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An American National Standard

Standard Terminology
Relating to Quality and Statistics[1]

This standard is issued under the fixed designation E 456; 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.

This standard has been approved for use by agencies of the Department of Defense.

ε^1 NOTE—E456 was updated editorially in February 2008.

—New terms were added and other terms corrected editorially in January 2009.

1. Scope

1.1 This standard is the general terminology standard for terms defined in the standards of Committee E11 on Quality and Statistics.

1.2 A term in this standard which lists an attribution to an E11 technical standard indicates that the standard is normative for that term. Any changes in the term definition in the normative standard will be editorially changed in this standard. Any terms added to an E11 standard will be editorially added to this standard with an attribution to that standard.

1.3 Term definitions that are similar to ISO 3534 will be noted in this standard, but ISO 3534 will not be considered normative for any E11 terms.

2. Referenced Documents

2.1 *ASTM E11 Standards with terms in this standard:*[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E 178 Practice for Dealing With Outlying Observations

E 1169 Practice for Conducting Ruggedness Tests

E 1325 Terminology Relating to Design of Experiments

E 1402 Guide for Sampling Design

E 1488 Guide for Statistical Procedures to Use in Developing and Applying Test Methods

E 1994 Practice for Use of Process Oriented AOQL and LTPD Sampling Plans

E 2234 Practice for Sampling a Stream of Product by Attributes Indexed by AQL

E 2281 Practice for Process and Measurement Capability Indices

E 2282 Guide for Defining the Test Result of a Test Method

E 2334 Practice for Setting an Upper Confidence Bound For a Fraction or Number of Non-Conforming items, or a Rate of Occurrence for Non-conformities, Using Attribute Data, When There is a Zero Response in the Sample

E 2489 Practice for Statistical Analysis of One-Sample and Two-Sample Interlaboratory Proficiency Testing Programs

E 2554 Practice for Estimating and Monitoring the Uncertainty of Test Results of a Test Method in a Single Laboratory Using a Control Sample Program

E 2555 Practice for Factors and Procedures for Applying the MIL-STD-105 Plans in Life and Reliability Inspection

E 2586 Practice for Calculating and Using Basic Statistics

E 2587 Practice for Use of Control Charts in Statistical Process Control Practice for Use of Control Charts in Statistical Process Control

E 2655 Guide for Reporting Uncertainty of Test Results and Use of the Term Measurement Uncertainty in ASTM Test Methods

2.2 *ISO Standards:*

ISO 3534 Statistics-Vocabulary and Symbols

Part 1: Probability and General Statistical Terms

Part 2: Applied Statistics

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3. Terminology

acceptance (control chart or acceptance control chart usage,), *n*—a decision that the process is operating in a satisfactory manner with respect to the statistical measures being plotted: action limits: *control limits.*

acceptance quality limit AQL , *n*— quality limit that is the worst tolerable process average when a continuing series of lots is submitted for acceptance sampling. **E 2234**

accepted reference value, *n*—a value that serves as an agreed-upon reference for comparison, and which is derived as: (*1*) a theoretical or established value, based on scientific principles, (*2*) an assigned or certified value, based on experimental work of some national or international organization, or (*3*) a consensus or certified value, based on collaborative experimental work under the auspices of a scientific or engineering group. **E 177**

accuracy, *n*—the closeness of agreement between a test result and an accepted reference value. **E 177**

aliases, *n*—*in a fractional factorial design,* two or more effects which are estimated by the same contrast and which, therefore, cannot be estimated separately. **E 1325**

area sampling, *n*—probability sampling in which a map, rather than a tabulation of sampling units, serves as the sampling frame. **E 1402**

assignable cause, *n*—factor that contributes to variation in a process or product output that is feasible to detect and identify (see special cause). **E 2587**

attributes data, *n*—observed values or test results that indicate the presence or absence of specific characteristics or counts of occurrences of events in time or space. **E 2587**

attributes, method of, *n*—measurement of quality by the method of attributes consists of noting the presence (or absence) of some characteristic or attribute in each of the units in the group under consideration, and counting how many units do (or do not) possess the quality attribute, or how many such events occur in the unit, group, or area. **E 2334**

average outgoing quality (AOQ)—the average percent defective of outgoing product including all accepted lots or batches, after any defective units found in them are replaced by acceptable units, plus all lots or batches which are not accepted after such lots or batches have been effectively 100 % inspected and all defective units replaced by acceptable units. **E 1994**

average outgoing quality limit (AOQL)— the maximum of the AOQs for all possible incoming percentages defective for the process, for a given acceptance sampling plan. **E 1994**

average quality protection—a type of protection in which there is prescribed some chosen value of average percent defective in the product after inspection (average outgoing quality limit (AOQL), that shall not be exceeded in the long run no matter what may be the level of percent defective in the product submitted to the inspector. **E 1994**

average run length (ARL)—the average number of times that a process will have been sampled and evaluated before a shift in process level is signaled. **E 2587**

average standard deviation, s̄, *n*—arithmetic average of sample standard deviations. **E 2281**

balanced incomplete block design (BIB), *n*—an incomplete block design in which each block contains the same number *k* of different versions from the *t* versions of a single principal factor arranged so that every pair of versions occurs together in the same number, λ, of blocks from the *b* blocks. **E 1325**

batch, *n*—a definite quantity of some product or material produced under conditions that are considered uniform.

Note1—A batch is usually smaller than a lot.

batch, in inspection, *n*—a collection of units of product produced under conditions that are considered uniform and from which a sample is drawn and inspected, and may differ from a collection of units designated as a batch for other purposes, for example, production, shipment, etc. **E 2234**

batch size, *n*—the number of units of product in a batch. **E 2234**

bias, *n*—the difference between the expectation of the test results and an accepted reference value. **E 177**

bulk sampling, *n*—sampling to prepare a portion of a mass of material that is representative of the whole. **E 1402**

c chart—control chart that monitors the count of occurrences of an event in a defined increment of time or space. **E 2587**

center line—line on a control chart depicting the average level of the statistic being monitored. **E 2587**

chance cause— source of inherent random variation in a process which is predictable within statistical limits (see **common cause**). **E 2587**

characteristic, *n*—a property of items in a sample or population which, when measured, counted or otherwise observed, helps to distinguish between the items. **E 2282**

check sample—see **control sample**. **E 2554**

classification of defects, *n*—the enumeration of possible defects of the unit of product arranged according to their seriousness, that is, critical, major, or minor defect. **E 2234**

cluster sampling, *n*—when the primary sampling unit comprises a bundle of elementary units or a group of subunits, the term cluster sampling may be applied.

Discussion—Examples of cluster sampling are: selection of city blocks as primary sampling units; selection of a household as a cluster of people (of which only one may be interviewed); selection of bundles of rods or pipe from a shipment; and selection, from a shipment, of cartons that contain boxes or packages within them. —sampling in which the sampling unit consists of a group of subunits, all of which are measured for sampled clusters

coefficient or variation, CV—for a nonnegative characteristic, the ratio of the standard deviation to the mean for a population or sample.   .   **E 2586**

collaborative study, *n*—interlaboratory study in which each laboratory uses the defined method of analysis to analyze identical portions of homogeneous materials to assess the performance characteristics obtained for that method of analysis.   **E 2489**

collaborative trial, *n*—see **collaborative study**.   **E 2489**

common cause—see **chance cause**.   **E 2587**

completely randomized design, *n*—a design in which the treatments are assigned at random to the full set of experimental units.   **E 1325**

completely randomized factorial design, *n*—a factorial experiment (including all replications) run in a completely randomized design.   **E 1325**

~~**component of variance,** *n*—a part of a total variance identified with a specified source of variability.~~

composite design, *n*—a design developed specifically for fitting second order response surfaces to study curvature, constructed by adding further selected treatments to those obtained from a 2^n factorial (or its fraction).   **E 1325**

confidence bound, *n*—see **confidence limit**.   **E 2334**

confidence coefficient, *n*—the value, C, of the probability associated with a confidence interval or statistical coverage interval. It is often expressed as a percentage.   **ISO 3534-1**   **E 2334**

confidence interval, *n*—an interval estimate of a population parameter, calculated such that there is a given long-run probability that the parameter is included in the interval.   **E 2334**

confidence level, *n*—see **confidence coefficient**.   **E 2334**

confidence limit, ~~*n*—each of the limits, T_1 and T_2, of the two sided confidence interval, or the limit T of the one sided confidence interval.   **E2334**~~ —**the upper or lower limit of a confidence interval for a population parameter.**   **E 2334**

confounded factorial design, *n*—a factorial experiment in which only a fraction of the treatment combinations are run in each block and where the selection of the treatment combinations assigned to each block is arranged so that one or more prescribed effects is(are) confounded with the block effect(s), while the other effects remain free from confounding.   **E 1325**

confounding, *n*—combining indistinguishably the main effect of a factor or a differential effect between factors (interactions) with the effect of other factor(s), block factor(s) or interactions(s).   **E 1325**

consumer's risk—the probability that a lot whose percentage defective is equal to the LTPD will be accepted by the plan.   **E 1994**

contrast, *n*—a linear function of the observations for which the sum of the coefficients is zero.   **E 1325**

contrast analysis, *n*—a technique for estimating the parameters of a model and making hypothesis tests on preselected linear combinations of the treatments (contrasts).   **E 1325**

~~**control—(evaluation)** , *n*—an evaluation to check, test, or verify; **(authority):** the act of guiding, directing, or managing; **(stability):** a state of process in which the variability is attributable to a constant system of chance causes.~~

control chart , *n*—-chart on which are plotted a statistical measure of a subgroup versus time of sampling along with limits based on the statistical distribution of that measure so as to indicate how much common, or chance, cause variation is inherent in the process or product.   **E 2587**

control chart factor, *n*—a tabulated constant, depending on sample size, used to convert specified statistics or parameters into a central line value or control limit appropriate to the control chart.   **E 2587**

~~**control chart method,** *n*—the method of using control charts to determine whether or not processes are in a stable state.~~

control limits, *n*—limits on a control chart that are used as criteria for signaling the need for action or judging whether a set of data does or does not indicate a state of statistical control based on a prescribed degree of risk.   **E 2587**

control sample, *n*—sample taken from a stable, homogeneous material for the purposes of monitoring the performance of a test method in a laboratory.   **E 2554**

critical defect, *n*—a defect that judgment and experience indicate would result in hazardous or unsafe conditions for individuals using, maintaining, or depending upon the product, or a defect that judgment and experience indicate is likely to prevent performance of the function of a major end item.   **E 2234**

critical defective, *n*—a unit of product which contains one or more critical defects and may also contain major and/or minor defects.   **E 2234**

defect, *n*—any nonconformance of the unit of product with specified requirements.   **E 2234**

defective, *n*—a unit of product which contains one or more defects.   **E 2234**

defects per hundred units, *n*—any given quantity of units of product is one hundred times the number of defects contained therein (one or more defects being possible in any unit of product) divided by the total number of units of product, that is:

$$\text{Defects per hundred units} = \frac{\text{Number of defects} \times 100}{\text{Number of units inspected}}$$

E 2234

dependent variable, *n*—See **response variable**.   **E 1325**

design of experiments, *n*—the arrangement in which an experimental program is to be conducted, and the selection of the levels

(versions) of one or more factors or factor combinations to be included in the experiment. Synonyms include experiment design and experimental design. **E 1325**

~~**deviation,** *n*—the difference between a measurement or quasi-measurement and its stated value or intended level.~~

~~Discussion—*Deviation* should be stated as a difference in terms of the appropriate data units. Sometimes these units will be original measurement units; sometimes they will be quasi-measurements; that is, a scaled rating of subjective judgments; sometimes they will be designated values representing all continuous or discrete measurements falling in defined cells or classes.~~

double sampling plan, *n*—a multiple sampling plan in which up to two samplings can be taken and evaluated to accept or reject a lot. **E 2555**

empirical percentile, *n*—estimate of a population percentile using the sample data. This is a sample value such that a percentage p of the sample is less than that value. **E 2586**

error of result, *n*—~~the test result minus the accepted reference value (of the characteristic).~~

~~Note2—It is not possible to correct for random error.~~ —a test result minus the accepted reference value of the characteristic. **E 2655**

expanded uncertainty, U, *n*—uncertainty reported as a multiple of the standard uncertainty. **E 2655**

evolutionary operation (EVOP), *n*— a sequential form of experimentation conducted in production facilities during regular production. **E 1325**

experimental design, *n*—see **design of experiments.** **E 1325**

experiment space, *n*—the materials, equipment, environmental conditions and so forth that are available for conducting an experiment. **E 1325**

experimental unit, *n*—a portion of the experiment space to which a treatment is applied or assigned in the experiment. **E 1325**

factorial experiment (general), *n*— in general, an experiment in which all possible treatments formed from two or more factors, each being studied at two or more levels (versions) are examined so that interactions (differential effects) as well as main effects can be estimated. **E 1325**

2^n **factorial experiment,** *n*—a factorial experiment in which n factors are studied, each of them in two levels (versions). **E 1325**

fractional factorial design, *n*—a factorial experiment in which only an adequately chosen fraction of the treatments required for the complete factorial experiment is selected to be run. **E 1325**

~~**frame,** *n*—a list, compiled for sampling purposes, which designates the items (units) of a population or universe to be considered in a study.~~

~~Discussion—When a frame is available, sampling schemes can be devised for selection of the units directly (one-stage), or in two or more stages. In multi-stage sampling, a frame is needed for each stage. As an example, the cartons of a lot could be the first-stage units, packages within the carton could be second-stage units, and items within the packages could be the third-stage units.~~ —a list, compiled for sampling purposes, which designates all of the sampling units (items or groups) of a population or universe to be considered in a specific study. **E 1402**

fully nested experiment, *n*—a nested experiment in which the second factor is nested within levels (versions) of the first factor and each succeeding factor is nested within versions of the previous factor. **E 1325**

hierarchical experiment, *n*—see **nested experiment**. **E 1325**

histogram, *n*—graphical representation of the frequency distribution of a characteristic consisting of a set of rectangles with area proportional to the frequency. **E 2586**

I chart, *n*—control chart that monitors the individual subgroup observations. **E 2587**

incomplete block design, *n*—a design in which the experiment space is subdivided into blocks in which there are insufficient experimental units available to run a complete set of treatments or replicate of the experiment. **E 1325**

inspection, *n*—the process of measuring, examining, testing, or otherwise comparing the unit of product with the requirements. **E 2234**

inspection by attributes, *n*—inspection whereby either the unit of product is classified simply as defective or non-defective, or the number of defects in the unit of product is counted, with respect to a given requirement or set of requirements. **E 2234**

interlaboratory comparison, *n*—organization, performance, and evaluation of tests on the same or similar test items by two or more laboratories in accordance with predetermined conditions. **E 2489**

interquartile range, IQR, *n*—the 75 th percentile (0.75 quantile) minus the 25th percentile (0.25 quantile), for a data set. **E 2586**

intermediate precision, *n*—the closeness of agreement between test results obtained under specified intermediate precision conditions. **E 177**

intermediate precision conditions, *n*— conditions under which test results are obtained with the same test method using test units or test specimens (see Practice E 691,[2] 10.3) taken at random from a single quantity of material that is as nearly homogeneous as possible, and with changing conditions such as operator, measuring equipment, location within the laboratory, and time. **E 177**

~~**item,** *n*—(*1*) an object or quantity of material on which a set of observations can be made: (2) an observed value or test result obtained from an object or quantity of material.~~

kurtosis, γ_2, g_2, *n*— for a population or a sample, a measure of the weight of the tails of a distribution relative to the center, calculated as the ratio of the fourth central moment (empirical if a sample, theoretical if a population applies) to the standard deviation (sample, s, or population, σ) raised to the fourth power, minus 3 (also referred to as excess kurtosis). **E 2586**

level (of a factor), *n*—a given value, a specification of procedure or a specific setting of a factor. **E 1325**

limiting quality level (LQL), *n*—quality level having a specified consumer's risk for a given sampling plan. **E 2555**

long term standard deviation, σ_{LT}, *n*—sample standard deviation of all individual (observed) values taken over a long period of time. **E 2281**

lot, *n*—see batch. **E 2234**

lot size, *n*—see batch size. **E 2234**

lot quality protection—a type of protection in which there is prescribed some chosen value of limiting percent defective in a lot (lot tolerance percent defective, (LTPD)) and also some chosen value for the probability (called the consumer's risk) of accepting a submitted lot that has a percent defective equal to the lot tolerance percent ~~defective.lot— lot size—~~ defective.lot. **E 1994**

lot tolerance percent defective (LTPD)— the percentage of defective units in a batch or lot for which, for purposes of acceptance sampling, the consumer wishes the probability of acceptance to be restricted to a specified low value, specifically 10 % for this practice. This is also referred to by the more general term *limiting quality* taken at 10 % consumer risk. **E 1994**

lower control limit (LCL), *n*—minimum value of the control chart statistic that indicates statistical ~~control..~~ control. **E 2587**

lower process capability index, C_{pkl}, *n*—index describing process capability in relation to the lower specification limit. **E 2281**

lower process performance index, P_{pkl}, *n*—index describing process performance in relation to the lower specification limit. **E 2281**

~~**lower tolerance limit (LTL) (lower specification limit) ,** *n*—a tolerance limit that defines the lower conformance boundary for an individual unit of a manufacturing or service operation.~~

main effect, average effect, *n*—a term describing a measure for the comparison of the responses at each level (version) of a factor averaged over all levels (versions) of other factors in the experiment. **E 1325**

major defect, *n*—a defect, other than critical, that is likely to result in failure, or to reduce materially the usability of the unit of product for its intended purpose. **E 2234**

major defective, *n*—a unit of product which contains one or more major defects, and may also contain minor defects but contains no critical defect. **E 2234**

mean , *n*—*of a population*, μ, average or expected value of a characteristic in a population – *of a sample,* $\bar{x}$ sum of the observed values in the sample divided by the sample size. **E 2586**

median $\tilde{X}$, *n*—the 50th percentile in a population or sample. **E 2587**

method of least squares, *n*—a technique of estimation of a parameter which minimizes Σe^2, where *e* is the difference between the observed value and the predicted value derived from the assumed model. **E 1325**

midrange, *n*—average of the minimum and maximum values in a sample. **E 2586**

minimum process capability index, C_{pk}, *n*—smaller of the upper process capability index and the lower process capability index. **E 2281**

minimum process performance index, P_{pk}, *n*—smaller of the upper process performance index and the lower process performance index. **E 2281**

minor defect, *n*—a defect that is not likely to reduce materially the usability of the unit of product for its intended purpose, or is a departure from established standards having little bearing on the effective use or operation of the unit. **E 2234**

minor defective, *n*—a unit of product which contains one or more minor defects but contains no critical or major defect. **E 2234**

mixture design, *n*—a design in which two or more ingredients or components shall be mixed and the response is a property of the resulting mixture that does not depend upon the amount of the mixture. **E 1325**

MR chart, *n*—control chart that monitors the moving range of consecutive individual subgroup observations. **E 2587**

multiple sampling plant, *n*—a sampling plan in which successive samples from a lot are drawn and after each sample is inspected a decision is made to accept the lot, reject the lot, or to take another sample, based on quality level of the combined samples. **E 2555**

natural process limits (NPL), ~~*multi-stage sampling,* *n*—~~limits which include a stated fraction of the individuals in a population.

~~NOTE3—*Natural process limits* will not ordinarily be the dimensional limits shown on an engineering drawing. They are mostly used to compare the natural capability of the process to tolerance limits.~~

~~Discussion—For populations with a normal (Gaussian) distribution, the *natural process limits* ordinarily will be at ±3 σ . If placed around the standard level, these limits identify the boundaries which will include approximately 99.7% of the individuals in a process that is properly centered and in a state of *statistical control*. In many circumstances (several machines making the same product that serially feed into the process) it is recognized that in addition to the variability around a single level, an acceptable zone of "standard" levels (for the different machines) is required. Then~~

~~the NPL may be placed around the Acceptable Process Levels (APL) that define this zone so that the NPL identify the boundaries within which at least 99.7% of the individuals will be included in a process located at the APL, or inside the zone. It should be noted that there is no assumption made that the process levels within the zone are random variables.~~—sampling in which the sample is selected by stages, the sampling units at each stage being selected from subunits of the larger sampling units chosen at the previous stage. **E 1402**

nested experiment, *n*—an experiment to examine the effect of two or more factors in which the same level (version) of a factor cannot be used with all levels (versions) of other factors. Synonym: hierarchical experiment. **E 1325**

nested sampling, *n*—same as multi–stage sampling. **E 1402**

non-conforming item, *n*—an item containing at least one non-conformity. **E 2334**

observation, *n*—the process of obtaining information regarding the presence or absence of an attribute of a test specimen, or of making a reading on a characteristic or dimension of a test specimen. **E 2282**

observed value, *n*—the value obtained by making an observation. **E 2282**

order statistic x $_{(k)}$, *n*— value of the kth observed value in a sample after sorting by order of magnitude. **E 2586**

orthogonal array, *n*—a table of coefficients identifying the levels, or some weight associated with the levels, for each factor to be used in the analysis of specified effects, which are arranged in such a manner that each effect will be independent of the other effects. **E 1325**

orthogonal contrasts, *n*—two contrasts are orthogonal if the contrast coefficients of the two sets satisfy the condition that, when multiplied in corresponding pairs, the sum of the products is equal to zero. See **contrast** and **contrast analysis.** **E 1325**

outlier—see **outlying observation**. **E 178**

outlying observation, *n*—an observation that appears to deviate markedly in value from other members of the sample in which it appears. **E 178**

p chart, *n*—control chart that monitors the fraction of occurrences of an event. **E 2587**

partially balanced incomplete block design (PBIB), *n*—an incomplete block design in which each block contains the same number *k*, of different versions from the *t* versions of the principal factor. **E 1325**

partially nested experiment, *n*—a nested experiment in which several factors may be crossed as in factorial experiments and other factors nested within the crossed combinations. **E 1325**

percent defective, *n*—any given quantity of units of product one hundred times the number of defective units of product contained therein divided by the total number of units of product, that is:

$$\text{Percent Defective} = \frac{\text{Number of defectives} \times 100}{\text{Number of units inspected}}$$

E 2234

Plackett-Burman designs, *n*—a set of screening designs using orthogonal arrays that permit evaluation of the linear effects of up to $n = t - 1$ factors in a study of *t*, treatment combinations. **E 1325**

population, *n*—the totality of items or units of material under consideration. **E 2586**

population parameter, *n*—summary measure of the values of some characteristic of a population. **E 2586, ISO 3534–2**

precision, *n*—the closeness of agreement between independent test results obtained under stipulated conditions. **E 177**

primary sampling unit, psu, *n*—the item, element, increment, segment or cluster selected at the first stage of the selection procedure from a population or universe. **E 1402**

probability proportional to size sampling, pps, *n*—probability sampling in which the probabilities of selection of sampling units are proportional, or nearly proportional, to a quantity (the "size") that is known for all sampling units. **E 1402**

probability sample, *n*—~~a sample of which the sampling units have been selected by a chance process such that, at each step of selection, a specified probability of selection can be attached to each sampling unit available for selection.~~

~~Note 4—These probabilities of selection need not be equal. If equal, see simple random sample. See the general term—sample. Also, see Practice E105²~~ ~~in this volume.~~—a sample in which the sampling units are selected by a chance process such that a specified probability of selection can be attached to each possible sample that can be selected. **E 1402**

process average, *in inspection,* *n*—the average percent defective or average number of defects per hundred units (whichever is applicable) of product submitted by the supplier for original inspection. **E 2234**

process capability, PC, *n*—statistical estimate of the outcome of a characteristic from a process that has been demonstrated to be in a state of statistical control. **E 2281**

process capability index, C$_p$, *n*—an index describing process capability in relation to specified tolerance. **E 2281**

process performance, PP, *n*—statistical measure of the outcome of a characteristic from a process that may not have been demonstrated to be in a state of statistical control. **E 2281**

process performance index, P$_p$, *n*—index describing process performance in relation to specified tolerance. **E 2281**

proficiency testing, *n*—determination of laboratory testing performance by means of interlaboratory comparisons. **E 2489**

proportional sampling, *n*—a method of selection in stratified sampling such that the proportions of the sampling units (usually, psu's) selected for the sample from each stratum are equal. **E 1402**

quota sampling, *n*—a method of selection similar to stratified sampling in which the numbers of units to be selected from each stratum is specified and the selection is done by trained enumerators but is not a probability sample. **E 1402**