Designation: ~~E105 – 16~~ E105 – 21

An American National Standard

Standard ~~Practice~~Guide for Probability Sampling of Materials[1]

This standard is issued under the fixed designation E105; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This ~~practice~~guide 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.

1.2 A system of units is not specified in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

E300 Practice for Sampling Industrial Chemicals

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:*~~*Definitions*

~~3.1.1 For general terminology, refer to Terminology E456 and Guide E1402.~~—Unless otherwise noted in this standard, all terms relating to quality and statistics are defined in Terminology E456.

3.1.1 *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.

3.1.2 *probability sampling plan, n*—a ~~sampling plan which makes use of the theory of probability to combine a suitable procedure~~

[1] This ~~practice~~guide 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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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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.procedure which provides a result from a randomly selected set of sampling units that will agree, within calculable limits of variation, with the population value.

3.1.2.1 *Discussion—*

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. Further discussion is provided in Practice E141.

3.1.2.2 *Discussion—*

Further discussion is provided in Guide E1402 and 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, Proper sampling requires 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.

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. To meet requirements of 5.1.1, the sampling plan must specify that the selection will be made objectively at random. To achieve random selection, a table of random numbers or a sequence of random numbers generated by a random number generator may be used. Random number generation is commonly available in commercial software. For a discussion of sample size related to specified precision, see Practice E122.

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. Selection of Sample

7.1 Calculation of the margin of error or the risk in the use of the results of samples is possible only if the selection of the items for test is made at random. This is true whether the procedure is stratified or unstratified.

7.2 For a method of sampling to be random it must satisfy statistical tests, the most common of which are the "run tests" and "control charts," and certain other special statistical tests. Randomness is obtained by positive action; a random selection is not merely a haphazard selection, nor one declared to be without bias. Selection by the proper use of a standard table of random numbers is acceptable as random. It is possible and feasible to adapt the use of random numbers to the laboratory, to the field, and to the factory.

7.3 Mechanical randomizing devices are sometimes used, but no device is acceptable as random in the absence of thorough tests. The difficulties in attaining randomness are greater than generally known. Thus, special randomizing devices intended for the production of random numbers have often failed to give satisfactory results until adjusted and retested with perseverance. However, mechanical selection is still usually preferable to a judgment-selection.

7.4 Some other methods of sampling should be mentioned that do not meet the requirements of randomness. For example, one may declare that a lot of item is "thoroughly mixed," and hence that any portion, even the top layer, would give every item an equal chance of selection. In the absence of elaborate steps to mix the product, followed by careful tests for randomness, such assumptions are risky, as they often lead to wrong results.

7.5 Again, another common practice is to take a systematic sample consisting of every kth item. Even if the first item is selected at random, this type of sample, although random, is actually a sample of only one of the k possible sampling units that can be formed with an interval of k. Hence, in the absence of knowledge concerning the order of the material, such a sample does not permit a valid calculation of the standard error. Moreover, it does not yield a comparison of the variances between and within groups of units, statistical information that might indicate the direction of change toward a more efficient sampling plan.

7.6 However, the use of 10 independent random starts between 1 and 10 k, together with every 10 kth unit thereafter, to form 10 independent systematic subsamples does permit a valid calculation of the standard error, together with some information on the variances between and within groups of units.

7.7 The foregoing paragraphs do not mean that nonrandom and judgment sampling are of no value. A preliminary judgment sample, for example, may provide useful information for the efficient design of a probability sampling plan. Again, if the material being inspected is known to vary but little, a "grab" sample will be helpful in assessing the level of the characteristic concerned.

7.8 It also should be noted that judgment plays an important role in the *design* of a probability sampling plan. For example, it may be used to assess costs, to estimate spreads and likely values of variances; also definitions of strata. In the actual probability sample, however, judgment is not used in the selection of the individual items of the sample, nor in making the inferences, nor in calculating the risks of decisions based wholly on the sample of succession of samples.

8. Sampling of Bulk Materials

8.1 Sampling of a bulk material involves some similar and some different principles from probability sampling of discrete units.

8.1.1 A sample from the population consists of increments, not items that can be individually identified. Sample size refers to weight or volume or the number of increments rather than the number of items.

8.1.2 Forms of systematic or stratified sampling may still be used to subdivide the population, but only in a limited sense. For example, one may stratify an area of land according to ground slope and wind direction. Still, once one starts to sample the actual material, groups of items, such as dirt particles, are obtained in increments.

8.1.3 It can be difficult to apply the basic principle that every portion of the population has a specified non-zero probability of being in the sample. This principle becomes impossible to apply when some units are inaccessible, such as in odd-shaped containers or cargo holds. Trying to get material near the side or bottom of a container can disturb the matter nearby. Denser or smaller particles might be near the bottom. Similar difficulties of access can affect sampling of discrete units.

8.1.4 Considerations outside the usual sampling sphere become important. Material may change chemically when exposed to different pressure, to light, or to the atmosphere.

8.2 In general, sampling variation can be reduced by taking smaller increments, taking more increments, reducing the particle size