MRA Systems, LLC

QUALITY SPECIFICATION

SPECIFICATION **M1002**
REVISION NUMBER -
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DATE ISSUED 04/29/2019

MRA Systems, LLC (MRAS) SUPPLIER REQUIREMENTS FOR CHARACTERISTIC ACCOUNTABILITY, VERIFICATION AND QUALITY PLANNING

This specification is in addition to and in no way limiting, superseding, or abrogating any contractual obligation as required by the applicable procurement document.

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MRAS PROPRIETARY INFORMATION

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A. Purpose

i) To ensure that all accountable characteristics of a product are addressed by the supplier in the manufacturing and quality plans and that planning includes controls adequate to ensure repeatable and reproducible conforming results of these characteristics.

ii) To provide requirements for documenting the results of First Article Inspection (FAI) and evaluations of changes after initial FAI documentation

B. Applicability and Use

A. This specification applies when flowed down via purchase order or long-term agreement.

B. This specification defines the product realization process for the first production run and ongoing production. This applies to all product supplied to MRAS suppliers (reference APPENDIX E for FAI applicability guidance)

   a. Unless otherwise specified in the purchase order or directed by the MRAS QR, this specification does not apply to:

      i. Procured standard catalog items, COTS or deliverable software

      ii. Unique single-run production orders not intended for ongoing production (i.e.; out of production spares)

      iii. Parts explicitly intended for development, prototype, and/or test only that are not considered part of the first production run

C. The supplier is responsible for performing product characteristic accountability and development of the quality plan in accordance with this specification. This shall be completed and approved by the MRAS QR before shipment of product to MRAS. MRAS reserves the right to witness the supplier's inspections and/or tests to determine the degree of conformance.

D. FAI content shall be presented and documented on the AS9102 forms. Any exceptions must be approved by the MRAS Quality Representative (MRAS QR) prior to use. FAI documentation (and supporting elements as described in Paragraph E) shall be considered a quality record and retained in accordance with M1000. All forms shall be completed either electronically or in permanent ink. All forms and supporting documentation shall be in English (native/non-English language may be included).

   i. Form 1: Part Number Accountability

   ii. Form 2: Product Accountability – Materials, Special Processes, and Functional Testing

   iii. Form 3: Characteristic Accountability, Verification, and Compatibility Evaluation

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E. This specification applies to MRAS drawings and specifications for all levels of parts within an assembly, assemblies, sub-assemblies, and detail parts, including castings and forgings, modifications to standard catalog or COTS items, and to all Suppliers who are responsible for producing accountable characteristics of the product. Supplier who receive the Purchase Order (PO)/Contract from MRAS are responsible for flow down of the applicable requirements of the latest issue of this specification to their sub-tier suppliers. If the FAI is completed by an independent 3rd party, the MRAS supplier remains fully responsible for the completeness and accuracy of the FAI.

F. In the event of conflict, requirements in other sourcing specifications or quality documents referenced on the PO/Contract take precedence over the requirements in this document.

G. Data shall be recorded in the Units of Measure specified on the drawing.

H. The Drawing Revision entry on the SAE AS9102 Form 1 shall reflect the revision applicable to the First Article part and contain a corresponding PO. Forms 2 and 3 do not need to be changed or submitted if a drawing revision does not affect accountable characteristics reported on those forms.

I. For any part or assembly with a lapse in manufacturing of 24 months of more (measured by the completion date of the last manufactured part and the start of the new part), a new full FAI shall be completed per this specification. The FAI shall also be approved by the MRAS QR prior to shipment.

J. For any part of assembly with a lapse in manufacturing of less than 24 months that are ordered to a revision other than the revision listed on the FAI, a delta/partial FAI shall be completed per this specification to account for all drawing and Parts List changes that have occurred. This FAI shall also be approved by the MRAS QR prior to shipment.

K. The supplier shall ensure secure transmission of FAI data package. The preferred method for transmission is the supplier-specific BOX collaboration portal or an encrypted email where the password is provided separately.

C. Establishment of Accountable Characteristics

A. Suppliers are responsible for all accountable characteristics, including those generated by their sub-tier suppliers (i.e. inspection data, OSP processes, test data, Acceptance Test Procedures, etc.). If sub-tier suppliers do not account for their characteristics, the prime supplier is responsible for initiating a separate FAI document or including the characteristics in their FAI document.

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B. A ballooned drawing shall be created, and accountable characteristics numbered for the manufactured part. Suppliers are responsible for ballooning the drawing themselves using the guidelines in this Section. The supplier has the ultimate responsibility for ensuring completeness and accuracy of the characteristic accountability. Each ballooned characteristic must be recorded on Form 3.

C. Characteristic numbers shall be assigned to each of the following drawing features (unless otherwise required or specified by the MRAS QR):

   i. Dimensional features, with the following provisions:

      1. Reference dimensions are not considered accountable characteristics and need not be ballooned.
      2. Basic dimensions should be referenced in relation to the respective measurable characteristic

   ii. Specifications

      1. Accountable characteristics produced by specification definition/requirements defined on the drawing shall be identified and listed for characteristic accountability and first article inspection on Form 3. However, the supplier shall evaluate any specifications that are referenced within those specifications listed on the drawing for additional accountable characteristics.
      2. The supplier is responsible for verifying the revision, accuracy, completeness of characteristic breakout of the specification as they apply to their FAI
      3. Unless otherwise approved by the MRAS QR, specification characteristics and results shall be included as part of the FAI package
      4. Accountability requirements regarding characteristics identified within process/special process specifications (i.e.: processing parameters such as heat treat temperature) will be defined by the MRAS QR.

   iii. Drawing notes

      1. Measurable features within notes
      2. Non-measurable characteristics: It is required that each non-measurable characteristic (including those in notes) be assigned a number

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3. Sequence of Operations – The sequencing of operations as defined on the drawing is considered an accountable characteristic and should be ballooned (i.e. heat treat prior to weld, etch prior to FPI, etc.)

iv. Tables (on drawing) – All tables should be ballooned using a letter and/or number grid as appropriate. Exceptions are as follows:
   1. NDE tables can be ballooned as one characteristic unless otherwise requested by the MRAS QR
   2. Configuration control tables – only cells associated with the part number being reported shall be ballooned
   3. Information tables such as datum tables do not need to be ballooned

v. Supplementary views, tabulated features and alternate methods of manufacture views
   1. When required for the part number being reported, all characteristics shall be ballooned.
   2. When not required for the part number being reported, a single characteristic may be used

D. First Article Inspection

First Article Inspection – a complete, independent, and documented physical and functional inspection procedure after all part processing unless the drawing or processing dictates that the characteristic be inspected prior to all processing being completed. FAI part shall be representative of a production run.

A. The first article inspection should be performed using an independent gaging method rather than the normal product acceptance plan. Production gaging may be used for first article inspection in cases where it is the only method of accurately checking a characteristic.

B. A characteristic inaccessible at final inspection may receive first article inspection when accessible during the process in lieu of disassembly/destruction. The supplier shall ensure that subsequent processing does not cause the characteristic to become nonconforming or unintentionally alter the characteristic.

C. Characteristics that cannot be evaluated non-destructively on a finished part may be re-evaluated using component parts prior to final assembly or by using hardware not useable because of reasons unrelated to the characteristic being re-evaluated.

D. Non-measurable characteristics: result such as “Acknowledge” or “Conform” or “For Information Only” shall be entered.

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E. Multiple characteristics (e.g. bolt circle, dovetail slots): Provide variable data for all occurrences of every characteristic or minimum/maximum readings along with the number of measurements taken unless additional data is required by the MRAS QR.

F. Continuous characteristics (e.g. radius along circumference, weld seams, edge breaks, surface finish, slot dimension, wall thickness and continuous features invoked by specifications): Measure a sufficient number of locations over the total extent of the characteristic to ensure total conformity. Provide variable data for all measurements or minimum/maximum readings along with the number of measurements taken unless additional data is required by the MRAS QR.

G. Nonconformances: Characteristics that are identified as nonconforming during first article inspection shall be documented appropriately using form SQ-1200. Additionally, the MRB tag number shall be linked to the characteristic in the FAI results or referenced in the AS9102 Form 3 results. The FAI is not ready for MRAS review until the MRB tag is closed by MRAS. Any nonconforming characteristic found on the FAI requires 100% characteristic evaluation until justification for an alternate acceptance plan per APPENDIX A is approved by the MRAS QR.

E. Supporting Elements of FAI

Items of this paragraph are required supporting elements of the FAI Data.

A. Part marking: Planning/operation sheets for the marking operations and a photo of all marking required unless otherwise directed by the MRAS QR.

B. Manufacturing routing sheets unless otherwise directed by the MRAS QR.

C. Applicable Supplier Problem Report Form (interpretations/specification options) (Form SQ-1100). NOTE: Completing an SQ-1100 form does not authorize shipment of material that doesn't meet engineering definition. An approved nonconformance document is required prior to shipment for all SPR types, unless directed by MRAS QR.

D. Certificates of conformance for all material, testing and sub-tier special processes, unless otherwise directed by the MRAS QR. Certificates shall be traceable to the documented information in the AS9102 Form 3 results column.

E. Ballooned drawing (drawing with characteristic numbers assigned).

F. Vendor Substantiated Engineering (VSE) (if applicable): VSE data package and evidence of approval by MRAS must be provided as part of the FAI package unless otherwise directed by the MRAS QR.

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F. Quality Planning and Acceptance Plans

A. Manufacturing and quality planning shall be in place before final acceptance of deliverable hardware to ensure that all accountable characteristics are included in the plans. See APPENDIX A for a recommended quality planning process map. The FAI shall be completed for the drawing referenced on the Purchase Document and the supplier MED (Master Envelope Drawing), where applicable. Where supplier/sub-tier product and process drawings exist that contain MRAS accountable/design characteristics, the supplier shall complete a compatibility assessment. Reference Paragraph 0.

B. The adequacy of the measurement system shall be considered when selecting inspection equipment for first article inspection and ongoing production. See 0 for recommended standard inspection equipment. If standard gages are not used, the functional or single-purpose gage number should be noted. A measurement systems analysis (MSA) should always be performed. Evidence of such should be provided as part of the FAI (i.e. Minitab results report, etc.)

C. The required acceptance plan is 100% inspection of each characteristic on every piece manufactured, except when implementing a Reduced Inspection Acceptance Plan per APPENDIX A Table 1: Reduced Inspection Acceptance Plans.

    i. Documented justification for less than 100% inspection is required and shall be available upon request by the GEQR. The documented justification shall be referenced in the FAI. The documentation shall contain the following information tags.

        1. Study number (if applicable) and supplier code
        2. Date study complete
        3. Part Number
        4. Gage Used for Study
        5. Machine/process that generated the feature
        6. Characteristic number/description
        7. Gage R&R results when required by MRAS QR
        8. The documentation shall consist of the raw data that is used to generate capability and the results of the study. Statistical methods defined in APPENDIX C are the preferred methods to use for CpK calculations.

D. Data utilized for process capability calculations shall be representative of the planned process and shall not include rework or work outside the normal process.

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E. Measurement of characteristics for product acceptance, whether completed during manufacturing or at final inspection, shall be performed by qualified inspectors or certified operators. Certification shall be achieved through a supplier certification program that meets the requirements of APPENDIX D.

F. Measurement of characteristics for product acceptance shall be performed using measurement and test equipment meeting the requirements of M1000 (Calibration).

G. Change Management

A. All requirements of this specification apply to accountable characteristics impacted by any of the changes listed below including those invoked by drawing specifications. The supplier shall notify the MRAS QR when a change occurs (as defined in i.-v. below) to determine if a full/partial FAI must be submitted to and approved by MRAS QR. The FAI may require additional characteristic accountability as deemed necessary by the change. When the submission of a full/partial FAI is not required, the supplier shall conduct an internal full/partial FAI and retain as part of record retentions requirements in M1000.

   i. Changes to a configuration of a previously approved part (i.e. -001 to -002, NOR 001 to NOR 002, etc.): Note, ALL changes; additions, deletions, and modifications of characteristics shall be accounted for and submitted to MRAS QR for approval.

   ii. Drawing or specification changes that do not change the part or assembly number. Note, ALL changes; additions, deletions, and modifications of characteristics shall be accounted for.

   iii. Process changes (including sub tier changes): Inspection method and/or frequency for affected characteristics of any process change shall be evaluated for impact.

   iv. Product Acceptance Change:

      1. Change in product acceptance plan. (see APPENDIX A)
      2. Change in production inspection equipment (e.g. from micrometer to functional gage).
      3. Changes to the point of inspection relative to the manufacturing process (e.g. move from final inspection to in-process).

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v. A repeat (full or partial) first article inspection shall be considered when any of the following events occur that could affect part characteristics: (This paragraph highlights some repeat FAI scenarios.)

1. A change in inspection methods or measurement equipment. Note: Refer to 0.
2. Relocation of a process and equipment within a Source (i.e.: changing a machining operation from one 5-axis machine to another; moving composite bondment curing from one autoclave to another)
3. A change to numerical control programs. Note: Refer to M1000.
4. A natural or man-made event that adversely affects characteristics.
5. Any change in the process or process sequence (examples: tooling, fixtures) or material that could potentially affect part characteristics.

B. The most current approved quality plan shall match the inspection method and frequency being used at the supplier and/or sub-tier suppliers. Supplier shall develop a plan to update FAI when manufacturing plans or inspection plans are revised.

C. Supplier shall have a process to ensure all engineering and manufacturing changes to the manufacturing planning are reviewed against the current quality plan. Changes shall be submitted as required.

H. Product/Process Audit

This section defines the minimum requirements of product audits. These requirements shall be incorporated into a Supplier Product Audit procedure.

A. The purpose of this audit is to verify that the established process controls and product acceptance plans continue to provide conforming material.

B. This audit is a full FAI for a fully processed production part. It is also an evaluation of the supplier's planning and procedures to ensure compliance with the requirements of this specification. Evaluation shall include variable results, inspection equipment, and the current acceptance plan per APPENDIX A.

C. Whenever possible, the re-evaluation shall be performed using a method of acceptance measurement independent of the planned acceptance measurement method. In cases where the production method of acceptance is the most accurate (e.g. CMM), it may be used as long as program verification or an independent check is completed. Characteristics that cannot be

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evaluated non-destructively on a finished part may be re-evaluated using component parts prior to final assembly or hardware that is not useable because of reasons unrelated to the characteristic being re-evaluated.

D. The supplier shall handle Product Audit non-conforming findings per the current revision of M1000.

E. Any finding during product audit will subject the supplier to additional audits at the MRAS QR's discretion.

F. Product Audit Family designations and parts assigned shall be submitted to the MRAS QR for review and approval. Product audit Planning and Family designations will be reported to MRAS QR on an annual basis. NOTE: Families defined either too broadly or too restrictively can defeat the purpose of a product audit, which is to evaluate effectiveness of the processes used to manufacture parts.

G. A minimum of one part per part family shall be audited annually and communicated to the MRAS QR. Any changes to the plan shall be approved by the MRAS QR. Once the audits are complete, audit completion information shall be reported to the MRAS QR.

H. Parts that have been audited should not be re-audited until all parts in the family have been completed. (Exception may be made for parts with quality issues, high volume parts or for parts not in production when the audit is performed).

I. The supplier shall retain Product Audit documentation including the completed FAI package.

J. Exception to Product/Process Audit Requirements may be achieved by the following:

    i. 100% lot-by-lot testing performed by a certified Test Laboratory may satisfy the requirements of the product audit. This applies to raw material and to processes that generate a certification of conformance for every manufacturing lot. Processes that are verified by a certified Test Laboratory but do not get a certification for every manufacturing lot (e.g. EDM, Laser, Heat Treat) require a re-certification and shall meet the requirements of this specification.

    ii. Provide the MRAS QR with appropriate current evidence that the supplier is following AS9145 or Production Part Approval Process (PPAP) elements.

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I. Supplier Designed Products

A. All requirements of this specification apply to the characteristics defined by MRAS or the MRAS Customer drawings unless specifically noted below.

B. Where supplier/sub-tier product and process drawings exist that contain MRAS accountable characteristics, the supplier shall complete a compatibility evaluation.

C. Product design specification documentation shall be completed only on the following:

   a. Acceptance/Inspection Tests defined in the Quality Assurance Provisions section of the design specification.

   b. Identification and Part Marking requirements of the design specification or specifications referenced therein.

D. As a minimum, the Supplier's system shall assure that characteristics defined by the Supplier/Sub-tier drawings are accounted for, documented, and controlled. The format(s) shall be defined by the Supplier and may be subject to review and disapproval by MRAS QR. The system shall include the following:

   a. The documented format(s), defined by the Supplier, shall include the same elements as shown on AS9102 Form 3.

   b. Changes to supplier's or sub-tier's drawing, manufacturing or quality plan shall be documented and approved under requirements defined by the supplier system for their characteristics.

E. First Article Inspection Package (FAI) Requirements for characteristics defined by MRAS Supplier/Sub-tier drawing(s).

   a. MRAS Drawing(s) and Characteristics: FAI package shall include all items required by Paragraph E and the following items:

      i. Results from product acceptance test and inspection requirements.

      ii. Evidence of MRAS engineering approval of applicable Test Procedures.

F. Supplier/Sub-tier Drawing(s) and Characteristics: First Article Inspection package shall include the following items that are to be retained at the Supplier facility unless otherwise directed by the procurement document:

   a. First Article Inspection results.

   b. Nonconformance document(s) referenced for accepting nonconforming characteristic(s).

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c. Referenced exhibits, e.g. functional test reports, evidence of part marking, certifications, etc.

NOTE: A copy of all MRAS-approved Test Procedures shall accompany first article data.

J. Definitions

See APPENDIX F

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Appendix

APPENDIX A Quality Planning and Reduced Inspection Acceptance Plans

A. Supplier product engineering and manufacturing should be involved in quality planning. Collaboration of quality, engineering and manufacturing is expected at the following times:
    a. PO review
    b. Initial product development
    c. Initial quality plan development
    d. Supplier engineering, inspection, process and/or manufacturing changes (including sub-tier changes)
    e. A change of inspection frequency is being substantiated
    f. MRAS drawing revision
    g. 24 month lapse in production

B. Key, Critical and/or Major characteristics should be considered for continued 100% inspection.

C. It is recommended that accountable characteristics be inspected at the earliest possible step in the manufacturing process if subsequent process steps will not alter the characteristic.

D. Following is a recommended map for the Quality Planning process followed by recommended checklist items for each step.

E. Table 1 shall be followed when selecting Reduced Inspection Acceptance Plans.

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F. Quality Planning Process Map:

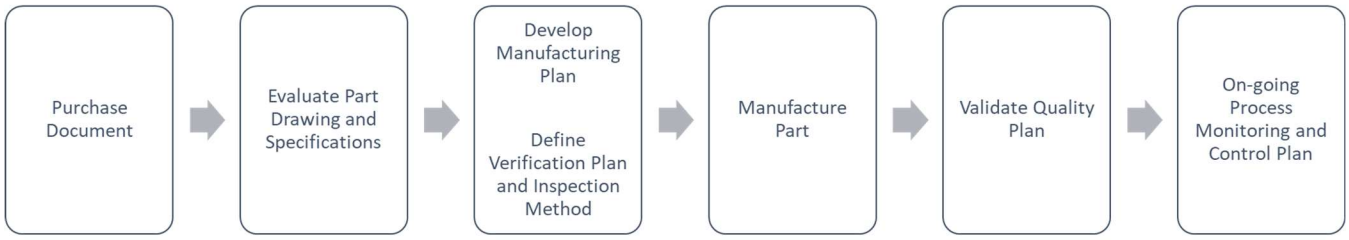

Figure 1: Quality Planning Process Map

Quality Planning Checklist

Purchase Document

- ☐ Verify PO matches the quote
- ☐ Review PO, quality requirements, engineering requirements, remarks, and Customer specific requirements
- ☐ Verify if the part is new or previously manufactured
- ☐ Identify if any NORs are issued but not included within the drawing
- ☐ Obtain engineering parts list
- ☐ Request OVFABs for review
- ☐ Identify whether ballooned drawing is available

Evaluate Part Drawing and Specifications:

- ☐ Review engineering parts list
- ☐ Review latest revision of drawings, NORs, OVFABs, as applicable
- ☐ Identify required specifications and verify current revisions
- ☐ Identify any drawing or manufacturing issues
- ☐ Identify stack-up concerns

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- ☐ Review part quality history and discuss with MRAS QR nonconformance and escape history
- ☐ For an existing PN, review internal and sub-tier quality history
- ☐ Review lessons learned for similar parts with similar manufacturing processes
- ☐ Request engineering models, Mylar etc. as needed
- ☐ Extract accountable characteristics from Digital Product Definition
- ☐ Identify education and training needs for applicable supplier personnel
- ☐ Submit Interpretation/Specification option as required (based on issues identified)

Develop Manufacturing Plan AND Define Verification Plan and Inspection Method

- ☐ After receiving responses to Interpretation/Specification option, identify risk abatement plans for open issues. Discuss with MRAS QR.
- ☐ Initiate FAI
- ☐ Balloon the drawing
- ☐ Verify ballooned drawing includes all accountable characteristics
- ☐ Request specifications not available on site (as needed)
- ☐ Review datum/transfer datum system.
  - Does the datum system control movement?
  - Is the datum system repeatable?
  - Is order of precedence maintained
  - Identify key manufacturing characteristics
- ☐ Develop proposed manufacturing plan sequence. Ensure operation sequence complies with engineering drawing
- ☐ Develop sequence of steps within each operation
- ☐ Identify operation step where each characteristic is generated
- ☐ Verify special processes sources are current and approved (whether performed in house or at sub-tier)
- ☐ Ensure fixture has needed controls: fixture height, size, tolerances, etc. Error proofing should be considered.
- ☐ Ensure fixture set-up has needed controls. Error proofing should be considered.

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- Determine where each accountable characteristic is verified. If an accountable characteristic is verified 'in process', evaluate the effect of subsequent processing (including manual benching).
- Select appropriate acceptance plan for each accountable characteristic: 100% Evaluation, special process, process parameter, variable data charting, die/mold, fixture/tool, software/numeric, & component/accountable characteristic stack-up. (See Table 1)
- Enter the acceptance plan for each characteristic into FAI or equivalent.
- Evaluate need for MSA on new gaging techniques. Refer to APPENDIX B
- For single purpose gages or functional gages, error-proof the gage and verify the gage meets the engineering requirements.
- Develop detailed inspection process sheets, including visual cell techniques
- Verify an Operator Acceptance Plan exists if applicable (See APPENDIX D)
- Define and execute necessary training for operators

Manufacture Part

- Ensure raw material, processes, equipment, and operators are production ready
- Verify gaging method meets minimum requirements of APPENDIX B
- Verify selected gage can be used with geometry / fixture combination
- Verify gaging method is understood by those performing the inspection.
- Ensure each accountable characteristic is verified by an inspector or certified operator (See APPENDIX D)
- For accountable characteristics requiring CMM inspection, verify CMM set-up and routines/programs satisfy engineering requirements
- Where single purpose or functional gages are used, perform independent inspections of accountable characteristics. Ensure that the gage correlates to the independent inspection.
- Apply statistical analysis if applicable

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Validate Quality Plans

- Ensure all accountable characteristics are included in the quality plan
- Ensure FAI part is representative of the defined production process
- Complete FAI and quality plan
- Ensure quality plan is reconciled to final engineering drawing
- If required, complete the “Frozen Process” package
- Evaluate the manufacturing/inspection process for improvements (evaluation to be done by product Engineering, manufacturing, and quality)
- Select appropriate acceptance plan for each accountable characteristic: 100% Evaluation, special process, process parameter, variable data charting, die/mold, fixture/tool, software/numeric, & component/accountable characteristic stack-up. (Table 1)

On-Going Monitoring and Control Plan

- Maintain On-going monitoring for reduced inspection per Table 1
- Evaluate quality plan periodically. Correct /update quality plan as required
- Update FAI as the process or quality plan changes (including subtier changes)
- Execute product audit plan per M1002

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Reduced Inspection Acceptance Plans

Table 1: Reduced Inspection Acceptance Plans

Reduced Inspection Acceptance Plans				
Plan No.	**Product Acceptance Plan / Description**	**Application**	**Requirements**	
			Initial Approval	**On-Going Monitoring/Control**
1	**100% Evaluation** Control by 100% EVALUATION OF ACCOUNTABLE CHARACTERISTICS Measure all occurrences of every accountable characteristic on every piece manufactured. This plan ensures accountable characteristic conformance through direct measurement of the characteristic on all parts to determine the conformance requirements	Plan required when justification does not exist for another plan.	No additional approval data is required to justify this plan.	Consider independent verification of the characteristic and the measurement technique. Consider Error-proofing.
2	**Special Process Control/Evaluation** This plan ensures accountable characteristic conformance through the control of the input of parameters as generated by a special process.	Applies to special processes when the characteristic is entirely controlled by the process	Establish control parameters through specific correlation studies, i.e. part or specimen cut-up, or through historical process knowledge. If a specimen is used, provide evidence that the specimen, represents the product as processed.	Evaluation may entail lot by lot or periodic testing proposed by the supplier in the justification for less than 100% evaluation. Plan shall be in compliance with the applicable engineering specification/s. Lot traceability shall be maintained through the manufacturing cycle.

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Reduced Inspection Acceptance Plans				
Plan No.	Product Acceptance Plan / Description	Application	Requirements	
			Initial Approval	On-Going Monitoring/Control
3	**Process Parameter Control** This plan ensures characteristic conformance through the control of the input parameters as generated by a non-special process.	Examples (setup, feeds, and speeds) For example, surface finish on a grinder where feeds and speeds are not software controlled and areas of features that may be inaccessible without destructive evaluation.	Establish control parameters through specific correlation studies, i.e. part or specimen cut-up, on-part evaluation, or through historical process knowledge. If a specimen is used, provide evidence that the specimen represents the product as processed.	A monitoring plan shall be proposed by the supplier in the justification for less than 100% evaluation. Periodic evaluation or additional testing may be required.
4	**Variable Data Charting/ SPC (e.g. Process Maintenance through Statistical Process Control)** The output of a process is statistically monitored to ensure characteristic conformance through verification of the process stability. Generally graphical output is used.	This method may be employed when it can be shown that the output from a process is stable and the capability is sufficient.	Use standard SPC techniques (Appendix C) to establish control limits. Data should include normal variation that is characteristic of routine production such as different operators and work shifts Define a data collection and plotting plan that ensures the ability to capture process shifts or other indications of loss of process stability. The classification of characteristics, rate of production, stability and complexity of process and method of control should be considered in selecting the frequency	If the process gives evidence of violating statistical stability, investigation and corrective action shall be performed. 100% evaluation shall be put in place until stability is revalidated. Stability measures such as control limits, limits on first/last piece, etc. shall be reevaluated whenever substantive changes are made to the process. When such limits are modified, the associated capability measure shall also be recalculated. See Appendix C for signs of process drift or instability

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Reduced Inspection Acceptance Plans				
Plan No.	Product Acceptance Plan / Description	Application	Requirements	
			Initial Approval	On-Going Monitoring/Control
5	**Die/Mold Control** This plan ensures accountable characteristic conformance through the control of the geometry and wear factors for the Die/Mold used to generate the characteristic.	Appropriate where a relationship exists between the geometry of Die/Mold being used to generate the accountable characteristics and the final product. Not appropriate if there are removable parts on the die/mold for which assembly cannot be error proofed.	Validate the ability of the Die/Mold to generate the characteristic through verification of the characteristic in the first run of the process. Per process in Appendix C, ensure process is statistically capable of producing characteristics in conformance with Engineering Requirements.	Verify correct Die/Mold is being used For each set-up of operation, first piece verification shall be completed to ensure proper setup. Periodically verify pieces and/or the die or mold to identify wear or shifts that could impact part conformity. Interval shall be documented as justification for less than 100% inspection along with CpK Value. Where rework/repair of the Die/Mold affects product conformance, re-verification shall be performed When wear of the Die/Mold is a factor, monitoring shall include periodic inspection of the part. Visually Inspect the Die/Mold periodically for damage and wear. **For Sheet Metal Forming:** In addition The last piece of a lot, run, or work shift (whichever occurs first) shall be verified to ensure no change has occurred that would affect conformity. Ensure parts are identified to the lot, run or work shift until last piece has passed verification.

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Reduced Inspection Acceptance Plans				
Plan No.	Product Acceptance Plan / Description	Application	Requirements	
			Initial Approval	On-Going Monitoring/Control
6	**Fixture/Tool Control** This plan ensures characteristic conformance through the control of the cutting tool and/or the fixture.	Appropriate where a relationship exists between the geometry of Fixture/Tool being used to generate the characteristics and the final product. Not appropriate if the feature is related to datums. Not appropriate if there are removable parts on the fixture for which assembly cannot be error proofed.	Conduct first article inspection for the established cutting tool/fixture combination. Inspection of the cutting tool is not an acceptable alternative to inspecting hardware for FAI. Planning should include identification of Fixture/Tool including ancillary parts Per process in Appendix C, ensure process is statistically capable of producing characteristics in conformance with Engineering Requirements. Fixture: Establish a plan for on-going monitoring. (e.g. periodic calibration of fixture)	Inspect all potentially affected part accountable characteristics after any modifications or rework to the fixture. Visually check Fixture/Tool for wear, distortion, damage, loose parts, etc. on a periodic basis. Changes to the Fixture, Tool, or Process require re-verification of capability. Cutting Tool: Verify first and last characteristic controlled by the Tool/Process. Verify characteristics on the first piece of a new work shift/operator change. NOTE: If it is not feasible to inspect actual part features during production (e.g. inaccessible characteristics), inspection of the cutting tool may be an accepted alternative

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Reduced Inspection Acceptance Plans				
Plan No.	Product Acceptance Plan / Description	Application	Requirements	
			Initial Approval	On-Going Monitoring/Control
7	**Software/Numerical Control** (All aspects of Software Control apply per M1000) This plan ensures conformance of accountable characteristics through programmed aspects of a machine (i.e., control of the cutter path of a machine tool.)	Appropriate for those characteristics that are generated through software/numerical control Not appropriate if the characteristic is affected by fixture/part set up and the fixture set up is not controlled. Note: If operator offset is required, the characteristics affected by the offset shall be verified on the first part produced after the offset adjustment.	Per process in Appendix C, ensure process is statistically capable of producing characteristics in conformance with Engineering Requirements. Verify and approve the NC program using an independent method. Assign unique program numbers and list the controlled program in the manufacturing planning. Identify the characteristics that will be accepted by the NC program. Establish a plan for on-going monitoring	Once software program has been proven to generate conforming hardware, all changes to the program shall be under revision control. Whenever the program is revised, process shall be re-qualified in accordance with the Initial Approval. Monitoring may have to be adjusted based on the change being made. Verify correct setup for each use, including cutting tool/probe. Periodically verify pieces to identify process shifts that could impact part conformity.
8	**Component/Characteristic Stack-Up** This plan ensures characteristic conformance through control and verification of engineering characteristics at lower drawing levels such that assembly of the components into the product result in conformance to the next higher-level engineering characteristics.	Plan is employed for the acceptance of characteristics generated by assembly of two or more components	Functional or engineering analysis showing that the higher-level characteristic will meet print given lower level characteristics are sufficiently controlled	Provide for periodic confirmation that the higher-level characteristics are meeting print requirements. Changes to sub-components, sub-component processes or sub-component control plans require re-evaluation.

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APPENDIX B Measurement and Test Equipment

A. The supplier is required to have a system in place to evaluate their measurement and test equipment (M&TE) through Measurement Systems Analysis (MSA). This system shall ensure that the M&TE utilized effectively evaluates part characteristics.

B. The purpose in conducting a MSA is to estimate the variation in the measurement system. Once quantified, it can determine if the level of variation can be tolerated or if actions must be taken to improve the measurement system or control effects of this variation.

C. An MSA should be considered for situations such as the following:
   i. A characteristic is defined as a key, major or critical on the Engineering Drawing.
   ii. A major process improvement effort is being initiated.
   iii. The characteristic being evaluated has failed a product audit due to gage concern.
   iv. The characteristic has experienced an inspection escape, such as a delivered nonconformance to an internal or external customer.
   v. The known process capability (+/- 3 sigma spread) exceeds the engineering requirement.
   vi. Recent changes in gage design, measurement method or measurement personnel.

D. The M&TE accuracy ratio for single purpose measurement equipment for effective characteristic evaluation is minimally 10:1. The M&TE accuracy ratio for standard measurement equipment is minimally 4:1. If the MSA or other knowledge of a gage's accuracy ratio proves this equipment does not meet this ratio, action is required. To assure characteristic conformance, typical actions could entail (particularly for part characteristics near a tolerance limit):
   i. Use of a different, more accurate type of gage.
   ii. Reducing the part characteristic acceptance limits to be tighter than the drawing tolerance.
   iii. Conducting redundant evaluation of the characteristic with an alternate means of inspection.
   iv. Modification of the part manufacturing process to reduce the characteristic variability.
   v. Analysis of the results of inadequate or questionable MSA studies to determine root cause and action to take. NOTE: Typical root causes are wrong gage for task, operator not following

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planning, inadequate planning, work area not suitable, material relaxes or changes due to environment, method changes when shift changes, etc.

E. Exceptions to APPENDIX B, Paragraph D requirements must be supported by data and/or studies to assure effective control of production parts. The MRAS QR must be notified if gaging cannot meet APPENDIX B, Paragraph D requirements above.

F. It is recommended that equipment used for measurement purposes be of sufficient accuracy to measure one decimal point beyond Engineering requirements (i.e. if the drawing requires 3 decimal points (.000), the equipment should be capable of reading to 4 decimal points (.0000)). All significant digits beyond the required accuracy capability should be truncated.

G. Other Recommendations:

i. An accuracy ratio of 10:1 is recommended for key, major and critical characteristics.

ii. Direct measurements are preferable to calculated measurements.

iii. Use radius gages for radii that are classified as minor only.

iv. A No-Go plug or pin should not be used for detecting over maximum conditions for characteristics generated by processes that may produce elongated holes.

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APPENDIX C Preferred Statistical Methods

NOTE: Throughout this document, any reference to Cp and Cpk implies long-term capability. It should be noted that some statistical software programs (e.g. Minitab) or statistical publications might refer to Pp and Ppk as long-term capability and Cp and Cpk as short-term capability.

Use the flow diagram below to determine what statistical method is appropriate for the characteristic data sample.

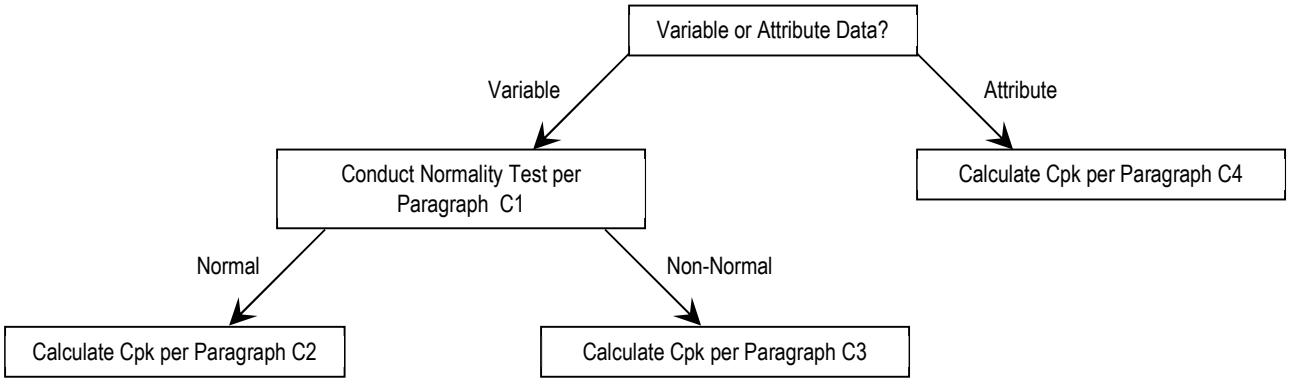

Figure 2: Attribute or Variable Data Flow Chart

A. Normality Test: Using a minimum of 25 data points, create a histogram of the characteristic measured. If the histogram is bell (or lump) shaped and fairly symmetric, the sample is normally distributed and should have the CpK calculated using methods described in section II. If the histogram is not bell shaped or is asymmetric, the sample is non-normal and should have the CpK calculated using methods described in section III. If still unsure about the normality of the sample, run a statistical test for normality (Wilks-Shapiro, Chi-squared, etc…)

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B. CpK Calculations for Normal Data: Sample Standard deviation, s, is calculated using the following equation:

$$s = \sqrt{\frac{\sum_{i=1\ to\ n}(x_i - \bar{x})^2}{n-1}}$$

The Process Capability Ratio is calculated as follows:

$$C_p = \frac{USL - LSL}{6 \cdot s}$$

$$C_{pK_{UPPER}} = \frac{USL - \bar{x}}{3 \cdot s}$$

$$C_{pK_{LOWER}} = \frac{\bar{x} - LSL}{3 \cdot s}$$

$$C_{pK} = \min(C_{pK_{UPPER}}, C_{pK_{LOWER}})$$

Cpk is reported as the smaller value of CpK Upper and CpK Lower.

C. CpK Calculations for Non-Normal Data: You can treat your data as attribute data and use the method described in APPENDIX C Paragraph Dbelow. Contact the Purchaser for assistance.

D. CpK Calculations for Attribute Data: Use one of the following methods depending on the criteria listed below.

   a. Method 1: Inspect each characteristic in your sample and identify as defective or non-defective. Then calculate: $p(defective) = \frac{(N_{defective})}{N_{sample}}$. Use a standard normal table to find Z and divide by 3 to find CpK or use the abridged Z/CpK table below to define the CpK.

   b. Method 2: Used if no defects are observed in the sample for Method 1 above:

      i. Calculate the estimated proportion defective, $p(d) = \frac{1}{(n+2)}$ where n is the number of characteristics inspected. Convert this number to a Z-score using the one-sided Z table and divide by 3 to obtain CpK or use the abridged Z/CpK table below:

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Probability of defective = p(d)	Estimated Z	Cpk
Greater than 0.16 or > 16%	< 1	< 0.33
0.16 to 0.023 or 16% to 2.3%	1 to 2	< 0.67
0.023 to 0.00135	2 to 3	< 1.0
0.00135 to 0.000032	3 to 4	> 1.0 but < 1.33
Less than 0.000032	> 4.0	> 1.33

c. Method 3: Used to estimate if Cpk > 1.0 with small samples. Cannot provide Cpk > 1.33 estimates. Given a very small sample (3 to 6 points) assessing process capability via direct calculation is not feasible. The approach outlined here assures that the process is well centered and has acceptable variation.

   i. Variation test, calculate range of your sample of characteristics measurements

      1. Provide assurance that standard deviation of process is <= 16.6% of tolerance (that is, Z = 3)

   ii. Centering test, calculate mean of your sample

      1. Make sure that xbar is at least one standard deviation away from either tolerance limit with 99% assurance.
      2. If your data satisfies both the mean and the range test as detailed in table below, you can estimate Cpk as > 1.0 (but not as high as 1.33).

# of Pieces	X Bar vs. Target	Range vs. Tolerance
2	+/- 3%	31%
3	+/- 9%	42%
4	+/- 12%	49%
5	+/- 14%	54%
6	+/- 16%	57%

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Typical Variable Data Charting / SPC Signs of Process Shift or Instability

d. The following warning rules are commonly used in conjunction with the zones shown in Figure below:

i. One Point falls beyond Zone A.

ii. Two out of three consecutive points on one side of the centerline fall in Zone A or beyond.

iii. Four out of five consecutive points on one side of the centerline fall in Zone B or beyond.

iv. Eight consecutive points fall anywhere on one side of the centerline.

v. Six consecutive points steadily increasing or decreasing.

vi. Eight consecutive points on both sides of the centerline with none in Zone C.

vii. Fourteen (14) consecutive points alternating up and down.

viii. Fifteen (15) consecutive points on both sides of the centerline all in Zone C. This is a warning that the data may be too consistent. There could be a gage problem or some other event that has caused a shift in the output and should be investigated.

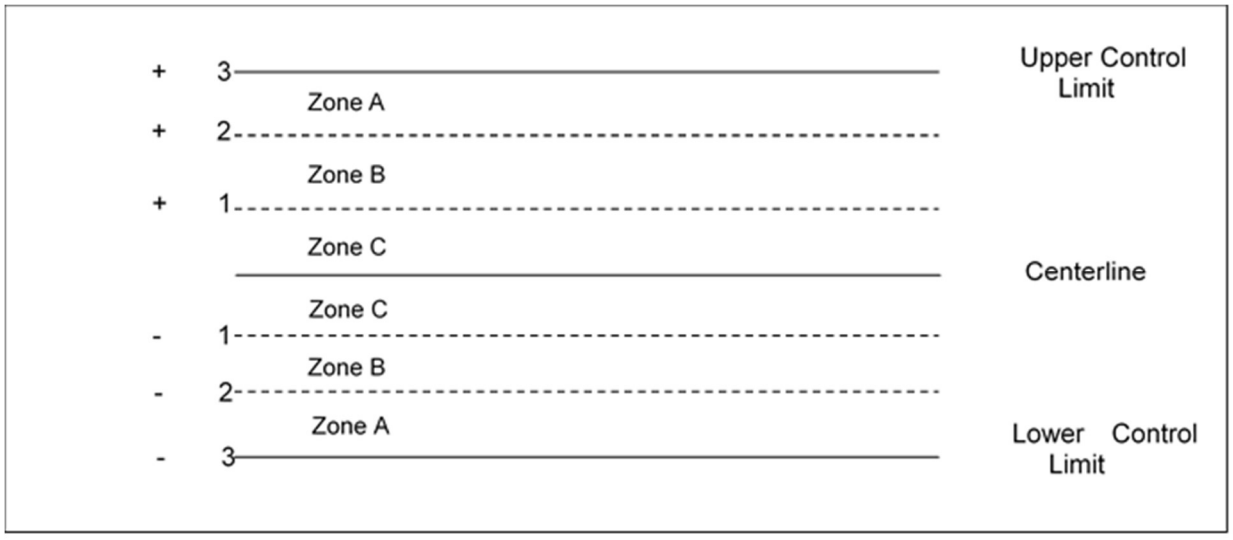

Figure 3: SPC Chart

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Table 2: Characteristic Acceptance Plan Matrix

CHARACTERISTIC TYPE	PROCESS CONTROL CAPABILITY EVALUATION PLAN	MEASUREMENT DATA TYPE	PROCESS PERFORMANCE	PLANS ALLOWED
Supplier Defined KC: Key Characteristics OR MRAS DRAWING: - Critical - Major - Key Characteristic See ([4])	Process is IN CONTROL and CAPABLE for characteristic "Control by Means other than 100% Characteristic Evaluation" permitted. Required to monitor by Control Chart	Variable	Cpk >= 1.33	Variable Data: Table 1 - #1 thru #8
		Attribute [1]	ZERO non-conformances for an adequate [2] process period	Attribute Data: Table 1 - All except #4
	Process is NOT IN CONTROL and/or NOT CAPABLE for characteristic "Control by Means other than 100% Characteristic Evaluation" is NOT permitted	Variable	Cpk<1.33	Variable Data: Table 1 - #1
		Attribute [1]	More than ZERO non-conformances for defined process [3]	Attribute Data: Table 1- #1
Non-Key Characteristics Except characteristics described by [4] below	Process is IN CONTROL and CAPABLE for characteristic "Control by Means other than 100% Characteristic Evaluation" permitted. Required to monitor by Control chart or Verification Plan	Variable	Cpk >= 1.0	Variable Data: Table 1 - #1 thru #8
		Attribute [1]	<1 nonconformance per 750 evaluations over an adequate [2] process period	Attribute Data: Table 1 - All except #4
	Process is NOT IN CONTROL and/or NOT CAPABLE for characteristic "Control by Means other than 100% Characteristic Evaluation" is NOT permitted	Variable	Cpk <1.0	Variable Data: Table 1 - #1
		Attribute [1]	>1 nonconformance per 750 evaluations [3]	Variable Data: Table 1 - #1
[4] Inaccessible or other characteristics controlled by a special plan	Requires MRAS approved Acceptance Plan; such plans must include process control provisions	Variable or Attribute	Generic process capability Study or other capability assessment	Requires special plan plus Table 1 - #2 thru #8

[*] Supplier establishes/explains a notation (other than above Drawing notations) e.g., [KC]. This notation included in the CLASS column of form AS9102 Form 3.

[1] Characteristics required by Drawing and evaluated by "Attribute" gages which accept/reject to specific limits. Does not include characteristics which are not generated intentionally (e.g. scratches, dents, tool marks). 100% characteristic evaluation must be performed for NDE (Nondestructive Evaluation), when required on the drawing or in a referenced specification.

[2] "Adequate" period considers all common causes for process variation. A written rationale is defined by supplier and accepted by MRAS Quality Representative.

[3] A process which produced nonconformances may be re-evaluated after introduction of corrective action.

[4] Certain characteristics (e.g. certain cast dimensions) may require or justify special MRAS approved Acceptance Plans.

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APPENDIX D Supplier Certified Operator Plan (S-COP)

A. Purpose

a. To establish minimum requirements for an Supplier Certified Operator Plan, hereafter referred to as S-COP. This plan will allow certified operators to verify characteristics at the point of generation. All elements of the plan are subject to purchaser disapproval.

B. Minimum Requirements

a. The supplier's S-COP shall identify provisions for training, certification, work station audits, disqualification, records and retention.

b. Only certified operators or inspectors shall perform final verification of product characteristics.

c. Characteristics generated by non-certified operators shall be verified by a certified operator or inspector.

d. Traceability of measured characteristics to the inspector/certified operator shall be maintained to the part/lot.

e. Recertification requirements shall be identified

C. Training

a. The Supplier's S-COP shall provide a process for training all operators on the procedures and work instructions that pertain to their immediate job function. Each operator shall be trained on the following, as applicable:

i. Measurement and test equipment

ii. Engineering drawings

iii. Router/Op sheets/Work Instructions, usage and documentation

iv. Non-conforming hardware

v. Safety and part handling

vi. Visual inspection techniques (e.g. tin soldier inspection)

vii. Geometric Tolerancing

b. Consideration shall be given to the following when developing individual operator's training.

i. Previous related experience

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ii. Performance reviews
iii. Job safety analysis results
iv. Non-conformance data
v. Customer complaints/returns
vi. Internal workstation audit results
vii. Difficulty and criticality of the operation

D. Certification

a. Each candidate shall be evaluated to assure their understanding of the training material and their ability to perform and document the required measurements.

E. S-COP Workstation Audits

a. Each certified operator shall be re-evaluated to an established audit plan. Audits shall be performed at least once per year, using a workstation audit form (see Exhibit B for an example)
b. Satisfactory workstation audit completion shall result in continued certification. The records shall be updated, and the next audit date shall be established.
c. If an operator fails the workstation audit, the Supplier will determine if re-training and/or increased audit frequency is necessary.
d. Upon failed audit, the Supplier shall have a process to determine root cause, recommend a corrective action, and investigate whether non-conforming material was shipped to The Purchaser.

F. Operator Disqualification - The Supplier shall develop a system for operator disqualification. Consideration shall be given to the following:

a. Failure to follow documented work instructions
b. Failure to pass an S-COP workstation audit
c. Inability to repeat/correlate measurements
d. Change in job function or classification

G. Record Retention

a. Records pertaining to the Operator Acceptance Planning shall include, but are not limited to:

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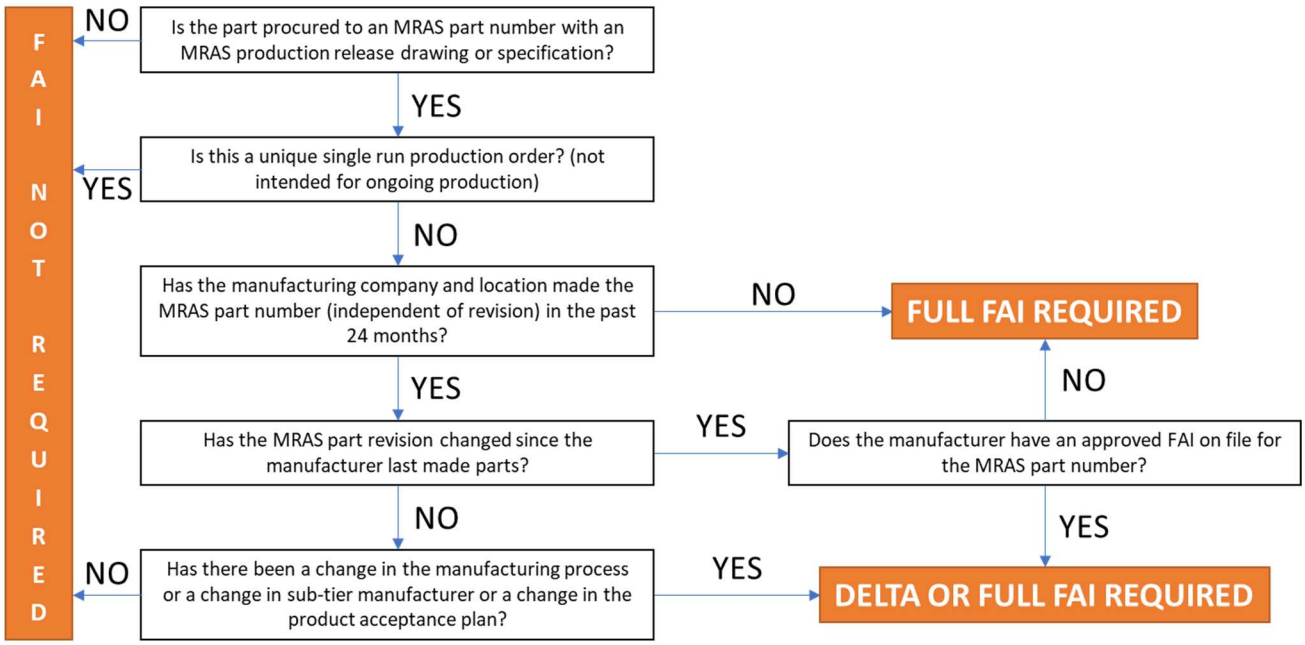
i. Evaluation and training (initial training and any re-training)

ii. Certification test results

iii. Audit results

b. Certification records shall be maintained for the entire duration of the operator's employment, and audit results retained as an administrative quality record in accordance with M1000.

APPENDIX E FAI Applicability Flow Chart



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APPENDIX F DEFINITIONS

ACCOUNTABLE CHARACTERISTICS (equivalent to Design Characteristic as defined in AS9102): Those dimensional, visual, functional, mechanical, and material features or properties, which describe and constitute the engineering definition of the article and can be measured, inspected, tested, or verified to determine conformance to the engineering definition or Digital Product Definition (DPD) requirements. Dimensional features shall include those features defined by the engineering definition such as target-machined (or forged/cast) dimensions on forgings, castings, and weld/braze joint preparation necessary for acceptance of finished joint. Material features or properties shall include processing variables and sequences that are specified by the engineering definition (e.g., heat treat temperature, fluorescent penetrant class, ultrasonic scans, sequence of welding, heat treat, etc.).

ACCURACY RATIO: The ratio between the total M&TE (Measurement & Test Equipment) Accuracy and the total part tolerance.

CALIBRATION TOLERANCE: Total permissible variation or limits allowed for calibration of M&TE (Measuring and Test Equipment).

CERTIFIED OPERATOR: An operator who has fulfilled all the qualifications, training and testing requirements for their assigned job description per the supplier S-COP (Supplier Certified Operator Plan). Certified Operators may verify characteristics which are inspected at the point of generation. See APPENDIX D.

CERTIFIED TEST LABORATORY: An MRAS approved independent test laboratory facility.

CHARACTERISTIC TOLERANCE: Difference between upper and lower limits of a part characteristic.

COMPATIBILITY EVALUATION: An evaluation of supplier/sub-tier product and process drawings containing MRAS engineering definition, to ensure that they specify the same engineering definition as the MRAS engineering definition.

CORRELATION: A characteristic that has been verified by an operator is re-verified by a different operator/inspector using the same gage type and results are equivalent within acceptable tolerance band.

CUSTOMER: The term customer, as used in this procedure, can mean external end users or internal customers.

DIGITAL PRODUCT DEFINITION (DPD) REQUIREMENTS: requirements of any digital data files that disclose, directly or by reference, the physical or functional design requirements. Reference AS9102 for additional information on DPD.

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ENGINEERING DEFINITION: Design engineering requirements as documented within the drawing, drawing notes, specifications on the drawing, or referenced specifications including digital product definition (DPD) requirements, if applicable.

FEASIBLE: Capable of being performed, within constraints (e.g., delivery, cost, technical) as agreed between MRAS and the Supplier.

FIND NUMBER: Find number or item number refers to the ordinal number that gives an ID tag to one of the constituents in a parts list (list of materials, bill of materials). Thus "fasten using Find Number 7 (or item number 7)" refers to a fastener that is listed as number 7 in the parts list or bill of material (BOM).

FIRST ARTICLE INSPECTION (FAI): A complete, independent, and documented physical and functional inspection process to verify that prescribed production methods have produced an acceptable item as specified by engineering drawings, DPD, planning, purchase contract, engineering specifications, and/or other applicable design documents

FIRST ARTICLE INSPECTION (FAI) REPORT: The forms and package of documentation for a part number or assembly, including FAI results, per this specification

MRAS QUALITY REPRESENTATIVE (MRAS QR): An MRAS employee or authorized representative with the authority to represent MRAS Sourcing Quality.

INSPECTOR: An individual who inspects and verifies characteristics but does not generate the characteristics.

INTERPRETATION OR SPECIFICATION OPTION: A documented process by the manufacturing source to submit a request for a drawing interpretation, specification interpretation, selection of a specification option, or report a possible drawing error, or a producibility proposal.

KEY CHARACTERISTIC (KC): The select few, measurable features of a specific part/drawing/specification/process where variation can significantly impact customer satisfaction, manufacturability, durability or performance.

MEASURING AND TEST EQUIPMENT (M&TE): All devices used to measure, gage, test, inspect or otherwise examine items to determine compliance with drawing or specification requirements.

MEASUREMENT SYSTEM ANALYSIS (MSA): Method to define and document the amount of variation in the process due to the measurement system. It is a tool that evaluates the measurement system's performance on specific characteristics in the process and under conditions that occur in the process.

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NONCONFORMANCE DOCUMENT: A document used for disposition of nonconforming characteristics, entered into a Nonconformance Report (NCR) System or similar system.

NOR (Notice of Revision): an engineering document which changes the content of the product definition. Could also be known as, ECO (Engineering Change Order, RN (Revision Notice) or other names.

OPERATOR: The individuals who physically perform the process. These individuals can be referred to as 'Individual Process Owners', 'Technicians', 'Process Team Members', or by other terminology suitable for the organization's program focus and cultural and customer environment.

PART FAMILY: A group of parts with similar processes, materials, complex form, and tolerances, which have been produced by similar manufacturing methods.

PROCESS CAPABILITY: The performance of which a process is capable, with all the effects of assignable cause variation removed. Process capability is typically quantified as + or – 3 standard deviations about the process mean.

PROCESS STABILITY: A process that is operating with only chance causes of variation present is said to be statistically stable.

PRODUCT ACCEPTANCE: Verification that characteristics of a part meet the engineering definition.

PRODUCT/PROCESS AUDIT: Evaluation of any or all accountable characteristics for conformance, independent of Product Acceptance evaluation. Also includes an appraisal of the Supplier's system to ensure stable processes are in place that continually generates conforming characteristics.

PURCHASE CONTRACT: Purchase Order, Purchase Agreement or other Purchase document

SIGMA VALUE: A statistical measurement, indicating the probability of producing a part characteristic within the drawing limits. The sigma value represents "Z", the number of process standard deviations between the process mean and the nearest specification limit.

SINGLE PURPOSE M&TE/GAGE: Gage which is designed to accommodate specific part configurations (e.g. airfoil guillotine gages).

SOURCE CHANGE: A change in manufacturing source or the addition of an alternate manufacturing source for a complete part.

STANDARD M&TE/GAGE: M&TE that is not controlled by a tool drawing, i.e., commercially available.

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STATISTICAL CONTROL: A quantitative condition which describes a process that is free of assignable/special causes of variation, e.g., variation in the central tendency and variance. Such a condition is most often evidenced on a control chart.

SUPPLIER: Sources (including distributors, warehouses,) other than MRAS, who supply material, parts, processes, or services for incorporation into MRAS products.

SUPPLIER CERTIFIED OPERATOR PLAN (S-COP): Supplier plan which defines the requirements, procedures and individual responsibilities for the certification of operators. See APPENDIX D

TEST PROCEDURE: Documented procedure describing the functional test methodologies, environmental conditions, equipment, specified values and tolerances.

VERIFICATION: Confirmation through objective evidence that specified requirements have been fulfilled.

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