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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. Referenced Documents

2.1 *ASTM Standards:*

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

E456 Terminology Relating to Quality and Statistics

E1402 Guide for Sampling Design

3. Terminology

3.1 *Definitions:*

3.1.1 For general terminology, refer to Terminology E456 and Guide E1402.

3.1.2 *judgment sampling, n*—a procedure whereby enumerators select a few items of the population, based on visual, positional, or other cues that are believed to be related to the variable of interest, so that the selected items appear to match the population.

3.1.3 *probability sampling plan, n*—a sampling plan which makes 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.

3.1.3.1 *Discussion*—For any given set of conditions, there will usually be several possible plans, all valid, but differing in speed, simplicity, and cost. Further discussion is provided in Practice E141.

4. Significance and Use

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

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

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

4.4 Whatever the purpose of the sample, adhering to the principles of probability sampling will allow the uncertainties, such as bias and variance of estimates or the risks of the rational disposition or action, to be calculated objectively and validly from the theory of combinatorial probabilities. This assumes, of course, that the sampling operations themselves were carried out properly, as well. For example, that any random numbers required were generated properly, the units to be sampled from were correctly identified, located, and drawn, and the measurements were made with measurement error at a level not exceeding the required purposes.

4.5 Determination of bias and variance and of risks can be calculated when the selection was only partially determined by random numbers and a frame, but they then require suppositions and assumptions which may be more or less mistaken or require additional data which may introduce experimental error.

5. Characteristics of a Probability Sampling Plan

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

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

5.1.2 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.

[1] This practice is under the jurisdiction of ASTM Committee E11 on Quality and Statistics and is the direct responsibility of Subcommittee E11.10 on Sampling / Statistics.

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5.2 The minimum requirements that must be met in order to obtain the characteristics mentioned in 5.1 appear in Section 6, which also indicates the minimum requirements for the description of a satisfactory sampling plan.

6. Minimum Standards for a Probability Sampling Plan

6.1 For a sampling plan to have the requirements mentioned in Section 5 it is necessary:

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

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

6.1.3 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.

6.2 To meet the requirements of 6.1.1 and 6.1.2, 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 6.1.3 may be met, in nonobvious ways, by various special methods of computation.

6.3 In meeting the requirements of 6.1.3, carefully state the purposes served by sampling, lest a relatively unimportant aim overbalance a more important one. For example, estimates of the overall 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 overall average quality. Similarly, in acceptance inspection, samples of equal size drawn from lots that vary widely in size serve primarily to provide consistent judgment with respect to each lot, and secondarily to provide an estimate of the process average. Where the estimate of the overall 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.

6.4 It is not easy to describe in a few words the many sorts of plans that will meet the requirements of 6.1.2 (see Guide E1402). 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.

6.5 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.

6.6 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:

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

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

6.6.3 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.

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

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

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

6.7.3 Consideration of a number of possible types of sampling plans, with comparisons of overall costs, precisions, and difficulties,

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

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

6.7.6 Reconsideration of all the preceding steps.

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

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

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

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

7.2 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. For further discussion of sample size related to specified precision, see Practice E122.

7.3 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