Introduction

The 9138 standard is used in aviation, space, and defense industry organizations to establish requirements for any method of statistical product acceptance to reduce inspection costs while still ensuring acceptable quality. The 9138 standard is an upgrade and replacement for the Aerospace Recommended Practice (ARP) 9013-series of documents prepared by the Americas Aerospace Quality Group (AAQG) and published by SAE in 2005.

The questions and answers are grouped into these categories.

General 9138 Questions

1. **Question: Who is the intended audience for 9138?**

   Answer: The intended audiences include engineering, quality, regulatory, and customer users. The 9138 document provides many means of satisfying 9100 requirements for accepting product. Each of the means in 9138 is intended to be invoked as a requirement when a customer (e.g., an IAQG member company) includes references to it in contract notes or technical specifications.

2. **Question: What criteria does 9138 offer to address the 9100 requirement for "appropriate for use" when "sampling is used as a means of product acceptance"?**

   Answer: Much of the length of 9138 is dedicated to answering this question. A statistical product acceptance procedure is appropriate for use if the statistical model matches the process and the outgoing quality level meets engineering criteria. The 9138 standard is focused on controlling the probability of conformance of delivered product.

3. **Question: What basis does 9138 offer to meet the 9100 requirement for "recognized statistical principles" when "sampling is used as a means of product acceptance"?**

   Answer: The “recognized statistical principles” are mathematical rules. The methods in or referenced by 9138 are based upon that mathematics. The mathematics is either already published for existing standards or included in 9138. New methods may be developed using recognized statistical principles. Preference is given to showing or referencing the mathematics used in each method.

4. Question: How will 9138 affect companies that do not currently use statistical methods of product acceptance?

Answer: It is important to remember that 9138 has no authority except where it is called out by a contract or other authority document. Where there is no contractual flowing of 9138, it remains only an optional tool.

However, there are some significant opportunities for these companies, if those companies decide to use 9138.

- Most companies purchase much of their product from suppliers or distributors who need to use sampling. Those suppliers or distributors need guidance if the customer company is to be able to rely on the protection from their statistical methods. So, those companies that do not currently use sampling may benefit by flowing 9138 to their suppliers.
- It may be beneficial for a company that does not have defined quality risk levels to consider the table of default values in 9138 Table A.1. Specifications and other command media may use generic wording (such as “Quality shall ensure the conformance of this product,”) that does not state the risk in operational terms.

  The operational terms that are helpful are these defined quality risk levels. These defined quality risk levels are especially helpful if the Engineering is based on experience from world fleets of the 1990’s or before. Such engineering is likely to be mathematically based on conformance rates indicated by the standards of that time. See Appendix E for more details.
- Some Engineering makes reference to AQL values instead of consumer protection metrics recommended in 9138. In those cases, the using company can transition to a consumer protection metric using Table 1 in 9138 that gives an AOQL value to match the specified AQL protection.

5. Question: In what ways does 9138 provide usability for non-specialists?

Answer: *The following enhance the usability of the document for non-specialists:*

- The 9138 is organized so that the technical explanations are segregated from the requirements as much as possible.
- There are flowcharts and tables within 9138 that are intended to guide users to sections most relevant to their needs.
- The section on product acceptance via process controls includes a Step-By-Step procedure that is new with 9138.
- Chapter 3.7 of the SCMH was created to make the most commonly referenced tables more accessible to users, especially for sub-tier suppliers, and to provide a place for helpful tips on how to best implement the requirements of 9138.
- The availability of the math is especially helpful for users who would be challenged to demonstrate the mathematical validity of their approaches. The math is here for the user to present to any reviewer to whom they need to explain their tools.
- The 9138 document is separated into sections so that users who are seeking only one tool do not have to read through all the other sections. Flowcharts have been added to help guide the user to which tools and associated sections are most appropriate.

6. Question: What will happen to ARP9013 upon the release of 9138?

Answer: The AAQG has stated the intent to “sunset” ARP9013 after the release of 9138. The word “sunset” is understood to mean “scheduled for cancellation”. The timing of the sunset will consider the fact that ARP9013 is stipulated in some contracts.

Dictionary Questions

7. Question: Why does 9138 have so many definitions?

Answer: The size of the field of statistical product acceptance is very large. Even with a large amount of material on the SCMH, the 9138 document is the largest so far of IAQG's documents. This is actually because of the complexity of the subject itself.

Consider the qualifications for a person to work as a statistical quality engineer. For example, the American Society for Quality (ASQ) has required for a long time that a person should have 8 years of quality engineering experience before they are allowed to sit for the ASQ Certified Quality Engineer examination. Then, only about half the candidates pass the exam on the first try. By the time a person wins the CQE designation from ASQ, they normally have as many years in preparation as a medical doctor has before being allowed to practice medicine. This makes sense because people's lives so often depend on our work just as much as on their doctor's work.

Statistical product acceptance needs many different terms to describe the correct application of statistics for the many different processes in aviation, space and defense industries.

8. Question: Could the definitions section be moved to the IAQG Dictionary?

Answer: The definitions in the IAQG dictionary are derived from existing IAQG documents. Many of the IAQG dictionary definitions are from ARP9013. The intent is to cancel ARP9013 after the publication of 9138. Therefore, if the definitions are not present in 9138, they will not be in the IAQG Dictionary either.

9. Question: Why did 9138 not always use ISO 9000 definitions?

Answer: The technical usage of words in 9138 sometimes required specific definitions that other documents did not provide. This 9138 document uses the same terms and definitions as ISO9000 except where 9138 re-defined them for specific statistical purposes.

Reference Questions

10. Question: How does one determine which of the extensive references listed in 9138 are required in a statistical product acceptance application?

Answer: Any required references are cited within 9138 in connection with their applicability. Not all of the references are relevant to any one acceptance plan. All other references are for explanations of the methods, and to show how they are "justified on the basis of recognized statistical principles" (see 9100).

11. Question: How does 9138 relate to current and future Quality Management System standards?

Answer: The exact paragraph numbers were included in 9138 at the time of its writing for the then-current revisions of 9100, 9110, and 9120, but there is language connecting 9138 to future revisions of 9100, 9110, and 9120. That language says, "For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. When a conflict in requirements between this document and the referenced standards/related writings exists, the requirements of this document shall take precedence; however, nothing in this document supersedes applicable laws, regulations, and contractual requirements." (See the first paragraph in section 2.)

12. Question: How does 9138 relate to previous standards like ANSI/ASQ Z1.4 or ISO2859/1?

Answer: These standards are organized around the AQL parameter, which is not a measure of consumer protection. By contrast, 9138 is based on consumer protection. To bridge the gap, 9138 shows a table developed by the US military to transition from AQL producer protection to AOQL consumer protection. This is Table 1.

There are two conditions for relating 9138 to these previous standards: 1) where a contract flows 9138 but the quality operations are built around a previous standard, or 2) where a contract flows the AQL and the previous standard, but the operations are built around 9138.

To succeed in the first condition, which is using ANSI/ASQ Z1.4, ISO2859/1 or similar standards in meeting an AOQL derived from 9138 Table A.1, see Appendix I.2 and SCMH chapter 3.7.2.

To succeed in the second condition, which is using 9138 to satisfy a requirement for an AQL under a previous standard, see Table 1 to find a level of consumer protection that should correspond to the required AQL.

Switching rules required by many previous standards are not required by 9138. Switching rules are complicated and can expose the customer to short-term risks.

13. Question: How does 9138 relate to 9103?

Answer: The goal of 9103 is Variation Management, which is a primary way to improve a process. As stated in the Introduction to 9138, the statistical methods for improving a process are not subject to the requirements of 9138. The 9103 methods are valuable tools to improve new processes to the point where the resulting product can be predicted to be conforming.

For processes with adequate quality, the subsequent and continuing proof of product conformance could then be provided under 9138.

14. Question: Why does the References section not include AS13002 Requirements for Developing and Qualifying Alternate Inspection Frequency Plans?

Answer: First, the list of references is not at all comprehensive. There were many other statistical documents, journals, standards and text books that were considered by the 9138 team but that were not expressly cited in 9138. AS13002 was considered.

AS13002 is a very different kind of document from 9138, in such a way that the two documents apply in very different conditions. The former is an Engineering tool, the latter is a Quality tool.

- AS13002 applies to measurable key characteristics that are selected by engineering authority. The engineering authority then has the role of verifying that the non-key characteristics are adequately controlled, the sample selection methods are adequately representative, the timing between samples maintains adequate retrievability, and the frequency of out-of-control conditions does not compromise the product reliability requirements. Only the direct involvement of such advanced technical oversight can achieve the goals of AS13002.

- By contrast, 9138 applies to the same scope as the legacy sampling standards that were replaced widely by ARP9013. Since the 1940's, such standards as ANSI/ASQ Z1.4 and ISO2859-1 have been applied in thousands of factories, each with hundreds of part numbers with multiple characteristics, with no Engineering oversight except for the quality parameter value. Almost all of these characteristics are non-key attribute characteristics (that is, pass-fail, with no measurements from which a Cpk or a Ppk could be calculated). It is the role of 9138 then to ensure the representativeness of the samples, the retrievability of any skipped production, the minimum probability of conformance necessary to satisfy the minimum probability of performance (that is, the reliability requirement for the product), and to do so with no Engineering resources required beyond determining the value of the quality parameter.

The deployment of either 9138 or AS13002 as requirements is dependent upon contracts.

Risk Related Questions

15. Question: Why does 9138 refer to both IRR values and AOQ values?

Answer:

An IRR (Initial Reliability Requirement) value is a benchmark of risk. Its definition is "the minimum probability of conformance for each unit of product accepted through the associated sampling plan for design purposes." Engineering should participate in establishing the IRR value.

An AOQ (Average Outgoing Quality) is a performance measure of the rate that nonconformances are escaping a sampling process. This is a measure of what Operations actually accomplishes.

The maximum AOQ for any sampling plan should be less than one minus the IRR for the plan to meet an IRR benchmark (see Question 16).

16. Question: Why is the AOQL less than 1-IRR?

Answer:

Two primary reasons explain why the AOQL is usually less than 1-IRR.

1. The evaluation of each sample unit classifies it as either conforming or nonconforming. This poses a risk of misclassification.

   For measured characteristics, measurement uncertainty is a risk.

   For pass-fail evaluations, there is a different kind of evaluation risk.

2. There is also the fact that sample sizes must be integers, which means usually the AOQL cannot exactly equal any specified target, including 1-IRR.

17. Question: How does 9138 address legal and contractual concerns such as the keeping of records?

Answer: This standard is only applicable when invoked in a purchasing contract or specification, or other authority. Therefore the authority of 9138 on such matters is limited to the authority given in those higher media.

The purchase contract/agreement may or may not identify the appropriate 9138 section(s) to be applied by the organization. All statistical methods of product acceptance under 9138 require the use of Sections 4 and 5. Section 5 contains the specific instructions relative to records and documentation.

Nothing in 9138 supersedes applicable laws, regulations, and contractual requirements.

See clauses 0.2, 1.2, 4.4.4 and 5.9 for further information.

18. Question: In Table A.1, is it expected to have multiple IRR values per part when a part has a number of different features?

Answer: It is valid either to 1) sample each feature or set of features to its own separate IRR or else 2) to group all requirements for the part together and to sample to the tightest requirement. Either way works. The latter is usually simpler but does involve somewhat more inspection.

Engineering however has the concern that if separate characteristics are given independent IRR "budgets", then the likelihood of the whole part being conforming becomes the product of the independent IRR values. In an extreme, if there were 100 different characteristics each with their own 99% IRR, relatively few of the products (0.99^100 =0.37) would be ensured to have every feature conforming. For this reason, there is value to Engineering to have only one or a very few independent sets of characteristics.

19. Question: How does the Risk Priority Number (RPN) in Process Failure Modes and Effects Analysis (PFMEA) relate to the probability of conformance?

Answer: The forms of PFMEA that would apply to 9138 would be required to be "justified on the basis of recognized statistical principles and appropriate for use" per 9100. These stipulations go beyond the standard calculation of an RPN.

20. Question: How does the AQL relate to an IRR value?

Answer: If an Operations organization has a contractual requirement for an AQL, and they want to use an AOQL or IRR-based system, then the table below based on Table 1 is one that has been widely used. The AQL relates indirectly to the IRR by way of the AOQL statistic. First, the AQL is a measure of producer protection whereas the IRR is a measure of consumer protection. For sampling plans that have been defined or indexed by an AQL, it is possible to compute the maximum escapement rate to consumers, the AOQL. A list of representative AOQL values for standard AQL indexed sampling plans was published by the United States military in MIL-STD-1235. The AOQL is a nonconformance rate and the IRR is the conformance rate. So, 9138 recommends converting any given AQL in the first row of the table below to the corresponding IRR value in the last row. This conversion process does not work backwards. If a specification has given an IRR, it is important not to use an AQL method to replace it.

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%
1-AOQL	99.982%	99.967%	99.954%	99.926%	99.887%	99.857%	99.802%	99.67%
IRR	99.98%	99.96%	99.95%	99.92%	99.88%	99.85%	99.8%	99.6%
AQL	0.40%	0.65%	1.00%	1.50%	2.50%	4.00%	6.50%	10.00%
AOQL	0.53%	0.79%	1.22%	1.90%	2.90%	4.94%	7.12%	11.46%
1-AOQL	99.47%	99.21%	98.78%	98.1%	97.1%	95.06%	92.88%	88.54%
IRR	99.4%	99.2%	98.7%	98%	97%	95%	93%	88%

21. Question: Does the table in Question 20 apply if an Engineering or standards authority is replacing AQL-based specifications with an IRR?

Answer: The following table is available for an Engineering authority to use to replace AQL-based sampling plans. This table presents the consumer protection of ISO2859-1 / ANSI/ASQ Z1.4 sampling plans in AOQLs, with a focus on lot sizes that are more commonly sampled. Whatever IRR level is chosen, it should reflect the authority's experience and judgment on what is a tolerable minimum probability of conformance.

For protection greater than 99% minimum probability of conformance, a variables sampling plan with ongoing SPC analysis should be considered rather than attribute (pass/fail) sampling. Other considerations include the suggested IRR values in 9138 Table 1 and Table A.1.

AQL	0.010%	0.015%	0.025%	0.040%	0.065%	0.100%	0.150%	0.25%
IRR	99.98%	99.97%	99.95%	99.93%	99.90%	99.85%	99.75%	99.65%
AQL	0.40%	0.65%	1.00%	1.50%	2.50%	4.00%	6.50%	10.00%
IRR	99.5%	99.2%	98.7%	98%	97%	95%	93%	88%

SCMH 3.7 and 9138 Questions

22. Question: Why are some materials in appendices and other materials on the SCMH?

Answer: First, the authority rests with the 9138 document. The SCMH is provided to help the users accomplish the requirements in 9138. Some material is needed in both places because it helps to explain what the requirements mean.

The 9138 document gives a simple statement of basic requirements for each of a wide diversity of processes. Appendix content adds detailed explanations, formulas and some step-by-step instructions. The SCMH then gives other advice, examples, and further explanations for each application and provides some references in the form of tables and computing code. Together, 9138 and the SCMH give a complete package.

This leverages the flexibility of the SCMH. The issues that matter to a customer center on the probability of product conformance that they need their supplier to ensure, so this material is in the document itself and will not change unless the document is revised. However, the technical methods do change, as new technologies are developed and better explanations for existing methods are written. The flexibility of the SCMH allows for rapid ongoing development and publication of new statistical tools while still preserving the constant contractual requirement for ensuring the necessary probability of conformance.

23. Question: Why are there not more examples in 9138?

Answer: The primary place for 9138 related examples and case studies is the SCMH (3.7) to help limit the page count of 9138. Additional case studies and examples are planned for the SCMH after the document itself is published.

24. Question: Why are there not hyperlinks in 9138 to SCMH 3.7?

Answer: Material in the SCMH is only accessible by logging in through the SCMH portal. The portal prevents directly linking to SCMH files. Also, such hyperlinks would not be maintainable, as the organization of the SCMH is subject to change (that is, chapter 3.7 may not always remain 3.7). There may also be copyright and licensing restrictions.

25. Question: Why are the sampling tables in the Supply Chain Management Handbook (SCMH) as opposed to being in 9138 itself?

Answer: Putting the tables on the SCMH has these advantages:

1) The IAQG direction was to put all requirements related to statistical product acceptance into one document. Including sampling tables into the document would have made it extremely long -- on the order of 10 times the length of any other IAQG document.

2) To mistake-proof the tables, we made it so that within any one table there is only one level of protection, so that the consumer protection is correct for any entry in the same table. This resulted in better usability than having many protection levels within each table, but it increased the number of tables. The placing of the tables into the SCMH made the number of tables transparent to the user – they just go to the Table of Contents and click on the right table, and never have to see or to work around the other tables.

3) After purchasing 9138, there is no additional cost to access the SCMH tables.

4) When additional statistical tools or new methods are published, the flexibility of the SCMH allows for rapid deployment of those new tools.

26. Question: What revision controls are there for future changes to the SCMH?

Answer: The SCMH is formally controlled in accordance with the IAQG_Procedure_105.5 "IAQG Guidance Material Management." The SCMH Support Manager takes all proposed changes (new or revisions) and presents them to the SCMH guidance committee that is IAQG's Product and Supply Chain Improvement (PSCI) Team for approval before they are published. IAQG_Procedure_105.5 recognizes explicitly the inputs from document representatives (IDRs & SDRs). While it is possible for others to submit proposed changes, such changes would still need to go through the Support Manager and PSCI before being published. The 9138 team focal for the SCMH and the IAQG IDR have worked closely with the SCMH Support Manager to publish Chapter 3.7 relating to 9138. If there is anything significant submitted, the Support Manager or a PSCI member will be alerted and will coordinate the change.

27. Question: How can the sample tables be verified?

Answer: The sampling tables in SCMH 3.7.4 can be verified using the accompanying code and / or the mathematics that appears in 9138 Appendix C. The sample sizes in SCMH 3.7.6 come directly from MIL-STD-1235.

Anyone detecting discrepancies should contact the SCMH Support Manager.

Mathematical Questions

28. Question: Does 9138 use 'C=0" sampling plans?

Answer: Yes. IAQG 9138 uses “C=0” as a default because many customers require the "C=0" policy. Under “C=0”, any nonconformance rate found in a lot would require its rejection and handling such that none of the lot's nonconformances escape.

29. Question: Why is there so much advanced statistical language in 9138?

Answer: Fundamentally, 9138 is a bridge connecting non-specialists to the most efficient statistical techniques for reducing costs while ensuring quality in keeping with technical design requirements. As such, it needs to have both technical language and practical language.

This 9138 is also intended as a document to be included by reference in contracts, and in purchasing and technical specifications. As such it needs to have the flexibility for suppliers to use different solutions within the same contract note, while still providing the necessary level of consumer protection. That flexibility is helped by having the math for each solution method in 9138.

Further, the 9100 QMS text which 9138 is to satisfy says that any statistical method used for product acceptance must be "justified on the basis of recognized statistical principles". This makes it important for 9138 to identify those "recognized statistical principles", and to connect the reader or auditor to the tables in the SCMH that satisfy those principles. The great breadth of diverse processes across the aviation, space and defense industry requires a corresponding range of tools to achieve efficient and effective inspection.

30. Question: What does “over representative” mean in the context of section 4.5?

Answer: A systematic sample is “over representative” of nonconforming product if the bias introduced by the systematic selection process results in a greater likelihood of finding a nonconforming unit than a random sample would provide.

31. Question: Why does 9138 not discuss SPC for attributes?

Answer: IAQG 9138 recognizes the impact of the "C=0" policy in SPC. For normal IRR values, the yield of the process must be high (100% or near 100%). This usually results in attribute control limits being so near 0 that any observed nonconformance is enough to show the process to not be in control. Therefore, the resulting attribute control chart would not add any more information than is already present by the declaration of one or more nonconformances.

32. Question: Why does 9138 not define what a right frequency is to measure for statistical process control?

Answer: The processes covered by 9138 include highly automated processes with few potential failure modes, highly manual processes with many potential failure modes, and all combinations in between. The Quality Management System drives consideration of the effects of production rate and the inventory maintained in a retrievable position. As a result, the guidance for the choice of the right frequency must be limited to the general principles applicable to many diverse processes. The "right frequency" is very much dependent on individual companies' production rates and time to shipment. The current wording guides the user to choose a frequency that ensures adequate retrievability under either planned shipment schedules or unplanned process changes.

33. Question: Why is Equation C32 on AOQ probabilities "the expected number of escapements divided by the expected number of delivered units", rather than "the expectation of the fractions of escapements divided by the delivered units"? In mathematical notation, this asks why to prefer:

$$AOQ = \frac{\mathrm{E}[e]}{\mathrm{E}[N_{out}]} \quad \textbf{instead of} \quad AOQ = \mathrm{E}\left[\frac{e}{N_{out}}\right].$$

Answer: Equation C32 accounts for changes in lot sizes. The second equation works if each delivered lot size is the same, even if their probability of escapement $\boldsymbol{e}$ is different.

Suppose the consumer gets inputs from 2 suppliers on a 50%/50% basis. For example, suppose that after inspection, the parts from Supplier A had 1 nonconformance in 4 that were delivered, and Supplier B had 2 nonconformances in 4 that were delivered. The resultant probability of a consumer getting a nonconformance is 3 out of 8. Either equation computes the correct 0.375 probability [.5(1)+.5(2)]/[.5(4)+.5(4)] or .5(1/4)+.5(2/4).

But suppose that in addition to having different escapement rates, the lot sizes are different. Say Supplier A delivered 1 nonconformance out of 4 and Supplier B delivered 2 nonconformance out of 20. The probability of the consumer selecting a nonconformance is (1+2)/(4+20) or 3/24 or 12.5%. The second equation above would compute .5(1/4)+.5(2/20)=17.5%, and 17.5% is noticeably different from 12.5%. Equation C32 would correctly evaluate the numbers as [.5(1)+.5(2)]/[.5(4)+.5(20)] = 12.5%.

34. Question: Why was the OQCL (Outgoing Quality Confidence Limit) lot sampling procedure introduced into 9138?

Answer: There were 5 contributing factors as to why the OQCL concept was introduced.

1) The main emphasis of 9138 is to control “the probability of conformance for delivered product” (clause 4.4.1). The ARP9013 ERP and RQL sampling plans are based on incoming probability of conformance and do not recognize the effects of inspection operations on the probability of outgoing conformances.

2) The ERP and RQL tables are based upon the hypergeometric distribution. If taken by itself, this distribution makes sample sizes generally rise with lot sizes, but occasionally dips erratically. It was deemed desirable to increase the sample sizes monotonically as the lot sizes increase. ARP9013 provided ERP and RQL sample tables that were computed by a method that smoothed the sample size increases. The method is explained in 9138 C.2.1. The OQCL provides a desirable progression as lot sizes increase.

3) Part of the goal of the OQCL was to compute the smallest sample size possible to maximize cost savings while at the same time assuring quality that is measured by the probability of conformance for delivered product.

4) In legacy standards, the most common method of specifying a minimum probability of conformance for accepted product was done with the AOQL metric. However, the AOQL model always included the condition that every rejected lot or grouping of product was dispositioned by screening and replacing all found nonconformances with known conforming units. This condition was not always satisfied, especially for destructive test applications. So OQCL material was introduced in 9138 to provide for other dispositions of lots while still providing the stated degree of consumer protection. Since the OQCL material was not in text books, it became extremely important to show its technical validity ("recognized statistical principles" in QMS language).

5) The AOQL parameter is an average probability of nonconformance. As such, it does not reflect an upper limit on local concentrations of nonconformances. The OQCL on the other hand does provide a chosen level of confidence in the quality of each lot or product grouping.

35. Question: If the OQCL is aligned with 9138 goals, why were the ERP and RQL acceptance criteria retained from ARP9013?

Answer: The ERP and RQL isolated lot acceptance plans in ARP9013 are currently being used. By including those into 9138 (and the tables into the SCMH), these tools can continue to be available after the eventual cancellation (sunsetting) of ARP9013 after the release of 9138.