



# Acceptable Quality Level (AQL): Issues and Resolution

By Forrest W. Breyfogle III

Acceptable Quality Level (AQL), which provides a sample size to determine if a lot should be accepted or rejected, statistically does not protect customer. Sampling plans are typically determined from tables as a function of an AQL criterion and other characteristics of the lot. Pass/fail decisions for an AQL-evaluated lot are based only on the lot's performance, not on previous product performance from the process. AQL sampling plans do not give a picture of how a process is performing.

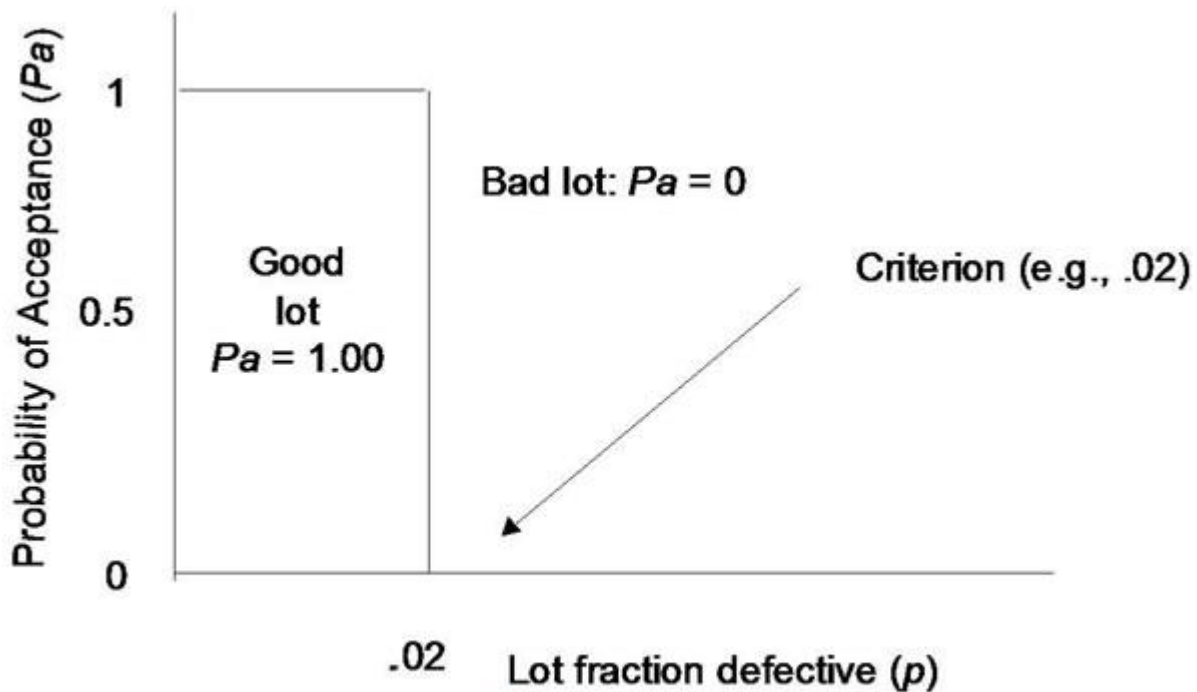
AQL sampling plans are inefficient and can be very costly, especially when high levels of quality are needed. Often, organizations think that they will achieve better quality with AQL sampling plans than is possible. The trend is that organizations are moving away from AQL sampling plans; however, many organizations are slow to make the transition. The following describes the concepts and shortcomings of AQL sampling plans.<sup>1</sup>

When setting up an AQL sampling plan, much care needs to be exercised in choosing samples. Samples must be a random sample from the lot. This can be difficult to accomplish. Neither sampling nor 100% inspection guarantees that every defect will be found. Studies have shown that 100% inspection is at most 80% effective.

There are two kinds of sampling risks:

- Good lots can be rejected.
- Bad lots can be accepted.

The operating characteristic (OC) curve for sampling plans quantifies these risks. Figure 1 shows an ideal operating curve.



From Figure 21.3, *Integrated Enterprise Excellence Volume III - Improvement Project Execution: A Management and Black Belt Guide for Going Beyond Lean Six Sigma and the Balanced Scorecard*, Forrest W. Breyfogle III, Bridgeway Books/Citius Publishing, Austin, TX, 2008.

**Figure 1: Ideal OC Curve**

Because an *ideal* OC curve is not possible, OC curves are described using the following terms:

#### Acceptable Quality Level (AQL)

- AQL is typically considered to be the worst quality level that is still considered satisfactory. It is the maximum percent defective that for purposes of sampling inspection can be considered satisfactory as a process average.
- The probability of accepting an AQL lot should be high. A probability of 0.95 translates to a risk of 0.05.

#### Rejectable Quality Level (RQL)

- This is considered to be unsatisfactory quality level.
- This is sometimes called *lot tolerance percent defective* (LTPD).
- This consumer's risk has been standardized in some tables as 0.1.
- The probability of accepting an RQL lot should be low.

#### Indifference Quality Level (IQL)

- Quality level is somewhere between AQL and RQL.
- This is frequently defined as quality level having probability of acceptance of 0.5 for a sampling plan.

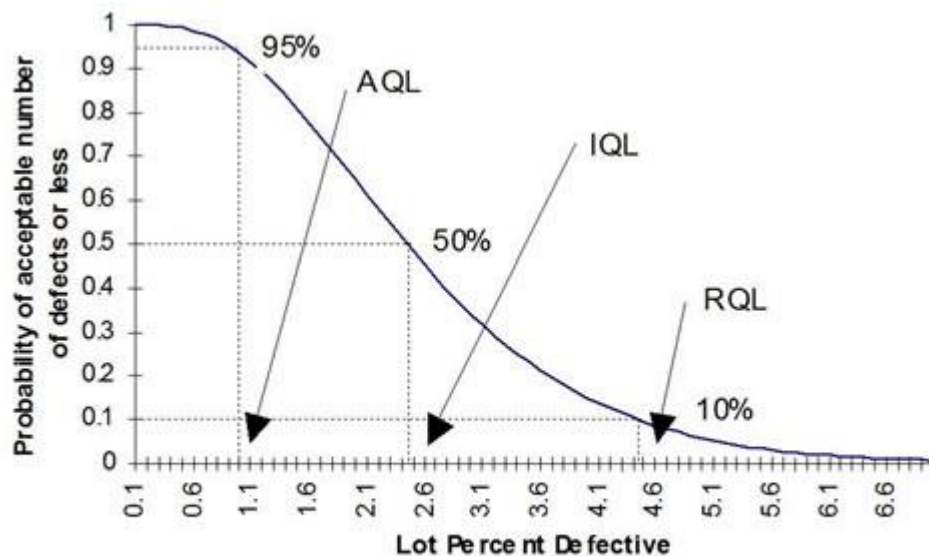
An OC curve describes the probability of acceptance for various values of incoming quality.  $P_a$  is the probability that the number of defectives in the sample is equal to or less than the acceptance number for the sampling plan. The hyper-geometric, binomial, and Poisson distributions describe the probability of acceptance for various situations.

The Poisson distribution is the easiest to use when calculating probabilities. The Poisson distribution can often be used as an approximation for the other distributions. The probability of exactly  $x$  defects [ $P(x)$ ] in  $n$  samples is

$$P(x) = \frac{e^{-np} (np)^x}{x!}$$

For  $\tilde{a}$  allowed failures,  $P(x \leq a)$  is the sum of  $P(x)$  for  $x = 0$  to  $x = a$ .

Figure 2 shows an AQL operating characteristic curve for an AQL level of 0.9%. Someone who is not familiar with the operating characteristic curves of AQL would probably think that passage of this AQL 0.9% test would indicate goodness. Well this is not exactly true because from this operating curve (OC) it can be seen that the failure rate would have to be actually about 2.5% to have a 50%/50% chance of rejection.



From Figure 21.4, *Integrated Enterprise Excellence Volume III - Improvement Project Execution: A Management and Black Belt Guide for Going Beyond Lean Six Sigma and the Balanced Scorecard*, Forrest W. Breyfogle III, Bridgeway Books/Citius Publishing, Austin, TX, 2008.

**Figure 2: An operating characteristic curve.  $N=150$ ,  $c=3$ .**

AQL sampling often leads to activities that are associated with attempts to test quality into a product. AQL sampling can reject lots that are a result of common-cause process variability. When a process output is

examined as AQL lots and a lot is rejected because of common-cause variability, customer quality does not improve.

### Example that highlights challenges with AQL testing

For  $N$  (lot size) = 75 and AQL = 4.0%, ANSI/ASQC Z1.4-1993 (Cancelled MIL-STD-105) yields, for a general inspection level II, a test plan in which

- Sample size = 13
- Acceptance number = 1
- Rejection number = 2

From this plan we can see how AQL sampling protects the producer. The failure rate at the acceptance number is 7.6% [i.e.,  $(1/13)(100) = 7.6\%$ ], while the failure rate at the rejection number is 15.4% [i.e.,  $(2/13)(100) = 15.4\%$ ].

Usually a sample size is considered small relative to the population size if the sample is less than ten percent of the population size. In this case, the population size is 75 and the sample size is 13; i.e., 13 is greater than 10% of the population size. However, for the sake of illustration, let's determine the confidence interval for the failure rate for the above two scenarios as though the sample size relative to population size were small. This calculation yielded:

#### Test and Confidence Interval for One Proportion

Test of  $p = 0.04$  vs  $p < 0.04$

95% Upper Exact

Sample X N Sample p Bound P-Value

1 1 13 0.076923 0.316340 0.907

#### Test and Confidence Interval for One Proportion

Test of  $p = 0.04$  vs  $p < 0.04$

95% Upper Exact

Sample X N Sample p Bound P-Value

1 2 13 0.153846 0.410099 0.986

For this AQL test of 4%, the 95% confidence bound for one failure is 31.6% and for two failures is 41.0%. Practitioners often don't realize how these AQL assessments do not protect the customer as much as they might think.

This example illustrates how a test's uncertainty can be very large when determining if a lot is satisfactory or not. A lot sample size to adequately test the low failure rate criteria in today's products is often unrealistic and cost prohibitive. To make matters worse, these large sample sizes would be needed for each test lot.

### **Does AQL testing answer the wrong (not best) question?**

With AQL testing, sampling provides a decision-making process as to whether a lot is satisfactory or not relative to a specification; however, this is often a very difficult, if not impossible, task to accomplish. When one is confronted with the desire to answer a question that is not realistically achievable, we should first step back to determine whether we are attempting to answer the wrong (or at least not the best) question. Sometimes we might be wasting much resource attempting to answer the wrong question with much accuracy; e.g., to the third decimal place.

When we are examining an AQL sample lot of parts, population statements are being made about each lot. However, in most situations, a lot could be considered a time series sample of parts produced from the process. With this type of thinking, our sampling can lead to a statement about the process that produces the lots of parts. With this approach, our sample size is effectively larger since we would be including data in our decision-making process from previous sampled lots.

Scoping the situation using this frame of reference has another advantage. If a process non-conformance rate is unsatisfactory, the statement is made about the process, not about an individual lot. The customer can then state to its supplier that the process needs to be improved, which can lead to specific actions that result in improved future product quality. This does not typically occur with AQL testing since focus in lot sampling is given to what it would take to get the current lot to pass the test. For this situation, it might end up being, without the customer knowing it, a resample of the same lot. This second sample of the same lot could pass because of the test uncertainty, as described earlier.

When determining an approach for assessing incoming part quality, the analyst needs to address the question of process stability. If a process is not stable, the test methods and confidence statements cannot be interpreted with much precision. Process control charting techniques can be used to determine the stability of a process.

Consider also what actions will be taken when a failure occurs in a particular attribute-sampling plan. Will the failure be "talked away"? Often, no knowledge is obtained about the "good" parts. Are these "good parts" close to "failure"? What direction can be given to fixing the source of failure so that failure will not occur in a customer environment? One should not play games with numbers! Only tests that give useful information for continually improving the manufacturing process should be considered.

Fortunately, however, many problems that are initially defined as attribute tests can be redefined to continuous response output tests. For example, a tester may reject an electronic panel if the electrical resistance of any circuit is below a certain resistance value. In this example, more benefit could be derived from the test if actual resistance values are evaluated. With this information, percent of population projections for failure at the resistance threshold could then be made using probability plotting techniques. After an acceptable level of resistance is established in the process, resistance could then be monitored using control chart techniques for

variables. These charts then indicate when the resistance mean and standard deviation are decreasing or increasing with time, an expected indicator of an increase in the percentage builds that are beyond the threshold requirement.

Additionally, Design of Experiments (DOE) techniques could be used as a guide to manufacture test samples that represent the limits of the process. This test could perhaps yield parts that are more representative of future builds and future process variability. These samples will not be "random" from the process, but this technique can potentially identify future process problems that a random sample from an initial "batch" lot would miss.

With the typical low failure rates of today, AQL sampling is not an effective approach to identify lot defect problems.

### **Alternative Methodology to AQL Testing**

In lieu of using AQL sampling plans to periodically inspect the output of a process, more useful information can be obtained by using [30,000-foot-level Reports with Predictive Measurements](#) to address process common-cause and special-cause conditions. Process capability/performance studies can then be used to quantify the process common-cause variability. If a process is not capable, something needs to be done differently to the process to make it more capable.

### **30,000-foot-level Charting Applications**

The described 30,000-foot-level charting technique has many applications, as described in [30,000-foot-level Performance Reporting Applications](#).

### **References**

1. Forrest W. Breyfogle III, *[Integrated Enterprise Excellence Volume III - Improvement Project Execution: A Management and Black Belt Guide for Going Beyond Lean Six Sigma and the Balanced Scorecard](#)*, Bridgeway Books/Citius Publishing, 2008

About the Author  
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In a professional career spanning over a quarter century, Forrest Breyfogle has established himself as a leading edge thinker, a prolific author, an innovative consultant, a world-class educator, and a successful business executive. His work is documented in eleven books and over ninety articles on the topic of quality improvement.

A professional engineer, Forrest is also a member of the board of advisors for the University of Texas Center for Performance Excellence. He is the founder and CEO of Smarter Solutions, Inc., an Austin, Texas based consulting firm offering business measurement and improvement consultation and education to a distinguished list of clients worldwide, including BAMA, CIGNA, Dell, HP, IBM, Oracle Packaging, Sherwin Williams, Cameron, TIMET, and TATA. He served his country on active

duty in the US Army for 2 years, and has played an active leadership role in professional and educational organizations. Forrest received the prestigious Crosby Medal from the American Society for Quality (ASQ) in 2004 for his book, *Implementing Six Sigma* (second edition). This award is presented annually by the American Society for Quality to the individual who has authored a distinguished book contributing significantly to the extension of the philosophy and application of the principles, methods, or techniques of quality management. Mr. Breyfogle was named Quality Professional of the Year for 2011 by Quality Magazine and in 2012 was awarded alumni of the year by Missouri University of Science and Technology.

He is a widely recognized authority in the field of management improvement and is a frequent speaker before professional associations and businesses. His earlier work in the field of management science has been widely acclaimed. A previous book, *Implementing Six Sigma*, sold over 40,000 copies and still ranks among the top Amazon books in Applied Mathematics/Engineering Statistics and Industrial Engineering /Quality Control.

He founded Smarter Solutions in 1992 after a 24-year career at IBM. The associates of Smarter Solutions specialize in helping companies throughout the world improve their bottom line and customer satisfaction through the implementation of techniques that are beyond traditional Lean Six Sigma and the balanced scorecard methodologies. His latest and most extensive work has been in the documentation of a new system of enterprise management, the Integrated Enterprise Excellence (IEE) system, in a series of four books. IEE provides a detailed roadmap that builds on and integrates the best practices of earlier disciplines like Six Sigma, Lean, TQM, PDCA, DOE, and TPS combined with innovative analytical tools to produce improvements at the highest level of an enterprise.

In addition to assisting hundreds of major clients in the wise implementation of improvement systems worldwide, Forrest has also developed over 300 hours of classroom instruction used to train executives, managers, and Black Belt practitioners to plan for, implement, and manage IEE systems. He also leads formal seminars and workshops worldwide.

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