REQUIREMENTS FOR THE PROCESS CAPABILITY APPROVAL FOR MANUFACTURING LINES OF NON-HERMETIC MICROELECTRONIC MODULES

ESCC Basic Specification No. 2566001

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DCR No.	CHANGE DESCRIPTION

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1 PURPOSE AND SCOPE

The purpose of this specification is to define the requirements for the Process Capability Approval (PCA) of a Manufacturing Line for Non-hermetic Microelectronic Modules intended for space applications.

This specification:

- provides the specific requirements which a Manufacturer has to fulfil in order to be successfully evaluated and capability approved for a set of materials and processes used on a manufacturing line to construct non-hermetic microelectronic modules.
- is applicable to chip-on-board technologies, to resin encapsulated stacked individual packages and to stacked populated substrates and to cavity modules utilizing non-hermetic seals (see Para. 3)
- shall be read in conjunction with ESCC Basic Specification No. 25600 which provides the general requirements for Process Capability Approval.

EXCLUSIONS:

- This specification does not enable the certification of the stacking of bare die or wafer product
- This specification does not enable the certification of manufacturing lines of products whose packaging technology is mainly based on moulded plastic packaging and its derivatives.

2 APPLICABLE DOCUMENTS

The following specifications form part of and shall be read in conjunction with this specification. The relevant issues shall be those in effect at the date of commencement of a particular task, as applicable, and as required for each stage of the sequence of activities which may lead to the PCA certification of the manufacturing line.

2.1 ESCC SPECIFICATIONS

- ESCC No. 21300, Terms, Definitions, Abbreviations, Symbols and Units.
- ESCC No. 21500, Calibration System Requirements.
- ESCC No. 22800, ESCC Non-Conformance Control System.
- ESCC No. 24600, Minimum Quality Management System Requirements.
- ESCC No. 24900, Minimum requirements for controlling environmental contamination of components.
- ESCC No. 24800, Resistance to solvents of marking, materials and finishes.
- ESCC No. 25600, Requirements for Process Capability Approval.
- ESCC No. 2026000, Checklist for Hybrids Manufacturers and Line survey.
- ESCC No. 2276000, Guidelines for the PID of Hybrid Manufacturers.

2.2 OTHER APPLICABLE DOCUMENTS

The following documents are applicable to the extent specified herein. The relevant issues shall be those in effect at the date of commencement of a particular task, as applicable, and as required for each stage of the sequence of activities which may lead to the PCA certification of the manufacturing line.

- ECSS-Q-ST-60-05, Generic Procurement Requirements for Hybrids
- ECSS-Q-ST-60-13, Commercial Electrical, Electronic and Electromechanical (EEE) components
- ECSS-Q-ST-70, Materials, Mechanical Parts and Processes
- ECSS-Q-ST-70-10, Qualification of Printed Circuit Boards
- ECSS-S-ST-00-01, Glossary of Terms
- MIL-STD-202, Test Method Standard Electronic and Electrical component parts
- MIL-STD-883, Test Method Standard Microcircuits
- MIL-STD-750, Test Method Standard Test Methods for Semiconductor Devices
- J-STD-020, IPC/JEDEC Standard for Moisture/Reflow Sensitivity Classification for Nonhermetic Surface Mount Devices
- JESD22-A101, EIA/JEDEC Standard Test Method: Steady-state Temperature-Humidity Bias Life Test
- JESD22-A110, EIA/JEDEC Standard Test Method: Highly Accelerated Temperature and Humidity Test (HAST)
- JESD22-A113, EIA/JEDEC Standard Test Method: Preconditioning of Nonhermetic Surface Mount Devices Prior to Reliability Testing

3 TERMS, DEFINITIONS, ABBREVIATIONS, SYMBOLS AND UNITS

The terms, definitions, abbreviations, symbols and units defined in ESCC Basic Specification No. 21300 and ECSS-S-ST-00-01 apply. In addition the following shall apply:

- **Microelectronic Module**: Module produced by the interconnection of various elements (individually-packaged or not packaged components and/or interconnection substrates fitted with added active or passive components) in order to perform a specified electronic function.
- **Capability Abstract**: Summary description on Manufacturer portfolio of products, services and capabilities included under the evaluation programme described on this standard.
- **Non-Hermetic Cavity Microelectronic Modules**: Microelectronic modules built in an enclosed cavity with a non-hermetic seal (e.g. polymeric seal)
- **Resin Encapsulated Microelectronic Modules**: Individual elements or electronic assemblies partially or completely protected by a polymeric material (e.g. glob top, resin mould, dam & fill) which provides physical protection against environment, acting as final encapsulation level. These microelectronic modules do not incorporate a hermetic sealed cavity or enclosure to protect the assembly from external influences during the subsequent testing, storage, integration or usage and service life of the component. Instead, they use a curing polymeric material to create a partially or completely covered assembly, acting as a final or ultimate encapsulation level. This definition includes 3D structured constructions that rely on a cured resin for protection of the electronic components or assembly/assemblies within the device or module. These devices are therefore not intended to be hermetic.

- **Stack**: A module produced by the interconnection along the vertical axis of various elements (individually-packaged or not packaged components and/or interconnection substrates fitted with added active or passive components), then resin encapsulated in order to perform a common electronic function.
- **Production lot**: Production Lot definition as per ECSS-Q-ST-60-05
- **Statistical Process Control (SPC)**: Statistical Process Control definition as per ECSS-Q-ST-60-05
- **Rework**: Action to correct a defect of a module that does not lead to a configuration item change.

  NOTES:
  1. Unlike repair, rework does not affect or modify parts of the defective module.
  2. No NCR needs to be raised.
- **Repair**: Action to correct a defect of a module that leads to a configuration item change.

  NOTES:
  1. Unlike rework, repair affects or modifies parts of the defective module.
  2. An NCR needs to be raised for the configuration item change.

- **Abbreviated Terms**

  The following abbreviations are used within this specification:
  - DPA: Destructive Physical Analysis
  - ECSS: European Cooperation for Space Standardisation
  - ESCC: European Space Components Cooperation
  - ESD: Electrostatic discharge
  - ETP: Evaluation Test Programme
  - HAST: Highly Accelerated Stress Test
  - MSL: Moisture Sensitivity Level
  - NCR: Non Conformance Report
  - PCA: Process Capability Approval
  - PID: Process Identification Document
  - QA: Quality Audit
  - QMS: Quality Management System
  - SEM: Scanning Electron Microscope
  - SAM: Scanning Acoustic Microscope
  - SPC: Statistical Process Control
  - THB: Temperature Humidity Bias (Life Test)
  - TVCA: Test Vehicle for Process Capability Approval
  - TVE: Test Vehicle for Evaluation

4 DEFINITION OF PROCESS CAPABILITY APPROVAL FOR MANUFACTURING LINES

The ESCC Process Capability Approval (PCA) of manufacturing lines for non-hermetic, microelectronic modules shall include the 4 stages specified in ESCC Basic Specification No. 25600, namely:

- Definition of the Process Capability Domain
- Manufacturer Evaluation
- Evaluation Phase
- PCA Phase testing

The successful completion of these stages requires, therefore, the definition of the PCA and its boundaries, the preparation, review and approval of the relevant PID, and the actual completion of test sequences specified for Evaluation testing and PCA testing.

5 DEFINITION OF THE PROCESS CAPABILITY DOMAIN AND ITS BOUNDARIES

In addition to the requirements of ESCC Basic Specification No. 25600, the following requirements are specific and applicable to the definition of the Process Capability Domain of manufacturing lines for non-hermetic microelectronics modules for the purpose of PCA.

5.1 GENERAL

The Manufacturer shall define the Process Capability Domain for which process capability approval is sought, as required in ESCC Basic Specification No. 25600. This definition shall result in the Capability Abstract and the Process Identification Document (PID).

The Capability Abstract and the PID have to demonstrate that the Process Capability Domain represents a structured, properly controlled and monitored manufacturing process for non-hermetic microelectronic modules.

The definition of the Process Capability Domain shall address the areas listed in this paragraph at least to the extent detailed. Additional information shall be supplied whenever required by the particular Process Capability Domain under approval.

When existing, heritage of non-hermetic microelectronic modules design, qualification and manufacturing activities shall be presented in order to define the capability abstract. Existing PID and data evidence shall be considered.

Within the definition of the Process Capability Domain, the following areas are of particular concern and are therefore the object of specific requirements in the remainder of this paragraph:

- Materials and processes
- EEE add-on components
- Physical design
- Inspection and tests
- Traceability

The Manufacturer shall describe the type of functions / products which are planned to be developed and manufactured, in term of power dissipation (Low/ High Power), maximum current / voltage, signal frequency (Low / Radio Frequency), digital / analogue functions, mixed functions, etc.

5.1.1 Materials and Processes

All materials and processes intended to be included in the Process Capability Domain shall conform to ECSS-Q-ST-70.

Appendix A herein provides guidelines for the materials and processes description to be included in the Process Capability Domain definition.

5.1.2 EEE Add-on Components

The selection and procurement of all active and passive, EEE add-on components shall conform to ECSS-Q-ST-60-05.

In the event, that commercial active components are also included in the module design, then ECSS-Q-ST-60-13 shall apply.

For commercial, plastic components susceptible to moisture absorption, the Moisture Sensitivity Level needs to be identified or assessed prior to start of the evaluation phase described in this specification.

5.1.3 Physical Design

The Manufacturer shall specify physical design rules that define the construction and composition of all items foreseen for the production of non-hermetic microelectronic modules within the Process Capability Domain. Methodologies and procedures used by the Manufacturer to validate their design shall also be addressed.

The design rules shall at least cover the following:

- Interconnection substrate and carrier physical constraints, as applicable (e.g. maximum & minimum dimensions, mass).
- Conductor, termination and wire bonding physical constraints.
- Components requirements (maximum dimensions, components' finishing).
- Electrical design constraints.
- Resin encapsulation and package assembly processing, if applicable.
- Post-encapsulation processing (e.g. sawing, connections, plating, etching, lead-forming, as applicable).

5.1.4 Inspection and Tests

The Manufacturer shall describe the methods applicable for inspections and tests, including references to the documents specifying those methods.

At least the following areas shall be covered:

- Materials', mechanical parts' and EEE add-on components' incoming inspection.
- In-process inspections.
- Internal and external visual inspection.

5.1.5 Traceability

The Manufacturer shall describe his methods for assuring traceability of materials, mechanical parts, EEE add-on components, and test and manufactured items. At least the following points shall be covered:

- The use of purchase orders and specifications
- The use of route sheets and travellers
- The traceability of materials, mechanical parts and EEE add-on components
- The traceability of test structures
- The traceability of manufactured items

5.2 THE PID OF A NON-HERMETIC MICROELECTRONIC MODULES MANUFACTURER

5.2.1 General

A PID for the Process Capability Domain to be approved shall be based on ESCC Basic Specification No. 2276000.

5.2.2 Review and Approval of the PID

The PID shall contain the complete definition of the Process Capability Domain and will be updated into a stable state at the end of the Evaluation Phase; accordingly, its review and approval by the ESCC Executive becomes a mandatory pre-requisite for the commencement of the PCA testing phase.

The complete PID, comprising all called-up specifications, shall be kept by the Manufacturer at the production plant. It shall be made available to the ESCC Executive or its designated representative for review and consultation.

Any deviation from the PID shall be subjected to the ESCC Executive for approval.

A condensed PID, comprising all basic information, e.g. flow-charts, lists of specifications, materials, processes, organization/responsibility, equipment and layouts but complemented by copies of only the agreed specifications, shall be kept by the ESCC Executive and treated as proprietary information.

6 MANUFACTURER EVALUATION

In addition to the requirements of ESCC Basic Specification 25600, the following requirements are specific and applicable to the evaluation of non-hermetic microelectronic modules for the purpose of PCA.

The following activities shall be carried out during the Manufacturer evaluation phase:

- Capability survey. This survey is made to assess a Manufacturer's general capability for the production of reliable non-hermetic microelectronic modules
- Line survey. This survey consists of an assessment of a Manufacturer's technology and production line based on applied processes and controls, and a detailed review of existing test data.

In general, to enable the survey team of the ESCC Executive to carry out the capability survey, the line survey and the manufacturer audit, the Manufacturer shall grant free access to the facilities concerned. He shall also enable the team to witness any development, engineering, production and quality assurance operations involved in the processes for which approval is sought.

To facilitate the evaluation procedure for capability survey, line survey and manufacturer audit, the checklist based on ESCC Basic Specification No. 2026000 shall be used, where applicable.

7 EVALUATION PHASE OF THE PROCESS CAPABILITY DOMAIN

7.1 GENERAL

The evaluation phase of the Process Capability Domain of manufacturing lines for non-hermetic microelectronic modules shall be as specified in ESCC Basic Specification No. 25600, with additional requirements as follows.

7.2 EVALUATION TEST PROGRAMME

7.2.1 General

The Manufacture of the non-hermetic microelectronic modules shall issue an Evaluation Test Programme (ETP) which shall, as a minimum, conform to the requirements of this paragraph.

The test structures used for Evaluation Testing are called test vehicles (TVE). The quantity and type of samples to be used for the ETP shall be agreed by the ESCC Executive and the Manufacturer. The samples shall also be the most suitable for highlighting those characteristics and parameters that are pertinent to an investigation on failure modes and weaknesses.

Upon completion of evaluation testing, the final definition of the Process Capability Domain and its boundaries shall be agreed between the Manufacturer and the ESCC Executive, and the Process Capability Abstract shall be issued.

7.2.2 Description of Test Vehicles (TVE)

On the basis of materials, processes and sub-techniques proposed by the Manufacturer for approval, the Manufacturer shall define the test vehicles implementing the different sub-techniques and their related limits.

To cover all the different sub-techniques, a minimum of two types of test vehicle shall be used:

- One type addressing the first level of interconnection, including the substrate technology, if applicable; this type of test vehicle shall be designated as TVE1.
- One type addressing the assembly of add-on components and the packaging technique; this type of test vehicle shall be designated as TVE2.

In order to cover the full Process Capability Domain, it might be necessary to define several Test Vehicles of the type TVE1 and/or TVE2 above.

The Manufacturer shall fabricate additional TVE1/TVE2 vehicles, or define and fabricate specific test vehicles for evaluation of specific applications (on/off or power cycling, high voltage, high current, etc.), and perform related specific tests to evaluate those.

If rework operations are foreseen by the Manufacturer and are accepted by the ESCC Executive, Evaluation Test Vehicles shall be intentionally reworked and the traceability of the various rework operations established accordingly. These reworked devices shall be clearly identified and submitted to the same test campaign as the non-reworked test vehicles.

The Manufacturer shall write a specification in accordance with ECSS-Q-ST-60-05 Annex B for each test vehicle to be evaluated and submit it to the ESCC Executive for approval.

7.2.2.1 Definition of TVE1 test vehicle

TVE1 test vehicle shall mainly address the evaluation of the interconnection substrate.

If multilayer Printed Circuit Boards are to be used as a substrate for the non-hermetic microelectronic modules, the evaluation test requirements specified in in ECSS-Q-ST-70-10 shall apply.

Electrical verification of Test Vehicles TVE1 shall cover characteristics as specified in the TVE1 specification, including as a minimum:

- Conductor resistance.
- Insulation resistance.
- Capacitance.
- Dielectric Strength.
- Key parameters of resistors network.

This test vehicle shall be representative of all major relevant characteristics, including as a minimum:

- Maximum X, Y dimensions.
- Maximum number of conductive layers and associated dielectric layers.
- Typical thicknesses of conductive and dielectric layers.
- Minimum and typical line width/space.
- Minimum and typical via/holes dimensions and typical density.

7.2.2.2 Definition of TVE2 test vehicle

TVE2 test vehicle shall address all relevant sub-techniques to be evaluated; e.g. wire bonding, soldering, glueing, moulding, stacking, etc.

At least one TVE2 shall be defined containing the full combination of sub-techniques used in the actual product. This test vehicle shall be designed to evaluate:

- The main electrical parameters related to the add-on passive and discrete active components (and integrated circuits, if possible).
- The mechanical (and electrical, when applicable) performance of the attachment medium (if applicable).
- The mechanical and electrical performance of the interconnections technologies.
- The behaviour of the non-hermetic encapsulation and the subsequent processing with respect to the environmental stresses (thermo-mechanical, humidity, contamination).

This test vehicle shall be representative in terms of the following key characteristics. The list might not be exhaustive:

- Worst case module physical dimensions.
- Representative substrate as described in Para. 7.2.2.1 (Definition of TVE1).
- Add-on components (e.g. active and passive components, carrier, substrate).
- Technology, Types and Manufacturers.
- Termination finish.
- Minimum and maximum dimensions.
- Attachment medium/process.
- Maximum number ‘n’ of layers stacked (3D stacking).
- Interconnection technologies.
- Each component shall be connected to the substrate (as applicable).
- Test patterns for interconnection technologies.
- Coating or encapsulation processes.
- Material, curing process.
- Module post-processing after encapsulation, as applicable.
- Sawing or re-shaping after moulding.
- External terminations.
- External Plating and etching.
- Module screening, as agreed by the ESCC Executive.
- If add-on components are identified to be moisture sensitive, a preconditioning step in accordance with JESD22-A113, shall be applied prior to the assembly in the TVE2, if necessary.

7.3 MANUFACTURER'S AUDIT

The Manufacturer Quality Management System Audit shall take place as part of the PCA evaluation stage. This audit shall assess the Manufacturer's quality management system and his ability to successfully execute a contract for the supply of high reliability, non-hermetic microelectronic modules. The Manufacturer shall have in place a Quality System according to ESCC Basic Specification No. 24600.

The Line Survey, shall take place in parallel to the QMS Audit, and shall be performed against all applicable requirements in the Check List ESCC Basic Specification No. 2026000.

7.4 EVALUATION TESTING

7.4.1 General

Evaluation testing of test vehicles shall consist of the tests and subgroups given in Chart 1.1 and Chart 1.2 of this specification. Test vehicles shall be randomly divided into the various test subgroups. Unless otherwise agreed with the ESCC Executive, when different types of test vehicles are being tested, each type shall be represented in each subgroup.

Chart 1.3 presents an alternate testing flow for TVE2 which may be implemented in place of Chart 1.2. This alternative approach introduces an additional verification by test on the capability of TVE2 to withstand accumulated mechanical and environmental stresses. Chart 1.3 shall become mandatory in the evaluation testing of modules/vehicles where organic substrates and soldering operations are combined together. For other processes/materials combinations, Chart 1.3 remains optional for the Manufacturer.

All test vehicles shall be serialized prior to testing. For each measurement or inspection performed, the results shall be recorded and summarised in terms of serial numbers and quantity tested, quantity passed and quantity rejected/failed.

All failed test vehicles shall be subjected to failure analysis. The depth of the analysis shall depend on the circumstances in which failure occurred and whether useful information can be gained. As a minimum, the failure mode shall be determined in each case.

After failure analysis, additional test structures, possibly including process improvement, can be used for replacements, with the agreement of the ESCC Executive. Test structures not failing catastrophically, i.e. those displaying out of tolerance electrical rejects, may not be removed from the test sequence but may be used, with the agreement of the ESCC Executive, as additional test samples in order to monitor and observe the degradation trends. In no case shall these parts substitute good parts.

For TVEs representative of large or complex products, the sample size may be reduced provided that the design of the TVEs includes statistically meaningful quantities of each sub-techniques. A proposal of sample size shall be introduced in the test plan to be submitted to ESCC Executive for approval.

7.4.2 Control Devices

A control device of each type of test vehicle shall be kept for comparison purposes. Whenever electrical measurements are performed on any test vehicle during evaluation testing, the control device of the same type shall also be measured.

7.4.3 Test Plans

Testing, analysis of test results and definition of the evaluation test programme shall be in accordance with the test plans per Charts 1.1, 1.2 and/or 1.3 for each test vehicle, TVE1 and TVE2.

The test methods and conditions applicable to the tests specified in Charts 1.1, 1.2 and 1.3 are listed in Table 1.

The test plans and the definition of test vehicles proposed by the Manufacturer shall be submitted to the ESCC Executive for approval prior to commencing the tests.

7.4.4 Destructive Physical Analysis

The number of samples submitted to DPA must be 1 minimum per subgroup.

Partial DPAs (e.g. wire pull, shear test, SAM) might be done on other test vehicles, subjected to the same test regime, in order to obtain a significant sampling data.

The DPA content (including partial DPAs) shall be proposed by the Manufacturer and subsequently agreed with the ESCC Executive. DPA shall be performed by a laboratory mutually approved by the Manufacturer and by the ESCC Executive.

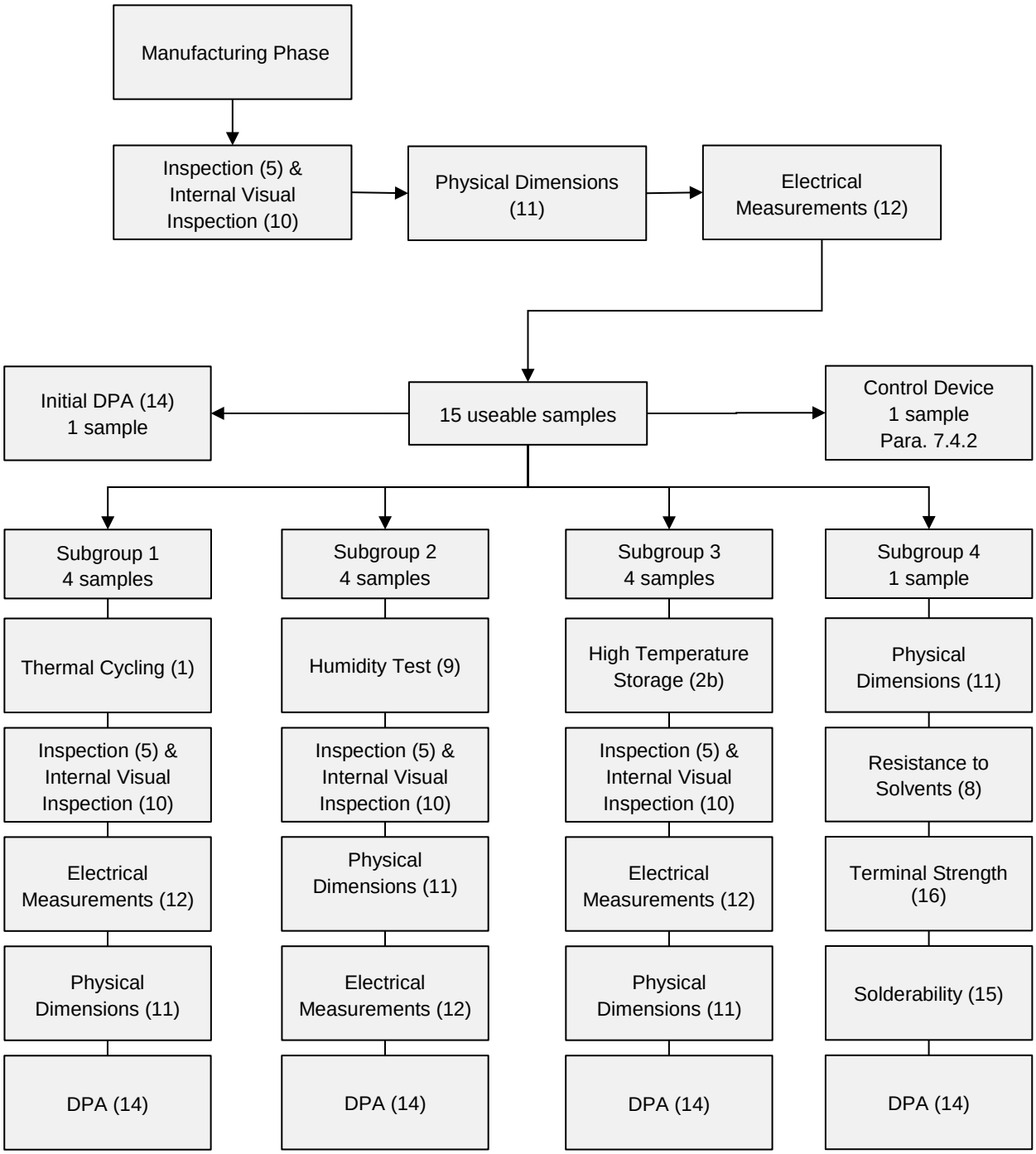
7.4.5 Evaluation Test Report

On completion of the evaluation testing, the Manufacturer shall prepare an evaluation report. This report shall include:

- Description of the Process Capability Domain technology tested: processes, materials and sub-techniques and how these were implemented in the devices tested.
- The Detail Specification for each Test Vehicle or circuit
- Production data for the test structures including details of any failures during production
- The evaluation test programme (ETP) giving details of all test methods and conditions and the number of test structures tested
- ETP detailed test results including: all electrical measurements and statistical analysis of the results, DPA reports, Failure Analysis reports (as applicable)
- Reference to the Manufacturer's alternative test data accepted as satisfying part or all of the ETP (as applicable)
- ETP summary and conclusions

The Evaluation report shall be sent to the ESCC Executive for review and acceptance.

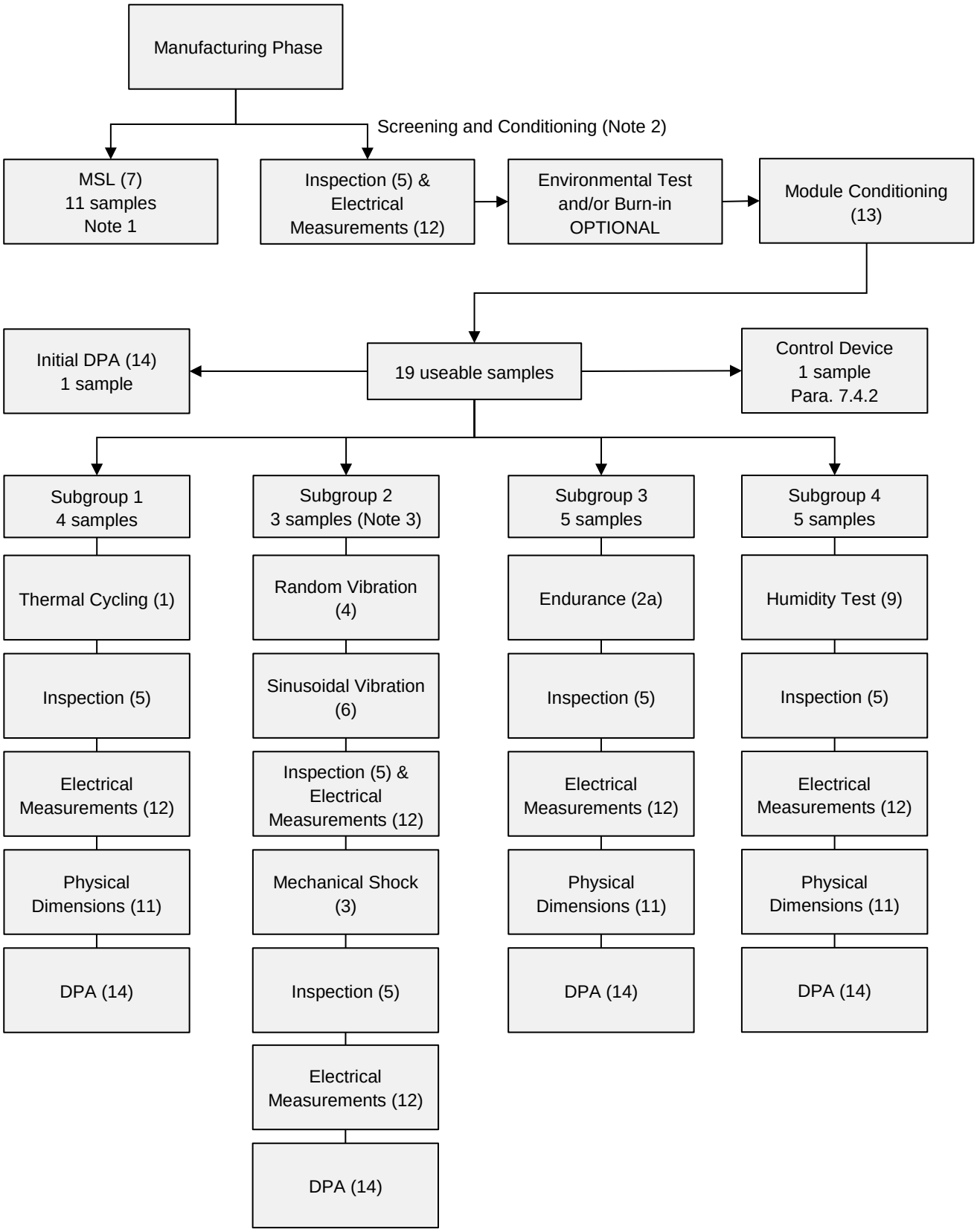
CHART 1.1 - EVALUATION TEST PLAN FOR TEST STRUCTURES TVE1 (NOTE 1)



NOTES:

1. The TVE1 technology/configuration drives the specific Evaluation Plan. The tailoring has to analyse the applicability and eventual replacement of a test (e.g. if solderability is not applicable, then it has to be replaced by other test e.g. bondability).
2. The test method and conditions for each test in Chart 1.1 are specified in Table 1 as indicated by the numbers in brackets for each test.

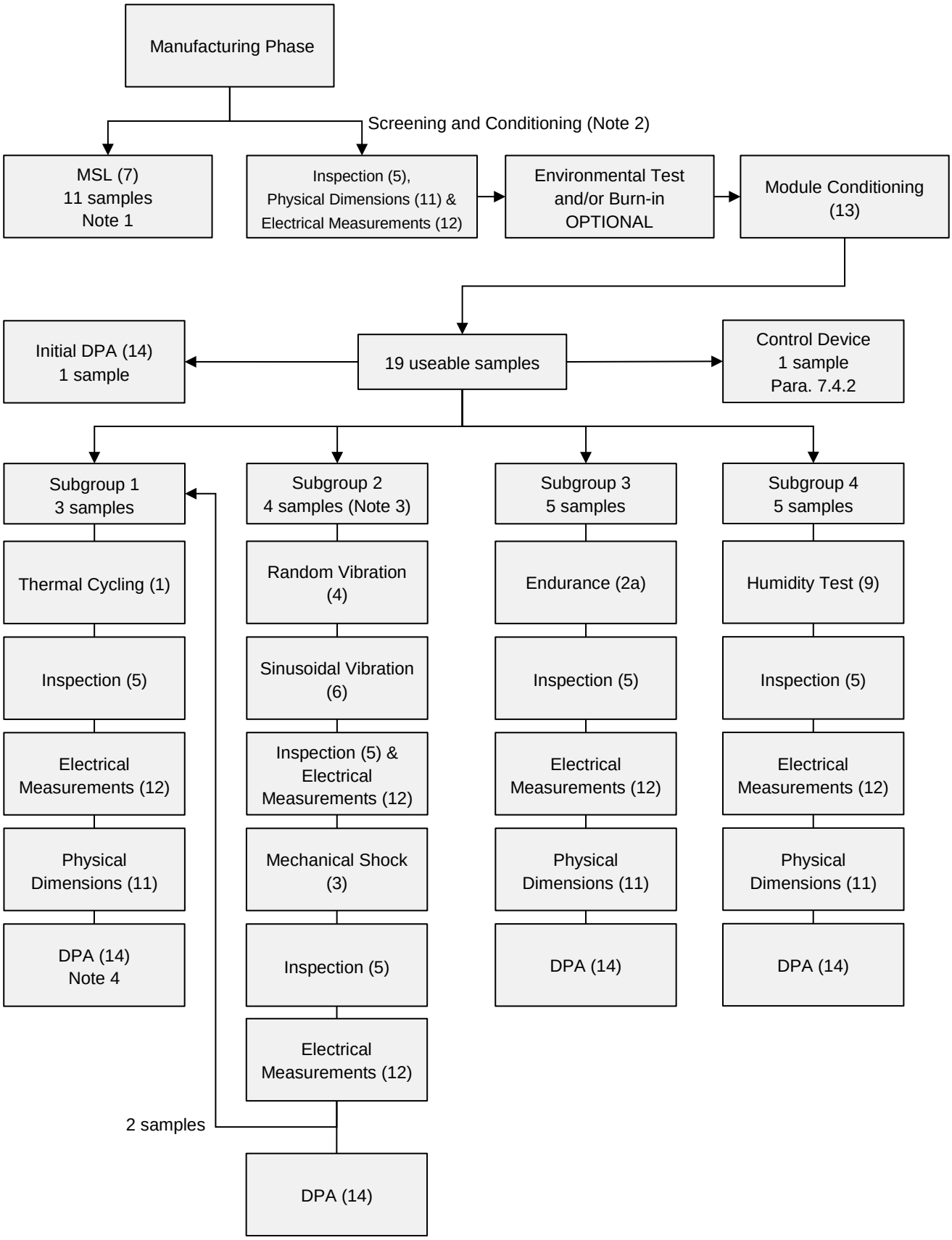
CHART 1.2 - EVALUATION TEST PLAN FOR TEST STRUCTURES TVE2



NOTES:

1. MSL must be performed prior to any further evaluation test. Applicable only to resin encapsulated assemblies/devices intended to be soldered at the next assembly level.
2. Screening and conditioning may be reduced in agreement with ESCC Executive.
3. Subgroup 2 may be not applicable, at the discretion of the ESCC Executive, in consideration of the encapsulation technology.
4. The test method and conditions for each test in Chart 1.2 are specified in Table 1 as indicated by the numbers in brackets for each test.

CHART 1.3 - EVALUATION TEST PLAN FOR TEST STRUCTURES TVE2 (OPTIONAL)



NOTES:

1. MSL must be performed prior to any further evaluation test. Applicable only to resin encapsulated assemblies/devices intended to be soldered at the next assembly level.
2. Screening and conditioning may be reduced in agreement with ESCC Executive.
3. Subgroup 2 may be not applicable, at the discretion of the ESCC Executive, in consideration of the encapsulation technology.
4. DPA on Subgroup 1 shall be performed as a minimum on the sample coming from the accumulated test.
5. The test method and conditions for each test in Chart 1.3 are specified in Table 1 as indicated by the numbers in brackets for each test.

TABLE 1 – EVALUATION TEST PLAN TEST METHODS AND CONDITIONS

No.	Test	MIL-STD	Method	Test Conditions and Remarks
1	Thermal Cycling	883	1010	Condition B, up to 500 cycles or failure. Intermediate inspections points every 100 cycles (Visual + Electrical measurements).
2a	Endurance	883	1005	2000 hours. Intermediate inspections points every 1000 hours (Visual + Electrical measurements). Ambient temperature will be defined to achieve $+125°C \leq T_j \leq +150°C$ (or maximum ratings). If the Tj of the most stressed part is lower than +125°C, the time shall be increased according to MIL-STD-883 Method 1005.
2b	High Temperature Storage	883	1008	Condition B, T_{amb} = +125°C, 2000 hours. Intermediate inspections points every 1000 hours (Visual + Electrical measurements). For TVE1 modules, accelerated testing might be possible provided that the Manufacturer can justify the Activation Energy and the temperature is kept below derated maximum temperature.
3	Mechanical Shock	883	2002	Condition B, 1500g. The test condition may be reduced, at the discretion of the ESCC Executive, in consideration of the size and mass. Shocks performed on Y1 and, depending on the module construction, on Y2, X and Z axes.
4	Random Vibration	883	2026	Condition IK, 44.8grms, 3 axes.
5	Inspection			
5a	External Visual Inspection	883	2009	
5b	SAM Inspection	883	2030	If applicable.
5c	Radiography	883	2012	When soldered items or gold wires are present.
6	Sinusoidal Vibration	883	2007	Condition B, 50g.
7	Moisture Sensitivity Level (MSL) Determination	-	-	J-STD-020
8	Resistance to Solvents	883	2015	ESCC No. 24800 may be used instead of the MIL Method

No.	Test	MIL-STD	Method	Test Conditions and Remarks
9	Humidity Test			THB or HAST, as specified below, shall be implemented in agreement with the ESCC Executive.
9a	Temperature Humidity Bias Life Test (THB)	JESD22	A101	T_{amb} = +85°C, 85% relative humidity, 1000 hours. Intermediate inspections points every 500 hours (Visual + Electrical measurements). For TVE1 samples, no bias is required.
9b	HAST	JESD22	A110	96 hours, 85% relative humidity, T_{amb} = +130°C. Test temperature must be in accordance with the materials' Tg. Alternatively, the following conditions may be implemented: 264 hours, 85% relative humidity, T_{amb} = +110°C.
10	Internal Visual Inspection	883	2017	Class K requirements.
11	Physical Dimensions	883	2016	According to test vehicle detail specification and construction. e.g. for TVE1: line width, space, vias diameter, substrate camber, etc. e.g. for TVE2: external dimensions, lid and package deformation, etc.
12	Electrical Measurements	-	-	As per TVE1 and TVE2 specification
13	Module Conditioning			
13a	Thermal Vacuum	-	-	10 cycles, T_{amb} = -30 to +70°C, pressure: ≤ 1mPa, dwell time: 2 hours, slope: 2°C/minute,
13b	Pre-conditioning	JESD22	A113	Only applicable for components intended to be soldered.
13c	SAM Inspection	883	2030	If applicable.
14	DPA (initial or final)			
14a	External Visual Inspection	883	2009	
14b	PIND	883	2020	Condition A. Only for cavity devices
14c	Radiography	883	2012	When soldered items or gold wires are present
14d	SAM Inspection	883	2030	May be used in substitution of radiography
14e	Delidding/ Decapsulation	-	-	
14f	Internal Visual Inspection (if applicable)	883 883 750 750 750 883	2017 2010 2072 2073 2074 2032	Class K. Condition A or ESCC equivalent for monolithic devices.
14g	Dielectric Strength	202	301	100Vdc: between conductive layers in a multilayer system; between conductors on same layer in a monolayer system
14h	Plasma Etching	-	-	If applicable (for encapsulant removal).

No.	Test	MIL-STD	Method	Test Conditions and Remarks
14i	SEM Inspection	883	2018	Provide photos of typical assemblies, non-conformances and anomalies.
14j	Bond Pull	883	2011	On TVE2 only. Pull all wires and ribbons.
14k	Die Shear	883	2019	On TVE2 only. Shear all chips and small substrates.
14l	Substrate Attach Strength	883	2027	When shear test cannot be performed in case of substrates or large chips.
14m	Adhesion	-	-	Peeling test on metallization according to the Manufacturer's specification and agreed by the ESCC Executive.
14n	Microsection	-	-	Microsectioning shall be performed to evaluate: multilayer substrates (conductors, dielectric, vias), assembly of add-on components, cross-overs, local encapsulations.
15	Solderability	202	208	Three terminals per test item.
16	Terminal Strength	883	2004	Flexible leads: condition A: F(N) = 30 x S (mm^2) (where F = strength, S = lead section). Rigid feed-throughs in packages: Diameter ≤ 1mm as above. Diameter > 1mm, condition C1, torque: 1.5N.cm.

NOTES:

1. The number of each test corresponds to that shown in brackets for each test in Charts 1.1, 1.2 and 1.3.

8 PROCESS CAPABILITY APPROVAL (PCA) PHASE

8.1 GENERAL

The PCA phase for manufacturing lines for non-hermetic microelectronic modules shall be as specified in ESCC Basic Specification No. 25600 with the additional requirements set in this paragraph.

The objective of the Process Capability Approval Phase is to demonstrate, on the operational manufacturing line, the ability of the Manufacturer to produce high reliability devices for space applications.

To this end the following prerequisites shall be satisfied:

- The evaluation phase has been completed successfully and the Process Capability Domain with its boundaries has been agreed between the Manufacturer and the ESCC Executive.
- The materials and processes, and related specifications have been frozen in a PID agreed by the ESCC Executive.
- The facilities, equipment and tools are operational and under control.
- The training and certification of personnel is completed and surveyed.
- All corrective actions derived from the manufacturer audit and line survey shall have been correctly and completely implemented.
- An ESD control plan, meeting the minimum requirements of ESCC Basic Specification No. 24900, is frozen. Such control plan shall include provisions for the handling of Class 0 devices as per MIL-STD-883, Method 3015.

The ESCC Executive shall verify the completion of the prerequisites listed above at the time of the PCA readiness review.

8.2 PROCESS CAPABILITY APPROVAL TESTING

Process capability approval testing to be performed on test vehicles in accordance with the PID, shall conform to ESCC Basic Specification No. 25600 and this paragraph.

This phase shall consist of the fabrication and testing of Process Capability Approval Test Vehicles (named TVCAs), covering the Process Capability Domain defined in the PID.

8.2.1 Definition and Requirements for Test Vehicles for PCA Testing

The process capability approval test vehicles (TVCAs) shall be one or several functional products and additional test structures, if necessary.

A Detail Specification shall be prepared by the Manufacturer and agreed by the ESCC Executive for each TVCA. The specification shall describe the production control and any screening testing to be conducted on the TVCAs prior to commencing the PCA testing. ECSS-Q-ST-60-05 (and ECSS-Q-ST-60-13, as applicable) may be used as a guideline for the preparation of the Detail Specification and for the definition of screening tests.

In order to validate rework procedures and limits, some of the TVCAs shall be intentionally reworked according to the methods described in the PID. At least one device per PCA test subgroup shall be reworked for that purpose.

The ESCC Executive shall be notified 3 weeks in advance of the following key points:

- before encapsulation/closing
- before screening
- end of screening (for a review of screening results).

8.2.2 PCA Test Programme

The PCA test programme shall consist of the tests and subgroups given in Chart 2 and/or Chart 3. Samples to be submitted to Chart 2 and/or Chart 3 shall be test vehicles as defined in Para. 8.2.1 and the Manufacturer's PID. These TVCAs shall be randomly divided into the various test subgroups. The sample size and the accept/reject criteria per test subgroup is given in Table 2. Unless otherwise agreed with the ESCC Executive, when different types of test structure are being tested, each type shall be represented in each subgroup.

All TVCAs shall be serialized prior to testing. For each measurements or inspection performed, the results shall be recorded and summarized in terms of serial numbers and quantity tested, quantity passed and quantity rejected.

A control device of each type of TVCA shall be kept for comparison purposes. Whenever electrical measurements are performed on any TVCA during PCA testing, the control device of the same type shall also be measured.

The test methods and conditions, applicable to the tests specified in Charts 2 and 3, are listed in Table 3.

Prior to the start of the PCA testing, the Manufacturer shall prepare and submit to the ESCC Executive, for approval, a test programme specifying:

- The tests sub-groups (sequences, conditions, limits).
- The electrical measurement steps as per the Detail Specification.
- The inspection steps with related accept/reject criteria.
- The sample size, and the accept and reject criteria per sub-group.
- The distribution of reworked modules per sub-group.

8.2.3 PCA Test Report

On completion of the PCA testing, the Manufacturer shall collect all test data and documentation in the form of a report. This report shall be sent to the ESCC Executive for review and approval.

The report shall contain the following information:

- Description of the Process Capability Domain tested including processes (including the associated equipment), materials and sub-techniques and how these were implemented in the devices tested.
- The Detail Specification for each test vehicle.
- Production data for the test vehicles including details of any failures during production.
- The PCA test programme giving details of all test methods and conditions and the number of test vehicles tested.
- The Test Plans carried out for Process Capability Approval Testing with indication of the allowable number of failed devices per test file and the test methods and conditions used.
- Detailed test results including all electrical measurements and statistical analysis of the results, DPA reports, and any non-conformance reports.
- Reference to the Manufacturer's alternative test data accepted as satisfying part or all of the PCA test programme (as applicable).
- PCA testing summary and conclusions.

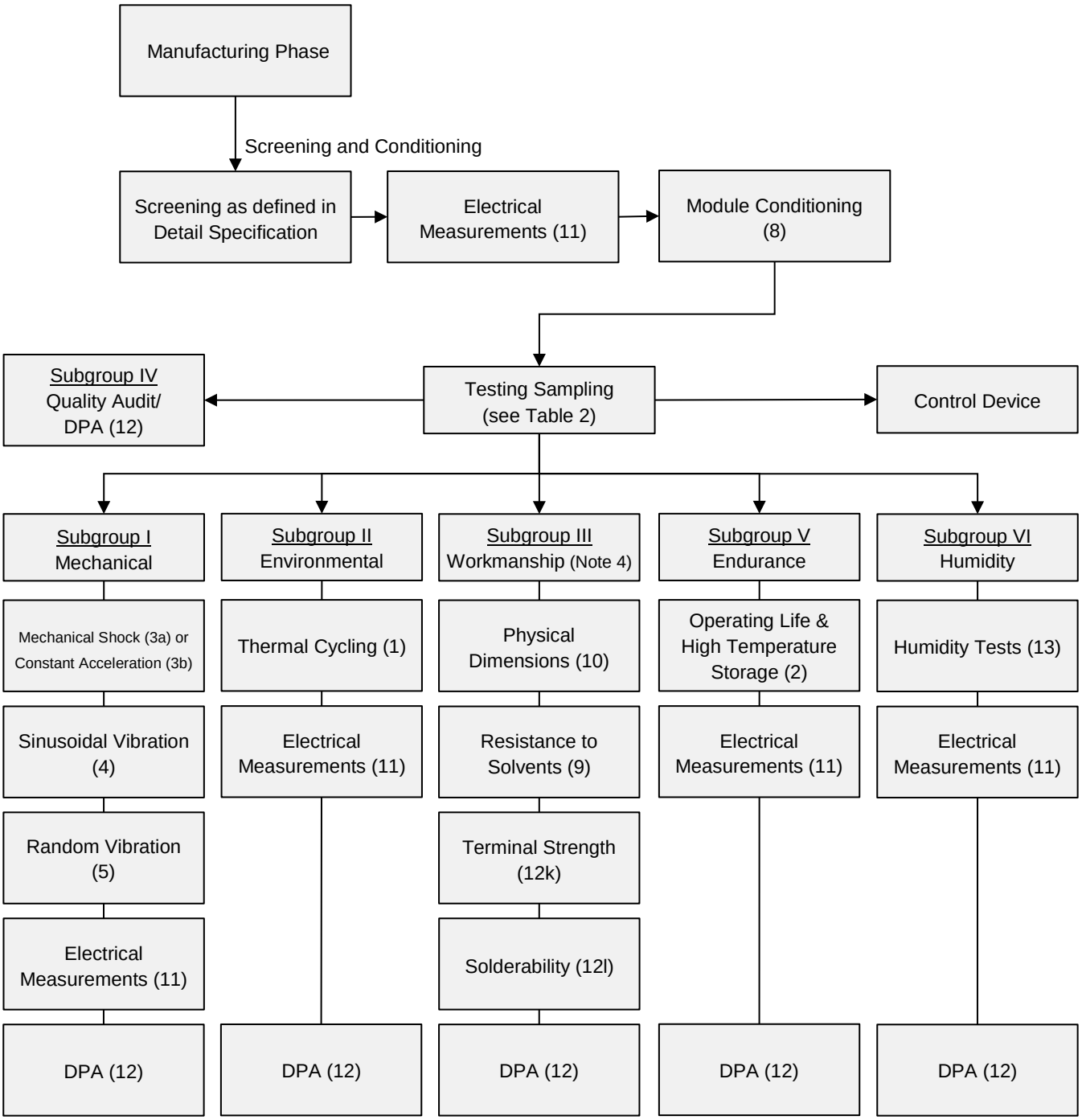
TABLE 2 - PROCESS CAPABILITY APPROVAL TESTING SAMPLING

Qty of Each TVCA Type	"N" TVCAs required per subgroup (Note 1)						Additional Samples	Total Per Type	Total Qty	Accept/ Reject Criteria
	SG I	SG II	SG III	SG IV	SG V	SG VI				
	Mechan-ical Tests	Thermal Cycling	Work-manship	QA/ DPA	Life Test	Humidity Tests	Control Device			
Chart 2										
1	6	6	2	1	10	10	1	36	36	a = 0, r ≥ 1
2	3	3	1	1	5	5	1	19	38	a = 0, r ≥ 1
3	2	2	1	1	3	5	1	15	45	a = 0, r ≥ 1
Chart 3										
1	6	2 (2)	2	1	10	10	1	32	32	a = 0, r ≥ 1
2	3	1 (3)	1	1	5	5	1	17	34	a = 0, r ≥ 1
3	2	1 (4)	1	1	3	5	1	14	42	a = 0, r ≥ 1

NOTES:

1. For complex modules, the sample size may be reduced provided that the design of the TVCA includes a statistically meaningful number of each sub-techniques. A proposal for the sample size shall be introduced in the PCA test plan to be submitted to the ESCC Executive for approval.
2. Plus 4 TVCAs coming from SG I
3. Plus 2 TVCAs coming from SG I
4. Plus 1 TVCA coming from SG I

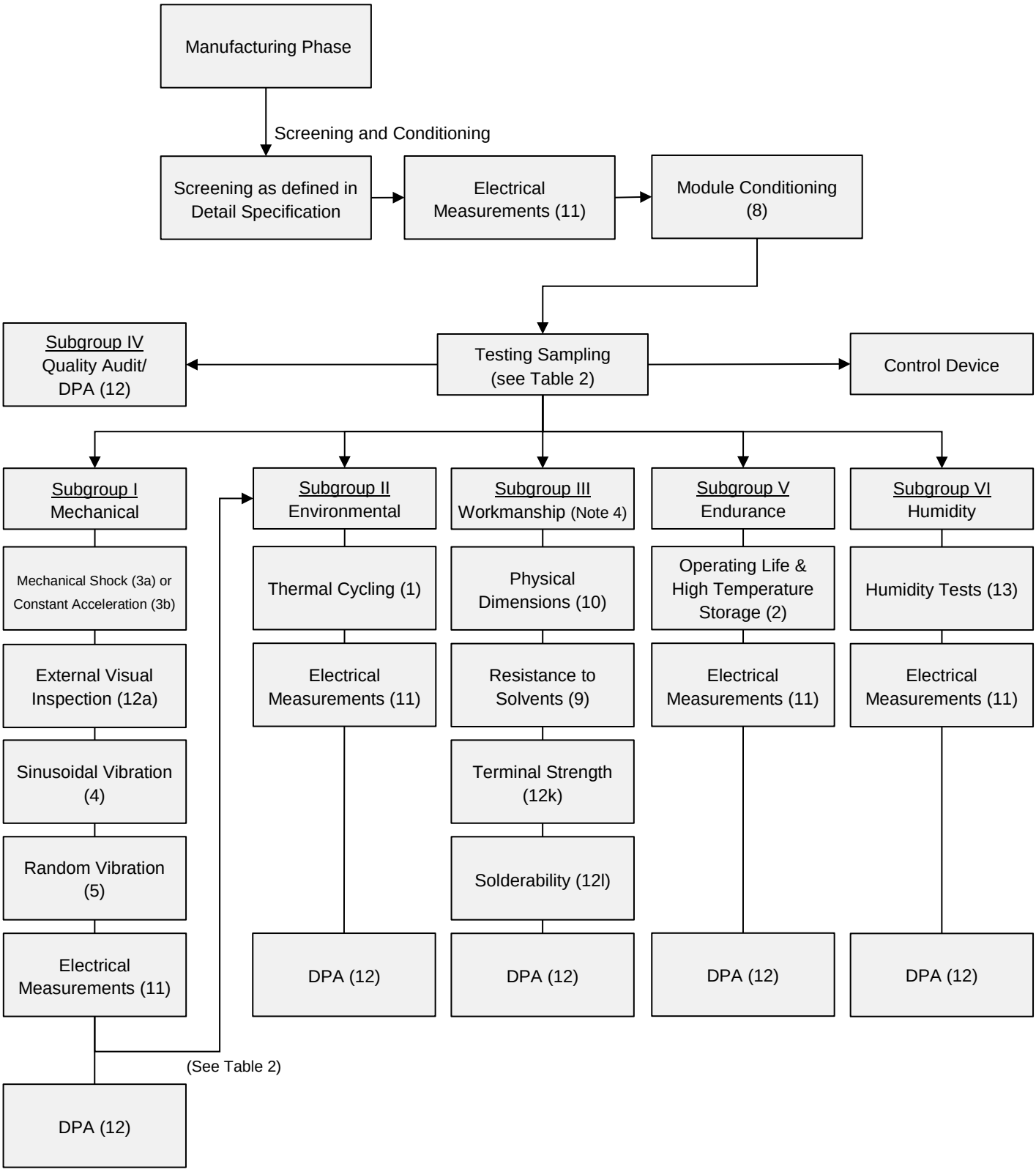
CHART 2 - PROCESS CAPABILITY APPROVAL TESTING



NOTES:

1. Tests on Subgroup III, might be waived if already performed during the Evaluation phase.
2. The test methods and conditions for each test in Chart 2 are specified in Table 3 as indicated by the numbers in brackets for each test.

CHART 3 - PROCESS CAPABILITY APPROVAL TESTING (OPTIONAL)



NOTES:

1. Tests of Subgroup III, might be waived if already performed during the Evaluation phase.
2. The test method and conditions for each test in Chart 3 are specified in Table 3 as indicated by the numbers in brackets for each test.

TABLE 3 - PROCESS CAPABILITY APPROVAL TEST METHODS AND CONDITIONS

No.	Test	MIL-STD	Method	Test Conditions and Remarks
1	Thermal Cycling	883	1010	Condition B, 100 cycles.
2a	Operating Life Test	883	1005	Duration 1000 hours + 1000 hours. Ambient temperature will be defined to achieve +125°C ≤ T_j ≤ +150°C (or maximum per maximum ratings). If the T_j of the most stressed part is lower than +125°C, the time shall be increased according to MIL-STD-883 Method 1005.
2b	High Temperature Storage	883	1008	Condition B, T_{amb} = +125°C, 2000 hours.
3a	Mechanical Shock	883	2002	Condition B, 1500g. The test condition may be reduced, at the discretion of the ESCC Executive, in consideration of the size and mass. Shocks on Y1, plus shocks on Y2, X and Z axes if required by the configuration.
3b	Constant Acceleration	883	2001	Condition B. The test condition may be reduced, at the discretion of the ESCC Executive, in consideration of the size and mass. Test performed on Y1 and, depending on the module construction, on Y2, X and Z axes.
4	Sinusoidal Vibration	883	2007	Condition A, 20g.
5	Random Vibration	883	2026	Condition IF, 20grms, 3 axes.
6	Thermal Vacuum			10 cycles, T_{amb} = -30 to + 70 °C, pressure: ≤ 1mPa, dwell time: 2 hours, slope: 2°C/minute.
7	PIND test	883	2020	Condition A. Only for cavity devices
8	Module Conditioning			
8a	Thermal Vacuum	-	-	10 cycles, T_{amb} = -30 to + 70°C, pressure: ≤ 1mPa, dwell time: 2 hours, slope: 2°C/minute.
8b	Pre-conditioning	JESD22	A113	Only applicable for components intended to be soldered
8c	SAM Inspection	883	2030	If applicable.
9	Resistance to Solvents	883	2015	ESCC may be used instead of the MIL Method
10	Physical Dimensions	-	-	According to module Detail Specification.
11	Electrical Measurements	-	-	According to module Detail Specification. Note: Initial electrical measurements can be the final measurements performed after Screening.
12	DPA (initial or final)			
12a	External Visual Inspection	883	2009	
12b	Radiography	883	2012	If soldered items or gold wires are present
12c	PIND			
12d	SAM Inspection	883	2030	May be used in substitution of radiography

No.	Test	MIL-STD	Method	Test Conditions and Remarks
12e	Delidding/ Decapsulation			
12f	Internal Visual Inspection	883 883 750 750 750 883	2017 2010 2072 2073 2074 2032	Class K Condition A. Or ESCC equivalent for monolithic devices
12g	SEM Inspection	883	2018	Provide photos of typical assemblies, non-conformances and anomalies
12h	Bond Pull	883	2011	Pull all wires and ribbons
12i	Die Shear	883	2019	Shear all chips and small substrates
12j	Substrate Attach Strength	883	2027	When shear test cannot be achieved for substrates or large chips
12k	Terminal Strength	883	2004	Only for Subgroup III - Workmanship. Flexible leads: condition A: F(N) = 30 x S (mm^2). (where F = strength, S = lead section) Rigid feed-throughs in packages: Diameter ≤ 1mm as above. Diameter > 1mm, condition C1, torque: 1.5N.cm.
12l	Solderability	202	208	Only for Subgroup III - Workmanship. Three terminals per test item.
13	Humidity Tests			THB or HAST, as specified below, shall be implemented in agreement with the ESCC Executive
13a	Temperature Humidity Bias (THB)	JESD22	A101	T_{amb} = +85°C, 85% relative humidity, 500 hours + 500 hours
13b	HAST	JESD22	A110	96 hours, 85% relative humidity, T_{amb} = +130°C. Test temperature must be in accordance with the materials' Tg. Alternatively, the following conditions may be implemented: 264 hours, 85% relative humidity, T_{amb} = +110°C.

NOTES:

1. The number of each test corresponds to that shown in brackets for each test in Charts 2 and 3.

8.3 PROCEDURES SPECIFIC TO PCA MANUFACTURING LINES FOR NON-HERMETIC MICROELECTRONIC MODULES

The following provisions are specific to PCA of manufacturing lines for non-hermetic microelectronic modules and supplement related requirements in ESCC Basic Specification No. 25600.

8.3.1 Extension or Change of the Process Capability Approval Domain

By a change of the Process Capability Approval Domain, it is intended to make an addition of, or change to, materials and/or processes and/or boundaries that were included in the previous PID.

The Extension of Process Capability Domain is a particular case of change.

Changes of the Process Capability Approval domain are categorized into two classifications:

(a) Major change: new materials, new processes, new production equipment, move of line location, new or modified inspection criteria, change of process parameters beyond PID limits.

(b) Minor change: addition of already-existing production equipment to the line, addition of a second supplier for an already-used material.

Upon application for change of the Process Capability Approval Domain by the Manufacturer concerned, the ESCC Executive will decide whether the change is major or minor.

Changes shall be validated by test programmes according to the test plan reviewed and approved by the ESCC Executive.

8.3.2 Maintenance, Suspension and Withdrawal of the Process Capability Approval

8.3.2.1 Maintenance of Process Capability Approval.

The maintenance of PCA can be achieved in two ways:

On one hand, the certification of PCA of manufacturing lines for non-hermetic microelectronic modules may be maintained by the successful repetition of the PCA test programme after a lapse period of 2 years.

On the other hand, Process Capability Approval may also be maintained by:

- The continuous production of devices according to the Process Capability Domain defined in the PID. At least two months prior to the expiry date of line approval, the Manufacturer shall send a letter to the ESCC Executive with the details of lots manufactured within the elapsed period.

  The letter will identify: lot numbers, delivered devices and numbers and a synthesis of failures during burn-in, environmental and life testing.

  If considered necessary, the ESCC Executive may require further details or a repetition of some tests on suitable test vehicles.

- Or, if devices have been manufactured and tested within the Process Capability Domain, and have a complexity covering the domain boundaries or part of them, these tests may suffice for the maintenance of PCA.

Modifications, additions or changes to the PID (domain), shall be submitted at the time of maintenance. Inclusion in the PID will be justified and supported by relevant Delta Qualifications.

The minimum requirement for Process Capability Approval is that, during the last 12 months lapse period, one lot of devices has been manufactured, screened and tested.

The ESCC Executive shall be provided with documented evidence that the lot in question has successfully passed the specified tests and inspections. The ESCC Executive shall be provided with DPA test reports on three devices successfully screened as part of the lot proposed to sustain the maintenance of PCA. This DPA exercise shall be consistent with requirements for DPA found at the end of PCA testing as defined in this specification.

Renewal of Process Capability Approval shall be valid either from the date on which:

(a) The previous approval expired or,
(b) The date on which lot acceptance testing was completed successfully if this date occurred more than 6 months prior to (a).

8.3.2.2 Suspension of Process Capability Approval.

The ESCC Executive reserves the right to suspend the approval status of a manufacturing line, or any part thereof, for the following reasons:

(a) failure(s) which cannot be remedied within a period of 6 months.
(b) failures of more than two consecutive lots.
(c) a complete stop in production at the manufacturing line for a period longer than 6 months.

NOTE:
Failures due to causes external to the PCA domain are not considered.

In the event of (a) and/or (b) or (c), the Manufacturer shall initiate any corrective action considered appropriate and, in order to achieve reinstatement of the approval status, shall supply the ESCC Executive with evidence that the cause of failure has been eliminated.

During the suspension period, the line shall not be considered as approved and not be used for the manufacture of high reliability circuits unless they serve for approval purposes.

8.3.2.3 Withdrawal of Process Capability Approval

Process Capability Approval status shall be withdrawn by the ESCC Executive:

(a) at the request of the Manufacturer.
(b) in case of persistent non-conformances to the PID requirements.

8.3.2.4 Renewal after Lapse of Process Capability Approval

Following the lapse of Process Capability Approval, a renewal of approval can be started within a period of 6 months. Provided the Manufacturer can demonstrate that the original evaluation of the Process Capability Domain is still valid, this renewal procedure shall comprise a destructive physical analysis of sample devices, a Manufacturer audit and a survey of test records generated in the lapse period. If this survey shows that the Manufacturer's data, are available and acceptable, the ESCC Executive may take such data into consideration for renewal of the Process Capability Approval. Where such data is not available or not acceptable, the manufacturing and successful testing of a number of devices to the requirements specified by the ESCC Executive shall be required for the renewal. The PCA testing specified in this specification shall be used as guideline for the definition of such a renewal testing campaign.

Failure to satisfy the requirements regarding the validity of the original evaluation of a Process Capability Domain will necessitate a completely new Process Capability Approval.

APPENDIX A - GUIDELINES FOR THE MATERIALS AND PROCESSES DESCRIPTION

1 GENERAL

The Manufacturer shall describe the type of functions / products which are planned to be developed and manufactured within the perimeter of the Process Capability Domain under approval. Such description shall include basic electrical characteristics as pertinent. For the purpose of fabricating these types of products, the Manufacturer shall define the extent of his Process Capability Domain, for which approval is sought, in terms of construction technologies, also called sub-techniques (type of interconnection substrates, components mounting and interconnection techniques, encapsulation, etc.), and their associated boundaries.

The Manufacturer shall describe the procedures for selection, procurement and control of materials used for production of structures within the Process Capability Domain.

The Manufacturer shall describe the processes within the Process Capability Domain. He shall also give reference to the documents specifying the processes. At least the following areas shall be covered including a statement on the equipment used:

- Interconnection substrate.
- Components assembly.
- Encapsulation processes.
- Rework procedures.

1.1 DEFINITION OF PROPOSED SUB-TECHNIQUES IN THE PCA DOMAIN

The different sub-techniques are defined by:

- The materials (composition, designation, Manufacturer).
- The processes (and process owner, if subcontracted).
- The associated limits in terms of dimensions and density of integration.

The definition of the sub-techniques within a Process Capability Domain depends on the interconnection substrate technology involved and the related needs for assembly and encapsulation. It is specified in the following paragraphs.

1.1.1 Interconnection Substrate

This paragraph lists some substrate technologies and the applicable requirements, in each case, for the appropriate definition of the related necessary sub-techniques.

1.1.1.1 Ceramic Substrate

- Type of ceramic technology (thick/thin film, HTCC, LTCC).
- Composition of the basic substrate (Al_2O_3, AlN, etc.): designation, Manufacturer/supplier.
- Minimum/maximum size, thickness, shape, etc.
- Cutting method.
- Holes drilling method, dimensions and number per square unit
- Conductor / dielectric / resistor (if applicable):
  - Composition, designation, Manufacturer, application
  - Maximum number of layers
  - Minimum track width/space for different layers (if applicable), thickness
  - Minimum vias/holes dimensions (if applicable)
  - Main electrical characteristics (Current density, resistivity, insulation resistance, withstanding voltage, etc.).
  - Trimming method (if applicable).
  - External conductor plating (if applicable): composition, plating method, thickness, etc.
  - Type of external connections: type, composition, attachment method, pitch, etc.

1.1.1.2 Organic Substrate(s)

- Substrate manufacturer.
- Raw material: designation, supplier.
- External maximum dimensions, total thickness.
- Maximum number of layers.
- Conductors (internal and external):
  - Composition.
  - Minimum track width/space and thickness for internal and external layers.
  - Minimum dimensions of via holes.
  - External conductor plating.
  - Main electrical characteristics: resistivity, current density, insulation resistance, withstanding voltage, etc.
  - Embedded passives (if applicable).

1.1.2 Assembly of Passive and Active Add-on Components

- Type of components (resistor, capacitor, inductance, etc.).
- Packaging (chip, package type, etc.).
- Minimum/maximum dimension.
- Terminations composition.
- Attachment process :
  - Mechanical/electrical attachment medium.
  - Process.

1.1.3 Encapsulation

- Stacking of components or populated substrates (3D construction, if applicable).
- Type of non-hermetic encapsulation (cavity type, resin encapsulation, etc.).
- Materials and processes.
- Type of external terminations (pins, leadframe, etc.):
  - Composition, plating.
  - Forming/cutting.