

Guide to the selection and usage of acceptance sampling systems for inspection of discrete items in lots —

Part 3: Guide to sampling by variables

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Committees responsible for this British Standard

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- Association for Road Traffic and Safety Management
- British Measurement and Testing Association
- City University
- Clay Pipe Development Association Ltd.
- Institute of Metal Finishing
- Institute of Quality Assurance
- Ministry of Defence — UK Defence Standardization
- Co-opted members

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Foreword

This part of BS 6000 has been prepared by Technical Committee SS/5. Together with BS 6000-1 and BS 6000-2 it supersedes BS 6000:1996, which is withdrawn.

BS 6000:2004, *Guide to the selection and usage of acceptance sampling systems for inspection of discrete items in lots* is in three parts:

Part 1: *General guide to acceptance sampling*

Part 2: *Guide to sampling by attributes*

Part 3: *Guide to sampling by variables*.

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

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iii, a blank page, pages 1 to 41 and a back cover.

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1 Scope

This British Standard gives guidance on the selection of an acceptance sampling system, scheme or plan for inspection by variables. It does this principally by reviewing the available systems specified by various British Standards and showing ways in which these can be compared in order to assess their suitability for an intended application. It is assumed that the choice has already been made to use sampling by variables in preference to sampling by attributes.

The guidance in this British Standard is confined to acceptance sampling of products that are supplied in lots and that can be classified as consisting of discrete items (i.e. discrete articles of product). Each item in a lot can be identified and segregated from the other items in the lot and has an equal chance of being included in the sample. Each item of product is countable and has specific characteristics that are measurable on a continuous scale. Each characteristic has, at least to a good approximation, a normal distribution or a distribution that can be transformed so that it closely resembles a normal distribution.

Standards on acceptance sampling by variables are applicable to a wide variety of inspection situations. These include, but are not limited to, the following:

- a) end items, such as complete products or sub-assemblies;
- b) components and raw materials;
- c) services;
- d) materials in process;
- e) supplies in storage;
- f) maintenance operations;
- g) data or records;
- h) administrative procedures.

Although this British Standard is written principally in terms of manufacture and production, this should be interpreted liberally as it is applicable to the selection of sampling systems, schemes and plans for all types of product and processes as defined in BS EN ISO 9000.

2 Terms and definitions

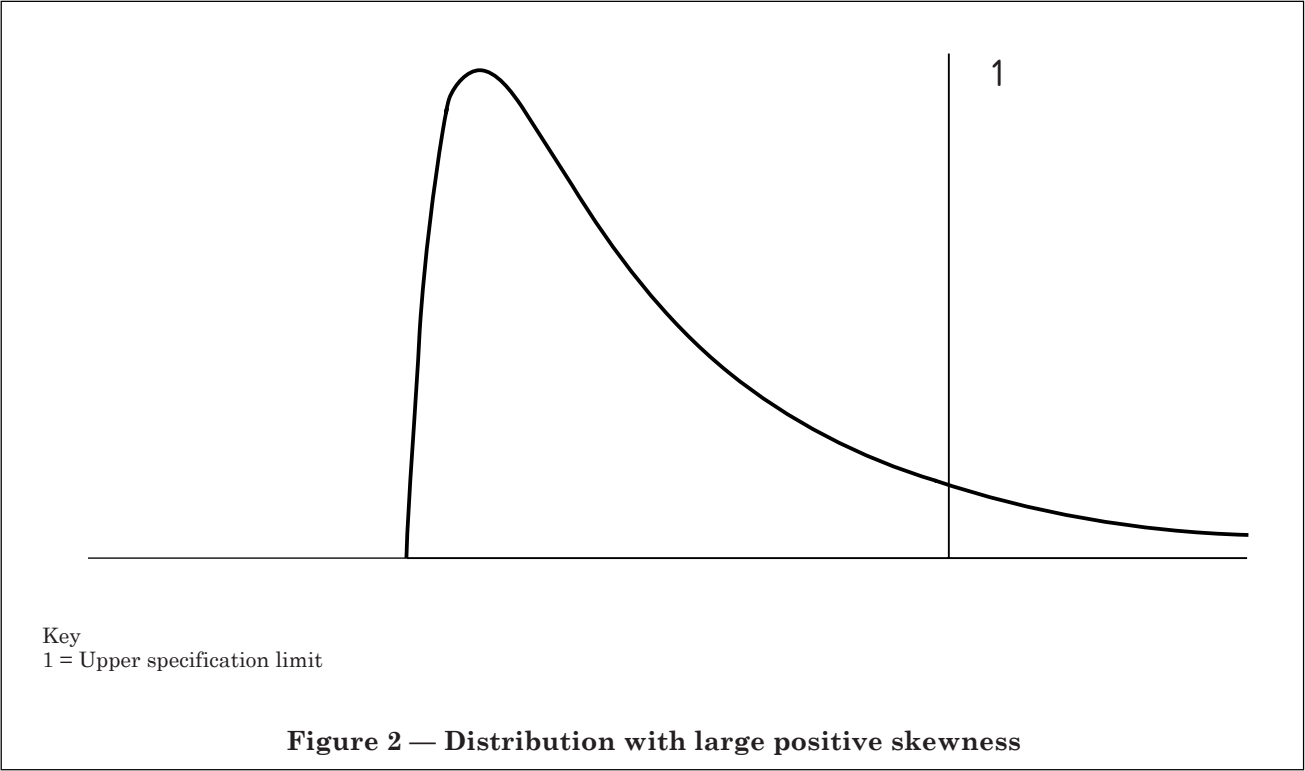
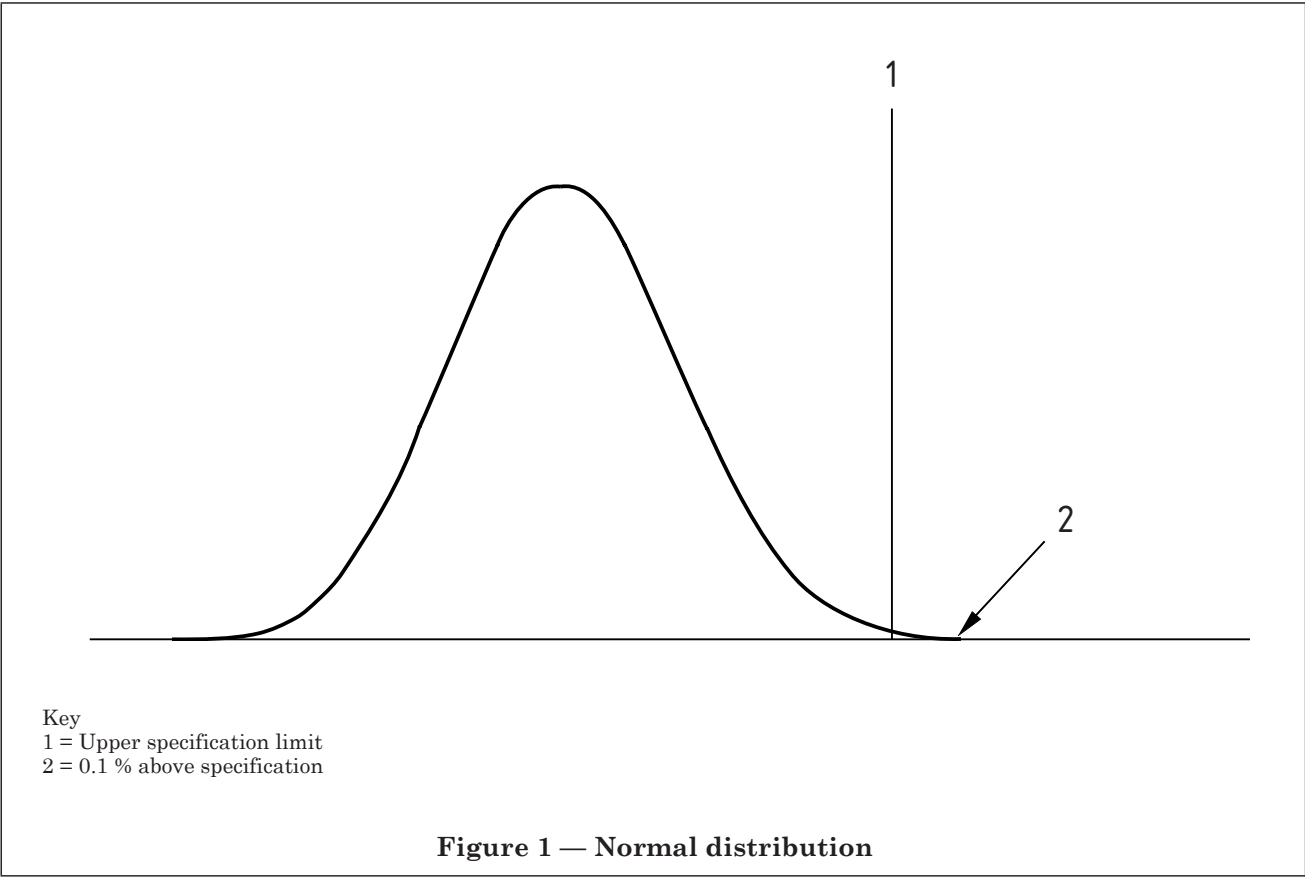
For the purposes of this British Standard, the terms and definitions given in BS ISO 3534-1, BS ISO 3534-2 and BS EN ISO 9000 apply.

3 Normality

3.1 Relationship between form of distribution of quality characteristic and percent nonconforming

A key aspect of sampling by variables is the form of the distributions of the quality characteristics. Consider a single quality characteristic. If it is normally distributed and if an upper specification limit is located at the mean plus two standard deviations, the percent nonconforming is about 2.5 %. If the specification limit is located at the mean plus three standard deviations, the percent nonconforming is about 0.1 %. However, if the distribution of the quality characteristic is not normal and has a large positive skewness, i.e. a long tail to the right, an upper specification limit located at the mean plus three standard deviations could conceivably yield a percent nonconforming approaching 10 % instead of about 0.1 % (see Figure 1 and Figure 2).

Therefore, whenever a sampling plan for inspection by variables for percent nonconforming is to be employed, it is highly desirable to check any assumptions about the shape of the distribution, especially in the tails of the distribution. If the AQL is very small, for example 0.1 %, a study of several thousand items should be made, including a test of distributional form.



3.2 Identifying departure from normality

3.2.1 Subjective assessment

The degree to which a sample appears to have come from a normal distribution can be subjectively assessed by means of a normal probability plot. Such a plot is constructed in the following way. Once the random sample has been selected and the quality characteristic x has been measured for each item, the values $x_1, x_2, \dots, x_n$ are arranged in ascending order $x_{[1]}, x_{[2]}, \dots, x_{[n]}$, such that $x_{[1]} \leq x_{[2]} \leq \dots \leq x_{[n]}$. The points with coordinates $\{x_{[i]}, (i - \frac{3}{8}) / (n + \frac{1}{4})\}$ are then plotted on a sheet of normal probability paper for $i = 1, 2, \dots, n$. In order to facilitate this process, an A4 sheet of normal probability paper is provided in Annex A.

Figure 3b) shows the normal probability plot of a random sample of size 100 from a normal distribution (Figure 3a) shows the density function). The graph paper is specially designed so that data from a normal distribution tend to lie close to a straight line. A straight line has been drawn by eye through the data, showing in this case that there are only minor departures from linearity.

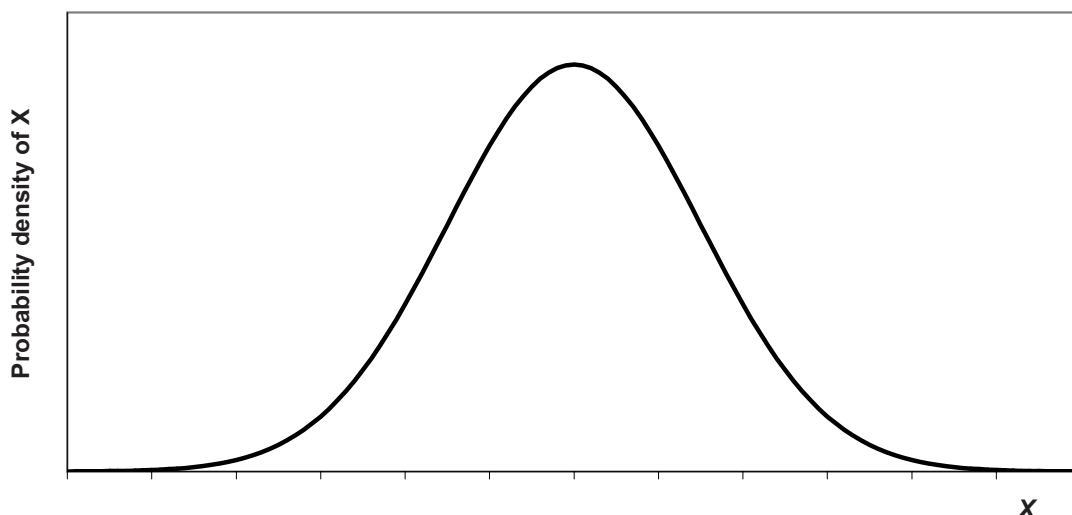


Figure 3a) — Normal distribution

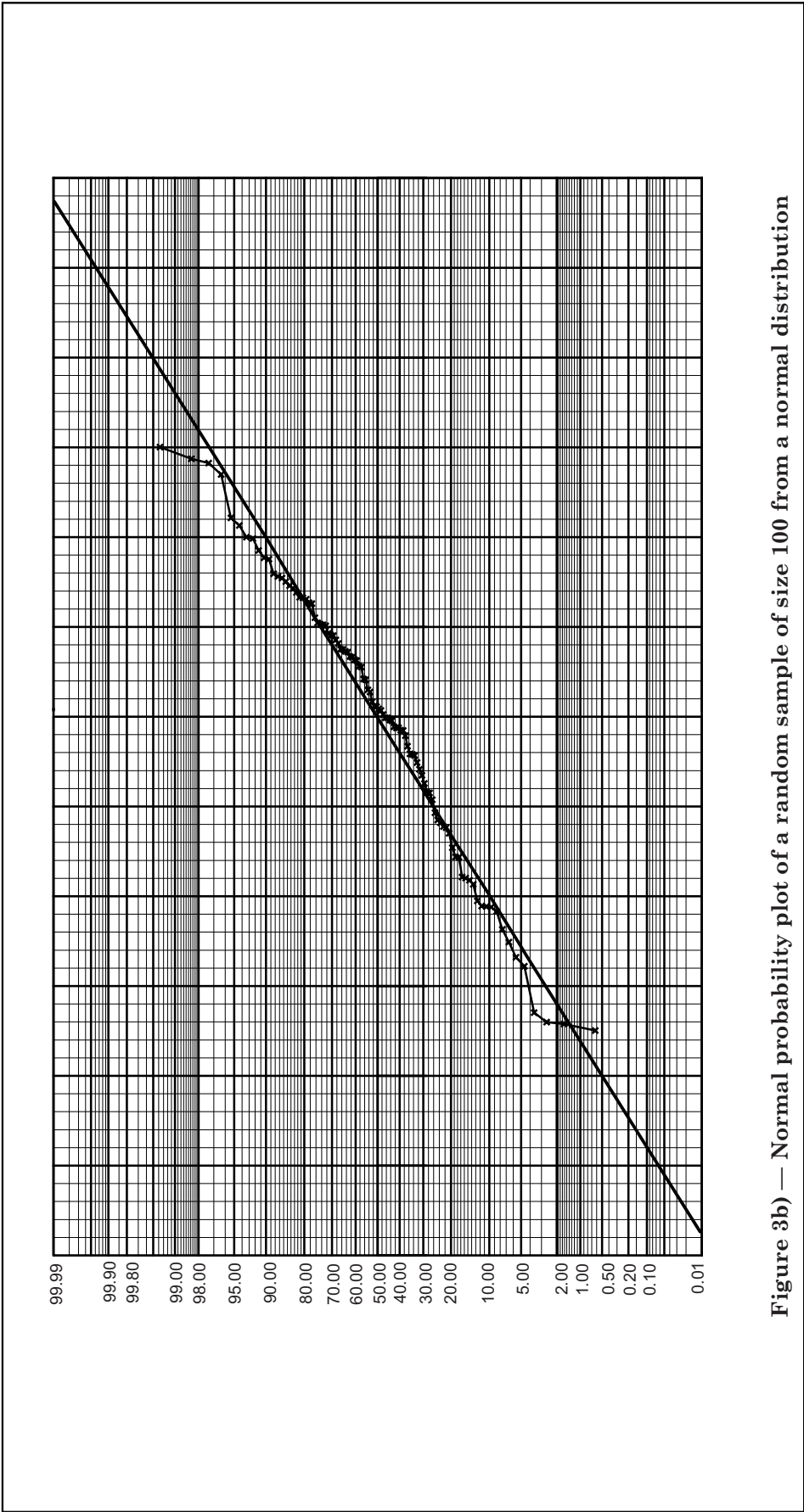
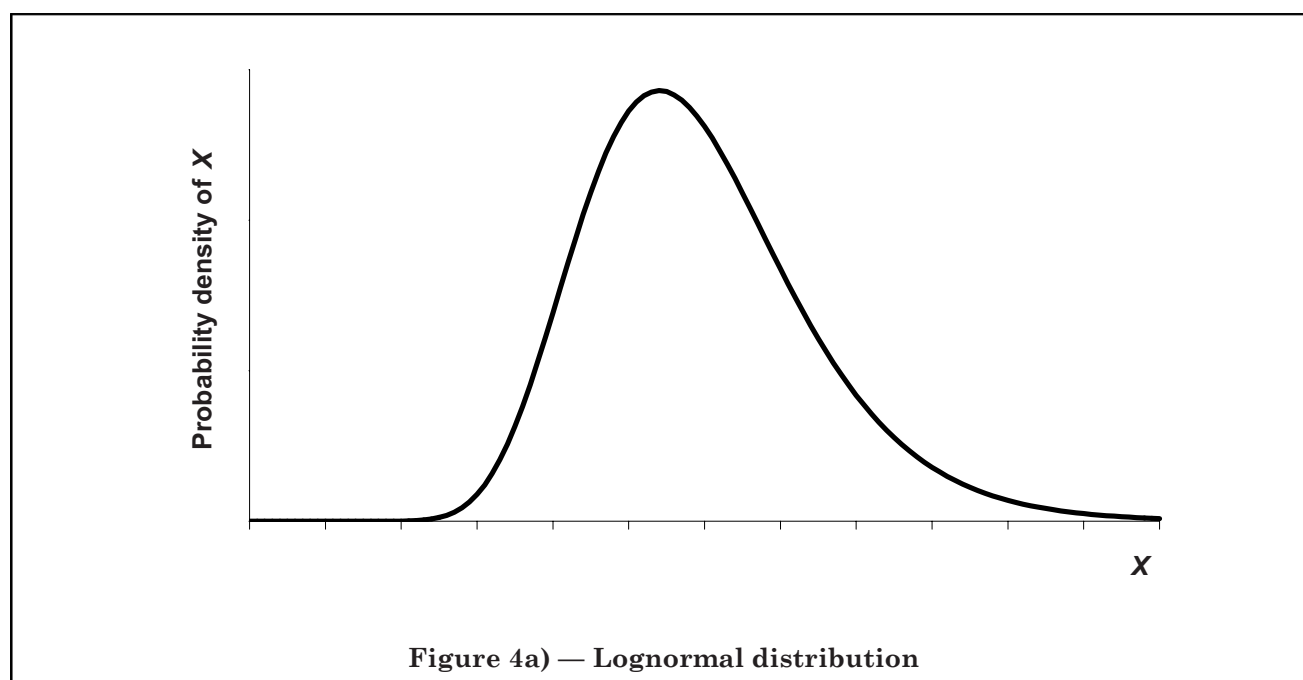


Figure 3b) — Normal probability plot of a random sample of size 100 from a normal distribution

When data originate from a normal distribution, departures of the probability plot from linearity are due solely to sampling fluctuations. Conversely, data from other types of distribution will tend to show departures from linearity of a characteristic type, helping in the determination of the family of distributions to which the data belong. Knowledge of this family can indicate the appropriate transformation to make to the data in order to bring these closer to normality.

Figure 4a) to Figure 8b) show the density functions and examples of normal probability plots based on a sample of size 100 for, respectively, a lognormal, “square-root-normal”, Cauchy, Laplace and exponential distribution. (For brevity, the distribution for which the square root of the variable has a normal distribution is referred to as the “square-root-normal” distribution.) On some of the normal probability plots, a straight line has been drawn through the data points to aid the eye in identifying the characteristic differences. For the lognormal distribution, there is a pronounced downward concavity. The normal probability plot of the square-root-normal distribution is similar to that of the lognormal distribution, except that the concavity is less pronounced. This is only to be expected, as both distributions can be transformed to normality with the Box-Cox transformation (see 3.3.4), but the value of Box-Cox parameter $\lambda = 0$ for the lognormal distribution is twice as far away from the null value $\lambda = 1$ as the value $\lambda = \frac{1}{2}$ required for the square-root-normal distribution.

The Cauchy distribution is almost indistinguishable from the normal distribution towards its centre, but the extra thickness of its tails results in the plot being relatively high for low values of x and relatively low for high values of x , the extremities of the plot being almost horizontal. The Laplace distribution is similar, except that there is a shorter region in the normal probability plot where the distribution is indistinguishable from the normal distribution, and the extremities of the plot are far from horizontal. The exponential distribution has a very characteristic shape, rising very steeply at the left and becoming almost horizontal towards the right.



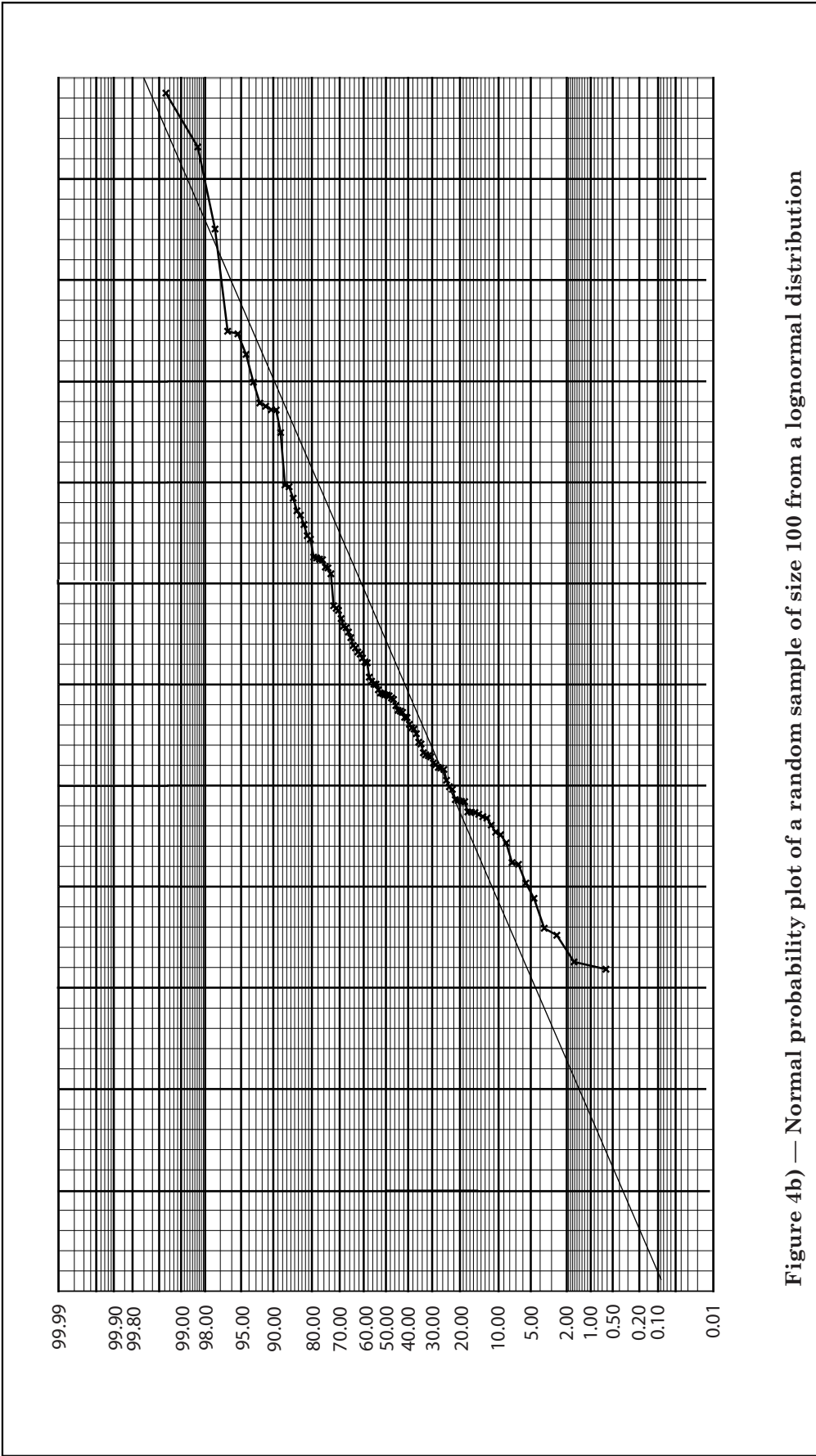


Figure 4b) — Normal probability plot of a random sample of size 100 from a lognormal distribution

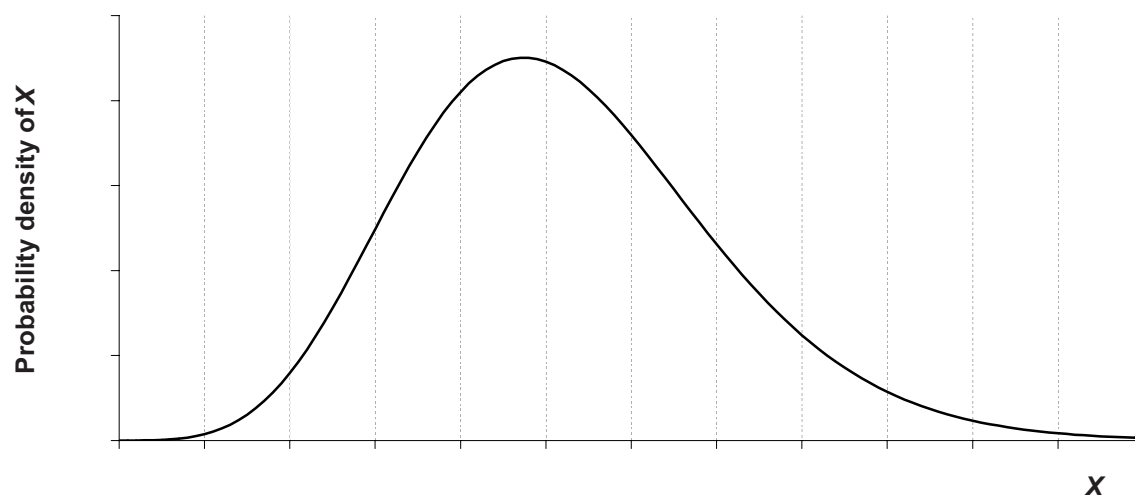


Figure 5a) — “Square-root-normal” distribution

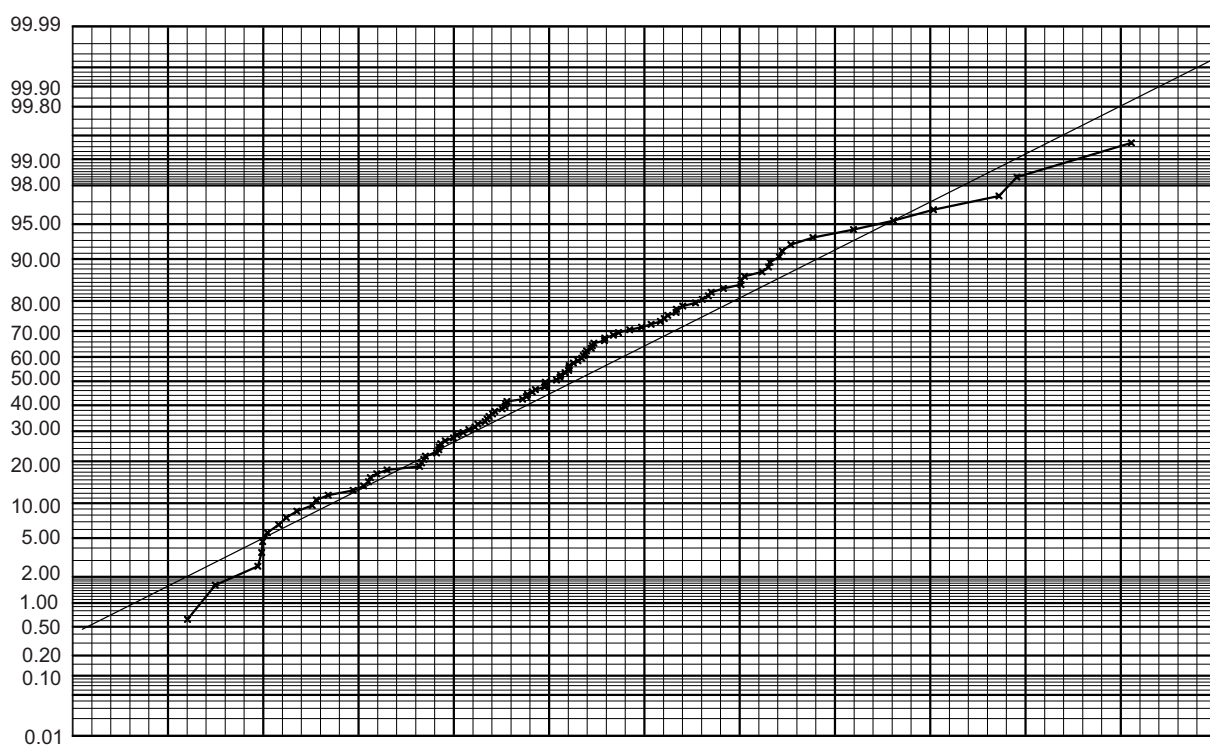


Figure 5b) — Normal probability plot of a random sample of size 100 from a Square-root-normal distribution

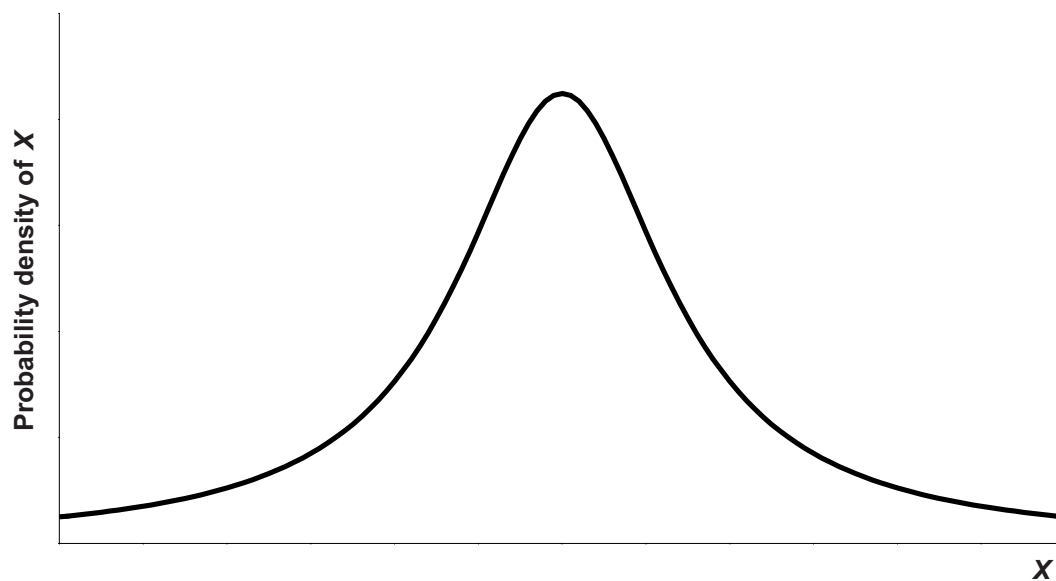


Figure 6a) — Cauchy distribution

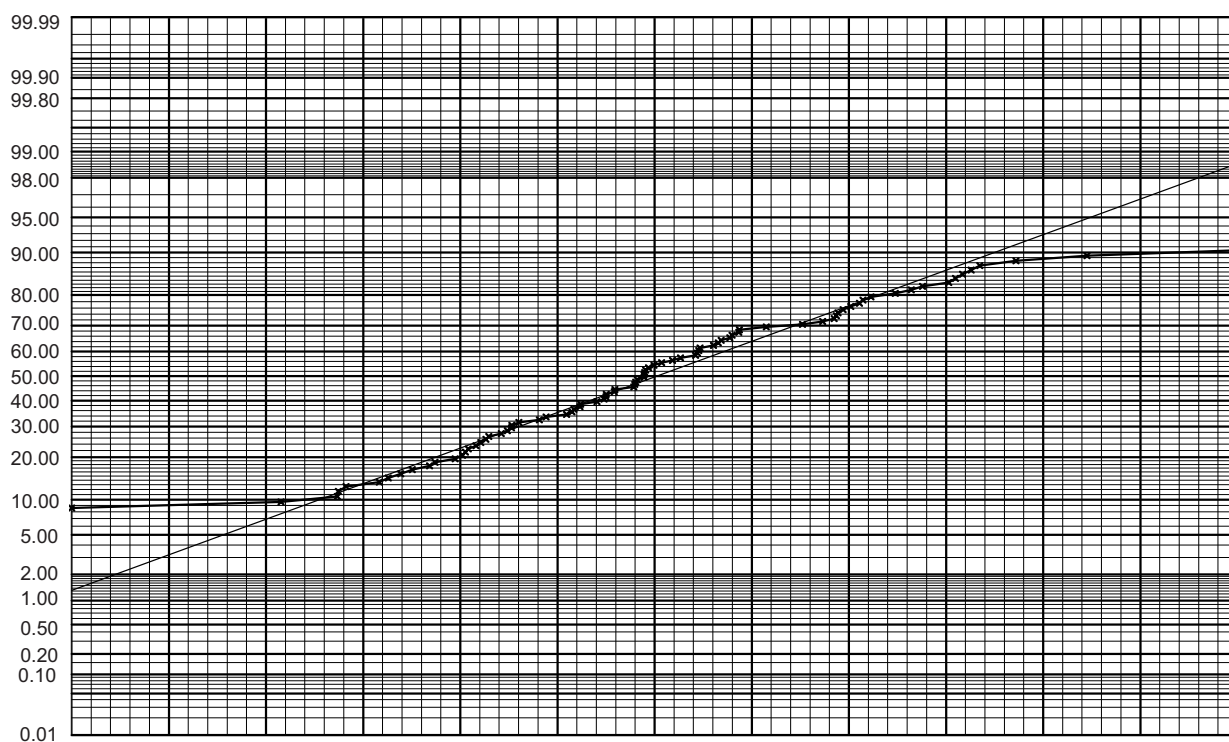


Figure 6b) — Normal probability plot of a random sample of size 100 from a Cauchy distribution

