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An American National Standard

Standard Practice for Probability Sampling Of Materials[1]

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1. Scope

1.1 This practice is primarily a statement of principles for the guidance of ASTM technical committees and others in the preparation of a sampling plan for a specific material.

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *probability sampling plans* make use of the theory of probability to combine a suitable procedure for selecting sample items with an appropriate procedure for summarizing the test results so that inferences may be drawn and risks calculated from the test results by the theory of probability. For any given set of conditions there will usually be several possible plans, all valid, but differing in speed, simplicity, and cost.

3. Aim of Probability Sampling

3.1 The purpose of the sample may be to estimate properties of a lot, pile, or shipment, such as the percentage of some constituent, the fraction of the items that fail to meet a specified requirement, the average weight or quality of an item, the total weight of the shipment, or the probable maximum or minimum content of some chemical.

3.2 The purpose may be the rational disposition of the lot or shipment, without the intermediate step of the formation of an estimate.

3.3 The purpose may be to provide aid toward rational action concerning the production process that generated the lot, pile, or shipment.

4. Characteristics of a Probability Sampling Plan

4.1 A probability sampling plan will possess certain characteristics of importance, as follows:

4.1.1 It will possess an objective procedure for the selection of the sample, with the use of random numbers.

4.1.2 It will include a definite formula for the estimate, if there is to be an estimate; also for the standard error of any estimate. If the sample is used for decision without the intermediate step of an estimate, the decision process will follow definite rules. In acceptance sampling, for example, these are often based on predetermined risks of taking the undesired action when the true levels of the characteristic concerned have predetermined values; for example, acceptable and rejectable quality levels may be specified.

4.2 The minimum requirements that must be met in order to obtain the characteristics mentioned in 4.1 appear in Section 5, which also indicates the minimum requirements for the description of a satisfactory sampling plan.

5. Minimum Standards for a Probability Sampling Plan

5.1 For a sampling plan to have the requirements mentioned in Section 4 it is necessary:

5.1.1 That every part of the pile, lot, or shipment have a nonzero chance of selection,

5.1.2 That these probabilities of selection be known, at least for the parts actually selected, and

5.1.3 That, either in measurement or in computation, each item be weighted in inverse proportion to its probability of selection. This latter criterion should not be departed from; for example, equal weights should not be used when the probabilities of selection are unequal, unless calculations show that biases introduced thereby will not impair the usefulness of the results.

5.2 To meet the requirements of 5.1.1 and 5.1.2, the sampling plan must describe the sampling units and how they are to be selected. It must specify that the selection shall be objectively at random. To achieve random selection, use random sampling numbers, since mechanical randomizing devices usually lead to biases and are not standard tools. The requirements of 5.1.3 may be met, in nonobvious ways, by various special methods of computation.

5.3 In meeting the requirements of 5.1.3, carefully state the purposes served by sampling, lest a relatively unimportant aim overbalance a more important one. For example, estimates of the over-all average quality of a stock of items may be less important than the rational disposition of subgroups of the stock of inferior quality. In this case the method of using subsamples of equal size drawn from each subgroup is more efficient, although at some expense to the efficiency of the estimate of the over-all average quality. Similarly, in acceptance inspection, samples of equal size drawn from lots that vary widely in size serve primarily to provide consistent

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judgment with respect to each lot, and secondarily to provide an estimate of the process average. Where the estimate of the over-all average of a number of lots is the important objective, samples proportional to the sizes of the subgroups will usually yield an efficient estimate. For other possible criteria, sizes intermediate between equal and proportional sampling from the subgroups will be appropriate.

5.4 It is not easy to describe in a few words the many sorts of plans that will meet the requirements of 5.1.2. Nor is it easy to describe how these plans differ from those that do not satisfy the requirement. Many standard techniques, such as pure random unstratified sampling, random stratified sampling, and sampling with probabilities in proportion to size, will satisfy the requirement; likewise every plan will do so where the sample is made up of separate identifiable subsamples that were selected independently and by the use of random numbers.

5.5 A probability sampling plan for any particular material must be workable, and if several alternative plans are possible, each of which will provide the desired level of precision, the plan adopted should be the one that involves the lowest cost.

5.6 A probability sampling plan must describe the sampling units and how they are to be selected (with or without stratification, equal probabilities, etc.). The sampling plan must also describe:

5.6.1 The formula for calculating an estimate (average concentration, minimum concentration, range, total weight, etc.),

5.6.2 A formula or procedure by which to calculate the standard error of any estimate from the results of the sample itself, and

5.6.3 Sources of possible bias in the sampling procedure or in the estimating formulas, together with data pertaining to the possible magnitudes of the biases and their effects on the uses of the data.

5.7 The development of a good sampling plan will usually take place in steps, such as:

5.7.1 A statement of the problem for which an estimate is necessary,

5.7.2 Collection of information about relevant properties of the material to be sampled (averages, components of variance, etc.),

5.7.3 Consideration of a number of possible types of sampling plans, with comparisons of over-all costs, precisions, and difficulties,

5.7.4 An evaluation of the possible plans, in terms of cost of sampling and testing, delay, supervisory time, inconvenience,

5.7.5 Selection of a plan from among the various possible plans, and

5.7.6 Reconsideration of all the preceding steps.

6. Some Problems Encountered in the Probability Sampling of Bulk Materials

6.1 There are two major difficulties that may be encountered in planning and carrying out the probability sampling of a lot of bulk material:

6.1.1 Lack of information on the pertinent statistical characteristics of the lot of material, and

6.1.2 The physical difficulties or the costs of drawing into the sample the specific ultimate sample units to be specified in the sampling plan.

6.2 There may be little information on the nature of the distribution of the desired property in any given lot or in the universe of such lots, or on the magnitude and stability of the components of variance involved. This circumstance is to be expected if the manufacturing process has not had the benefit of statistical methods to eliminate assignable causes of variability. It will then be difficult to specify in advance the exact size of sample for a prescribed degree of precision.

6.3 As experience is acquired, however, the sample can be increased or decreased to meet the requirements more exactly and more economically. In any case, a valid estimate can be made of the precision provided by any probability sample that was selected, based on an examination of the sample itself. In this connection, random fluctuations that arise from the measurement process must be considered and appropriate allowance made, if necessary.

6.4 Because of the physical nature, condition, or location of the material at the time of intended sampling, selection of the units specified in a proposed sampling plan may not be feasible, physically or economically. No matter how sound a given sampling plan is in a statistical sense, it is not suitable if the cost involved is prohibitive or if the work required is so strenuous that it leads to short cuts or subterfuge by those responsible for the sampling.

7. Planning for Sampling

7.1 Different problems or difficulties are encountered with various kinds of materials, and they require specific solutions for individual cases. Some general features of solutions to common difficulties are as follows:

7.1.1 Lack of specific information on the pertinent statistical characteristics of the class of material to be sampled may sometimes be overcome to a satisfactory degree, without excessive cost or delay, by investigation and utilization of existing, apparently unrelated data and general information.

7.1.2 The cost of a sampling plan is not confined to the direct monetary costs of sampling and testing. Plans that secure greater simplicity, convenience, or speed at the expense of higher direct costs sometimes have lower total costs and may then be appropriately adopted.

7.1.3 Random error can sometimes be reduced by proper stratification. Where physical difficulties are encountered in stratified sampling, the statistician requires the cooperation of the engineer for possible solutions; in any case, the knowledge and cooperation of the engineer will be helpful in choosing the nature and extent of stratification.

7.1.4 Economic reduction in the variance of the ultimate sampling unit is sometimes possible, as by a change in size or shape, or by a choice of units that cut across natural strata.

7.1.5 Inability to obtain economically the desired sampling units from a lot of material in place is frequently a major stumbling block in the actual sampling of such material. For such units to become accessible, the material must be handled