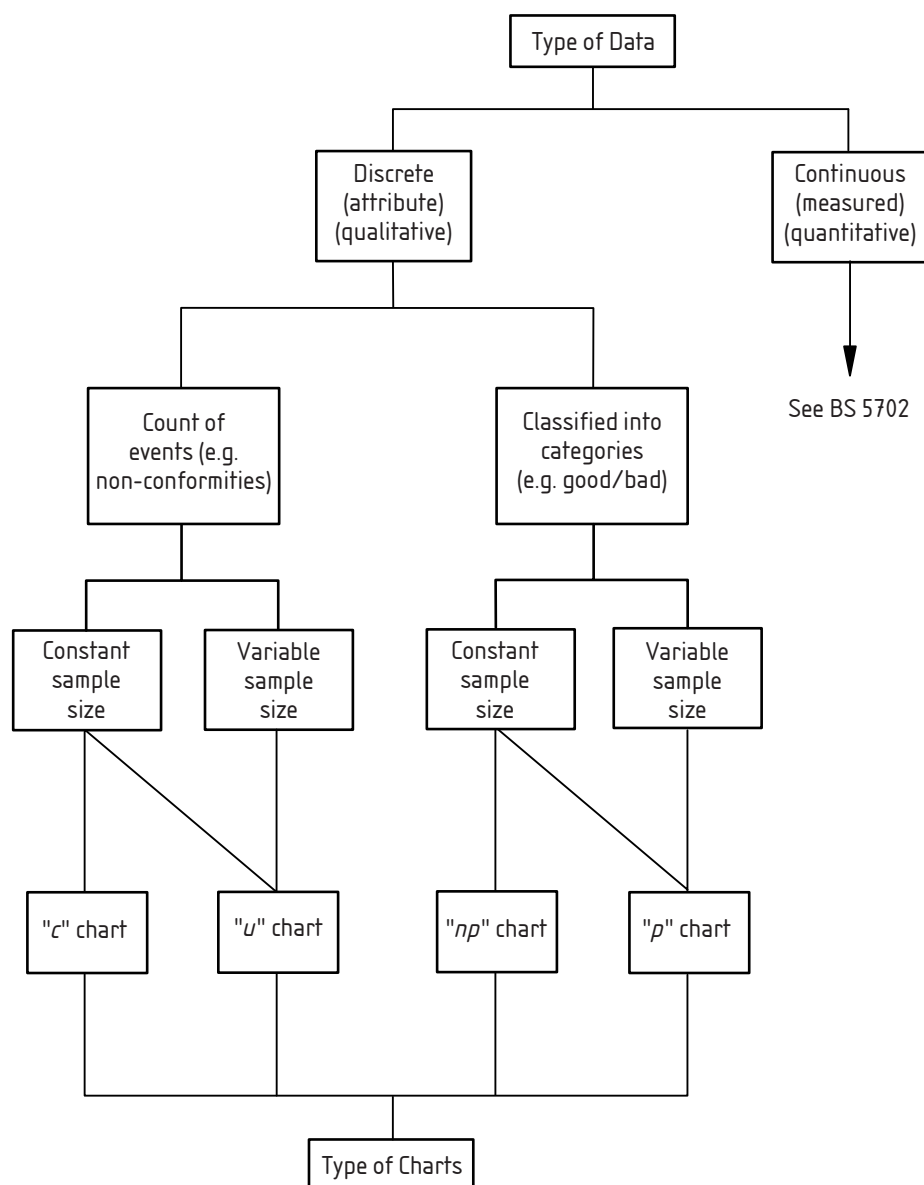


Figure 1 — Standard charts to monitor different types of qualitative data

5.1.2 Step 1 – Select the sample size and frequency

Select a sample size that is large enough so that the expected number of non-conformities (c) observed per sample is more than four.

A useful source of information to assist this selection is any recent history of the process. It can be in the form of inspection records. From such or similar information it can be possible to establish a level of occurrence of the non-conformity, e.g. the total number of non-conformities recorded divided by the total number of items inspected. From this value, it would be possible to estimate a sample size that would have an expected number of non-conformities greater than four.

For example, if past records indicate that of the most recent inspections 2 545 items had been taken and 140 non-conformities had been observed amongst them. The level of occurrence of the non-conformity can be estimated as 0.055, i.e. $140/2\,545$. Using this estimate, if a sample of 75 were selected, the expected number of non-conformities per sample would be 4.125, i.e. 0.055×75 . The minimum sample size required is $4/0.005\,5 = 72.7$, rounded up to 73. After running the chart for a while, a review should be undertaken to check the appropriateness of the selected sample size and adjust it as necessary.

If there is no information, it is suggested that an audit is carried out on the process. During this audit, a random sample is taken from the output of the process and inspected for the non-conformity. The result is used as described above.

The selection of the frequency of sampling should be determined according to those events within the process that are likely to have an impact on the occurrence of the non-conformity, e.g. a change of operator or a shift change. This is sometimes known as the assessment of process dominance. The sampling scheme should be selected so that the full effect of such process events will be observed. The sampling frequency also needs to take account of any production rate. It would be nonsense to specify a sample size so large that the production rate would not produce that quantity in the time allowed.

A further consideration about the sampling frequency is how quickly information about the process will be collected. Clearly, a shorter time interval with a smaller sample size will provide more rapid information but will not be as powerful at detecting lesser special causes. A larger sample taken over a longer time interval is more powerful but is not so rapid.

Figure 2 illustrates where this information can be recorded on a control chart. See “Step 1” in the figure.

5.1.3 Step 2 – Record the sample information

In the appropriate rows and columns, record the information concerning each sample. The chart requires the date, sample size (n) and the number of non-conformities (c). In the case of a “ c ” chart, the sample size is a constant and so it can be entered as shown in Figure 2.

All subsidiary information relevant to the process should also be collected. For example, if it is thought important to record information such as a batch number or which shift was working at a particular time then other rows can be added to the chart.

5.1.4 Step 3 – Select a scale for the control chart

The vertical scale of the chart should be labelled according to the non-conformity that the samples are inspected for. The scaling should be selected to begin at zero and extent to about three times the expected average number of non-conformities ($\bar{c}$).

This scale should be enough to enable control lines to be drawn and most sample observations to be plotted.

5.1.5 Step 4 – Plot the number of non-conformities

Plot the number of non-conformities (c) for each sample.

Ensure that every plotted point is joined to its neighbours by straight lines. This is so that trends can be more easily identified and should any points be missing, they will be more obvious.

Control Chart for Attribute Data - Single Characteristic

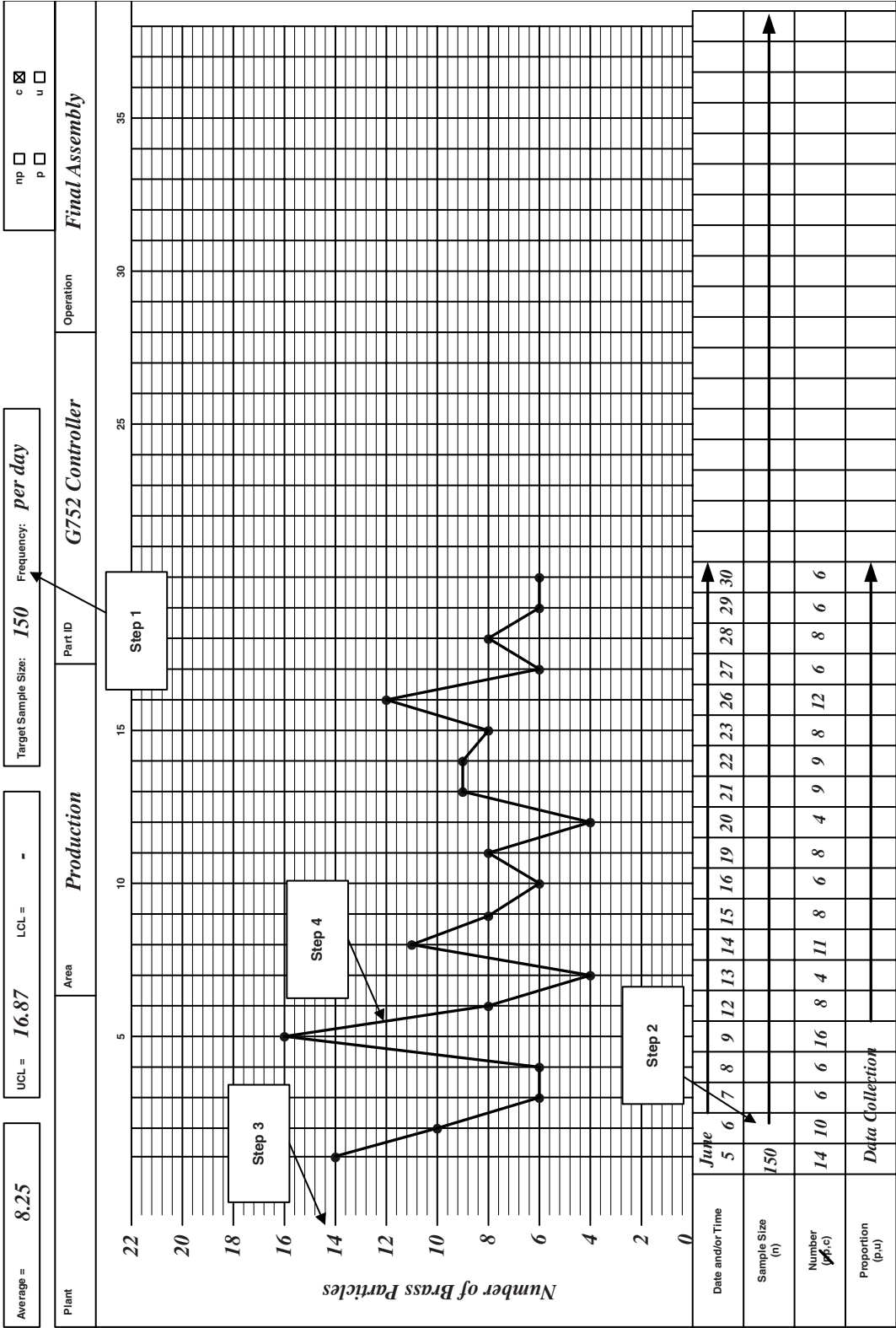


Figure 2 — Single characteristic “c” chart

5.1.6 Step 5 – Calculate the process average

To establish the level of the process average, data gathering should be done over a suitably long enough period. This period should be at least 20 samples long and the period should be indicated on the control chart. In Figure 2, it has been written at the bottom of the chart.

The average number of non-conformities ($\bar{c}$) can be found by summing all of the non-conformities observed during the data collection period. Divide this sum by the number of samples (k) taken. For example, from the data given in Figure 2:

$$\bar{c} = \frac{\sum c}{k} = \frac{14+10+\dots+6}{20} = \frac{165}{20} = 8.25$$

where $k = 20$, here.

This calculation can be recorded at the top of the chart, as shown in Figure 3.

5.1.7 Step 6 – Calculate the control limits

Annex B provides the formulae for the control limits. The use of the formulae is illustrated in Figure 3.

$$UCL_c = \bar{c} + 3\sqrt{\bar{c}} = 8.25 + 3\sqrt{8.25} = 16.87$$

$$LCL_c = \bar{c} - 3\sqrt{\bar{c}} = 8.25 - 3\sqrt{8.25} < 0$$

Here, the calculated value for the lower control limit (LCL) is less than zero. Since this is an illogical result, because the number of non-conformities can never be less than zero, the lower control limit (LCL) is not plotted. The technical reasons for this are explained in BS 5701-3.

5.1.8 Step 7 – Draw the control and centre lines onto the chart

Draw the centre and control lines as follows:

- *centre line* – draw the process average ($\bar{c}$) onto the chart using a dashed horizontal line. Some practitioners prefer to draw this line in a green colour if a colour coding system is chosen.
- *control lines* – draw the upper (and lower, if applicable) control line onto the chart using a solid horizontal line. This line is often drawn in red.

5.1.9 Step 8 – Establish the control limits for on-going control

Review the chart for any out-of-control signals for the data gathered during the data collection period. If there are no out-of-control signals during this period, the calculated limits can be used for the future control of the process. The centre line and the control lines can be drawn forwards on the control chart as shown in Figure 4.

Should some of the plotted points gathered during the data collection period produce out-of-control signals, it will be necessary to investigate the reason. Depending on the outcome, a further data collection period might be necessary. If such a reason is found, and should action be taken to prevent a future occurrence of the same, then the control limits can be recalculated excluding the sample that contained the “special cause”. If the remaining samples now indicate an “in-control” pattern within the revised limits, these revised limits can then be used for on-going control of the process.

A control chart showing a number of out-of-control signals indicates a rather unstable process. A prudent approach would then be to examine the process very thoroughly and to fully correct that which is wrong rather than remove many samples from the calculation of the control limits. It should be possible to eliminate up to three samples without affecting the statistical efficiency of the estimation of the process average too much.

Control Chart for Attribute Data - Single Characteristic

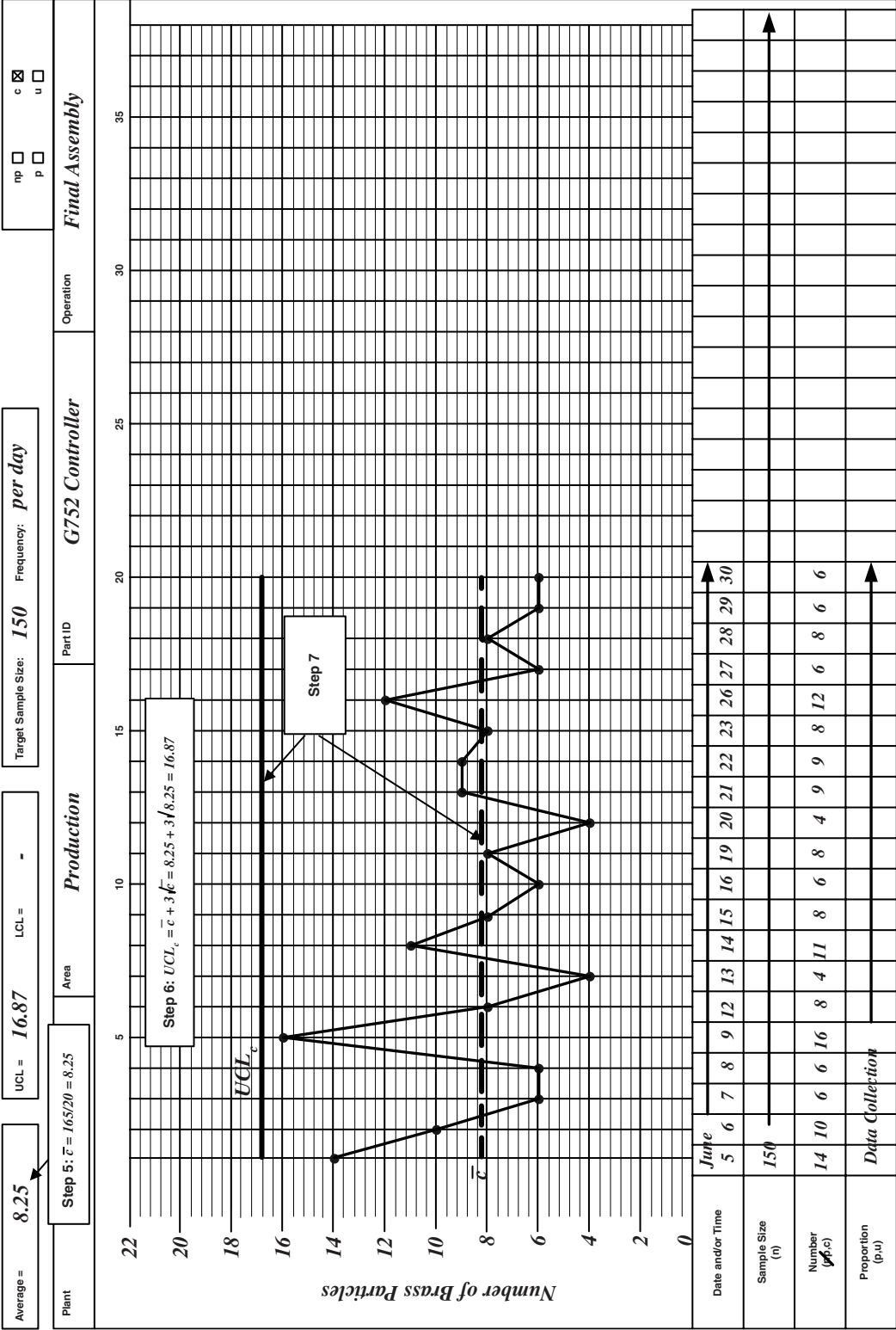


Figure 3 — “c” chart set up