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Standard Terminology for Relating to Quality and Statistics[1]

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1. Scope

1.1 This terminology includes those quality and statistical terms in wide use in ASTM for which standard definitions appear desirable.

2. Referenced Documents

2.1 *ASTM Standards:*

E 177 Practice for the Use of the Terms Precision and Bias in ASTM Test Methods[2]

E 1325 Terminology Relating to Design of Experiments[2]

E 1402 Terminology Relating to Sampling[2]

3. Significance and Use

3.1 This terminology is the general terminology standard for terms defined by Committee E-11.

3.2 Citation is made to other E-11 standards which contain more extensive information regarding the particular term and its usage. These references may be to other practices and guides or to more specific terminology standards, such as Terminology E 1325.

4. Terminology

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

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.

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

NOTE 1—The term accuracy, when applied to a set of test results, involves a combination of a random component and of a common systematic error or bias component.

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**

assignable cause, *n*—a factor that contributes to variation, and which is feasible to detect and identify.

NOTE 2—Many factors will contribute to variation but it may not be feasible (economically or otherwise) to identify some of them.

attribute data, *n*—observed values or determinations which indicate the presence or absence of specific characteristics.

DISCUSSION—Items or units of material may be evaluated by counting or measurement. Attributes are counted whereas variables are measured. Attribute distributions are discrete. See **variables data**.

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.

average run length (ARL)—(*1*) **sample sense,** *n*—the average number of times that a process will have been sampled and evaluated before a shift in process level is signaled, and (*2*) **unit sense,** *n*—the average number of units that will have been produced before a shift in level is signaled.

DISCUSSION—A long ARL is desirable for a process located at its specified level (so as to minimize calling for unneeded investigation or corrective action) and a short ARL is desirable for a process shifted to some undesirable level (so that corrective action will be called for promptly). ARL curves are used to describe the relative quickness in detecting level shifts of various control chart systems.

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.

NOTE 3—A batch is usually smaller than a lot.

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

[1] This terminology is under the jurisdiction of ASTM Committee E-11 on Quality and Statistics and is the direct responsibility of Subcommittee E11.60 on Terminology.

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

NOTE 4—Bias is the total systematic error as contrasted to random error. There may be one or more systematic error components contributing to the bias. A larger systematic difference from the accepted reference value is reflected by a larger bias value.

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

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.

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**

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.

NOTE 5—All factor level combinations are included in the experiment. **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).

NOTE 6—Confounding is a useful technique that permits the effective use of specified blocks in some experiment designs. This is accomplished by deliberately preselecting certain effects or differential effects as being of little interest, and arranging the design so that they are confounded with block effects or other preselected principal factor or differential effects, while keeping the other more important effects free from such complications. Sometimes, however, confounding results from inadvertent changes to a design during the running of an experiment or from incomplete planning of the design, and it serves to diminish, or even to invalidate, the effectiveness of an experiment. **E 1325**

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

NOTE 7—With observations Y_1, Y_2,..., Y_n, the linear function $a_1Y_1 + a_2Y_2 + ... + a_n Y_n$ is a contrast if, and only if $\Sigma a_i = 0$, where the a_i values are called the contrast coefficients. **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).

NOTE 8—Contrast analysis involves a systematic tabulation and analysis format usable for both simple and complex designs. When any set of orthogonal contrasts is used, the procedure, as in the example, is straightforward. When terms are not orthogonal, the orthogonalization process to adjust for the common element in nonorthogonal contrast is also systematic and can be programmed. **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 factor, *n*—a factor, usually varying with sample size, to convert specified statistics or parameters into a central line value or control limit appropriate to the control chart.

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 which are used as criteria for signaling the need for action, or for judging whether a set of data does or does not indicate a state of statistical control.

conventional true value of a quantity, *n*—value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose.

NOTE 9—′′Conventional true value” is sometimes called ′′assigned value”, ′′best value”, ′′conventional value”, or ′′reference value”. ′′Reference value”, in this sense, should not be confused with ′′reference value” in the sense of an influence quantity affecting a measuring instrument.

NOTE 10—Frequently, a number of results of measurements of a quantity is used to establish a conventional true value.

DISCUSSION—When warning limits are used, the control limits are often called “action limits.” Action may be in the form of investigation of the source(s) of an “assignable cause”, making a process adjustment, or terminating a process. Criteria other than *control limits* are also used frequently.

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

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.

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

NOTE 11—It is not possible to correct for random error.

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.

NOTE 12—The unit may be a patient in a hospital, a group of animals, a production batch, a section of a compartmented tray, etc. **E 1325**

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

NOTE 13—The principal theses of EVOP are that knowledge to improve the process should be obtained along with a product, and that designed experiments using relatively small shifts in factor levels (within production tolerances) can yield this knowledge at minimum cost. The range of variation of the factors for any one EVOP experiment is usually quite small in order to avoid making out of tolerance products, which may require considerable replication, in order to be able to clearly detect the effect of small changes. **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.

NOTE 14—This procedure is sometimes called fractional replication.

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.

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**.

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**

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

NOTE 15—The specific measure and the specific conditions must be specified for each intermediate measure of precision; thus, ′′standard deviation of test results among operators in a laboratory,” or ′′day-to-day standard deviation within a laboratory for the same operator.”

NOTE 16—Because the training of operators, the agreement of different pieces of equipment in the same laboratory and the variation of environmental conditions with longer time intervals all depend on the degree of within-laboratory control, the intermediate measures of precision are likely to vary appreciably from laboratory to laboratory. Thus, intermediate precisions may be more characteristic of individual laboratories than of the test method.

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.

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.

DISCUSSION—The second usage in the definition is generally limited to generic descriptions such as in the definition of “population.” Terms such as “observation,” “measurement,” “test result,” “unit,” “value” or “yield” are more common in specific applications. A set as used here may be one or more variables.

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

NOTE 17—′′Version” is a general term applied both to quantitative and qualitative factors. The more restrictive term ′′level” is frequently used to express more precisely the quantitative characteristic. For example, two versions of a catalyst may be presence and absence. Four levels of a heat treatment may be 100°C, 120°C, 140°C, and 160°C. **E 1325**

lot—a definite quantity of a product or material accumulated under conditions that are considered uniform for sampling purposes.

lower control limit (LCL), *n*—control limit for points below the central line.

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.

NOTE 18—The term ′′main effect” may describe the parameter in an assumed model or the estimate of this parameter. **E 1325**

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.

NOTE 19—The proportions of each of the q components (X_i) in the mixture shall satisfy the conditions $O \leq X_i \leq 1$ and $\sum_{i=1}^{c} X_i = 1$; and each experimental point is defined in terms of these proportions.

NOTE 20—In some fields of application the experimental mixtures are described by the terms ′′formulation” or ′′blend.” The use of mixture designs is appropriate for experimenting with the formulations of manufactured products, such as paints, gasoline, foods, rubber, and textiles.

NOTE 21—In some applications, the proportions of the components of the mixture may vary between 0 and 100 % of the mixture (′′complete domain”). In others, there may be operative restraints, so that at least one component cannot attain 0 or 100 % (′′reduced domain”). **E 1325**

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**

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

NOTE 22—*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 $\pm 3\ \sigma$. 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.

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**

observation, *n*—(*1*) 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, or (*2*) the attribute or measurement information obtained from the process. (The term ″observed value" is preferred for this second usage.)

NOTE 23—See Annex A1.

observed value, *n*—the value obtained by carrying out the complete protocol of the test method once, being either a single test determination or an average or other specified combination of a specified number of test determinations.

NOTE 24—See Annex A1.

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**

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.

NOTE 25—The arrangement is such that not all pairs of versions occur together in the same number of the blocks; some versions can therefore be compared with greater precision than others. **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.

NOTE 26—It is not unusual to find that experiments consist of both factorial and nested segments. See **nested experiment.** **E 1325**

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.

DISCUSSION—The word "items" may be interpreted in the sense of measurements, or possible measurements, for a single characteristic, or occasionally for multiple characteristics, on all items or units of material being considered. The word "totality" may refer to items not available for inclusion in samples as well as those which are available.

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

NOTE 27—Precision depends on random errors and does not relate to the true value or the specified value.

NOTE 28—The measure of precision usually is expressed in terms of imprecision and computed as a standard deviation of the test results. Less precision is reflected by a larger standard deviation.

NOTE 29—″Independent test results" means results obtained in a manner not influenced by any previous result on the same or similar test object. Quantitative measures of precision depend critically on the stipulated conditions. Repeatability and reproducibility conditions are particular sets of extreme stipulated conditions.

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 30—These probabilities of selection need not be equal. If equal, see simple random sample. See the general term—sample. Also, see Practice E 105[2] in this volume.

random error of result, *n*—a component of the error which, in the course of a number of test results for the same characteristic, varies in an unpredictable way.

randomization, *n*—the procedure used to allot treatments at random to the experimental units so as to provide a high degree of independence in the contributions of experimental error to estimates of treatment effects.

NOTE 31—An essential element in the design of experiments is to provide estimates of effects free from biases due to undetected assignable causes within the experimental space. Randomization is a process to minimize this risk. The operational procedure for assignment ″at random" involves the use of random numbers or some similar method for assuring that each unit has an equal chance of being selected for each treatment. **E 1325**

randomized block design, *n*—a design in which the experiment space is subdivided into blocks of experimental units, the units within each block being more homogeneous than units in different blocks.

NOTE 32—In each block the treatments are allocated randomly to the experimental units within each block. Replication is obtained by the use of two or more blocks, depending on the precision desired, and a separate randomization is made in each block. **E 1325**

randomized block factorial design, *n*—a factorial experiment