



AEROSPACE RECOMMENDED PRACTICE	ARP9013™	REV. A
	Issued 2005-10 Cancelled 2018-06	
	Superseded by AS9138	
Statistical Product Acceptance Requirements		

RATIONALE

This document is Cancelled and Superseded by AS9138. AS9138 is an upgrade and replacement for the Aerospace Recommended Practice (ARP) 9013-series of documents (i.e., ARP9013, ARP9013/1, ARP9013/2, ARP9013/3, ARP9013/4) prepared and published by the Americas Aerospace Quality Group (AAQG) in 2005. Technically equivalent standards are published in all International Aerospace Quality Group (IAQG) sectors (i.e., Americas, Asia-Pacific, Europe).

CANCELLATION NOTICE

This Technical Report has been declared "CANCELLED" as of June 2018 and has been superseded by AS9138. By this action, this document will remain listed in the respective index, if applicable. Cancelled Technical Reports are available from SAE.

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FOREWORD

To assure customer satisfaction, aerospace industry organizations shall produce, and continually improve, safe, reliable products that meet or exceed customer and regulatory authority requirements. The globalization of the aerospace industry, and the resulting diversity of regional/national requirements and expectations, has complicated this objective. End-product organizations face the challenge of assuring the quality of, and integrating, product purchased from suppliers throughout the world and at all levels within the supply chain. Aerospace suppliers and processors face the challenge of delivering product to multiple customers having varying quality expectations and requirements.

The aerospace industry established the International Aerospace Quality Group (IAQG) for the purpose of achieving significant improvements in quality and safety, and reductions in cost, throughout the value stream. This organization includes representation from aerospace companies in the Americas, Asia/Pacific, and Europe. This recommended practice has been prepared by the Americas Aerospace Quality Group (AAQG).

This document standardizes, to the greatest extent possible, the requirements on statistical techniques for product acceptance in the aerospace industry. The establishment of common requirements, for use at all levels of the supply-chain, by organizations around the world, should result in improved quality and safety, and decreased costs due to the elimination or reduction of organization-unique requirements and the resultant variation inherent in these multiple expectations.

INTRODUCTION

This recommended practice's series of documents establishes the general requirements applicable to any of the methods of statistical product acceptance to reduce inspection costs while still assuring acceptable quality. There is no single specific plan that can be considered best suited for all applications or processes. This ARP9013 document contains the basic requirements needed to implement the statistical methods described in ARP9013/1 through ARP9013/4 series to control outgoing quality. All applicable requirements of this ARP9013 document shall be met when using one or more of the ARP9013/1 through ARP9013/4 recommended practices.

This document does not apply to statistical methods that are separate from product acceptance. Many companies use excellent statistical methods solely to monitor and improve their product quality, and those methods are not subject to the requirements of this document. This document applies only to those statistical methods used for product acceptance.

The requirements are contained in the main body of this recommended practice. This recommended practice also includes several appendices, which are offered for guidance or recommendation purposes only. Each appendix herein contains only nonmandatory suggestions, examples, or further discussion on specific topics that the authorship believes will aid the successful implementation of this recommended practice for the user organization.

Products which may be eligible for the methods defined in this recommended practice's series include but are not limited to end items; cast, forged, wrought, machined, fabricated, plastic, molded, powdered metal, or stamped components and raw material; electronic, electrical, and mechanical components; lots subjected to receiving inspection, in-process inspection, and final inspection; supplies in storage; and services, any of which may be produced in batches, large or small lots, continuous processes, or single-piece flow manufacturing processes.

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1. SCOPE:

1.1 Purpose:

This SAE Aerospace Recommended Practice (ARP) establishes the general requirements when implementing any of the statistical product acceptance methods as defined in ARP9013/1, ARP9013/2, ARP9013/3, and ARP9013/4. This recommended practice also establishes the minimum content required to be covered in an organization's documented procedures that govern their application of statistical product acceptance methods. These general requirements and documented procedures apply the requirements of AS9100 plus requirements for retrievability, safety/critical characteristics, quality parameters, and that these parameters protect the customer. This recommended practice is to be used in conjunction with the variety of sampling strategies, statistical techniques, and process control methods of the ARP9013/1 through ARP9013/4 recommended practices as chosen by the organization.

1.2 Field of Application:

This recommended practice is applicable when invoked in a purchasing contract or specification, other contractual document, customer agreement, or adopted by the organization. The appropriate slash-numbered recommended practice(s) in this series applied by the organization may or may not be specified by the purchaser's contract, but does form a part of the ARP9013 flowdown requirement.

If desired to sample a series of lots without using ARP9013/1, ARP9013/2, or ARP9013/3, the requirements of ARP9013/4 shall be used.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. Nothing in this document, however, supersedes applicable laws, regulations, and contractual requirements.

- 2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

ARP9013/1 Statistical Product Acceptance Requirements Using Isolated Lot Sampling Methods

ARP9013/2 Statistical Product Acceptance Requirements Using Attribute or Variable Lot Acceptance Sampling Plans

ARP9013/3 Statistical Product Acceptance Requirements Using Process Control Methods

ARP9013/4 Statistical Product Acceptance Requirements Using Continuous Sampling, Skip-Lot Sampling, or Methods for Special Cases

AS9100 Quality Management Systems - Aerospace - Requirements

AS9103 Variation Management of Key Characteristics

- 2.1.2 ANSI/ASQC Publications: Available from the American Society for Quality (ASQ), 600 North Plankinton Avenue, Milwaukee, WI 53203, Tel: 800-248-1946 or 414-272-8575, www.asq.org

ANSI/ASQC B1 Guide for Quality Control Charts

ANSI/ASQC B2 Control Chart Method of Analyzing Data

ANSI/ASQC B3 Control Chart Method of Controlling Quality During Production

ANSI/ASQC Q3 Sampling Procedures and Tables for Inspection of Isolated Lots by Attributes

ANSI/ASQC S1 An Attribute Skip-Lot Sampling Program

ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes

ANSI/ASQC Z1.9 Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming

- 2.1.3 Applicable References: Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, <http://assist.daps.dla.mil/quicksearch/>.

MIL-STD-1235 Single and Multi-Level Continuous Sampling Procedures and Table for Inspection by Attributes

NOTE: MIL-STD-1235 has been cancelled but may be used as a guide for derivation and application of continuous sampling plans. Appendix A of ARP9013/4 contains the essential text and tables of MIL-STD-1235C with some editing, reformatting, and paragraph renumbering; however, all the functional curves have been purposely omitted to conserve the length of the recommended practice.

2.2 Related Publications:

ISO 2859/2 "Sampling Plans Indexed by Limiting Quality (LQ) for Isolated Lot Inspection," may be obtained from any ISO Licensor's members or from the ISO Secretariat, Case Postale 56, 1211 Geneva 20, Switzerland.

N. L. Squeglia, "Zero Acceptance Number Sampling Plans," ASQ Quality Press, 611 East Wisconsin Avenue, P.O. Box 3005, Milwaukee, WI 53201-3005.

Braverman, Jerome D., "Fundamentals of Statistical Quality Control," New Jersey: Prentice Hall, 1981.

Grant, Eugene L. and Leavenworth, Richard S., "Statistical Quality Control," New York: McGraw Hill Company, 1996.

Dodge, H. F., "Chain Sampling Inspection Plan," Industrial Quality Control, 11, No. 4 (January 1955), 10-13.

Besterfield, Dale H., "Quality Control", Additional Acceptance Sampling Plan Systems, 7, Third Edition, 1990, 272-275.

Scheaffer, R. L. and McClave, J. T., "Probability and Statistics for Engineers," 2nd Edition, PWS Publishers, Duxbury Press, 1986, 280-281.

2.3 Definitions:

ACCEPTABLE QUALITY LEVEL (AQL): The maximum percentage or proportion of nonconforming units in a lot or batch that, for purposes of acceptance sampling, would be considered satisfactory as a process average. See 3.3 and Appendix A.

ACCEPTANCE SAMPLING: Inspection in which decisions are made to accept or not accept a lot (or other grouping of product or material) based on the results of a sample or samples selected from that lot or grouping.

ANALYSIS OF VARIANCE (ANOVA): An arithmetic process developed for the purpose of comparing several sample means by partitioning the total variation of a set of data into components associated with recognized sources of variation.

ATTRIBUTE DATA: Qualitative data that counts the presence or absence of a characteristic evaluated to a specified criterion, rather than data from a discrete measurement on a continuous scale. Attribute data is typically measured on a go/no-go, pass/fail, or yes/no basis.

AVERAGE OUTGOING QUALITY (AOQ): The average quality of outgoing product after sampling inspection for a given steady value of incoming product quality. Achieving reasonable values of the AOQ usually requires that units found nonconforming are replaced with units known to be conforming. Both incoming and outgoing quality are generally expressed in terms of the percent of nonconforming product.

AVERAGE OUTGOING QUALITY LIMIT (AOQL): Maximum AOQ over all possible values of incoming product quality level for a given acceptance sampling plan.

AVERAGE RUN LENGTH (ARL): The average number of plotted points on a control chart or the average number of items inspected before a shift in process level may be expected to be signaled. A typical benchmark is the average number of samples before a 2-sigma shift in the process produces a signal. A measure of effectiveness of detecting sustained shifts.

2.3 (Continued):

BERNOULLI TRIALS MODEL: A model where (1) the same kind of trial is repeated several times; (2) on each trial there are two possible outcomes, for example, conforming or nonconforming; (3) repeated trials (units of product) are independent; and (4) the probability of each outcome remains the same for each trial. In a Bernoulli trials model, the probability of exactly k nonconforming units in n trials is given by:

$$b(n, k; p) = \binom{n}{k} p^k (1-p)^{n-k} \quad (\text{Eq. 1})$$

where:

$b(n, k; p)$ is the probability of k nonconforming items in n trials

n is the fixed number of Bernoulli trials

k is the number of nonconforming units in n trials

p is the probability of a nonconforming unit and $(1-p)$ is the probability of a conforming unit. This is called a binomial probability.

BINOMIAL DISTRIBUTION: In the literature of statistics, the binomial as a probability distribution results from a Bernoulli trials model of the process.

C=0: An acceptance-sampling plan that requires rejection of the lot if the sample contains one or more nonconformances.

CAPABILITY: The range of six standard deviations of the values in a process having no changes in its mean or any other characteristic of its distribution. The inherent variation in a stable process. For the case of attribute data, it is usually defined as the average proportion or rate of defects or defectives (e.g., centerline of an attribute control chart). The Bayesian estimator for defect rate when no defects are observed in the current sample is:

$$P(d) = \frac{1}{(n+2)} \quad (\text{Eq. 2})$$

where:

$P(d)$ is the probability of a defect (the defect rate)

n is the number of representative observations of the process, no defects observed

2.3 (Continued):

COMBINATIONS: The number of distinct groupings of m distinct objects taken i at a time, where order of selection is immaterial, as 123, 321, and 213.

$$\binom{m}{i} = \frac{m!}{i! (m - i)!} \quad (\text{Eq. 3})$$

where:

$$m! = m \times (m-1) \times (m-2) \times \dots \times 3 \times 2 \times 1$$

CONFORMANCE: When a characteristic of a product or process meets its requirements. Fulfillment of specified requirements. Also called "Conformity."

CONSUMER'S RISK: The probability that a lot with a fraction of nonconforming material equal to a stated index value will be accepted by a sampling plan. Also referred to as beta (β) risk.

CONTINUOUS ACCEPTANCE SAMPLING: Inspection intended for application on continuous flow of individual items of product that involves acceptance or nonacceptance on a unit-by-unit basis using periods of one-hundred percent (100%) inspection and periods of sampling, depending on the quality of the observed product.

CONTINUOUS MANUFACTURING PROCESS: A combination of manufacturing methods used in the continual flow of individual items of product that does not have any known source of variation or quality risk other than those operating on the first and last units of the production run. Where production is continuous, the formation of inspection lots between the start and finish is somewhat artificial.

CRITICAL CHARACTERISTIC: A characteristic designated by the design authority, where the responsibility for its definition is outside the scope of this recommended practice.

CUSTOMER: The buying entity that is the issuer of a contract to a sub-tier supplier.

DEFECT: Non-fulfillment of a requirement related to an intended or a specified use. A departure of a quality characteristic from its intended level or state that occurs with a severity sufficient to cause an associated product or service not to satisfy intended normal, or foreseeable, usage requirements.

DETERMINE: To reach a decision beyond reasonable doubt that each accepted unit conforms to its requirements.

2.3 (Continued):

EQUAL RISK POINT (ERP): The fraction nonconforming at which the probability of rejecting a lot is fifty percent (also noted as $p_{.50}$). At this fraction nonconforming, the risk to the producer and consumer are the same. When no integer number of nonconforming units produces exactly 50% probability of acceptance, the equal risk point for that sample size is computed as the weighted average of the two nearest points on its discrete OC curve. This is also the point where a straight line connecting those two points would cross the line $Pa = .50$.

EXPECTED OUTGOING QUALITY (EOQ): The probability that a unit accepted by sample inspection is nonconforming, given both the sampling plan and a statement of what quality patterns have been demonstrated for the process. An EOQ can only be computed if there is a hypothetical distribution whether based upon parameters or an empirical distribution and it depends upon the AOQ values.

GAGE REPEATABILITY AND REPRODUCIBILITY (GAGE R&R): A study used to determine the degree of variability within a measurement system, and to separate this variability into components associated with the gage and the use of the gage.

HOMOGENEOUS PROCESS: A process where there is a repetitive production running under the same conditions.

HYPERGEOMETRIC DISTRIBUTION: Applies whenever one is computing the probability of accepting a single finite lot, but is especially valuable when the sample is large compared to the population size. A discrete probability distribution with probability function:

$$P_r[X = x] = \frac{\binom{M}{x} \binom{N-M}{n-x}}{\binom{N}{n}} \quad (\text{Eq. 4})$$

where:

$x = 0, 1, 2, \dots, \min. (M, n)$

$N = 1, 2, \dots$ (population size)

$M = 1, 2, 3, \dots, N$ (occurrences in population)

$n = 1, 2, \dots, N$ (sample size)

$$\binom{M}{x} = \frac{M!}{x!(M-x)!}$$