



AEROSPACE RECOMMENDED PRACTICE	ARP9013™/4	REV. A
	Issued 2005-10 Cancelled 2018-06	
	Superseded by AS9138	
Statistical Product Acceptance Requirements Using Continuous Sampling, Skip-Lot Sampling, or Methods for Special Cases		

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This document is Cancelled and Superseded by AS9138.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This Technical Report has been declared "CANCELLED" as of June 2018 and has been superseded by AS9138.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 for product acceptance using continuous sampling, skip-lot sampling, and special case statistical methods 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.

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1. SCOPE:

1.1 Purpose:

The purpose of ARP9013/4 is to ensure conformance for each product characteristic being verified under these methods. ARP9013/4 provides the requirements for continuous sampling, skip-lot sampling, and for statistical methods for product acceptance that do not derive from industry standard tables.

1.2 Field of Application:

This recommended practice is applicable when accepting product based on continuous sampling, skip-lot sampling, or special statistical methods not documented in other industry standards. Several of these sampling strategies are not currently included in any other released standards, but are provided as valuable alternatives for efficiently meeting technical requirements. The customer may require notification or approval prior to use of these special sampling techniques.

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	Statistical Product Acceptance Requirements
ARP9013/1	Statistical Product Acceptance Requirements Using Isolated Lot Sampling Methods
ARP9013/3	Statistical Product Acceptance Requirements Using Process Control Methods

- 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 S1	An Attribute Skip-Lot Sampling Program
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- 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 herein 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 this recommended practice.

2.2 Related Publications:

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

Abraham Wald, "Sequential Analysis" (New York: John Wiley & Sons, Inc.) 1947

2.3 Definitions:

See ARP9013 paragraph 2.3.

3. GENERAL REQUIREMENTS:

Requirements defined in ARP9013 shall be followed when using this recommended practice document. This ARP9013/4 document provides additional requirements to those described in ARP9013 for accepting products based on continuous sampling, skip-lot sampling, or methods for special cases.

4. CONTINUOUS SAMPLING:

Continuous sampling may apply whenever product is being accepted one unit at a time. All continuous sampling plans shall include one or more 100% inspection phases until some sequence of units is inspected without any nonconformances being found. When not on 100% inspection, one or more fractions of the units are sampled and inspected. Whenever a sampled unit is found to be nonconforming the specified sampling plan requirements shall be followed, usually increasing inspection.

4.1 Quality Parameter:

When writing an acceptance plan that uses continuous sampling, the AOQL parameter shall be shown in the documentation. If the quality requirement is stated as an AQL, then Table 1 provides an acceptable AOQL replacement. See Appendix A for guidance.

TABLE 1 - AQL TO AOQL CONVERSION

AQL	0.010%	0.015%	0.025%	0.040%	0.065%	0.100%	0.150%	0.25%
AOQL	0.018%	0.033%	0.046%	0.074%	0.113%	0.143%	0.198%	0.33%

AQL	0.40%	0.65%	1.0%	1.5%	2.5%	4.0%	6.5%	10.0%
AOQL	0.53%	0.79%	1.22%	1.90%	2.90%	4.94%	7.12%	11.46%

4.2 Inspection Sequence:

Under continuous sampling inspection, units shall be submitted consecutively for inspection. See Appendix A for guidance.

4.3 General Conditions:

Any skipped units shall be retrievable at the point in time when the results of the next inspected unit become known. Appendix A offers further guidelines on implementation.

5. SKIP-LOT SAMPLING:

Skip-lot sampling uses continuous sampling procedures to decide which lots to inspect out of a process, and uses lot sampling procedures to decide which units in those lots to inspect.

5.1 General Conditions:

Skip-lot sampling shall be permitted provided (1) there is objective evidence that the minimum quality levels defined by this recommended practice have been obtained; (2) the required objective evidence shall be reestablished when a lot is rejected and there is no documented evidence of a special cause with corrective action; and (3) any skipped lots shall be retrievable at the point in time when the results of the next inspected lot become known. See Appendix B for guidelines.

5.2 Quality Protection Equivalency:

Each skip-lot sampling plan shall show its AOQL. If the quality requirement is stated as an AQL, then Table 1 above provides the equivalent AOQL requirement.

5.3 Considerations for Subsequent Lots:

As with other continuous sampling plans, if quality results dictate an increase in inspection, then the units on which that inspection would be performed shall be inspectable. For that reason, if there is a time delay for an inspection process, all subsequent lots presented for inspection during that time shall be held where they are available for the increased inspection if that becomes necessary.

NOTE: This stipulation may place additional storage and inventory information requirements on the skip-lot inspection process.

6. SAMPLING STRATEGIES FOR SPECIAL CASES:

The sampling strategies in this section are provided as valuable alternatives for efficiently meeting technical requirements. The customer may require notification or approval prior to use of these special sampling techniques. See ARP9013 paragraph 4.8.

In each case, if the organization chooses to use sampling strategies for special cases, the organization shall demonstrate the statistical validity of these approaches before they are used. This section addresses what is needed to establish that statistical validity.

6.1 First and Last of a Lot Produced by a Continuous Manufacturing Process:

Statistical evidence for using autoregressive or auto-correlated statistical analysis, if used, shall compare the prediction interval for the last measurement in a lot to specifications when the first measurement is given. The time series model used for analysis shall be documented together with parameter estimates, and prediction intervals. See Appendix B for guidance.

- 6.1.1 Showing that any “first and last” model applies shall require showing the exact sequence of unit quality in lots that are of mixed quality. Attribute data from lots that are 100% conforming or 100% nonconforming does not demonstrate that the first and last units in the lot are more likely to be nonconforming than the others.
- 6.1.2 When doing this on an attribute basis, the number of mixed lots in which the sequence of conforming and nonconforming units is shown depends on both the quality requirement and the degree to which the actual data matches the model. The model shall show evidence that among lots in which the fraction nonconforming equals the RQL, the fraction of those lots which would pass this sample (that is, that have both the first and last units good) shall be less than or equal to 5%.

6.2 Predicting Quality From Correlated Variables:

The quality of a product feature may be accepted on the basis of measurements taken from something else if the measurements are shown to be predictive. Under these conditions, there are two sets of characteristics, and both shall be measurable, or countable with large enough counts to be treated as measurable (for example, particle counts). One of the sets of characteristics is directly subject to engineering requirements, and shall be accepted as conforming before the product having those characteristics can be used to produce aerospace deliverables. This is the “dependent” set of characteristics.

The other set, the “independent” characteristics, may or may not be directly subject to engineering requirements, but is related so closely to the first set that their values can be used to predict the acceptability of the first set. The conditional probability of the dependent characteristics being acceptable, given the measure or count of the independent characteristics, shall satisfy the required quality parameter.

Studies showing this conditional probability shall be sufficient to understand the ongoing relationship of such parameters and their resulting influence on the deliverable property or characteristic. An adequate relationship shall show that the probability is high (relative to the quality parameter) that the inspected feature will predict when the uninspected feature is nonconforming. Records of these correlation studies or other evidence of validity shall be maintained for as long as this method is used in the acceptance of product. See Appendix B for an example of this concept.

6.3 Chain Sampling Inspection Plan¹:

This is a special type of lot-by-lot acceptance sampling plan for attributes when destructive or costly tests are required to determine quality characteristics. The sample size will be small out of necessity. Chain sampling plans use cumulative results of several preceding samples. When using a chain sampling technique the following conditions shall be met:

- 6.3.1 This applies when the lots of a continuing series of products are sampled in substantially the order of production.
- 6.3.2 Customers can normally expect the lots to be essentially the same quality. Provision for an occasional nonconformity is satisfactory for major or minor classifications, but not for safety/critical classifications.

¹ H.F. Dodge, "Chain Sampling Inspection Plan," Industrial Quality Control, 11, No. 4 (January 1955), pages 10-13

6.4 Sequential Sampling:

Sequential Sampling² is used for destructive or costly tests, with a subgroup size of 1, thereby making it an item-by-item plan. Item-by-item sequential sampling is based on the concept of the sequential probability ratio test (SPRT).

6.5 Other Methods for Special Cases:

When a sampling strategy for a special case is developed that is not described in ARP9013/4, it shall satisfy the requirements of ARP9013. Its mathematical basis shall be documented and available for review. See Appendix C for examples and guidance.

PREPARED UNDER THE JURISDICTION OF
SAE COMMITTEE G-14, AMERICAS AEROSPACE QUALITY GROUP (AAQG)

² Abraham Wald, "Sequential Analysis" (New York: John Wiley & Sons, Inc.) 1947

APPENDIX A CONTINUOUS SAMPLING PLAN GUIDELINES

The guidelines in this Appendix are considered nonmandatory and not subject to compliance audits, but are intended as an aid to the organization for better understanding of requirements, planning, and implementation of statistical product acceptance methods. The authorship of this recommended practice believes that following these recommendations to the extent possible will enhance the success of statistical applications that affect, improve, and maintain product quality.

A.1 GUIDELINES FOR 4.1 QUALITY PARAMETER:

There are many operations in which product is submitted on a continuous basis. In such cases the product is frequently referred to as moving product. When dealing with moving product, it is often difficult and sometimes impossible to collect the product into lots or batches in order to apply lot-to-lot acceptance sampling techniques.

Continuous sampling plans are designed to control the AOQL. Consequently, they are indexed by AOQL. In order to be consistent with lot-by-lot sampling plans, however, an index value of the AQL is also provided. See Table 1. These values are taken from the U.S. military standard MIL-STD-1235C, which served for decades as the primary industry standard for continuous sampling.

A.2 GUIDELINES FOR 4.2 INSPECTION SEQUENCE:

As practical, it is recommended that the sequence of inspection be in the order produced. For example, the product may be presented on a moving conveyor belt as they come from a continuous production line.

A.3 GUIDELINES FOR 4.3 GENERAL CONDITIONS:

Continuous sampling inspection may be required or desirable when (1) storage facilities are inadequate or otherwise impractical to accumulate products into lots or batches for the purpose of inspection; or (2) the assembly of small lot sizes greatly increases the amount of inspection and thus results in increased inspection costs.

The customer may specify other retrievability requirements than shown in 4.3, depending on their usage of the product.

A.4 CONTINUOUS SAMPLING PLANS:

This Appendix section 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 this recommended practice. In doing so, this section provides the tables and procedures for applying five different types of continuous sampling plans for inspection by attributes:

- CSP-1, a single-level continuous sampling procedure, which provides for alternating between sequences of 100% inspection and sampling inspection.
- CSP-F, a variation of the CSP-1 plans in that CSP-F plans are applied to a relatively short run of product, thereby permitting smaller clearance numbers to be used.
- CSP-2, a modification of CSP-1 in that 100% inspection resumes only after a prescribed number of defect-free units separate any two nonconforming sample units.
- CSP-T, a multi-level continuous sampling procedure that provides for reducing the sampling frequency upon demonstration of superior product quality.
- CSP-V, a single-level continuous sampling procedure that is an alternative to CSP-T in that these plans provide for reducing the clearance number in good quality situations where reduction of sampling frequency has no economic merit.

A.4.1 Scope:

A.4.1.1 Purpose: This Appendix establishes continuous sampling plans and procedures for inspection by attributes.

A.4.1.2 Applicability: The conditions that are recommended to exist before the sampling plans can be used are:

- a. Moving product (see ARP9013 paragraph 2.3).
- b. Ample space, equipment and manpower at or near the site of inspection to permit rapid 100% inspection when required.
- c. Relatively easy and quick inspection.
- d. A process that is producing, or is capable of producing, material whose quality is stable. See A.4.7.2.b.i, A.4.8.2.b.i, A.4.9.2.b.i, A.4.10.2.b.i, and A.4.11.2.b.i.
- e. The inspection is non-destructive.

A.4.1.2 (Continued):

The sampling plans designated herein are applicable, but not limited, to inspection of various entities, namely, end items, components, raw materials, data or records, and any other entities, provided that the foregoing conditions are satisfied.

Use of the protection mathematics in accordance with the guidelines presented elsewhere in this document may assist the user in determining the procedure most suitable for his/her application. Approval of the use of any procedure is reserved to the customer.

A.4.2 Submission of Product:

A.4.2.1 Lot or Batch: Although lot or batch size is not used to select a continuous sampling plan, the formation of lots or batches may remain desirable for reasons of homogeneity, shipping convenience, and facilitation of payment.

A.4.2.2 Order of Production: All inspection is recommended to be performed in the order in which the units of product are produced, in order that the source of quality problems can be more easily spotted and corrective action taken. In those situations where maintaining the order of production is not possible, for example when product from two or more identical production lines is merged prior to inspection, the plans herein may still be used provided that the mixing of product from the lines is thorough, thereby assuring a random spacing of any nonconforming units in the flow of product.

A.4.2.3 Units of Product Submitted: When using continuous sampling, all units for which disposition is sought shall pass each inspection station. This does not prevent process inspection by the organization prior to arrival of the product at the inspection station, nor does this prohibit the organization from removing or correcting units containing nonconformities prior to submittal of the product. (The customer may require that nonconformities not be corrected before submitting the lot for inspection, in order to show the true process capability; any such requirement shall be documented appropriately.) However, if, in the opinion of the customer, the organization's method of scheduling process inspection results in a flow of product during periods of screening inspection which is not representative of the flow of product which can be expected to be encountered during subsequent sampling inspection, the customer reserves the right to cause the organization to modify the method of scheduling process inspection.

A.4.3 Acceptance And Rejection:

- A.4.3.1 Responsibility: Although both the customer and organization may reject nonconforming material of the organization, only the customer possesses the authority to accept (purchase) the organization's material. However, since the organization is responsible for providing material that satisfies contractual requirements, the organization shall inspect the product through use of a sampling plan indexed by the designated quality parameter to determine whether or not to submit the product to the customer.
- A.4.3.2 Special Reservation for Critical Nonconformities: The organization may be required at the discretion of the responsible authority to inspect every unit for critical nonconformities or to follow some other procedure with regard to the inspection of critical nonconformities. If a critical nonconformity is found on any unit of product, even if that unit has not been selected for inspection for critical nonconformities, the organization shall carry out the procedure specified by the customer for critical nonconformities.
- A.4.3.3 Disposition of Rejected Product: Units found to be nonconforming by either the organization or customer shall be removed and kept apart from the flow of product. The organization may correct these units, in which case they shall be screened and resubmitted to the customer apart from the regular flow of product. If they are accepted by the customer, then they may be returned to the production line right after the inspection station for the nonconformities concerned.
- #### A.4.4 Drawing of Samples:
- A.4.4.1 Sample: Under continuous sampling a sample consists of one unit of product drawn from the production line as it passes a given station.
- A.4.4.2 Frequency of Sampling: Certain values of sampling frequency, f , are provided for each of the plans.
- A.4.4.3 Sample Selection: The sample units shall be selected at the chosen sampling frequency, f , so as to give each unit of product an equal chance of being inspected. It is recommended that the inspector may choose sample units so that the interval between sample units varies randomly rather than draw sample units according to a rigid pattern. All five sampling methods in this appendix distinguish roles for a screening crew from those of a regular inspection staff. These terms have been in use for many years in MIL-STD-1235, with corresponding definitions and precedent. This document (ARP9013/4) only requires that the evaluations performed by both groups are accurate, independent, and free from conflict of interest.

A.4.5 Sampling Plans:

- A.4.5.1 Code Letters: Sampling plans are designated by code letters. Table A1 provides permissible code letters based on the number of units that are retrievable at the time a unit is inspected. The units that are retrievable at the time that a unit is inspected are called the “production interval.” A code letter and its associated sampling frequency are to be selected after considering such influencing factors as inspection time per unit of product, production rate, and proximity to other inspection stations. When idle inspector time is a significant consideration, a plan with a higher sampling frequency and lower clearance number is usually preferred.

TABLE A1 - Sampling Frequency Code Letters

Number of Units in Production Interval	Permissible Code Letters
2-8	A, B
9-25	A through C
26-90	A through D
91-500	A through E
501-1200	A through F
1201-3200	A through G
3201-10,000	A through H
10,001-35,000	A through I
35,001-150,000	A through J
150,001 and Over	A through K

- A.4.5.2 Obtaining Sampling Plans: The quality parameter and an appropriate code letter shall be used to obtain the sampling plan from Tables A2, A4 through A16, A18, and A20. For CSP-F, it is also necessary to determine N (see A.4.8.2.a).
- A.4.5.3 Types of Sampling Plans: Five types of sampling plans: CSP-1, CSP-F, CSP-2, CSP-T and CSP-V are provided in Tables A2, A4-A15, A16, A18, and A20 respectively. A selection of the appropriate plan can be made by a consideration of their individual features. CSP-1 is the simplest. CSP-F is a CSP-1 plan with clearance number adjusted to handle a shorter run of product. CSP-2 provides advance warning when a screening crew may have to be assembled. CSP-T provides for a reduction in sampling frequency in good quality situations. CSP-V provides for a reduction in clearance number in good quality situations, and is an alternative to CSP-T in those situations where a reduction in sampling frequency has no economic merit.

A.4.6 Discontinuation of Inspection:

A.4.6.1 Long Periods of Screening: When the use of A.4.7.2.f, A.4.8.2.f, A.4.9.2.f, A.4.10.2.f, and A.4.11.2.f give indication that an excessively long period of screening has been in progress, it is recommended that corrective action be taken to improve the production process and the customer may reserve the right to suspend product acceptance. The provisions of A.4.7.2.f, A.4.8.2.f, A.4.9.2.f, A.4.10.2.f, and A.4.11.2.f do not prevent the organization from taking corrective action to improve the production process prior to reaching the limits described in the aforementioned paragraphs.

A.4.6.2 Ineffective Screening: If, during a period of 100% inspection, a checking inspector finds a nonconformity, it is recommended that the customer be notified, and corrective action be taken to improve the effectiveness of the screening crew. If a second nonconformity is found by the checking inspector during this period of 100% inspection, it is recommended that the organization take the same action, and the customer may reserve the right to suspend product acceptance. In the case of critical nonconformities, the customer reserves the right to suspend acceptance upon the finding of the first critical nonconformity by the checking inspector during a period of 100% inspection.

A.4.7 Sampling Plan CSP-1:

A.4.7.1 Purpose of CSP-1: CSP-1 is a single-level continuous sampling procedure which provides for alternating sequences of 100% inspection and sampling inspection with no limit as to the number of such sequences. CSP-1 requires a return to 100% inspection whenever a nonconforming unit is discovered during sampling inspection. See Figure A1 for a summary of the operation of CSP-1. Tables A2 and A3 list parameters associated with this procedure.

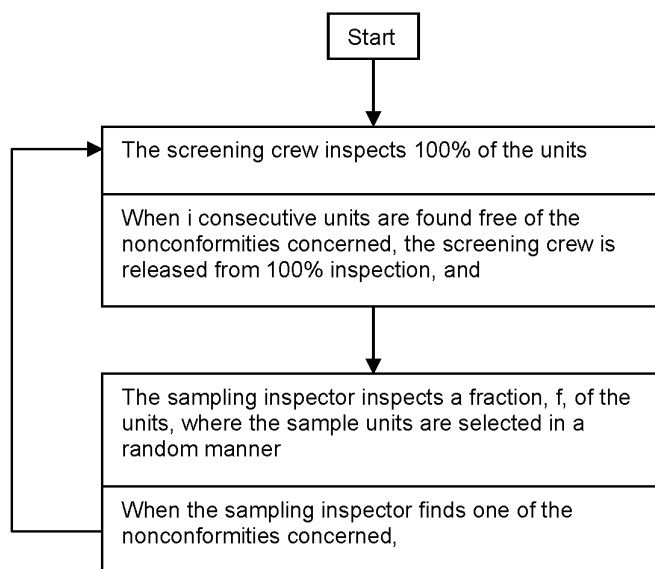


FIGURE A1 - Procedure for CSP-1 Plans

TABLE A2 - Values of i for CSP-1 Plans

	Sample Freq Code Letter	A	B	C	D	E	F	G	H	I	J	K	
	f	1/2	1/3	1/4	1/5	1/7	1/10	1/15	1/25	1/50	1/100	1/200	
AQL* in %	0.010	1540	2550	3340	3960	4950	6050	7390	9110	11730	14320	17420	0.018
	0.015	840	1390	1820	2160	2700	3300	4030	4970	6400	7810	9500	0.033
	0.025	600	1000	1310	1550	1940	2370	2890	3570	4590	5600	6810	0.046
	0.040	375	620	810	965	1205	1470	1800	2215	2855	3485	4235	0.074
	0.065	245	405	530	630	790	965	1180	1450	1870	2305	2760	0.113
	0.10	194	321	420	498	623	762	930	1147	1477	1820	2178	0.143
	0.15	140	232	303	360	450	550	672	828	1067	1302	1583	0.198
	0.25	84	140	182	217	270	335	410	500	640	790	950	0.33
	0.40	53	87	113	135	168	207	255	315	400	500	590	0.53
	0.65	36	59	76	91	113	138	170	210	270	330	400	0.79
	1.0	23	38	49	58	73	89	108	134	175	215	255	1.22
	1.5	15	25	32	38	47	57	70	86	110	135	165	1.90
	2.5	10	16	21	25	31	38	46	57	72	89	106	2.90
	4.0	6	10	13	15	18	22	27	33	42	52	62	4.94
	6.5	5	7	9	11	13	16	19	23	29	36	43	7.12
	10.0	3	5	6	7	8	10	12	14	18	22	26	11.46

* AQL's are provided as indices to simplify use of this table, but have no other meaning relative to the plans.