Manufacturing Equipment
Statistical Qualification Requirements

Global Common

SD-002

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1. Scope

The intent of this specification is to assure the production equipment supplied to Nexteer Automotive will consistently produce products which meet engineering requirements. Equipment qualification is not complete until the equipment has demonstrated acceptable Process Performance on Nexteer's plant floor under normal operating conditions. This specification defines the minimum requirements for machine qualification. Additional requirements may be necessary (i.e. longer runs, additional parts, etc.), for specific equipment. Any additions, clarifications, or exceptions shall be clearly identified in the Manufacturing Engineering Equipment Purchase Specification (T-Spec). The Chief Manufacturing Engineer shall have the final authority for any deviations to the MQ plan, length of runoff, and any other portion of SD-002.

This specification and the statistical qualification requirements within have been developed consistent with the Automotive Industry Action Group (AIAG):

- Statistical Process Control (SPC) Manual
- Measurement Systems Analysis MSA

2. Verification of Dimensions and Requirements

All dimensions and requirements to be evaluated during an operation shall be listed in the Machine Qualification (MQ) plan. The MQ plan should be approved by the receiving plant's Manufacturing Engineering Manager.

3. Process Capability & Performance

Applies to all equipment except those listed in section 3.4.

Preferred statistical software:

- Minitab®
- SPC5 (Nexteer developed software package)
- Other SPC software may be used if approved by the Engineer in Charge

The values shown in the table below shall be used as acceptance criteria for evaluating process study results.

- Cpk values shall be used when evaluating stable processes.
- Ppk values shall be used when evaluating processes with known allowable special causes of variation and data meeting dimensional specifications.

Dimension Type		MQ1 and MQ2
CL1	Bilateral	Cpk or Ppk > 1.67
	One Sided	Cpk or Ppk > 1.67
CL2	Bilateral	Cpk or Ppk > 1.67
	One Sided	Cpk or Ppk > 1.33
CL3*	Bilateral	Cpk or Ppk > 1.33
	One Sided	Cpk > 1.33 or Ppk > 1.18
CL4	Bilateral	Cpk or Ppk > 1.67
	One Sided	Cpk or Ppk > 1.33
CL5 Yellow	Bilateral	Cpk or Ppk > 1.33
	One Sided	Cpk > 1.33 or Ppk > 1.18
CL5 Red	Bilateral	Cpk or Ppk > 1.67
	One Sided	Cpk or Ppk > 1.33
STD*	Bilateral	Cpk or Ppk > 1.33
	One Sided	Cpk > 1.33 or Ppk > 1.18

* Not all DSS features designated as STD or CL3 dimensions are required to have capability data collected during the MQ run. The MQ plan will document the features and verification methods to be used during the formal equipment qualification run.

NOTE: Nexteer approved and documented Customer requirements may supersede these requirements. Customer specifications should be comprehended before MQ plan creation and approval. Program specific PDT should work with the Customer to understand all Customer specific requirements.

For CL3 and CL5, where process capability is not met, acceptable action plan would be a 100% inspection or approval using the Extreme Tolerance / Capability Approval form found in the runoff book.

For those DSS features designated as CL1, CL2 and CL4 dimensions, approval of the Extreme Tolerance / Capability approval form is mandatory for all dimensions not meeting capability requirements.

In those instances, where an analysis of the process data results in Cpk or Ppk values which fail to meet the required level, and where the Cp or Pp values (for the same data set) meet the required level, after proper root-cause analysis and review of current tolerancing scheme, it is at the discretion of the Engineer in Charge, with the approval of the Chief Manufacturing Engineer, to use the Cp and Pp values to determine machine acceptance. An explanation of the machines ability to center the data shall be documented in the respective statistical (Cpk / Ppk) column or MQ Requirement column in the MQ plan.

For those locations or applications where Nexteer has agreed to analyze equipment data in terms of the Machine Capability Index (Cmk) in place of the Process Capability Index (Cpk), all data shall be collected sequentially.

NOTE: The formulas for the two indexes are the same with the Cmk being calculated from the standard deviation of the measured sequential sample data while the Cpk is calculated from the standard deviation based upon the data from the process' control chart information. Therefore, an acceptable Cmk would always result in an acceptable Cpk.

3.1 Stability

Special causes of variation are signaled by one or more data point(s) which are beyond the process control limits or non-random patterns of data points which are within the process control limits. Special causes of variation may be allowable if they are understood and when there is not a risk of making products which do not meet specification. Special causes which are known to be inherent within the process, and therefore allowable, should be identified and documented with the MQ data (For example; machine warm-up, tool change, grinding wheel dress frequency, multiple stations, incoming material lots, etc).

Even with processes that are within statistical control, the probability of getting a false signal increases as more data points are reviewed. It should be recognized that the signals may be due to random variation with no underlying process problem. When a signal has been determined to be false, no action is required, it should be noted as such in the MQ data summary.

Non-Normal distributions or One-sided Specifications

The above criterial assume normality and two-sided specification. When this is not true, using this analysis may result in unreliable information. Alternate acceptance criteria may require a different type of index or method of transformation of the data. The focus should be on understanding the reasons for the non-normality and managing variation. Refer to the SPC reference manual for further guidance.

When analyzing data for process capability, first check whether the distribution follows a normal distribution by reviewing the Anderson-Darling (AD) statistic and corresponding p-value.

- If the data is determined to be normally distributed the Cpk / Ppk values shall be representative of the data and reported.

- If the data is determined not to be normally distributed it should be analyzed with a 3-parameter Weibull distribution. The Ppk value shall be representative of the process capability and recorded.
- If the 3-parameter Weibull analysis does not provide acceptable AD and p-values than alternate distribution fits may be pursued.

Any alternate distribution methods used should be evaluated based on the probability plot, the goodness-of-fit test results, and physical or historical knowledge of the process.

In cases where Cpk / Ppk values are high and normality tests fail, further efforts to achieve normality is not required and the process shall be deemed acceptable.

3.2 Extreme Tolerances

For processes with extremely tight tolerances or unattainable tolerances, lower Cpk / Ppk may be acceptable, provided the appropriate additional control or action plans are used. The "Extreme Tolerance / Capability approval" form, found in the runoff book, shall be used to document the feature and proposed alternative control method. The form must be approved before the plan is in effect.

3.3 True Position

When inspecting parts with features of true position, assessment may be conducted using either attribute or variable inspection methods. When collecting data via a CMM, the separate X and Y components of the data may be analyzed independently.

3.4 Special Equipment

The following types of equipment may have special requirements pertaining to Pre-qualification, and Qualification. These special requirements are created by the type of equipment being verified or by the time and difficulty required to perform the feature measurement.

3.4.1 Assembly Equipment

Equipment used in assembly processes fall into several categories. Special consideration may be required when qualifying an individual device making up the process. It is essential that there exists a clear understanding of the process and the design intent of each device prior to the approval of the MQ plan. It is also important to understand the various type of assembly equipment involved and the expectation of each device.

Type 1: Assembly to a targeted value – Ex: Driving a fastener to a torque

The nature of this process indicates that the amount of data variation will be limited only by the response time and accuracy of the device used. In a targeted process, the statistical expectation of normality is therefore often not applicable. If the test for normality fails, due to lack of data variation, further efforts to achieve normality shall be unnecessary. For further analysis of non-normal data refer to the procedure in Section 3.1.

Type 2: Assembly to range through iterative processing – Ex: Rake Lever Effort

An iterative process is a process in which there is a pre-established range for pass / fail criteria. Results are based on processing the workpiece until a data value is obtained which falls within the pass/fail window, therefore normality and Cpk / Ppk shall not apply.

Type 3: Verification of function – Ex: Final function test (motors, switches, sensors, etc)

In the case of equipment used solely for the verification of product function or for the measurement of product features, qualification shall consist of a gage capability study. The equipment's measurement device shall be considered a gage. Attribute measurement devices should also be qualified using an attribute gage study. Refer to Nexteer Specification SD-005, General Gage Specification, for guidance relative to evaluating measurement systems.

Type 4: Assembly with monitored results – Ex: Bearing Press with Running Load

The results for these types of processes may be dictated by factors upstream which are not adjustable and uncontrollable by the process being qualified to achieve capability. Machine acceptance should be based on measurement system analysis (per SD-005) however FTQ/RTY targets shall also be achieved and documented in the MQ Plan.

NOTE: Type 1 – 4 special equipment exceptions may apply to other non-assembly equipment. The Type 1-4 exceptions shall be documented in the MQ plan prior to approval.

3.4.2 Induction / Conduction Heating

Pre-qualification

The first ten (10) pieces off each spindle shall be collected. The 1st, 5th, and 10th piece from each spindle shall be cut and all case depth and hardness values shall be measured and recorded. The results shall be submitted to the Engineer in Charge for approval.

Qualification for Shipment Approval

The equipment supplier shall collect five subgroups of material, per each machine spindle. The subgroups shall be collected at equal intervals throughout the run. Each subgroup shall consist of three workpieces. The samples shall be statistically analyzed and shall meet the requirements defined in Section 3.

All surface hardness, case depth, and heat treat runout measurements shall not be statistically analyzed for capability purposes due to the inherent gage R&R issues. Refer to the MQ plan for specific analysis requirements.

3.4.3 Furnace Heating

Furnace heat treat equipment cannot be completely qualified at the Supplier's facility since the support equipment required to do so is generally not available. The following qualification requirements shall be performed at Nexteer's facility receiving the heat treatment equipment:

- Since furnace heat treatment operations are normally a batch type process, control charting is not required, and Process Capability does not apply.
- Process Performance studies are required, however the number of samples required for the study shall be reduced. Reference the following:
  - For batch type furnaces, eight (8) samples per load for three (3) loads totaling twenty-four (24) pieces shall be analyzed for the appropriate metallurgical properties.
  - For pusher carburizers, one (1) part per tray, for twenty-five (25) trays totaling twenty-five (25) pieces shall be analyzed for the appropriate metallurgical properties.
  - Draw type furnaces shall not require statistical analysis.

3.4.4 Joining

Dimensional requirements produced in joining processes shall be evaluated as described in Section 4.2, 4.3, and 4.4.

- Joint integrity checks used to determine joint strength shall utilize 30 samples equally spaced throughout the run. Joint Integrity checks shall consider industry standard integrity testing along with the part print requirements when developing the test methods.
- Checks requiring cut and etch procedures for analysis shall use 15 samples equally spaced throughout the run.
- If lower quantities for destructive checks are to be utilized, it shall be documented in the approved MQ plan.

3.4.5 Test Machines, Gages

Test machines and gages should be qualified using the gage capability process defined in Nexteer Specification SD-005. The equipment's operation shall be qualified by the typical MQ run sequence described in Section 4 without the analysis of statistical data.

3.4.6 Coatings and Painting

Statistical analysis is only be required for those finishes that are defined by the part print. In-process coatings do not require statistical analysis.

3.4.7 Material Handling, Washers

These types of equipment do not normally provide variables type data and therefore do not require statistical analysis. Acceptance criteria shall be documented in the approved MQ plan.

3.4.8 Surface Finish Requirements

Surface finish data does not often follow a normal distribution. Refer to Section 3.1 for the procedure to analyze non-normal data.

3.4.9 Straightening Equipment for features of runout

The process of the workpiece straightening does not generate normally distributed data. Workpiece straightening is an iterative process in which there is a pre-established range for pass / fail criteria. The results are achieved by processing the workpiece until a data value is obtained which falls within the pass / fail window. Qualification of straightening equipment for features of runout shall consist of two components:

- The measuring devices used during the straightening process shall be qualified through a measurement system analysis (MSA) under the guidelines of Nexteer Specification SD-005.
- The equipment's operation shall be qualified by the typical MQ run sequence described in Section 4 without the analysis of statistical data.

Refer to Section 3.4.1 Type 2 for more information on iterative processes.

4. Steps to Complete Machine Qualification (MQ)

- Verification of Machine Cycle (Dry Cycle)
- Pre-qualification (30pc) on Supplier Floor
- MQ1 (Machine Qualification 1) on Supplier Floor
- Pre-qualification (30pc) on Nexteer Floor
- MQ2 (Machine Qualification 2) on Nexteer Plant Floor

4.1 Verification of Machine Cycle (Dry Cycle)

The minimum intent of the verification of machine cycle is to identify potentially faulty or defective equipment components. Additionally, the test run is to confirm the equipment will cycle as specified over a minimum pre-determined time period without malfunction.

- It is recognized that some types of equipment may not be effectively tested in this way. For these types of equipment, the use of an appropriate substitute test may be used. The test shall meet the minimum intention of this section.
- Substitute tests shall require the approval of the Engineer in Charge.

The verification of machine cycle shall be as follows:

- Continuous for 10 hours.
- Overnight complete shutdown.
- Restart equipment and continue the run for 10 consecutive hours.

During the dry cycle run, the equipment shall be:

- Cycled at its quoted rate.
- Cycled in its automatic mode.
- Cycled in its final configuration (i.e. panels in place, doors closed, etc.).
- Cycled using parts to demonstrate the equipment's material handling capability.

  NOTE: When dry cycling the equipment using production material the parts should not be altered or modified.

- Monitored for any malfunctions or deviations to the equipment's standard processing sequence.

  NOTE: The supplier should maintain a log of the test run. All malfunctions or process deviations shall be documented along with the associated corrective action and supplied to the engineer in charge.

  NOTE: Major malfunctions may cause the test to be repeated. The Engineer in Charge shall decide if the severity of the malfunction requires the test to be repeated.

The supplier shall notify the Engineer in Charge prior to initiating the run. Attendance of Nexteer personnel shall be at the discretion of Nexteer.

4.2 Pre-qualification (30pc)

After the verification of machine cycle and prior to the MQ1 run, the Vendor shall run a minimum of 30 consecutive workpieces. Attendance of Nexteer personnel will be at the discretion of Nexteer. The Supplier shall notify the Engineer in Charge when the equipment is ready for the Pre-qualification run.

The Pre-qualification shall be as follows:

- The equipment should be set to produce material at the feature's nominal dimension, or at some appropriate target value.
- In the case of devices with multiple spindles, 30 consecutive pieces shall be produced from each spindle. The 30 pieces shall be produced with no unscheduled interruptions.
- The 30-piece study will be performed using production tooling.
- All adjustments shall be performed prior to the run. No adjustments should be made during the run unless the process is known to require tool adjustments within the 30-piece time period.
- The 30-piece run shall be performed at quoted cycle rate.

Compliance to the Pre-qualification requirements (see Section 3, Process Capability & Performance) is the responsibility of the Supplier. Upon successful completion of the pre-qualification run, the Supplier shall forward the data and related charts to the Engineer in Charge.

NOTE: The Engineer in Charge may request the actual parts produced be delivered to Nexteer for verification or further testing.

4.3 MQ1 (Machine Qualification 1) on Supplier Floor

After the Pre-qualification run has been successfully completed and data verified by Nexteer personnel, the MQ1 run shall be scheduled. The Supplier shall notify the Engineer in Charge prior to initiating the run. Attendance of Nexteer personnel shall be at the discretion of Nexteer.

The MQ1 run shall meet the following conditions:

- The MQ1 qualification run shall begin after all setup adjustments have been completed.
- Measurement devices shall be mastered prior to the run.
- There shall be no unscheduled adjustments to the machine permitted during the MQ1 run.
- Any unscheduled machine interruptions shall be documented along with the corrective action(s) undertaken. The Engineer in Charge shall determine if the MQ1 run shall be restarted for those features where an adjustment was required.
- The equipment shall produce material at its quoted cycle rate.
- The MQ1 run shall ensure enough material has been produced to perform a statistical analysis of the data collected.
- If the equipment incorporates automatic tool compensation devices, a significant number of samples shall be manufactured with the tool compensation disabled. The disabling of the tool compensation device is to provide data regarding the effectiveness of the compensation and shall be monitored to avoid the generation of non-conforming material.
- All measured parts are to be identified as to their production spindle, fixture, or station. Pieces shall be measured and recorded in consecutive order on a control chart.

Sample Size:

- The sample data, shall consist of a minimum of 25 subgroups comprising of (a minimum of) 125 pieces total.
- The MQ1 run shall consist of the manufacture of 125 pieces or 4 hours of production, whichever is greater.
- In the case of multiple spindle devices, the sample shall consist of a minimum of 25 subgroups with a minimum of 125 pieces per spindle.
- Shorter runoffs shall be permissible with the written authority of the Chief Manufacturing Engineer.

Subgroups:

- Each subgroup size should consist of 5 pieces for all equipment, except the Special Equipment described in Section 3.4.
- Subgroup data should be taken in consecutive order with no machine adjustments within each subgroup.

The resulting control chart will be analyzed to confirm the process and equipment meet Nexteer's Process Capability and Process Performance requirements (see Section 3).

- If the equipment's data is found not to meet Nexteer requirements, corrective action shall be undertaken and the MQ1 run shall be repeated.
- Control charts shall include documentation of any assignable causes which have been identified during the run.
- Machine variables (e.g. speeds, feeds, etc.) should be documented and included with the control charts.

Equipment shipping approval shall be given after the above requirements have been met, and only after approval has been obtained from the Nexteer Manufacturing Engineering Manager.

4.4 MQ2 (Machine Qualification 2) on Nexteer Plant Floor

The MQ2 shall include a Pre-qualification (30pc) and a final Qualification identical to the MQ1 verification process. These tests shall be done by Nexteer Automotive personnel. The receiving plant's Manufacturing Engineering Manager has the authority to reduce the quantity of parts to be manufactured during the MQ2 run.

5. Part Control during all steps of the Machine Qualification (MQ)

All parts used in the qualification process are to be identified to ensure traceability:

- The identification of the material is the responsibility of the equipment Supplier.
- Allowable locations for the identification mark(s) will be determined by Nexteer.
- Measured parts which are to be used in the statistical data are to be segregated, identified and retained to ensure Traceability.
- The order of production of the measured parts shall be preserved.
- All parts produced during the qualification process, which do not conform to process print dimensions, shall be identified and segregated by the equipment Supplier for disposition by Nexteer.

6. Measurement Systems

All measurement devices used during machine qualification, including standard tool room or inspection instruments, must be evaluated for repeatability, reproducibility, and accuracy.

Any measurement device(s) that are supplied as a part of the purchase order shall be qualified by the equipment Supplier. The procedure for the qualification of the measurement system is outlined in Nexteer Specification SD-005.

7. References

- G1331 – Product and Process Characteristics
- SD-005 – General Gage Specification
- SPC5 – Statistical Software Package
- AIAG – Statistical Process Control (SPC) Manual
- AIAG – Measurement System Analysis (MSA) Manual
- Stats Pack 1 – Statistical Software Package

RECORD OF REVISIONS

Revision No	Date	Section	Description
001	01MR93	ALL	Original approval & issue date.
002	18OC94	ALL	PPK indices increased to 1.67.
003	01FE95	ALL	Changed to Delphi Saginaw Steering Systems.
004	10SE98	8.1	5-day runoff changed 2 days.
005	01MR99	8.1	5-day runoff changed 2 days.
006	07JA02	ALL	Completely revised and rewritten.
007	02AU06	9.1, 10.11	Sections added.
008	16JA08	ALL	CPK indices increased to 1.67.
009	21OC08	ALL	QCI references added and KCC reference removed.
010	02FE09	2.0	Document all characteristics not verified at Machine Qualification.
011	06NO09	ALL	Company name updated. All SD documents are global common.
012	27NO12	ALL	Completely revised and rewritten.
013	03JA14	3.1.4	Added: joint integrity testing shall consider industry standard integrity testing.
014	03JA14	3.1.4	Reference to Section 6.0 and 7.0 revised to Section 4.2, 4.3, and 4.4. Mistake when document was rewritten.
015	01JL15	2.0	Added: dimensions verified by CMM, see reference publication MEP-001: How to Create a CMM Program to Inspect Part Features.
016	31MR16	3.0	Updated Process capability to match G1741 update. Eliminated Economical Control Limits, Mirror Image Transformation, Positional Capability / Positional Ppk and Appendix A.
017	11JA19	ALL	Reformatted entire document for consistency with other specifications. Renumbered Section 3, updated Section references within the document.
018	11JA19	ALL	1.0 Deleted “Effective Date for rev. 016”. 2.0 Deleted ref. to CMM publication MEP-0011. 3.0 Deleted ref. to G1331 Attachment D #7. 3.0 Deleted ref. to Policy Letter PL0044. 3.0 Added CL3 to * note about STD dimension capability. 3.0 Added a section to describe Cmk. 4.0 Added Pre-qualification for MQ2 in “steps” section., 6.0 Deleted “Gage Error Effect on Capability” paragraph and graph.
019	22JA21	ALL	Minor editing in Sections 1, 2, 5, and 6. Updated Section 3 and 4 significantly to better align with MSA, PPAP Manual, and other statistical references. Added clarification where appropriate along with qualification direction.