Procedure

Cover Page

WWOPS Product Lifecycle and Technology: Component Qualification Size Guidelines for Use in Manufacturing

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Overview: This document describes a sample sizing methodology used for the generation of Operations qualification plans for new or updated components introduced on Oracle Hardware products.

Provide a brief explanation as to what the document is about.

Audience: This document is for Operations Product Engineers who define qualification test plans for introducing new or updated components to new or existing Oracle hardware platforms. This document can also be informative for others who contribute to or review the qualification test plan, such as design engineers, test engineers, and program managers.

Provide a list of functional groups impacted by the document, each functional group requires at least one Approver.

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Primary Information

Introduction

This document describes how product engineers can use statistical methods to help them decide what sample plans to use for new component qualifications. The basic tenets of their methodology described in this document are the following:

1. If risk assessment indicates that a manufacturing pilot or PVT is needed (at board-test, assembly, or system-test levels), find out what line yield loss you can afford at the critical assembly or test steps that the component affects, and base your sample size for the pilot on the size necessary to assure, with good confidence, that you can detect failure levels which would approach that line yield impact.

2. If risk assessment indicates that qualification testing is more stringent than the manufacturing test process is warranted, use an appropriate sample size and test plan to assure, with good confidence, that the component meets the necessary component time-zero goals for product field quality.

3. An Excel spreadsheet containing the statistical information to develop a sample plan based on the methods outlined in this document is available as 7305621, *WWOPS Product Lifecycle and Technology: Critical DPM and Sample Size Calculator* at (as well as in Agile for Oracle employees):

   https://beehiveonline.oracle.com/teamcollab/overview/AQP_General_Supplier_Information_Group_Workspace

NOTE 1: The AQP BeeHive link only works if you are a workspace member.

1 Creating a Component Qualification Plan

A qualification plan for a new or changed component on a particular system platform must define the following items:

- What tests the components (within the system) experience?
- How many components are sampled, and in what system configurations?
- What is the pass or fail criteria for the testing?

Each of these factors is reviewed in the following sections.

1.1 Choosing a Test Process for Qualification

The choice of a test process for a component qualification depends on what kinds of defects you try to expose and what kinds of risks you try to mitigate by running the qualification.

For example, if the risks are high that a standard process verification test (PVT) does not expose the types of defects you try to find, but they can be experienced by the end customer (due to a long time to fail [TTF], for example), you must run tests that are outside the PVT process. Conversely, if the risks are very low that the types of defects expected with this new component occur outside the board test process, you do not need to run the qualification in the system test in addition to the board test.

Experience is key to choosing an appropriate test plan. Because it is difficult to predict or model theoretically the effect that a new component can have on system quality or performance, the best decisions can often be made by using the collective experience of the engineering community who performed similar qualifications in the past. Experience with qualification failures and component defect modes is especially valuable.

1.2 Choosing a Sample Plan and Pass or Fail Criteria for Manufacturing Pilot

1.2.1 Excessive Risk

If you decide that the risks associated with qualification are such that you must check the quality level of the component in your manufacturing test process, you must choose a sample plan for a component qualification.

The manufacturing pilot (or PVT) only detects defects that the manufacturing assembly and test process are capable of exposing. If the types of defects hidden in your new component have a TTF that is outside the manufacturing test time, or if the defects require diagnostics you do not yet have in manufacturing test, the manufacturing pilot obviously cannot reveal these defects. In that case, you must run tests, such as reliability testing or accelerated testing outside the PVT, to catch these defects. Also, because it is a limited sample of parts, the pilot only exposes defects if those defects are at a high enough level to be statistically exposed by the sampling plan.

You cannot assume that there will always be a relationship between the defects caught outside the manufacturing process and defects caught within the manufacturing test process (for example, time-zero defects proportional to long TTF defects). Therefore, the main purpose of a manufacturing test pilot must be to ***protect the manufacturing test process itself from excessive risk*** which can be introduced by the new component under qualification.

Excessive risk is defined in the following way:

- A safety risk to those doing the manufacturing

- The possibility of excessive yield fallout of the new component causing severe disruption of the manufacturing throughput of your line

This could be either a functional or non-functional yield problem. The yield fallout ***due to the component under qualification*** in manufacturing assembly or test is related to the component defectivity level detected by the assembly or test process, and the number of qualification components used in the system. This component-specific yield fallout can be called the 'yield impact' of the component under qualification.

1.2.2 Yield Impact

Considering each component in the system as an independent contributor to yield, the yield impact of a particular component can be expressed as *Equation 1*, below.

Equation 1:

Yield Impact = 1 – Rolled Yield of system due to component under qualification

where:

Rolled Yield = [1 – (DPM / 1,000,000) ^ (components per system)].

DPM (see *Appendix A*, on page 12) is Defects per Million, measured by Oracle's assembly or test process, not by the component supplier's process.

NOTE 2: If the component is configurable in the system (for example, CPUs or DIMMs) you must use a typical or average configuration to determine the correct number to use for components per system.

When the projected yield impact of a component is such that the manufacturing line can no longer meet its throughput goals, the risk of using the component under test in manufacturing is deemed excessive and the 'Acceptable Test Capacity Impact Limit' is exceeded.

1.2.3 Determining the Component's Critical DPM

To determine the maximum acceptable impact on manufacturing throughput, consider the capacity of the manufacturing line at various assembly and test steps. Usually, line capacity has some flexibility (flex-capacity) for peak throughput times (for example, at quarter end) and for unexpected demand. In Oracle manufacturing, the flex-capacity for unexpected demand is approximately 10% greater than the estimated peak. The recommendation for the maximum acceptable test capacity impact (at the test step most affected by the component under qualification) is an additional 5%.

NOTE 3: This is a recommendation. More conservative qualifications must use values less than 5%.

The manufacturing line was already sized to account for the yield fallout or DPM typically expected from components. If the manufacturing line typically runs more than two or three qualifications simultaneously, the additional yield impact allowed must be less than 5% in order to manage risk. Using an additional 5% yield impact as the trigger point gives a critical DPM (*DPMcrit*) to adhere to qualification, so that, statistically, the standard +5% yield impact is not exceeded. *DPMcrit* is the highest tolerable defect rate that just passes the qualification sample plan.

Using *Equation 1*, on page 5, gives *Equation 2*, below.

Equation 2:

Critical Rolled Yield = Typical Yield - 0.05 * (Typical Yield) =
[1 – (*DPMcrit* / 1,000,000)] ^ (components under qualification per system under test)

or:

DPMcrit = {1 - [(Typical Yield – 0.05* (Typical Yield)) ^ (1 / (components under qualification per system under test)) x 1,000,000

Example:

If the typical DPM for a component is 1500, and the component is used eight times in an average system, according to *Equation 1*, on page 5, the typical yield for the impact of that component only is:

Typical Yield Impact (Component Only) = (1- .0015) ^ 8 = 0.988

Let the Typical Yield for the test step as a whole = 85%. Then, from *Equation 2*, on page 6 the minimum yield for that component at that test step, using the recommended 5% level for yield impact flexibility, is:

Critical Rolled Yield = 0.988 - .05*(0.85) = 0.9455

then:

(0.9455) ^ (1/8) = 1 – *DPMcrit* / 1,000,000

or:

0.993 = 1 – *DPMcrit* / 1,000,000

and, therefore:

DPMcrit = 7000

In this case, to ensure that the yield is not affected by more than negative 5% at a particular test step, you must ensure that the component DPM during the qualification does not exceed 7000. To be more conservative, use the same calculation with a yield impact flexibility less than 5%.

Section 1.3 below, describes how to use statistics and sample plans to ensure that the yield is not affected more than can be tolerated by the manufacturing process.

1.3 Defect Sensitivity and Sample Plans

The sensitivity of a pilot test, or PVT, to a given defect level depends greatly on the sample size of the pilot. The greater the sample size, the lower the defect level that the test can detect at a given confidence level. The confidence level is the inverse of the level of risk that the pass or fail criteria meets even though the sub-population does not meet the quality goal (that is, exceeds the DPM goal). This is also called the 'consumer's risk' or 'beta risk' in acceptance sampling.

Some basic principles cited in *Applied Reliability*, by Tobias and Trindade, Second Edition, 1995, are summarized below:

- Sampling plans recommended for component qualifications are based on the assumption of a negative binomial distribution for the percent defective in a population. To use this model, the data in the pilot must be randomly sampled from the base population.
- The confidence level for the sampling plan is defined as 100% minus the statistical risk of a 'false pass' based on the pass or fail criteria of the sampling plan. The risk of a 'false pass' is also called the 'consumer's risk' or 'beta risk'.
- For a given sample size and pass or fail criteria, the confidence limit increases as the DPM goal for the sample increases, and decreases as the DPM goal decreases. For example, the confidence level of a 150-component sample plan with two failures allowed would only be 57.9% for a 20k DPM goal, but it would be 98.4% for a 40k DPM goal

NOTE 4: A 1.6% risk of the sample having a 'real DPM' higher than 40k does not mean that the 1.6% risk is equally applicable to all defect levels higher than 40k DPM. The risk decreases as the DPM level increases.

- In acceptance of the sampling terms, the relation of probability of acceptance against incoming lot tolerance percent defective (LTPD) (or DPM if converted to parts per million) is described by the 'operating characteristic' curve for a given sample size and acceptance criteria. For details, see *Applied Reliability*, Tobias and Trindade, Second Edition, 1995.

Consider the following three variables below when defining a sampling plan. If an underlying binomial distribution of the percentage defective data is assumed, the required sample size can be defined.

1. **DPM goal**: The DPM which the sample must not exceed at the chosen confidence level in order to pass the qualification. In acceptance sampling terms, the DPM goal (as a percentage rather than in parts per million) is called the LTPD (Lot Tolerance Percent Defective). For details, see *A General Excel Solution for LTPDN Type Sampling Plans*, David C. Trindade and David J. Meade, at www.trindade.com/publications.html.

2. **Confidence level**: Determines the level of risk you take for this sample plan. For the purposes of this document, confidence level is defined as 100% minus the consumer's risk for the sampling plan. At a given DPM and pass or fail criteria, the sample size increases as the confidence level increases.

3. **Allowable failure criteria**: Defines how many defective parts you allow while still confirming a passing qualification which does not exceed your DPM goal. The sample size increases as the number of defective parts allowed increases.

Routines available in Excel are available to calculate sample sizes for plans, given the above variables as inputs, with the assumption that the observations being examined are in one of two states for example: "pass" or "fail." If each observation is statistically independent, then one can model the behavior of the discrete data using the Negative Binomial Distribution.

For the DPM level goal for the qualification, use the DPMcrit parameter as defined in *Equation 2*, on page 6. *Equation 2* can be tweaked if the flexibility of the manufacturing line capacity is, at any given assembly or test step, more or less than 5%. Target DPM must be based on the yield impact that the manufacturing line can afford to absorb, at least until root cause and corrective action (RCCA) on the component failures is complete, so that the risk you try to reduce using the manufacturing pilot is mainly the risk to the manufacturing line itself.

For many component types, an attempt to verify the DPM targets that suppliers project as quality levels that Oracle will experience during assembly or test results in either an unacceptably large sample plan or a meaninglessly small confidence level. If an acceptable level of risk to the manufacturing line is appropriately modeled by the DPMcrit parameter, it is reasonable to use this parameter as the cut-off value for a successful qualification.

If several qualifications over a short period of time marginally pass with DPMs just under the DPMcrit values, the manufacturing line can undergo excessive yield loss. However, if you have sufficient upside manufacturing line capacity, and you choose conservative confidence levels for the sample plans, this outcome is very unlikely.

NOTE 5: For conservatism and simplicity, use a fixed confidence level of 90% for the sampling plans which use the DPMcrit parameter as the quality goal. A confidence level of 90% corresponds to a standard LTPD sampling plan with 10% consumer's risk. This kind of sampling plan reduces the risk to the manufacturing line to reasonable levels.

For pass or fail criteria for component qualifications it is best to **choose a sample plan which allows for at least one or two failures,** so that there is a greater possibility of detecting fail mechanisms on which you can do analysis for continuous improvement, while still consuming the new component in manufacturing if the pass or fail criteria are met.

You must balance all these considerations against cost and risk considerations. However, if the potential risk warrants a PVT, it is probably appropriate to make the sample size large enough to detect a DPM level which is critical to line yield.

1.4 Using the Sample Size Calculator Spread Sheet

A sample size calculator based on the binomial distribution is located as *7305621, WWOPS Product Lifecycle and Technology: Critical DPM and Sample Size Calculator* at (as well as in Agile for Oracle employees):

https://beehiveonline.oracle.com/teamcollab/overview/AQP_General_Supplier_Information_Group_Workspace

There are two sheets in the spreadsheet. To use the tool, perform the following steps:

1. Enter the following information into the first sheet (called 'Critical DPM'):
   - Typical or measured DPM
   - Number of components on each board
   - Number of boards in each system in an average or typical configuration
   - Maximum additional test capacity impact allowed. This is the maximum acceptable impact to line capacity from failures attributed to the component under qualification at the critical test step (that is, the test step for which yield impact is calculated). For this tool, the maximum additional test capacity impact allowed is 5%.
   - Typical yield for the board or system under test at the critical test step
2. Enter the following information into the second sheet (named 'Sample Size'):
   - Initial sample size in boards (an estimate of the sample size)
   - Sample size interval-boards (to tweak the granularity of the data output)
   - Number of acceptable failures (components)

NOTE 6: The tool also outputs this value for 'Fixed Sample Size' situations.

When you entered the data, the ***`Confidence Level`*** column colors are the following:

Red: the confidence level is below 80%.

Yellow: the confidence level is between 80% and 90%.

Green: the confidence level is above 90%.

To determine the minimum sample size to meet a 90% confidence level, select the number from the Sample Size column which corresponds to the **first** green row of the ***`Confidence Level`*** column.

You can also use the sample size calculator with **constrained (or fixed) sample size**. In that case, use the top-right section of the Sample Size sheet to enter the given sample size. The tool then varies the number of allowable failures and again indicates the risk using the colors in the ***`Confidence Level`*** column.

To determine the maximum number of allowable failures to meet a 90% confidence level with a given sample size, select the number from the Failure column which corresponds to the **last** green row of the ***`Confidence Level`*** column.

1.4.1 Guidelines Incorporated Into the Calculator

The following guidelines and restrictions were incorporated into the sample sizing calculator according to the recommended practices.

- The ratio of the critical DPM to the target DPM must not be excessive. That ratio is set to a maximum of 20X (for components with DPM target less than 1000) and a maximum of 2X (for components with DPM target of 5000 or greater), with linear interpolation in between. See the following table.

Target DPM (from Supplier Engineering)	***Ratio of DPMcrit/DPMtarget***
<1000	20X or less
1000 to <5000	Ratio = −.0045 x Target_DPM + 24.5 (linear interpolation between 2X and 20x)
5000 or greater	2X or less

- The Maximum Additional Test Capacity Impact allowed is 5%, regardless of the DPMcrit or DPMtarget ratio.

- Sample size is generated assuming zero or greater failures allowed, with >80% confidence on DPMcrit.

The addition of these guidelines to the calculator can cause sample size output column entries to turn red (not recommended) even if the Test Throughput impact is less than 5% and the confidence interval for meeting DPMcrit is >= 80%.

Appendix A: Definition of Terms

AML (approved manufacturers list): The Oracle-approved list of vendors or suppliers qualified to supply a component.

Confidence level: The percentage of all possible samples that can be expected to contain the true population parameter (in this case the true proportion of failures). For the purposes of this document, confidence level is defined as 100% minus the 'Consumer's Risk' for a sampling plan. Consumer's risk is the probability of acceptance of an individual sampled lot with defectivity equal to the LTPD limit, or greater. For example, an LTPD sampling plan with 10% consumer's risk has a confidence level of 90%.

DPM (defects per million): A measure of defect density of a component as experienced in the Oracle or Oracle external manufacturer (EM) test process. This term is used in the same sense as defects per million opportunities (DPMO), where an opportunity exists every time a component is used on a system BOM.

DPU (defects per unit): The number of defects for a specific unit. In the case of component qualification, the unit is a computer system.

RPM (replacements per million): Often this term is used in lieu of DPM because component replacements may be made during failure analysis which are not necessarily defective components. RPM is a measure to approximate a ‘verified’ DPM when timely feedback is needed.

DVT (design verification testing): The subset of testing done during a component qualification that is targeted at finding any design compatibility issues between the new component and the system design. DVT is usually performed by design engineering (the New Product Introduction [NPI] or Continuation Engineering groups) on a small sample of components and systems. The testing usually includes margining (for example, voltage, frequency, and temperature) and detailed measurements on the system.

PVT (process verification testing): The testing done during a component qualification that is targeted at finding any manufacturing process compatibility issues between the new component and the system or board level assembly and test processes. PVT is usually performed by Operations Engineering on a statistically significant sample. The testing usually includes the standard product manufacturing test. Sometimes called the “Ops Qualification” or “Manufacturing Pilot.”

FCT (four corners test): Typically, a functional test of a system or board which includes both voltage and temperature margining.

FMEA (failure modes and effects analysis): A method to understand the criticality of errors and defects that can result in a threat to quality, safety, or reliability.

LTPD (lot tolerance percent defective): An allowable percentage of defective material which can be considered as the borderline between a satisfactory lot and an unsatisfactory one. Also called 'rejectable quality level.'

ORT (ongoing reliability testing): Ongoing system-level testing performed after a product is made generally available (GA) to assess ongoing system reliability

Appendix B Acknowledgments

Acknowledgments to:

Lisa Curhan, for authoring the original white paper on which this document is based.

Brett Ong, for statistical consulting and his major efforts on the Excel sample sizing tool.

The original Sun Microsystems 'VSP' organization product engineering staff, many now in Oracle WWOPs, for review and agreement on guidelines for the ratio of 'critical DPM' to 'target DPM'.

Dave Trindade, previously of the Sun RASCAL group, who provided critique and input to Lisa Curhan's original white paper.

Reference Documents and Records

<table>
<tr><th rowspan="2">Document Title</th><th rowspan="2">Number</th><th colspan="2">ESO Controlled</th><th colspan="2">Quality Record</th></tr>
<tr><th>Yes</th><th>No</th><th>Yes</th><th>No</th></tr>
<tr><td>WWOPS Product Lifecycle and Technology: Critical DPM and Sample Size Calculator found at (as well as in Agile for Oracle employees) : https://beehiveonline.oracle.com/teamcollab/overview/AQP_General_Supplier_Information_Group_Workspace</td><td>7305621</td><td>x</td><td></td><td></td><td>x</td></tr>
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Document History and Approvals

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Related Information

Reason for Change:

Updated from Sun to Oracle and add reference Excel spreadsheet version of Sample Size Calculator, 7305621. Remove reference to 914-1741 and link to Stat Trek. Update link to NIST/SEMATECH and add reference to Sean A. Wallis' article.

URL Link(s) to Other Documents:	1. NIST/SEMATECH e-Handbook of Statistical Methods,Section 3.3.3.3 (Selecting Sample Sizes) at http://www.itl.nist.gov/div898/handbook/ 2. www.trindade.com/publications.html.

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Other Documents Non-URLs:	*Applied Reliability*, *3rd ed.,* Dave Trindade and Paul Tobias, 2012, Chapman &Hall/ CRC
	Wallis, Sean A. (2013). "Binomial confidence intervals and contingency tests: mathematical fundamentals and the evaluation of alternative methods". *Journal of Quantitative Linguistics* **20** (3): 178–208. doi:10.1080/09296174.2013.799918.

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